Original Article

Effects of high-intensity interval training using "*Tabata protocol*" on respiratory parameters, special endurance, and 800-m runners' performance

MOHAMED MEGAHED[1] , MAHMOUD AL-TORBANY[2], MOHAMED AL-GHOOL[3], ZAHRAA TAREK[4]

[1]*Department of Track and Field Competitions. Faculty of Physical Education. Arish University. Egypt.*
[2]*Department of Biosciences and Sports Health. Faculty of Physical Education. Arish University. Egypt.*
[3]*Department of Physical Training and Sports Movement Sciences. Faculty of Physical Education. Arish University. Egypt.*
[4]*Computer Science Department. Faculty of Computers and Information. Mansoura University. Egypt.*

ABSTRACT

This study aims to investigate the effects of high-intensity interval training using the Tabata protocol on respiratory parameters, special endurance (cardiorespiratory endurance, anaerobic speed endurance, and strength endurance), and 800-m runners' performance. A total of 20 well-trained males in the 800-m running were assigned into two equal groups, the experimental group, and the control group, and all mentioned variables were measured before and after 8 weeks of the intervention. Respiratory parameters were assessed by using a BTL-08 Spirometer device. Cooper's 12-min running test was used to measure cardiorespiratory endurance. A repeated sprint test (6x30-m) was used to assess anaerobic speed endurance. Tests for strength endurance consisted of repeated squat and sit-ups tests. The main findings indicate that the experimental group showed greater improvement in respiratory parameters, cardiorespiratory endurance, anaerobic speed endurance, strength endurance, and 800-m runners' performance than the control group; where (ES≈ 0.42:0.65, 0.34, 0.31:0.76, 0.48:0.63 and 0.72) (p < .05), respectively. Both groups significantly increased the respiratory parameters, cardiorespiratory endurance, and strength endurance tests from pre- to post-test (p < .05). The experimental group significantly increased the repeated sprint test values from pre to post-test (p = .000, < .05). The control group significantly increased the peak and mean sprinting speed from pre to post-test (p = .039, .005, < .05), while there were no significant differences in the fatigue index (p = .051 > .05). Our results suggest that runners after Tabata protocol interventions can obtain better pulmonary function, endurance, and event time benefits with more efficient performance and time-efficient manner compared with traditional training.

Keywords: Performance analysis of sport, HIIT, Pulmonary function, Cardiorespiratory endurance, Speed endurance, Strength endurance, Middle-distance running.

Cite this article as:
Megahed, M., Al-Torbany, M., Al-Ghool, M., & Tarek, Z. (2023). Effects of high-intensity interval training using "*Tabata protocol*" on respiratory parameters, special endurance, and 800-m runners' performance. *Journal of Human Sport and Exercise, 18*(4), 842-857. https://doi.org/10.14198/jhse.2023.184.09

Corresponding author. *Faculty of Physical Education, Department of Track and Field competitions, Arish University, Egypt.* *https://orcid.org/0000-0003-4355-7653*
E-mail: mohamed.mgahed@phy.aru.edu.eg
Submitted for publication April 04, 2023.
Accepted for publication May 02, 2023.
Published October 01, 2023 *(in press* May 29, 2023).
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202.

doi:10.14198/jhse.2023.184.09

INTRODUCTION

The 800-m running event is one of the middle-distance running events in athletics, that are run at a lower intensity than sprint events but at a higher intensity than long-distance running (Brandon, 1995). Performance in middle-distance running events is faced with the unique challenge being to run at high velocities between 6 and 8 m/s while still maintaining the economic movement as possible (M. A. Thompson, 2017; Williams et al., 1987). The 800-m requires big contributions from both the anaerobic and aerobic energy systems (Støren et al., 2021). Numerous studies have shown that the ratio of aerobic to anaerobic energy used during the 800-m naturally increases with race time, from roughly a 60/40% distribution in runners using less than 120s to nearly a 70/30% distribution using more than 150s (Støren et al., 2021; Nevill et al., 2008; Spencer & Gastin, 2001). Therefore, 800-m runners must have good special endurance which consists of cardiorespiratory endurance, anaerobic speed endurance, and strength endurance to improve runners' performance (P. Thompson, 2009). Currently, there are several ways to improve special endurance, and High-Intensity Interval Training (HIIT) is considered the most effective of them (Munandar et al., 2021).

Tabata protocol, first introduced in 1996 by Izumi Tabata and colleagues, is a type of workout used for high-intensity interval training, which compels you to work out at a very high intensity for a brief period (Tabata et al., 1996). The benefits of the Tabata protocol include enhancing both the aerobic system, which is utilized for endurance training, and the anaerobic system, which is responsible for brief, high-intensity exercises such as sprints (Munandar et al., 2021; Sumpena & Sidik, 2017). Tabata et al., (1996) compared the effects of a mid-intensity protocol with a high-intensity interval training protocol. The findings revealed that the Tabata protocol, lasting 4 minutes, significantly increased both the anaerobic and aerobic capacities of physically active individuals, whereas an hour of moderately intensive exercise only enhanced aerobic capacity (Tabata et al., 1996; Viana et al., 2018). The protocol for this investigation included 7-8 bouts of the 20s on a cycle ergometer at a minimum cadence of 85 rpm, followed by a passive recovery period of 10s (Tabata et al., 1996). Later, the same research team found elevated levels of VO2 recorded in a six-week program that included 6-7 high-intensity bouts (at 170% of the intensity at which VO2max) and short durations of work/rest intervals (20s work/ 10s rest). The results showed that it improved anaerobic capacity by 28% and increased aerobic capacity at levels comparable to mid-intensity continuous exercise. Evidently, the findings from both studies were used to create the Tabata protocol. This protocol consists of eight movements, each movement lasts the 20s of intense exercise followed by 10s of rest, and is repeated until four minutes are finished in total (Viana et al., 2018).

