



The Effectiveness of Tabata Circuit and Fartlek Training Models on Aerobic Endurance and Reactive Agility in Squash Athletes Based on Gender

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ABSTRACT

This study analyzed the effectiveness of Circuit Tabata and Fartlek training in improving aerobic endurance and reactive agility among POPB DKI Jakarta squash athletes, stratified by gender. An experimental method with a 2x2 factorial design was employed. The subjects consisted of 20 squash athletes aged 14–17 years (12 male and 8 female). Athletes were assigned to either the Circuit Tabata or Fartlek group using an ordinal pairing technique. The training program spanned four weeks, with sessions held four times per week. Aerobic endurance was measured using the Multistage Fitness Test, while reactive agility was assessed via the Squash Shadow Reactive Agility Test. Data analysis included descriptive statistics, the Shapiro–Wilk test, Levene’s test, the Paired-Samples t-test, and Two-Way ANOVA at a significance level of 0.05. The results indicated that both training methods improved aerobic endurance and reactive agility. Fartlek training yielded greater improvements in aerobic endurance, with a mean VO_2Max gain of 7.820, compared to 4.880 for Circuit Tabata. The training method had a significant effect on aerobic endurance gains ($F(1,16) = 34.332, p < 0.001, \text{partial eta squared} = 0.682$). Conversely, Circuit Tabata produced greater improvements in reactive agility, with a mean gain of 0.682 seconds, compared to 0.288 seconds for Fartlek. The effect of the training method on reactive agility gains was also significant ($F(1,16) = 117.557, p < 0.00, \text{partial eta squared} = 0.880$). No significant interaction effect was observed between the training method and gender. Therefore, Fartlek training is recommended for enhancing aerobic endurance, whereas Circuit Tabata is more suitable for developing reactive agility.

Keywords: Squash athlete, Tabata circuit, aerobic endurance, Fartlek, reactive agility.

INTRODUCTION

Developments in competitive sports indicate that matches are increasingly characterized by high speed and intensity. Such conditions demand optimal physical fitness from athletes, particularly regarding aerobic endurance capacity and the ability to move and respond rapidly to changing game situations. These demands are especially relevant in racket sports—such as tennis, badminton, and squash—which are characterized by high-intensity, intermittent play. Matches in these sports involve repeated short-distance sprints, acceleration and deceleration, and sudden changes of direction. These activities require the simultaneous engagement of both aerobic and anaerobic energy systems, with aerobic capacity remaining a crucial component for maintaining consistent performance throughout a match. Consequently, developing aerobic endurance and agility must be a key aspect of training racket sport athletes, utilizing methods that align with the specific demands of the game. In this context, training cannot be viewed merely as spontaneous physical activity; rather, it must be regarded as a

planned, science-based system designed to achieve specific performance goals tailored to the characteristics of the sport [1]. Consistent with this perspective, training for competitive sports is a progressive, planned, and continuous development process aimed at enhancing an athlete's physical capabilities, technical mastery, tactical understanding, and mental readiness through the precise management of training volume, intensity, frequency, and variety [2].

Squash is a racket sport that places high physical demands on players due to its intermittent, high-intensity nature, which involves repeated running, acceleration, deceleration, and rapid changes of direction. These characteristics necessitate good aerobic endurance to sustain match intensity, alongside the agility required for quick, repetitive changes of direction. Endurance is one of the ten human biomotor components and plays a crucial role in enabling athletes to maintain performance during prolonged physical activity [3]. Squash relies predominantly on the aerobic energy system, supplemented by anaerobic contributions during high-intensity phases. In elite

players, oxygen consumption during matches can reach approximately 86% of VO_2max , with significant portions of the match played at intensities exceeding 90% of VO_2max [4]. These findings are supported by a study of 31 elite squash players, which identified aerobic capacity, repeated-sprint ability (RSA), and change-of-direction speed (COD) as key components of a player's performance profile; VO_2max also showed a strong correlation with performance on the Squash-Specific Physical Performance Test (SPPT) [5]. Furthermore, a systematic review of the physiological demands of racket sports confirms that measuring VO_2max , oxygen consumption, heart rate, and lactate levels provides essential indicators for understanding physiological load and designing training programs tailored to the sport's specific characteristics [6].

These physiological demands indicate that squash performance is determined not only by the ability to maintain aerobic capacity but also by the capacity to accelerate, perform short sprints, change direction, and rapidly respond to game stimuli. Reactive agility and aerobic endurance are crucial factors that significantly influence a player's performance [7]. Players must adjust their movements in response to the ball's trajectory and the opponent's position within a relatively confined court space. Consequently, reactive agility is a vital component in supporting squash performance. Unlike general agility, which focuses solely on the ability to change direction quickly, reactive agility entails responding to external stimuli through a process of perception, decision-making, and movement execution. Therefore, developing reactive agility is highly relevant in squash training, as the nature of the game requires athletes to constantly adapt their movements to rapidly changing situations.