The literature used the Tabata Protocol in the training process of many sports, including taekwondo (Mischenko et al., 2021), badminton players (Nugroho et al., 2021), gymnasts (Gencay et al., 2021), swimmers (Gussakov et al., 2021; Invernizzi et al., 2014) and cyclists (Paton & Hopkins, 2005). When analysing the literature, we found many subsequent studies used the original Tabata protocol (Invernizzi et al., 2014; Paton & Hopkins, 2005; Logan et al., 2016; Scribbans et al., 2014; Olson, 2013). On the other hand, some literature created a great variety of Tabata-like protocols (Viana et al., 2019), where the "*Tabata Protocol*" was modified using other activities (i.e. running, calisthenics, and resistance exercises) (Logan et al., 2016; McRae et al., 2012). Similarly, elite soccer players showed marked improvements in their aerobic and anaerobic capacities after undergoing a sprint training program lasting 9 weeks and consisting of 4 repetitions of 30s high-intensity runs (Helgerud et al., 2007). A. E. Tjnna et al. found that nonathletes who performed a single, intense, 4-minute bout on treadmills at 90% of their heart rate peak, three times a week for 10 weeks, saw a 10% improvement in their cardiorespiratory fitness without experiencing any negative side effects (Tjønna et al., 2013). Several studies of literature have compared the effect of endurance exercise and high-intensity interval training, and all reports demonstrated an increase in cardiorespiratory fitness in favour of high-intensity interval training groups (Tabata et al., 1996; Trapp et al., 2008; Helgerud et al., 2007). The bulk of research on the Tabata protocol's impacts focuses on several variables related to the cardiorespiratory and/or muscular systems. To our knowledge, we did not find any studies that dealt with the effect of the Tabata protocol on special endurance for 800m runners. Additionally, there is a dearth of data on pulmonary function, which controls the pace at which oxygen is transferred from the lungs to the bloodstream and is responsible for oxygen transport. Accordingly, this study's objective was to look into the influences of HIIT using Tabata protocol on respiratory parameters, special endurance, and 800-m runners' performance.

MATERIAL AND METHODS

Participants

Participants comprised 20 male runners selected from the track and field competitions department at the Physical Education Faculty, who excelled in middle-distance running competitions. They were well-trained on the 800m running before starting the study. Then they were assigned into two equal groups: an experimental group (EG) and a control group (CG). All of the following conditions were fulfilled for inclusion: all samples, (i) were enthusiastic about the opportunity and stuck with the training; (ii) had no pre-existing illnesses or musculoskeletal problems that might compromise their performance; (iii) They have the ability and skill to perform the 800m race well; and (iv) Their records do not exceed 150 s. The participants were told about the study's objectives, and procedures, and provided their voluntary assent, also the Faculty of Physical Education. The Ethics Committee of Mansoura University approved this study (code:22022012018). The participants' equivalence and homogeneity as described in Table 1.

Table 1. General characteristics of participants (mean ± SD) and *p*-value between both groups.

	The experimental group (n = 10)		**Control group (n = 10)**		**T**	***p***	**Sig**
	Mean ± SD	CV	Mean ± SD	CV			
Height (cm)	174.7 ± 4.67	2.67	177.8 ± 3.99	2.25	-1.596	.228	NS
Body mass (kg)	63.8 ± 4.83	7.56	65 ± 3.80	5.85	-0.618	.544	NS
Age (year)	21.5 ± 0.53	2.45	21.8 ± 0.632	2.90	-1.152	.265	NS

Note. n = sample size; p = p-value; CV = Coefficient of Variation; NS = No statistically difference between groups.

Study design

Researchers conducted a nonrandomized trial study on two groups: an experimental group and a control group using a pre-and post-test. This paper was divided into four phases: (i) Phase 1 was a preparatory study that took place over the course of one week and was used to familiarize the subjects with the assessment methods, exercises, and Tabata routine. Additionally, during this phase, the reliability of the tests used in the study, equipment, and gadgets was verified. During the familiarization meetings, demographic information was gathered; (ii) Phase 2 included a week of pre-testing; (iii) Phase 3, which involved individuals completing eight weeks of training; and (iv) Phase 4, which included a week of post-testing. The pre-test and post-test procedures were the same protocol.

Testing procedures

The participants were evaluated at two places (the laboratory and the field) with 24 h intervals, respectively. The laboratory measurements were conducted on the same day, while field tests were performed in three separate sessions at 48 h intervals. All tests lasted for one week and were performed pre and post- 8 weeks of training. Tests were performed during similar hours before and after the intervention. The subjects were asked not to exercise for the 48 hours before the testing and to avoid caffeinated drinks. Also, avoid eating large meals for a few hours before the tests.

Laboratory measurements

The participants were instructed to present themselves at 9:00 am to perform measurements. The respiratory parameters [Vital Capacity (VC), Forced Vital Capacity (FVC), Forced Expiratory Volume In 1s (FEV1), Peak Expiratory Flow (PEF), and Tiffeneau-Pinelli Index (FEV1/VC)] were measured with a BTL-08 Spirometer device. Spirometry measurements were made in a relaxed seated position with the subjects' noses closed with a latch. The units were recorded in litres. Each measurement was made twice, and the device's best value was recorded (Gencay et al., 2021; Yapici-Oksuzoglu, 2020; Baker et al., 2022).

Field tests

Three separate sessions with 48-hour intervals were used to assess the subjects. In the first session, was carried Cooper's 12 min running test. In the second session, the following three assessments were carried out: The repeated sprint test (6 x 30-m) and the repeated squat and sit-ups tests during 60 s. A 45-min interval between tests was adopted. In the third session, the 800-m runners' performance test. Before the assessments began, a 10-minute warm-up with low-intensity workouts including jogging and stretching was carried out. The tests had been carried out as follows:

Cardiorespiratory endurance was evaluated using Cooper's 12-minute running test. The subjects were asked to complete as many laps as they could on a normal 400-meter track during the 12-minute test time. The total distance run was recorded by measures obtained from the activity band. Each subject performed two trials that were separated by 24 hours of rest. This test is considered a valid and reliable field-based(Kumar & Zemková, 2022; Cooper, 1968; Lu et al., 2021).

The repeated sprint test (6 x 30-m) was used to assess anaerobic Speed Endurance. The repeated sprint test comprised 6 repeated maximal intensity sprints of 30-m. From a standing stance behind the starting line, participants were instructed to complete six 30-meter sprints at maximum pace. After each sprint, each participant returns to the opposite end to prepare for the next sprint, which will be raced in the opposite direction as the previous sprint. The second 30-meter sprint begins 20 seconds after the first. This cycle will continue until the completion of six sprints. Time is recorded to the nearest 0.01s. Three scores were calculated; average 6 sprints time, peak sprint speed time, total sprint time (for the 6 sprints), and fatigue index, the last one was computed as the percentage decrement: 100 – (total time / ideal time × 100); where the ideal time equals 6× best time. This test is considered valid and reliable field-based. (Pyne et al., 2008; Hermassi et al., 2017).

Repeated squat and sit-ups tests are used to measure muscular endurance. The test of repeated squats was assessed to evaluate lower-body strength endurance. While the sit-up test evaluated the hip flexors endurance and the abdominal muscles. The subjects were told to complete as many repetitions as possible in 1-minute. Only reps performed using the right technique were recorded. These tests are considered valid and reliable field-based. (Vaara et al., 2012; Alaranta et al., 1994; Ryman Augustsson et al., 2009).

The 800-m runners' performance was evaluated using a manual stopwatch (Casio, Japan) that measures to the nearest 0.01s, according to the IAAF rules(IAAF Rules, 2020).