In the context of performance development, the physiological and movement characteristics of squash indicate that training programs must be designed based on the game's demands, which are intermittent, high-intensity, and multidirectional in nature. Research on elite squash players shows that conditioning, ghosting, match play, and other forms of training generate varying internal and external loads; consequently, the management of training volume, intensity, and frequency must be tailored to the specific physical adaptations sought [8]. Recent studies also confirm that squash is a high-intensity sport placing significant demands on the aerobic system during matches, with elite players reportedly operating at an average intensity of approximately 92% of VO_2max [9]. These findings highlight the importance of employing training methods capable of delivering structured, repetitive physiological stimuli that align with match demands. One applicable approach is High-Intensity Interval Training (HIIT), as it allows for the systematic management of work and recovery intervals to generate high-intensity training stimuli. HIIT is increasingly adopted in training programs because it delivers high-intensity stimuli within a relatively efficient timeframe while offering the potential to enhance athletes' aerobic capacity and various physical performance components

[10]. Circuit training is one approach that can be implemented within the HIIT framework; it consists of multiple stations, each featuring a different exercise. The variation in movements and the organization of exercises across stations allow for diverse physical stimuli within a single session, making it an efficient method for developing various fitness components while increasing training variety for athletes [11]. In this context, Tabata circuits and fartlek training are two methods worthies of examination, as they offer distinct training stimulus characteristics and have the potential to meet the physical requirements of squash players. Research on Tabata circuits involving young squash players has investigated the impact of a 12-week training program on the development of their physical fitness and psychological aspects [12].

Tabata circuit training is a form of high-intensity interval training that combines a circuit format with short work and recovery intervals. The commonly used protocol consists of repeated cycles of 20 seconds of high-intensity activity followed by 10 seconds of recovery. These characteristics enable athletes to achieve a high-intensity training stimulus within a relatively short duration. Domestic studies indicate that Tabata training can improve athletes' VO_2max and physical fitness [13], [14]. These findings suggest that Tabata has the potential to serve as a stimulus for developing aerobic endurance alongside the physical capabilities required for high-intensity sports. However, given that Tabata circuit training prioritizes high-intensity work intervals with relatively brief recovery periods, its impact on reactive movement capabilities in sports characterized by frequent changes of direction such as squash requires further investigation.

Unlike Tabata circuits, fartlek is an endurance training method that incorporates varying speeds—such as jogging, moderate running, and sprinting—into a single training session. This variation in intensity provides a more dynamic training stimulus than constant-speed running and allows for repeated shifts in intensity. Fartlek training, which combines elements of continuous and interval training, has been studied for its potential to enhance these physical attributes [15]. Domestic research indicates that fartlek training can improve VO_2max in athletes and players of team sports [16]. Other studies have reported a positive effect of fartlek training on VO_2max , with more recent research demonstrating improvements in VO_2max among “pencak silat” athletes and futsal players following fartlek interventions [17], [18]. Thus, fartlek is a relevant method for developing aerobic endurance and the ability to maintain performance amidst fluctuating activity intensities. However, the impact of fartlek on reactive agility—particularly for squash athletes who require movement responses to external stimuli—has not yet been extensively studied.

The distinct characteristics of Tabata circuit training and fartlek training warrant investigation within the context of squash. Tabata circuit training delivers a stimulus through high-intensity work and structured, brief recovery periods, whereas fartlek

training introduces intensity variations through changes in running tempo. While both methods have the potential to enhance aerobic capacity, they differ in their training stimulus mechanisms and movement characteristics. These differences may lead to varying responses regarding aerobic endurance and reactive agility. Meanwhile, domestic research on reactive agility indicates that this attribute can be measured using valid and reliable instruments, and that training incorporating reactive stimuli can be employed to develop athletes' movement response capabilities [19], [20]. Consequently, research into training methods capable of providing a physiological stimulus while simultaneously supporting movement response capabilities is crucial for the development of squash training programs.

In addition to differences in training methods, responses to training must also be considered in relation to gender. Physiological characteristics and aerobic capacity can vary between male and female athletes; therefore, the response to a specific training program cannot simply be assumed to be identical for both groups [21]. Gender is considered in this study not merely to compare performance outcomes, but also to identify whether there are differences in responses to Tabata circuit training and fartlek training regarding aerobic endurance and reactive agility. This approach enables a more specific analysis of training effectiveness based on the athletes' characteristics.

Initial observations and discussions with coaches indicate that some POPB DKI Jakarta squash athletes experience a decline in movement intensity during the second game or during relatively long rallies. This condition is characterized by slower recovery to the ready position, delayed reactions in reaching the ball, and an increase in non-technical errors. These preliminary findings suggest a need for a training program designed not only to improve aerobic endurance but also to maintain the athletes' ability to move and respond quickly to game stimuli while fatigued. This issue is particularly relevant given the nature of squash, which requires athletes to sustain their performance repeatedly throughout the match.