Training intervention

The training program was started on 21/01/2023. During the eight weeks intervention, the experimental group completed 24 sessions, i.e., 3 sessions/ week, each lasting from 70 to 75 min. A minimum of 48 hours of inter-session recovery was allowed between running sessions. The subjects warmed up for 15 minutes with jogging, flexibility, and stretching exercises before each session (Megahed & Tarek, 2023b). Then, HIIT using the Tabata protocol was carried out lasting from 10 to 20 min. Following that, subjects trained for 30 to 35 minutes in 800-m skills, and the last ten minutes of the session were spent cooling down (Megahed & Tarek, 2023a). The control group kept up their normal training routine during the same time.

Table 2. Details of Tabata Protocol intervention.

Stations		**Station 1**	**Station 2**	**Station 3**	**Station 4**
Movements	**1**	High knees sprint	Squat Step-Ups	High knees sprint	Jump squats
	2	sprint	Toe-Tap Hops	Sand sprint	Split Jacks
	3	Butt kicks sprint	Jump squats		Burpees W/tuck
	4	sprint	Burpees	High knees sprint	Jumping lunges
	5	High knees sprint	Sprawls	Sand sprint	Plank Leg Raises
	6	sprint	lunges		Climbers
	7	Butt kicks sprint	Jumping jacks	Butt kicks sprint	Sprawls
	8	sprint	Tuck Jumps	Sand sprint	Burpees with Rotations

8-Week Tabata Protocol Program								
Weeks	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Stations	1-2	1-3	1-2-3	1-4-3		1-2	1-3	1-2-3-4
Station duration					4 min			
(Workload – Recovery) time					(20 sec - 10 sec)			
Sets per station			1			2		1
Sets duration	4 x 2 = 8 minutes			4 x 3 = 12 minutes			4 x 4 = 16 minutes	
Rest between sets					2 minutes			

Tabata protocol

The experimental group performed Tabata protocol stations, where each station consisted of eight movements, which lasted for 4min. The Tabata protocol consisting of eight movements was applied in the form of the 20s working and 10s active recovery interval method. They performed Tabata exercises for each training session in 2 sets during the 1st and 2nd weeks, 3 sets during the 3rd to 5th weeks, and four sets during the 6th to 8th weeks. The rest interval was 2 minutes between sets. (See Table 2)

Statistical analysis

The data distribution's normalcy was checked using the Shapiro-Wilk test, and all variables displayed a normal distribution. Means and standard deviations (SD) were used to display the descriptive statistics. To compare differences between both groups at baseline and post-tests, an independent t-test was carried out. We used paired sample t-test to identify significant differences within the groups between baseline and post-tests. The change ratio (Δ%) was utilized to verify differences within the groups between baseline and post-tests. The effect size (ES) was assessed using partial eta-squared (η^2) values, as a small from 0.20 to 0.49, moderate from 0.50 to 0.79, or large effect >0.80. The IBM SPSS Statistics version 26.0 program was used to analyse all of the data. The level of significance used in the statistical analyses was .05.

RESULTS

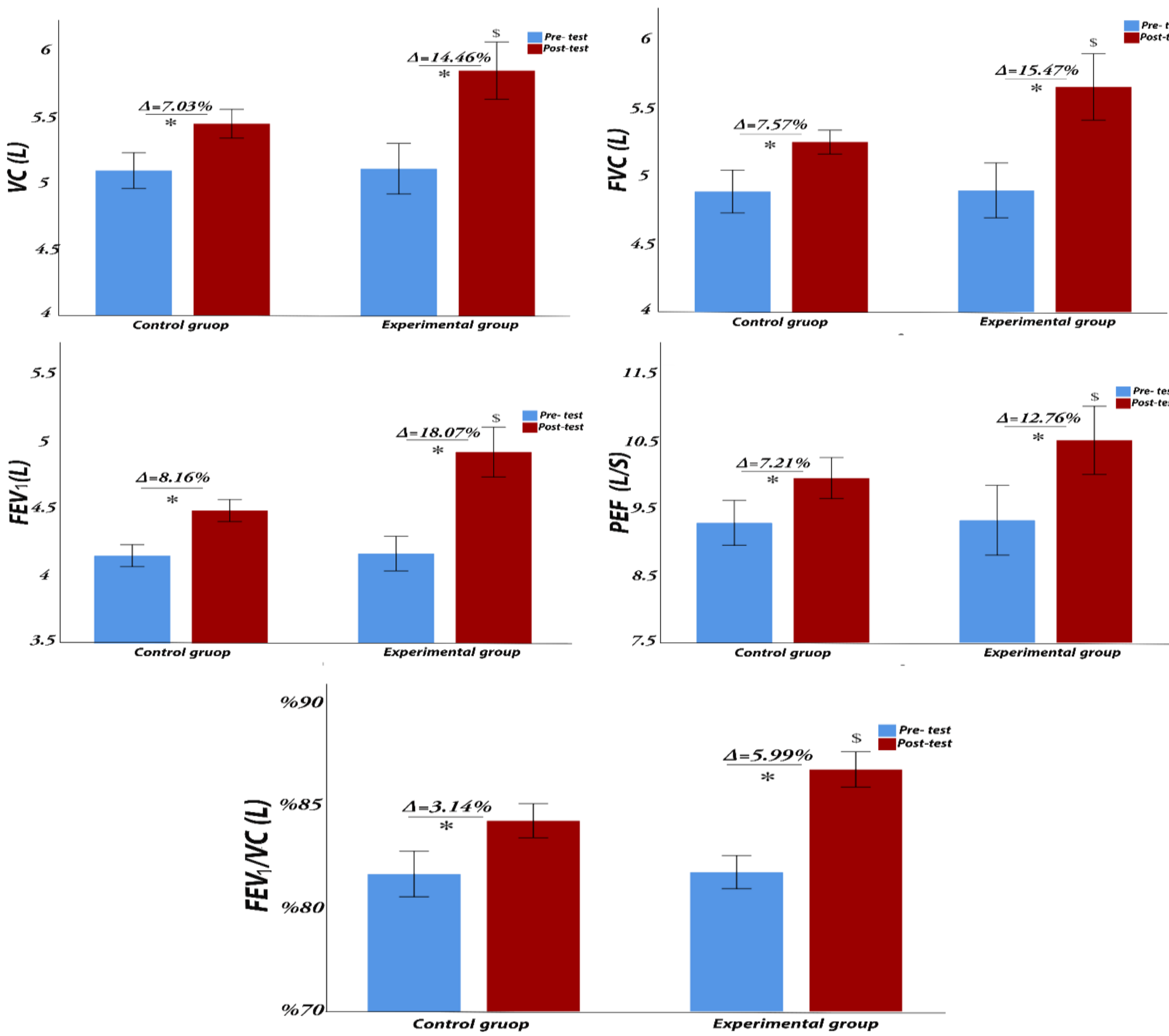
Baseline data

There were no statistically significant baseline differences in the variables measured between both groups at the pre-test, where [t-test = .153 to 1.040, p = .312 to .880 (p > .05)]. All participants completed an eight-week training period with an average training attendance of 100%.