Given the foregoing, there is a need to obtain empirical evidence regarding the effectiveness of different training methods—specifically Tabata circuit training and fartlek training—on physical components relevant to the demands of squash, namely aerobic endurance and reactive agility, while also considering gender-based responses. Research specifically comparing Tabata circuit training and fartlek training in relation to these two variables among squash athletes remains limited. Therefore, a study titled “The Effectiveness of Tabata Circuit and Fartlek Training Models on Aerobic Endurance and Reactive Agility in Squash Athletes: A Gender-Based Analysis” was conducted to analyze the effectiveness of these two training methods on the aerobic endurance and reactive agility of POPB DKI Jakarta squash athletes, as well as to examine responses regarding these variables based on gender. The study's findings are expected to provide

empirical evidence concerning athletes' performance responses to these two distinct training methods and serve as a foundation for developing more structured squash training programs that align with the physiological and movement demands of the sport.

RESEARCH METHODS

This study employs a quantitative approach with a 2×2 factorial design, specifically a non-equivalent control group pretest–posttest design. The first factor is the training method—namely, Tabata circuit and fartlek—while the second factor is gender (male and female). The dependent variables comprise aerobic endurance, represented by VO_2max , and reactive agility. This design is used to examine the main effects of training method and gender, as well as the interaction between the two, on changes in the athletes' physical capabilities.

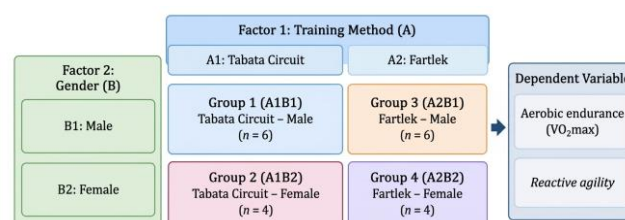


Figure 1. 2x2 Factorial Research Design

The study was conducted in 2026 at the Koja Youth Center (Gelanggang Remaja Koja) in North Jakarta, with training sessions held at the Koja Sports Hall (GOR Koja) squash court and the Rawamangun Athletics Stadium. The experimental program spanned four weeks, featuring four training sessions per week, each lasting 120 minutes. In total, the experiment comprised 18 sessions: one pre-test, 16 treatment sessions, and one post-test.

The study population consisted of 30 squash athletes from the DKI Jakarta POPB program. The sample comprised 20 athletes aged 14–17 who met the POPB athlete criteria and possessed competitive experience at the school, regional, or national level. The sample included 12 male and 8 female athletes. Subjects were grouped by gender and then proportionally assigned to either the Tabata circuit or fartlek training group using matched-subject ordinal pairing based on baseline VO_2max and reactive agility scores. Each group consisted of 10 athletes, with a distribution of 6 males and 4 females.

Measurements were taken before and after the intervention. Aerobic endurance was measured using the Multistage Fitness Test (MFT/bleep test) on a 20-meter track, while reactive agility was measured using the Squash-Specific Reactive Agility Test (Squash Shadow). In the MFT, participants ran back and forth following a progressively faster beep cadence until they could no longer maintain the pace. The Squash Shadow test involved moving from the "T" position toward four target areas (front right, front left, back right, and back left) in response to randomized visual or auditory stimuli. Both instruments were used for the pre-test and post-test, employing identical measurement procedures.

Prior to the intervention, all participants underwent a pre-test to establish baseline values for $VO_2\text{max}$ and reactive agility. Subsequently, participants engaged in a 16-session training program consisting of either Tabata circuit training or fartlek training. The training program was validated by experts experienced in squash coaching and physical conditioning to ensure the appropriateness of the content, intensity, frequency, and load progression relative to the athletes' characteristics. Upon completion of all intervention sessions, participants underwent a post-test using the same instruments and procedures as the initial assessment.

Data analysis was performed using SPSS version 29 with a significance level of $\alpha = 0.05$. Changes within each group were analyzed using a paired-samples t-test or, if the assumption of normality was not met, the Wilcoxon signed-rank test. Furthermore, differences in improvement between training methods and genders—as well as the interaction between the two—were analyzed using a 2×2 factorial ANOVA, conducted separately for $VO_2\text{max}$ and reactive agility. Improvement scores were calculated as the post-test minus pre-test difference for $VO_2\text{max}$, and the pre-test minus post-test difference for reactive agility. If a significant effect was found, the analysis proceeded with a Tukey test.

RESULT AND DISCUSSION

This study involved squash athletes from POPB DKI Jakarta and aimed to evaluate the effectiveness of Tabata circuit training and fartlek training in improving aerobic endurance and reactive agility, analyzed by gender. The study employed a 2×2 factorial experimental design involving two factors: training method and gender. The training method factor comprised Tabata circuit training and fartlek training, while the gender factor consisted of male and female athletes. The study was conducted over 18 sessions, comprising one pre-test session, 16 training program sessions, and one post-test session. Athletes' aerobic endurance capacity was measured using the Multistage Fitness Test (Bleep Test), while reactive agility was measured using the Squash Shadow Reactive Agility Test (SSRAT). Aerobic endurance was expressed in terms of $VO_2\text{max}$, whereas reactive agility was measured in seconds; in the reactive agility measurement, a shorter completion time indicated better performance.