The effects of training intervention after eight-week

The effect on respiratory parameters

A significant difference in respiratory parameters measurements was observed in favour of the experimental group compared to the control group, where [CV, T-test = 3.738, η^2 = 0.44, p = .002; FVC, t-test = 3.537, η^2 = 0.53, p = .004; FEV1, t-test = 4.839, η^2 = 0.65, p = .000; FEV1 / VC, t-test = 4.737, η^2 = 0.55, p = .000; PEF, t-test = 3.626, η^2 = 0.42, p = .002; (p > .05)]. (See Figure 1).



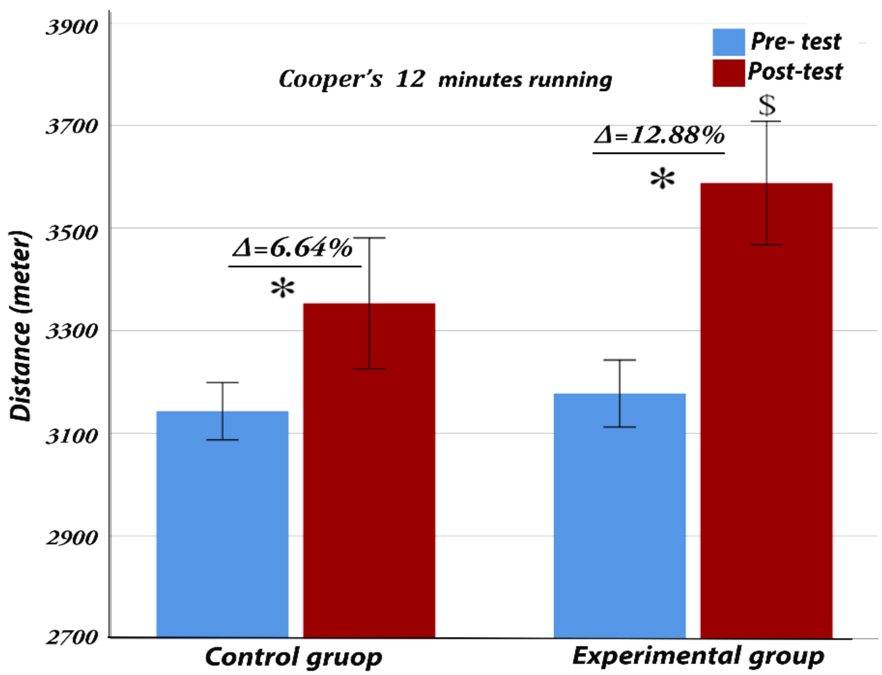
Note. $ Significant difference from the control group. ∗ Significant difference from the pre-test. Δ Change ratio % from the pre-test. *p*-value set at .05.

Figure 1 The effects of training intervention on respiratory parameters (VC, FVC, FEV1, PEF, and FEV1/VC).

Moreover, both groups significantly increased respiratory parameters (VC, FVC, FEV1, PEF, and FEV1/VC) from pre [(CG 5.09 ± 0.188 l, 4.88 ± 0.218 l, 4.15 ± 0.115 l, 9.28 ± 0.464 l/s, and 81.58 ± 1.521%); (EG 5.11 ± 0.267 l, 4.89 ± 0.281 l, 4.17 ± 0.181 l, 9.31 ± 0.72 l/s, and 81.67 ± 1.105%), respectively] to post [(CG 5.45 ± 0.152 l, 5.25 ± 0.122 l, 4.49 ± 0.115 l, 9.94 ± 0.425 l/s, and 84.58 ± 1.131%; ∆% = 7.03%, 7.57%, 8.16%, 7.21%, and 3.14%; η^2 = 0.77, 0.73, 0.79, 0.78 and .71; *p* = .000 to .001 <.05); (EG 5.85 ± 0.302 l, 5.65 ± 0.339 l, 4.93 ± 0.26 l, 10.5 ± 0.704 l/s, and 86.56 ± 1.175%; ∆% = 14.46%, 15.47%, 18.07%, 12.76%, and 5.99%; η^2 = 0.99, 0.97, 0.99, 0.96 and 0.99), respectively; *p* = .000 < .05]. (See Figure 1).

The effect on cardiorespiratory endurance

There was a significant difference was observed for Cooper's 12 minutes running test favouring the experimental group compared to the control group, where (t-test = 3.027, η2 = 0.34, *p* = .007). Also, both groups significantly increased Cooper's 12 minutes run from pre [CG 3143.3 ± 78 m; EG 3177.7 ± 91.24 m) to post [(CG 3353.4 ± 178.53 m; ∆% = 6.64%; η^2 = 0.75, *p* = .001 <.05); (EG 3588.1 ± 168.02 m, ∆% = 12.88%; η^2 = 0.95, *p* = .000 <.05)]. (See Figure 2).



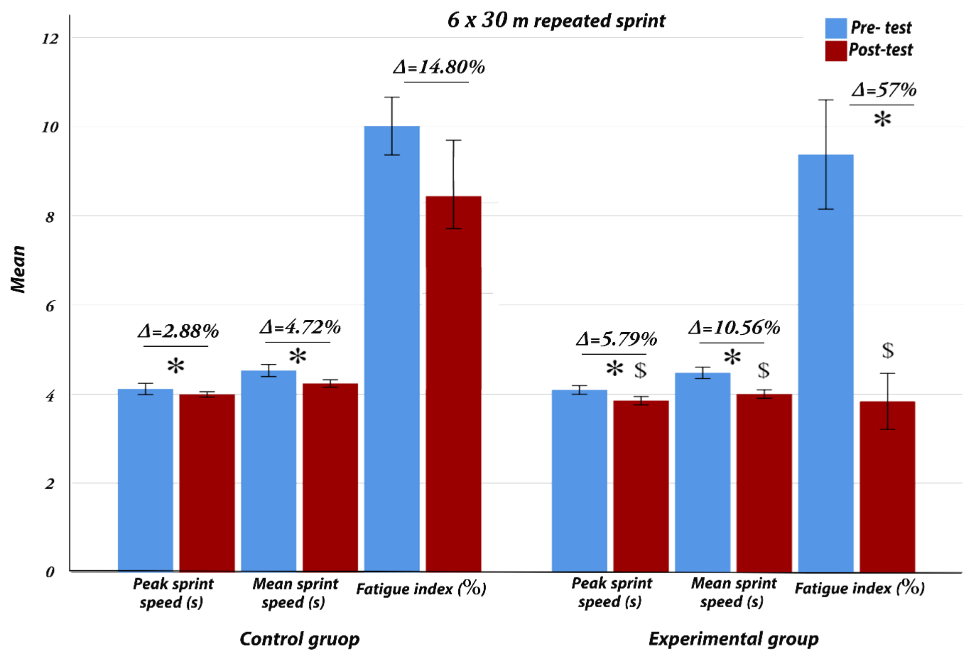
Note. $ Significant difference from the control group. ∗ Significant difference from the pre-test. ∆ Change ratio % from the pre-test. p-value set at .05.