The study involved 20 squash athletes from POPB DKI Jakarta who met the criteria for the research sample. All subjects were assigned to one of two treatment groups: the Tabata circuit training group or the fartlek training group. Each treatment group included both male and female athletes. The grouping of research subjects based on gender distribution is presented in Table 1.

Table 1. Distribution of Research Subjects Based on Training Method and Gender

Gender	Tabata Circuit	Fartlek	Total
Male	6	6	12
Female	4	4	8
Total	10	10	20

Based on Table 1, the total number of research subjects was 20 athletes, comprising 12 males (60%) and 8 females (40%). The subjects were divided into two training method groups—Circuit Tabata and Fartlek—with 10 athletes in each group. The Circuit Tabata group consisted of 6 male and 4 female athletes. The Fartlek group had the same composition: 6 male and 4 female athletes. Thus, the gender distribution across both training groups was identical, with a

proportion of 60% males and 40% females. This equal distribution indicates a balanced gender composition in both groups, thereby facilitating the analysis of differences in training responses based on method and gender. Furthermore, to illustrate aerobic endurance in relation to the combination of training methods and gender, the measurement results are presented in Figure 2.

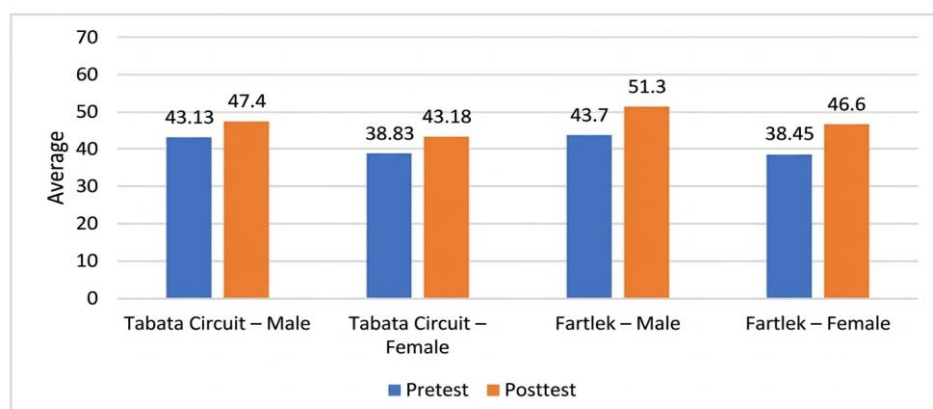


Figure 2. Comparison of aerobic endurance based on training method and gender

Based on Figure 2, there was an improvement in aerobic endurance across all study groups following the intervention. In the male group participating in Circuit Tabata, the mean score rose from 43.13 at the pretest to 47.40 at the posttest, representing a gain of 4.27 or a 9.89% increase. In the female group, the mean score increased from 38.83 to 43.18, a gain of 4.34 or an 11.20% increase. These results indicate that Circuit Tabata improved aerobic endurance in both male and female athletes, with a relatively larger percentage increase observed in the female group.

A more substantial improvement was observed in the group participating in Fartlek training. Male athletes experienced an increase in their mean score from 43.70 at the pretest to 51.30 at the posttest, a gain of 7.60 or a 17.39% increase. Meanwhile, female athletes improved from 38.45 to 46.60, a gain of 8.15 or a 21.19% increase. Based on the magnitude of the gain and the percentage increase, the Fartlek group demonstrated greater changes in aerobic endurance compared to the Circuit Tabata group, for both male and female athletes. The highest percentage increase was found in the female

Fartlek group (21.19%), while the lowest was in the male Circuit Tabata group (9.89%).

Descriptively, these patterns of change indicate that the response in aerobic endurance improvement varies according to the training method and gender. However, these descriptive differences are insufficient to conclude that one training method is statistically more effective than the other. Therefore, interpretations regarding the effects of training methods, gender, and potential interactions between the two require confirmation through inferential statistical analysis.

In addition to changes in aerobic endurance, this study also examined changes in reactive agility, a key component of squash athlete performance. This ability relates to an athlete's capacity to respond rapidly to stimuli while effectively changing direction. Therefore, reactive agility was measured to observe patterns in how athletes' movement response capabilities changed—based on gender—following Circuit Tabata and Fartlek training. The reactive agility measurement results for each study group are presented in Figure 3.