Figure 2 The effects of training intervention on Cooper's 12 minutes running.

The effect on anaerobic speed endurance

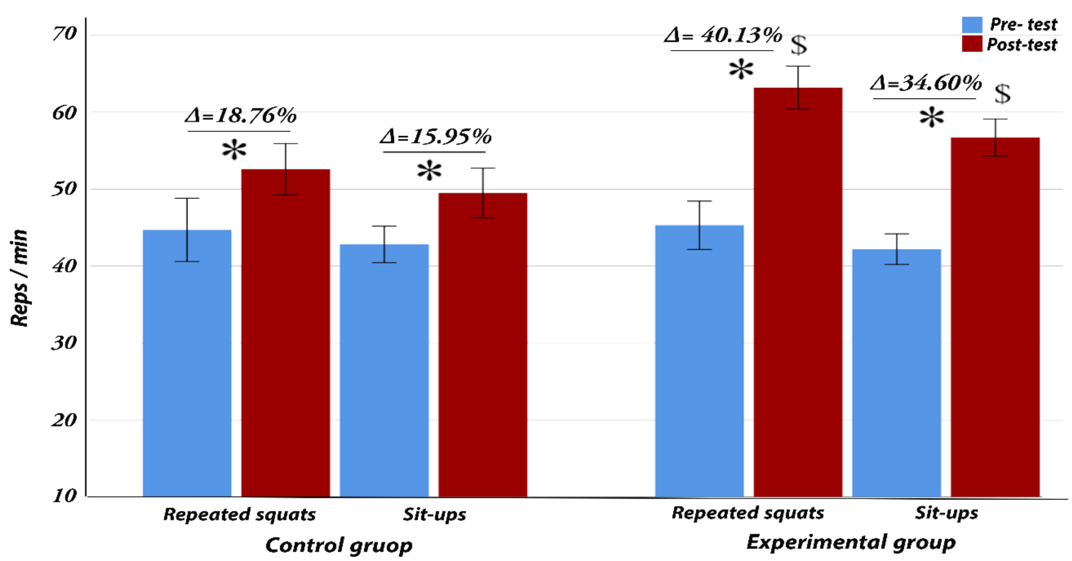
The 6 x 30-m repeated sprint test results showed that there were significant differences in the peak, and mean sprinting speed and the fatigue index favouring the experimental group compared to the control group. Where the peak sprinting speed (t-test = 2.782, η^2 = 0.31, *p* = .012 < .05); The mean sprinting speed (t-test = 5.482, η^2 = 0.63, *p* = .000 < .05); The fatigue index (t-test = 7.469, η^2 = 0.76, *p* = .000 < .05). The experimental group significantly increased the peak, and mean sprinting speed and the fatigue index from pre (4.094 ± 0.137 s, 4.478 ± 0.179 s, 9.375 ± 1.713%), respectively to post (3.855 ± 0.132 s 4.003 ± 0.132 s, 3.838 ± 1.713 %; ∆% = 5.79%, 10.56%, and 57%; η^2 = 0.80, 0.93, and 0.83; respectively; (*p* = .000 < .05). The control group significantly increased the peak and mean sprinting speed from pre (4.118 ± 0.177 s, 4.53

± 0.19 s), respectively to post (3.994 ± 0.087 s 4.312 ± 0.12 s; Δ% = 2.88%, 4.72%; η^2 = 0.39, .60; p = .039, .005 (p < .05); respectively). While the control group had no significant differences in the fatigue index from pre to post-test (p = .051 > .05). (See Figure 3).



Note. $ Significant difference from the control group. ⁎ Significant difference from pre-test. Δ Change ratio % from pre-test. p-value set at .05.

Figure 3 The effects of training intervention on peak and mean sprinting speed (6 x 30-m) and the fatigue index during the repeated sprint test.



Note. $ Significant difference from the control group. ⁎ Significant difference from pre-test. Δ Change ratio % from pre-test. p-value set at .05.

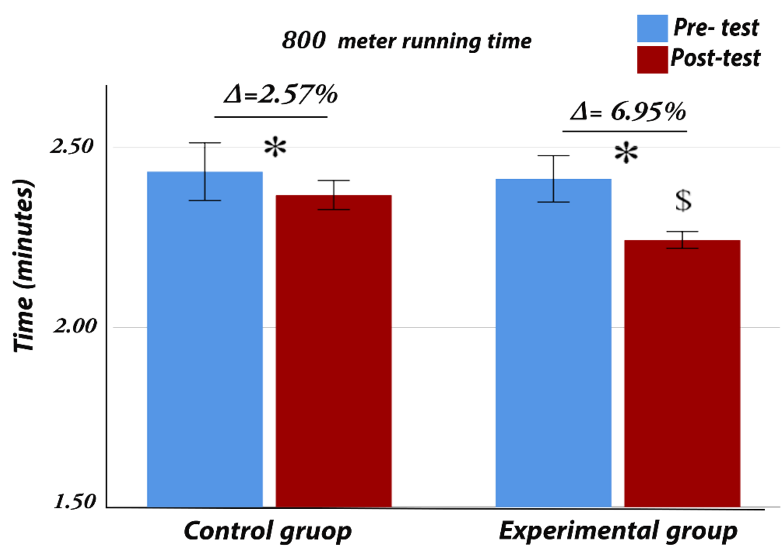
Figure 4 The effects of training intervention on repeated squats and sit-ups.

The effect on strength endurance

There were significant differences were observed for repeated squats and sit-ups tests favouring the experimental group compared to the control group, where the repeated squats test (t-test = 5.519, $\eta^2 = 0.63$, *p* = .000 < .05); The sit-ups test (t-test = 4.049, $\eta^2 = 0.48$, *p* = .001 < .05). Both groups significantly increased the repeated squats and sit-ups from pre [(CG 44.7 ± 5.736 reps/min, 42.8 ± 3.327 reps/min); (EG 45.3 ± 4.398 reps/min, 42.2 ± 2.781 reps/min), respectively] to post [(CG 52.6 ± 4.67 reps/min, 49.5 ± 4.503 reps/min; ∆% = 18.76% and 15.95%; $\eta^2 = 0.79$ and 0.76; respectively; *p* = .000 < .05); (EG 63.2 ± 3.882 reps/min, 56.7 ± 3.368 reps/min; ∆% = 40.13% and 34.6%; $\eta^2 = 0.98$ and 0.97; respectively; *p* = .000 < .05)]. (See Figure 4).

The effect on 800-m runners' performance time

There was a significant difference was observed for the 800-m time favouring the experimental group compared to the control group, where (t-test = 6.071, $\eta^2 = 0.72$, *p* = .000). In addition, both groups significantly increased 800-m time from pre [CG 2.433 ± 0.112 min; EG 2.413 ± 0.09 min) to post [(CG 2.368 ± 0.0564 min; ∆% = 2.57%; $\eta^2 = 0.53$, *p* = .011 < .05); (EG 2.243 ± 0.033 min; ∆% = 6.95%; $\eta^2 = 0.83$, *p* = .000 < .05)]. (See Figure 5).



Note. $ Significant difference from the control group. ⁎ Significant difference from pre-test. ∆ Change ratio % from pre-test. p-value set at .05.

Figure 5 The effects of training intervention on 800-m running time.

DISCUSSION

The main findings indicate that after eight-week, the experimental group showed greater improvement in respiratory parameters, cardiorespiratory endurance, anaerobic speed endurance, strength endurance and 800-m runners' performance than the control group. HIIT using the Tabata protocol seem to be necessary to provoke additional improves endurance and respiratory parameters due to the high-intensity movements applied in the form of the 20s working and 10s recovery interval, as it increased all parameters. Regarding the literature on respiratory parameters, one of the most notable physiological adaptations brought on by HIIT is the rise in tidal volume accompanied by a decrease in respiratory frequency. And this is a better indicator of increased pulmonary function, which leads to respiratory efficiency (Batra & Zatoń, 2016; Gross, 1989; McArdle WD, Katch FI, 1994). This study showed that HIIT using Tabata protocol had a large effect (ES≈ 0.96:0.99) upon pulmonary function by the increased VC(14.46%), FVC(15.47%), FEV1(18.07%), PEF(12.76%), FEV1/VC(5.99%), which was significantly higher than the improvement seen in the control group by 7.03%, 7.57%, 8.16%, 7.21% and 3.14% and 6%, respectively, as shown in Figure1, resulting in moderate effect size in performance between both groups (ES≈ 0.42:0.65). Throughout the previous works concerning the effects of HIIT on respiratory parameters, there is a paucity of pulmonary function literature. We came across a study by Dunham and Harms, which reported an increase in pulmonary function following Interval training over the course of four weeks versus a traditional endurance training program of the same length (Dunham & Harms, 2012). Gencay Cüce et al. observed a significant difference in respiratory functions (FVC and FEV1) of aerobic gymnasts after 6 weeks of using plyometric and Tabata training. Tabata group showed statistically significant improvements in respiratory function indicators (Gencay et al., 2021). These findings are consistent with the data we discovered after eight weeks, which may help to explain why the experimental group increased respiratory functions. The 800m running requires significant contributions from both aerobic and anaerobic energy (Støren et al., 2021). High-intensity repetitive activities during training cause an increase in the pulmonary function of athletes. The pulmonary function of subjects was increased during high-intensity repetitive workouts. Our results support the notion that anaerobic stimuli have a greater impact on increasing airflow speed than aerobic stimuli do on increasing vital capacity (Yapici-Oksuzoglu, 2020). It is believed that the changes in respiratory functions following the Tabata protocol in the current research are caused by the intense use of repetitive, high-intensity motions. Therefore, it can be concluded that interval training encourages adaptive changes in skeletal muscle oxygen extraction based on the changes in respiratory functions (Batra & Zatoń, 2016).

In terms of endurance, our study suggests that HIIT training using the Tabata protocol interventions lasting shorter intervals has slightly better training effects about cardiorespiratory endurance compared with traditional training. Where the HIIT using the Tabata protocol increased cardiorespiratory endurance by Cooper's 12 minutes running test (12.88%), which outweighed the control group that improved by 6.64%. However, there was a small effect size between both groups (ES≈.34). Our findings are consistent with studies concentrating on high-intensity interval training to improve cardiorespiratory fitness. For example, some literature indicated that endurance and VO2 max were enhanced by high-intensity interval training after a 6-week training for recreational runners (Tong et al., 2016) and eight weeks for taekwondo(Batra & Zatoń, 2016) and hockey players (Sarkar et al., 2019). Additionally, Usha Nair and Geethu Mohan found that after six weeks, swimmers' VO2 max significantly increased by 10.50% (Usha S Nair, 2017). The increase in cardiorespiratory endurance is associated with improved oxygen uptake in the lungs and heart. VO2 max is influenced by some factors, such as the cardiac output, the lungs' capacity to diffuse oxygen, the blood's capacity to transfer oxygen, the muscles' capillary density, and the mass of mitochondria (Kind et al., 2019). The workouts, work periods, and rest periods were chosen for the intervention have an impact on these factors because they support peripheral adaptations that increase the ability to extract and use available oxygen (Foster et al., 2015; Sarkar et al., 2019), resulting in increased cardiorespiratory endurance. On the other hand, In the previous studies that have been done, it has been assumed that the increased muscular stimulus will cause intracellular signalling sequences, which will then lead to an increase in the 5-AMP-activated protein kinase (AMPK) activity in muscle cells, and an excess in the mRNA and protein expression of the mitochondrial oxygenation enzyme, and a raise in peroxisome proliferator activated receptorcoactivator-1α (PGC-1α) mRNA and protein, and eventually an enhancement in aerobic capacity (Atakan et al., 2022)(Terada et al., 2005). According to other literature, regular training that focuses on the anaerobic glycolytic system boosts oxidative enzyme activities like cytochrome oxidase, β-Hydroxyacyl-CoA dehydrogenase (β-HAD), and citrate synthase (CS), in addition to promoting numerous structural, molecular, and neuronal adaptations, all these changes ultimately lead to an increase in VO2max (Burgomaster et al., 2008; Gibala & McGee, 2008).