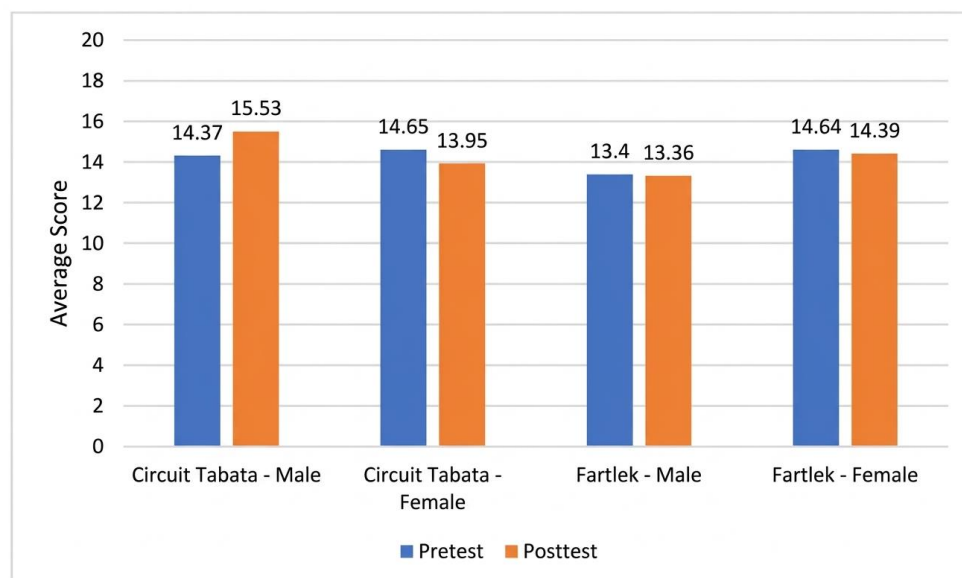


Figure 3. Comparison of reactive agility based on training method and gender

With the Tabata circuit method, the male group saw their score rise from 14.37 in the pre-test to 15.53 in the post-test, an increase of 1.16 points. Conversely, the female group experienced a score decrease from 14.65 to 13.95, a change of -0.70 points. These findings indicate that the response to Tabata circuit training differs by gender, with scores increasing in the male group and decreasing in the female group. With the Fartlek method, changes in scores were relatively smaller. The male group experienced a slight decline from 13.40 to 13.36 (-0.04 points), while the female group also saw a decrease from 14.64 to 14.39 (-0.25 points). Thus, compared to the Tabata circuit method, the Fartlek method showed smaller pre-test to post-test changes in both groups.

Secara deskriptif, peningkatan terbesar terjadi pada Descriptively, the greatest increase occurred in the male group using the Tabata circuit method, while the

greatest decrease occurred in the female group using the same method. These results illustrate differing patterns of performance change based on the combination of training method and gender; these patterns require further confirmation via inferential statistical analysis to determine whether the changes are statistically significant.

As shown in the data visualizations in Figures 2 and 3, there are differing trends regarding improvements in aerobic endurance and reactive agility based on training method and gender. The female group tended to show greater improvements in aerobic endurance, particularly with the Fartlek training method. Meanwhile, the male group tended to show greater improvements in reactive agility, especially with the Tabata circuit training method. To summarize the differences in improvement responses across the two training methods for each variable, a descriptive

statistical analysis covering minimum and maximum values, means, and standard deviations is presented in

the following table.

Table 2. Descriptive Statistical Analysis

Group	Minimum	Maximum	Mean	Std.Deviation
Aerobic Endurance (Tabata Circuit)	2.90	5.70	4.300	0.9522
Aerobic Endurance (Fartlek)	6.30	8.90	7.820	0.8942
Reactive Agility (Tabata Circuit)	0.58	0.78	0.676	0.0681
Reactive Agility (Fartlek)	0.14	0.43	0.288	0.0922

Based on the description above, the fartlek training group demonstrated a superior average improvement in aerobic endurance capacity, whereas the Tabata circuit training group showed a greater average improvement in reactive agility. To assess

changes in aerobic endurance before and after the implementation of Tabata circuit training, a paired-samples t-test was conducted on the pre-test and post-test scores of the Tabata circuit training group. The results of this analysis are presented in Table 3.

Table 3. Paired-Samples t-test Results for Aerobic Endurance in the Circuit Tabata Group

Variable	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Difference	t	df	Sig. (2-tailed)	Interpretation
Aerobic endurance	40.82 $\pm$ 4.51	45.71 $\pm$ 4.27	4.89	-11.56	9	0.000	Significant

Based on the Paired-Samples t-test results, a t-value of -11.56, degrees of freedom (df) of 9, and a two-tailed significance value of 0.00 were obtained. Since the significance value is lower than 0.05 ($0.000 < 0.05$), it can be concluded that there is a significant difference between the pretest and posttest scores for aerobic endurance in the Tabata circuit group. The negative sign on the t-value arises because SPSS calculates the difference based on the pretest-to-posttest sequence; consequently, the difference value is negative when the posttest score is higher than the pretest score. Thus, the

implementation of Tabata circuit training is proven to yield a significant improvement in the athletes' aerobic endurance.

To determine changes in reactive agility before and after the Tabata circuit training, a Paired-Samples t-test was conducted to compare pretest and posttest scores within each study group, thereby identifying whether significant changes occurred after the athletes completed the training program. The results of this test are presented in Table 4.

Table 4. Results of Paired-Samples t-test Reactive agility Tabata Circuit Group

Variable	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Difference in Time	t	df	Sig. (2-tailed)	Interpretation
Reactive agility	14.23 $\pm$ 0.94	13.55 $\pm$ 0.94	0.68	32.53	9	0.000	Significant

The Paired-Samples t-test yielded a t-value of 32.53, degrees of freedom (df) of 9, and a two-tailed significance value of 0.00. Since the significance value was lower than 0.05 ($0.000 < 0.05$), it can be concluded that there was a significant difference between pretest and posttest reactive agility times in the circuit Tabata group. A reduction in time indicates an improvement in reactive agility, as a shorter completion time reflects faster responses and quicker changes of direction. Thus, the implementation of circuit Tabata training was

proven to have a significant effect on improving the athletes' reactive agility.

To identify changes in aerobic endurance before and after the implementation of fartlek training, a Paired-Samples t-test was conducted on the pretest and posttest scores of the fartlek training group to determine whether the training program produced significant changes in the variable under study. The results of this analysis are presented in Table 5.

Table 5. Paired-Samples t-test Results for Aerobic Endurance of the Fartlek Group

Variable	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Difference	t	df	Sig. (2-tailed)	Interpretation
Aerobic endurance	41.66 $\pm$ 4.25	49.42 $\pm$ 3.77	-7.76	-28.96	9	0.000	Significant

Based on the Paired-Samples t-test, the test statistic, degrees of freedom, and a two-tailed significance value of 0.00 were obtained. Since the significance value is less than 0.05, it can be concluded that there is a significant difference between the pretest and posttest aerobic endurance scores in the fartlek

group. The negative sign in the value arises because SPSS calculates the difference by subtracting the posttest score from the pretest score; consequently, a negative figure is produced when the posttest score is higher than the pretest score. Therefore, fartlek training

is proven to have a significant effect on improving the athletes' aerobic endurance.

To determine changes in reactive agility before and after fartlek training, a Paired-Samples t-

test was conducted by comparing the pretest and posttest scores of the group that underwent the training. The results of this analysis are presented in Table 6.

Table 6. Paired-Samples t-test Results for Reactive Agility: Fartlek Group

Variable	Pretest Mean $\pm$ SD	Posttest Mean $\pm$ SD	Mean Difference in Time	t	df	Sig. (2- tailed)	Interpretation
Reactive agility	14.06 $\pm$ 0.88	13.77 $\pm$ 0.91	0.29	9.87	9	0.000	Significant

The Paired-Samples t-test results yielded the test statistic, degrees of freedom, and a two-tailed significance value of 0.00. Since this significance value is less than 0.05, it can be concluded that there is a significant difference between pretest and posttest reactive agility times in the fartlek group. A decrease in time indicates an improvement in reactive agility, as a shorter time reflects a greater ability to respond to stimuli and change direction rapidly. Thus, fartlek training has a significant effect on improving athletes' reactive agility.

To determine the effects of the training method, gender, and the interaction between the training method and gender on improvements in aerobic endurance, a Two-Way ANOVA was conducted. This analysis utilized aerobic endurance gain scores as the dependent variable, with the training method and gender serving as fixed factors. The Two-Way ANOVA results are presented in Table 7.

Table 7. Two-Way ANOVA Results for Aerobic Endurance Gain Scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	43.857	3	14.619	12.655	0.000	0.704
Intercept	795.675	1	795.675	688.524	0.000	0.977
Training Method	39.675	1	39.675	34.332	0.000	0.682
Gender	3.675	1	3.675	3.180	0.094	0.166
Training Method $\times$ Gender	0.507	1	0.507	0.439	0.517	0.027
Error	18.490	16	1.156			
Total	908.022	20				
Corrected Total	62.347	19				

Based on Table 7, the Two-Way ANOVA results indicate that the overall model is significant, with an F-value of $F(3,16) = 12.655$ and a significance value of 0.000 ($p < 0.05$). The Partial Eta Squared value of 0.704 indicates that the model—comprising training method, gender, and the interaction between the two—explains 70.4% of the variation in aerobic endurance gain scores. The training method factor yielded an F-value of $F(1,16) = 34.332$; the analysis showed a significance value of 0.000 and a Partial Eta Squared value of 0.682. These findings demonstrate that the training method significantly influences the improvement of aerobic endurance. The Partial Eta Squared value indicates that the training method has a strong effect on aerobic endurance gain scores. The gender factor yielded an F-value of $F(1,16) = 3.180$, with a significance value of 0.094 ($p > 0.05$) and a Partial Eta Squared value of 0.166. Thus, no significant difference in aerobic endurance improvement was found between male and female athletes.

The analysis of the interaction between training method and gender yielded a significance value of 0.517 and a Partial Eta Squared value of 0.027. Consequently, there is no significant interaction between training method and gender regarding the improvement of aerobic endurance. This means that the effectiveness of the training method in improving aerobic endurance does not differ significantly between male and female athletes. Overall, it can be concluded that the improvement in aerobic endurance is significantly influenced by the training method, but not by gender or the interaction between the training method and gender.

To determine the effects of training method, gender, and the interaction between training method and gender on reactive agility improvement, a Two-Way ANOVA was conducted. The analysis utilized reactive agility gain scores as the dependent variable, with training method and gender as fixed factors. The Two-Way ANOVA results are presented in Table 8.

Table 8. Results of Two-Way ANOVA Gain Reactive Agility Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	0.789 ^a	3	0.263	39.691	0.000	0.881
Intercept	4.497	1	4.497	678.410	0.000	0.977
Training Method	0.779	1	0.779	117.557	0.000	0.880
Gender	0.001	1	0.001	0.079	0.783	0.005
Training Method $\times$	0.010	1	0.010	1.439	0.248	0.083

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Gender						
Error	0.106	16	0.007			
Total	5.392	20				
Corrected Total	0.895	19				

Based on Table 4.13, the Two-Way ANOVA results indicate that the overall model is significant, with an F-value of $F(3,16) = 39.691$ and a significance value of 0.000; the Partial Eta Squared value of 0.881 demonstrates that the training method, gender, and the interaction between the two collectively explain 88.1% of the variation in reactive agility gain scores. The training method factor yielded an F-value of $F(1,16) = 117.557$, with a significance value of 0.000 and a Partial Eta Squared of 0.880. These findings confirm that the training method has a significant effect on the improvement of reactive agility. The Partial Eta Squared value of 0.880 indicates that the training method exerts a very strong effect in differentiating reactive agility gain scores. The gender factor yielded an F-value of $F(1,16) = 0.079$, with a significance value of 0.783 ($p > 0.05$) and a Partial Eta Squared of 0.005; consequently, no significant difference in reactive agility improvement was found between male and female athletes.

The combined effect of the interaction between training method and gender yielded an F-value of $F(1,16) = 1.439$, with a significance value of 0.248 ($p > 0.05$) and a Partial Eta Squared of 0.083. These findings indicate that there is no significant interaction between training method and gender regarding the improvement of reactive agility. Thus, the effect of different training methods on reactive agility improvement tends to be similar or consistent for both male and female athletes. Overall, it can be concluded that the improvement of reactive agility is significantly influenced by the training method, but not significantly influenced by gender or the interaction between the training method and gender.

The research results indicate that both Tabata circuit training and fartlek training improve the aerobic endurance of squash athletes, though fartlek training yielded greater improvements. Analysis further reveals that the training method significantly influenced aerobic endurance improvements, whereas gender—and the interaction between training method and gender—did not show a significant effect. Descriptively, improvements in aerobic endurance via fartlek training were observed in both male and female athletes. These findings suggest that, within the context of this study, the characteristics of the training stimulus played a more significant role in enhancing aerobic endurance than gender. The results also reinforce findings from [16] showing that fartlek training can increase athletes' $VO_2\text{Max}$. However, as that previous study found no significant difference in impact between fartlek and HIIT, the current findings provide additional evidence that responses to training methods can vary depending on sample characteristics, the nature of the training, and the specific sport being studied.

The effectiveness of fartlek training in enhancing aerobic endurance can be attributed to its characteristic combination of varying intensities within a single session. Alternating between jogging, moderate running, fast running, and sprinting requires athletes to perform activities with constantly changing intensities, thereby stimulating the cardiorespiratory system. Fartlek is an effective method for improving $VO_2\text{max}$ due to the intensity variations it provides during training. These findings are supported by [22], who reported that fartlek training can increase maximal oxygen uptake in participants. Thus, the dynamic intensity shifts inherent to fartlek training may explain why this method resulted in greater improvements in aerobic endurance in the present study.

These findings are relevant to the nature of squash, a sport that demands intermittent activity involving fluctuations in intensity. Athletes must execute rapid movements over short durations, followed by recovery periods before engaging in the next rally. Consequently, enhancing aerobic capacity relates not only to the ability to sustain activity over long periods but also to the capacity to maintain performance and recover between bouts of high-intensity activity. [23] also reported that fartlek training improves cardiovascular endurance and agility in handball players. These findings indicate that fartlek training has the potential to be applied to sports that require repeated changes in activity intensity.

Although fartlek training yielded greater improvements, Tabata circuit training also enhanced aerobic endurance. These findings align with [24], which demonstrated that the HIIT method using the Tabata protocol significantly improved $VO_2\text{Max}$ in Central Java handball athletes. [14] also reported that Tabata training could improve physical fitness—including $VO_2\text{Max}$ —in female futsal athletes. Thus, the results do not indicate that Tabata circuit training is ineffective for improving aerobic endurance; rather, they show that fartlek training produced greater improvements given the specific characteristics of the program and the study sample.

The differences in outcomes between Fartlek and Tabata circuit training can be attributed to the stimulus characteristics of each method. Fartlek involves speed variations within a relatively continuous activity, whereas Tabata employs a high-intensity work pattern interspersed with brief recovery periods. Physiologically, high-intensity interval training is known to enhance aerobic capacity; for instance, [25] demonstrated that HIIT can increase cardiac output and $VO_2\text{max}$. Similarly, [26] showed through a systematic review and meta-analysis that HIIT yields benefits for cardiorespiratory fitness. Thus, the increase in $VO_2\text{max}$

observed in the Tabata circuit group in this study has a solid physiological basis, while the greater improvement seen in the Fartlek group likely stems from the suitability of the training stimulus for developing aerobic endurance in the specific type of athletes studied.

Regarding the reactive agility variable, all groups demonstrated improved capabilities following the training program; however, the Tabata circuit yielded greater improvements compared to the fartlek method. Two-Way ANOVA results indicated that the training method had a significant effect on the improvement of reactive agility, whereas gender and the interaction between training method and gender did not show a significant effect. The pattern of greater improvement in the Tabata circuit group was observed in both male and female athletes. These findings suggest that the movement characteristics inherent in the Tabata circuit provide a more suitable stimulus for developing rapid movement capabilities compared to fartlek training.

The benefits of Tabata circuit training for reactive agility can be attributed to the nature of the workout, which involves high-intensity effort, acceleration, deceleration, changes of direction, stabilization, and movement coordination. When Tabata circuit exercises are tailored to the specific needs of squash, athletes receive a stimulus that mirrors the movement demands of a match. Squash players must move from the center of the court to various corners, execute lunges, change direction, maintain balance, and return to a ready position. Consequently, training that repeatedly incorporates acceleration and changes of direction can enhance an athlete's ability to execute rapid movement responses.

However, reactive agility is not solely about the ability to change direction rapidly. [27] explains that reactive agility involves components of perception, anticipation, and decision-making in response to external stimuli. This concept distinguishes reactive agility from change-of-direction speed, as planned changes of direction do not require the athlete to respond to unexpected stimuli. Thus, improvements in reactive agility in this study should be understood as the ability to respond to stimuli through a combination of physical capabilities and decision-making processes.

These findings explain why Tabata circuits can provide a greater stimulus for reactive agility when training incorporates multidirectional movements. Agility training must account for an athlete's ability to change direction and respond to movement demands, rather than focusing solely on linear speed. In the context of this study, the high-intensity, repetitive movements characteristic of Tabata circuits offers athletes enhanced opportunities to develop acceleration, deceleration, body control, and change-of-direction capabilities. Consequently, the resulting adaptations involve not only physical capacity but also the neuromuscular coordination required to execute rapid, controlled movements.

The absence of an observed effect of gender on improvements in aerobic endurance or reactive agility

indicates that, under the conditions of this study, the responses of both groups were relatively similar. These results do not imply that the physiological characteristics of male and female athletes are identical; rather, they suggest that the observed differences in improvement were not substantial enough to yield statistically significant disparities. Furthermore, the lack of interaction between training method and gender indicates that the patterns of improvement—Fartlek training for aerobic endurance and Tabata circuit training for reactive agility—were relatively consistent across both groups. This interpretation should take into account the relatively small sample size and the fact that the group composition was not entirely balanced.

Methodological aspects must also be considered when interpreting the research findings. The reactive agility gain data met the assumptions of normality and homogeneity of variance, lending relatively stronger support to the Two-Way ANOVA results for this variable. Conversely, the variance for aerobic endurance gain was not homogeneous. This indicates that the distribution of VO_2Max improvement responses varied across the groups. Therefore, although the analysis revealed an effect of the training method on aerobic endurance, the superiority of the fartlek method should be interpreted with caution, taking into account the violation of the homogeneity assumption and the limited sample size.

Overall, the research findings demonstrate that training effects are specific to different components of physical fitness. Fartlek training yields greater improvements in aerobic endurance, whereas Tabata circuit training results in greater gains in reactive agility. This pattern can be explained by the stimulus characteristics inherent to each method. Fartlek training emphasizes intensity variations and continuous activity that stimulate the cardiorespiratory system, while Tabata circuit training can be designed to incorporate explosive movements and changes of direction that challenge neuromuscular capabilities. Consequently, these two methods need not be viewed as mutually exclusive alternatives; rather, they can be employed complementarily based on the athlete's specific physical conditioning goals.

In the context of squash athlete training, fartlek can serve as a method to develop aerobic capacity and the ability to sustain activity, whereas Tabata circuits can target high-intensity work capacity, acceleration, deceleration, and changes of direction. The application of both methods must be tailored to the training phase, the athlete's initial condition, training load, and specific match requirements. These research findings also highlight the importance of designing training that aligns with the demands of the game, as improving an athlete's physical condition requires not only aerobic capacity but also the ability to generate rapid movement responses in reaction to changing game situations.

CONCLUSION

Research results indicate that both Tabata circuit training and fartlek training yield significant

improvements in the aerobic endurance and reactive agility of POPB DKI Jakarta squash athletes. Fartlek training demonstrated greater effectiveness in enhancing aerobic endurance, whereas Tabata circuit training proved more effective for improving reactive agility. These findings suggest that the distinct characteristics of each method provide different stimuli for the athletes' physical conditioning components; consequently, the choice of training method should be aligned with the specific physical development goals targeted.

Gender did not significantly influence improvements in either aerobic endurance or reactive agility, nor was there a significant interaction between training method and gender regarding these variables. Thus, the effectiveness patterns—fartlek for aerobic endurance and Tabata circuit for reactive agility—remained relatively consistent across both male and female athletes. Both methods can be employed complementarily within squash training programs, provided that training objectives, periodization phases, baseline conditions, and individual athlete responses are taken into account. However, findings concerning the effectiveness of fartlek training for aerobic endurance require cautious interpretation due to the presence of variance heterogeneity in the aerobic endurance improvement scores.

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