As to anaerobic speed endurance, we found a large effect (ES≈.80:.93) during the repeated sprint test (6 x 30-m) by the improved peak sprinting speed (5.79%), mean sprinting speed (10.56%) and the fatigue index (57%). This was greater than the control group improved by 2.88%, 4.72% and 14.80%, respectively, (see Figure 3) leading to a medium effect size between both groups [ES≈ 0.63 (mean sprinting speed) and 0.76 (the fatigue index)]. But there is a small effect size between both groups (ES≈ 0.31) at peak sprinting speed. It was worth noting that the fatigue index had significant differences in the experimental group from pre to post-test and there were no significant differences in the control group. In this context, The literature investigating the effects of high-intensity exercise on speed endurance showed greater improvement compared with speed training (Mohr et al., 2007), endurance training (Iaia et al., 2008) and short-term tapering (Thomassen et al., 2010). Unlike our findings, there is a study by Naimo et al. where university students participated in HIIT training for four weeks (Naimo et al., 2014). In another study by Astorino et al., twenty women and twenty men participated in HIIT training on a short-term basis (Astorino et al., 2012) and there was not a significant in the fatigue index in these two studies. Our result was aligned with A., Cigerci & Harun Genc, who found a significant increase in fatigue index value after HIIT training applied to university students for nine weeks compared to the traditional training in which there were no differences (Cigerci & Genc, 2020). It also agreed with Karahan's study, which reported that eight weeks of skill-based maximal HIIT such as Tabata for female futsal players improved the fatigue index (Karahan, 2012). Through training, longer physiological stimulants can hasten lactic acid transfer and removal, delaying the start of fatigue. To promote anaerobic speed endurance during rigorous intermittent exercise for 800-meter runners, HIIT using the Tabata technique appears to be a very effective training regimen.

The present study showed that HIIT using Tabata protocol had a large effect on strength endurance by the increased repeated squats test (40.13%) and sit-ups test (34.6%), which was greater than the control group that improved by 18.76% and 15.95%, respectively, (see Figure 4). We only came across studies intended for HIIT and their impact on strength endurance when we examined the literature on studies about strength endurance. Thomas Bossmann et al. observed that HIIT sessions lead to significant improvement in strength endurance for physical education students by the increased sit-ups test (Bossmann et al., 2023). The 800-m runners' performance time increased significantly in experimental group (6.95%), which was greater than the control group improved by 2.57% (see Figure 5) leading to a medium effect size between both groups (ES≈ 0.72). Our findings are consistent with study of Driller et al., which reported increase the 2000-m rowing performance time 8.2s following a period of high-intensity interval training (Driller et al., 2009), and improved anaerobic and aerobic endurance, in our opinion, is what caused this increase.

CONCLUSION

This paper attempted to reveal the impact of HIIT using the Tabata protocol on respiratory parameters, endurance, and performance of 800-meter runners. HIIT using the Tabata protocol was applied three days a week for 8 weeks, and it resulted in the development of the respiratory parameters (vital capacity, forced vital capacity, peak expiratory flow, forced expiratory volume in 1s, and Tiffeneau-Pinelli index). Also, there was an improvement in special endurance (cardiorespiratory endurance, anaerobic speed endurance and strength endurance), and performance of 800-meter runners. These improvements are due to the greater exercise intensity during the Tabata protocol intervention compared to conventional training. So, runners can obtain better pulmonary function, endurance, and event time benefits with more efficient performance and time-efficient manner. Accordingly, we recommend coaches of middle-distance runners consider HIIT using the Tabata protocol because it may lead to improvements in their athletes' cardiorespiratory endurance, anaerobic speed endurance, and strength endurance, freeing up more time to focus on other aspects of practice.

AUTHOR CONTRIBUTIONS

Conception and design study: Megahed, M., & Tarek, Z. Data collection and literature search: Megahed, M., Al-Torbany, M., & Al-Ghool, M. Statistical analysis and results interpretation: Megahed, M., & Tarek, Z. Manuscript preparation: all authors. All authors approved the published version of the manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

ACKNOWLEDGMENTS

The authors would like to appreciate everyone who took part in the study.

REFERENCES

Alaranta, H., Hurri, H., Heliövaara, M., Soukka, A., & Harju, R. (1994). Non-dynamometric trunk performance tests: reliability and normative data. Scandinavian Journal of Rehabilitation Medicine, 26(4), 211-215.

Astorino, T. A., Allen, R. P., Roberson, D. W., & Jurancich, M. (2012). Effect of high-intensity interval training on cardiovascular function, VO2max, and muscular force. The Journal of Strength & Conditioning Research, 26(1), 138-145. https://doi.org/10.1519/JSC.0b013e318218dd77

Atakan, M. M., Guzel, Y., Shrestha, N., Kosar, S. N., Grgic, J., Astorino, T. A., Turnagol, H. H., & Pedisic, Z. (2022). Effects of high-intensity interval training (HIIT) and sprint interval training (SIT) on fat oxidation during exercise: a systematic review and meta-analysis. British Journal of Sports Medicine, 56(17), 988-996. https://doi.org/10.1136/bjsports-2021-105181

Baker, J. S., Bal, B. S., Supriya, R., Kaur, P., & Paul, M. (2022). Effects of Anulom Vilom Pranayama and Rope Mallakhamb Training on respiratory parameters in young females with athletic backgrounds. Pedagogy of Physical Culture and Sports, 26(3), 199-209. https://doi.org/10.15561/26649837.2022.0308

Batra, A., & Zatoń, M. (2016). Effect of high intensity interval training on cardiopulmonar function in Taekwon-do ITF athletes. J Comb Sports Mart Arts, 7, 73-79. https://doi.org/10.5604/20815735.1225636

Bossmann, T., Bickmeyer, M., Woll, A., & Wagner, I. (2023). Effects of whole-body high-intensity interval training and different running-based high-intensity interval training protocols on aerobic capacity and strength endurance in young physical education students. Journal of Physical Education and Sport, 23(2), 360.

Brandon, L. J. (1995). Physiological factors associated with middle distance running performance. Sports Medicine, 19(4), 268-277. https://doi.org/10.2165/00007256-199519040-00004

Burgomaster, K. A., Howarth, K. R., Phillips, S. M., Rakobowchuk, M., MacDonald, M. J., McGee, S. L., & Gibala, M. J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. The Journal of Physiology, 586(1), 151-160. https://doi.org/10.1113/jphysiol.2007.142109

Cigerci, A. E., & Genc, H. (2020). The Investigation of the Physical and Performance Effects of High-Intensity Interval Training (HITT) on Sedentary University Students. International Education Studies, 13(7), 57-64. https://doi.org/10.5539/ies.v13n7p57

Cooper, K. H. (1968). A means of assessing maximal oxygen intake: correlation between field and treadmill testing. Jama, 203(3), 201-204. https://doi.org/10.1001/jama.1968.03140030033008

Driller, M. W., Fell, J. W., Gregory, J. R., Shing, C. M., & Williams, A. D. (2009). The effects of high-intensity interval training in well-trained rowers. International Journal of Sports Physiology and Performance, 4(1), 110-121. https://doi.org/10.1123/ijspp.4.1.110

Dunham, C., & Harms, C. A. (2012). Effects of high-intensity interval training on pulmonary function. European Journal of Applied Physiology, 112, 3061-3068. https://doi.org/10.1007/s00421-011-2285-5

Foster, C., Farland, C. V, Guidotti, F., Harbin, M., Roberts, B., Schuette, J., Tuuri, A., Doberstein, S. T., & Porcari, J. P. (2015). The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. Journal of Sports Science & Medicine, 14(4), 747. https://doi.org/10.1249/01.mss.0000476771.63318.52

Gencay, C., Yapici, A., & Atabaş, E. G. (2021). The Effect Of Plyometric And Tabata Training On Jump Performance, Respiratory Function Parameters On Aerobic Gymnasts. Turkish Journal of Sport and Exercise, 23(3), 374-383.

Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain? Exercise and Sport Sciences Reviews, 36(2), 58-63. https://doi.org/10.1097/JES.0b013e318168ec1f

Gross, M. T. (1989). American College of Sports Medicine Resource Manual for Guidelines for Exercise Testing and Prescription. The Journal of Rehabilitation, 55(4), 70-72.

Gussakov, I., Nurmukhanbetova, D., Kulbayev, A., Yermakhanova, A., Lesbekova, R., & Potop, V. (2021). The impact of the high level of intensity training process on the performance and recovery of young swimmers at the national level. Journal of Physical Education and Sport, 21(1), 440-443.

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Simonsen, T., Helgesen, C., Hjorth, N., & Bach, R. (2007). Aerobic high-intensity intervals improve VO2max more than moderate training. Medicine and Science in Sports and Exercise, 39(4), 665. https://doi.org/10.1249/mss.0b013e3180304570

Hermassi, S., Schwesig, R., Wollny, R., Fieseler, G., van den Tillaar, R., Fernandez-Fernandez, J., Shephard, R. J., & Chelly, M.-S. (2017). Shuttle versus straight repeated-sprint ability tests and their relationship to anthropometrics and explosive muscular performance in elite handball players. The Journal of Sports Medicine and Physical Fitness, 58(11), 1625-1634. https://doi.org/10.23736/S0022-4707.17.07551-X

IAAF Rules. (2020). World Athletics Competition and Technical Rules 2020 Edition. In International Association of Athletics Federations, In force from 1 November 2019 (2020th ed.). IAAF. Retrieved from: https://athleticsfiji.com/iaaf-competition-rules/

Iaia, F. M., Thomassen, M., Kolding, H., Gunnarsson, T., Wendell, J., Rostgaard, T., Nordsborg, N., Krustrup, P., Nybo, L., & Hellsten, Y. (2008). Reduced volume but increased training intensity elevates muscle Na+-K+ pump α1-subunit and NHE1 expression as well as short-term work capacity in humans. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 294(3), R966-R974. https://doi.org/10.1152/ajpregu.00666.2007

Invernizzi, P. L., Longo, S., Scurati, R., Maggioni, M. A., Michielon, G., & Bosio, A. (2014). Interpretation and perception of slow, moderate, and fast swimming paces in distance and sprint swimmers. Perceptual and Motor Skills, 118(3), 833-849. https://doi.org/10.2466/27.29.PMS.118k23w0

Karahan, M. (2012). The effect of skill-based maximal intensity interval training on aerobic and anaerobic performance of female futsal players. Biology of Sport, 29(3), 223-227. https://doi.org/10.5604/20831862.1003447

Kind, S., Brighenti-Zogg, S., Mundwiler, J., Schüpbach, U., Leuppi, J. D., Miedinger, D., & Dieterle, T. (2019). Factors associated with cardiorespiratory fitness in a Swiss working population. Journal of Sports Medicine, 2019. https://doi.org/10.1155/2019/5317961

Kumar, R., & Zemková, E. (2022). The Effect of 12-Week Core Strengthening and Weight Training on Muscle Strength, Endurance and Flexibility in School-Aged Athletes. Applied Sciences, 12(24), 12550. https://doi.org/10.3390/app122412550

Logan, G. R. M., Harris, N., Duncan, S., Plank, L. D., Merien, F., & Schofield, G. (2016). Low-active male adolescents: a dose response to high-intensity interval training. Medicine & Science in Sports & Exercise, 48(3), 481-490. https://doi.org/10.1249/MSS.0000000000000799

Lu, Y., Wiltshire, H. D., Baker, J. S., & Wang, Q. (2021). The effects of running compared with functional high-intensity interval training on body composition and aerobic fitness in female university students. International Journal of Environmental Research and Public Health, 18(21), 11312. https://doi.org/10.3390/ijerph182111312

McArdle WD, Katch FI, K. V. (1994). Exercise Physiology. Phladelphia: Lea & Febiger.

McRae, G., Payne, A., Zelt, J. G. E., Scribbans, T. D., Jung, M. E., Little, J. P., & Gurd, B. J. (2012). Extremely low volume, whole-body aerobic-resistance training improves aerobic fitness and muscular endurance in females. Applied Physiology, Nutrition, and Metabolism, 37(6), 1124-1131. https://doi.org/10.1139/h2012-093

Megahed, M., & Tarek, Z. (2023a). Improving Spatio-Temporal Stride Parameters, Lower Limb Muscles Activity and Race Walkers' Records After 12-Weeks Special Exercises Using Rhythmic Auditory. SPORT TK-EuroAmerican Journal of Sport Sciences, 12(2).

Megahed, M., & Tarek, Z. (2023b). Suspension training versus free weight training: effects on explosive power, dynamic balance, and discus throwers performance. Pedagogy of Physical Culture and Sports, 27(2), 102-111. https://doi.org/10.15561/26649837.2023.0202

Mischenko, N., Kolokoltsev, M., Gryaznykh, Ä., Vorozheikin, A., Romanova, E., & Suslina, I. (2021). Endurance development in Taekwondo according to the Tabata protocol. Journal of Physical Education and Sport, 21, 3162-3167.

Mohr, M., Krustrup, P., Nielsen, J. J., Nybo, L., Rasmussen, M. K., Juel, C., & Bangsbo, J. (2007). Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 292(4), R1594-R1602. https://doi.org/10.1152/ajpregu.00251.2006

Munandar, R. A., Setijono, H., & Kusnanik, N. W. (2021). The Effect of Tabata Training and High Intensity Interval Training toward The Increasing of Strength, and Speed. International Journal of Multicultural and Multireligious Understanding, 8(10), 80-85. https://doi.org/10.18415/ijmmu.v8i10.3007

Naimo, M. A., De Souza, E. O., Wilson, J. M., Carpenter, A. L., Gilchrist, P., Lowery, R. P., Averbuch, B., White, T. M., & Joy, J. (2014). High-intensity interval training has positive effects on performance in ice hockey players. International Journal of Sports Medicine, 61-66. https://doi.org/10.1055/s-0034-1382054

Nevill, A. M., Ramsbottom, R., Nevill, M. E., Newport, S., & Williams, C. (2008). The relative contributions of anaerobic and aerobic energy supply during track 100-, 400-and 800-m performance. Journal of Sports Medicine and Physical Fitness, 48(2), 138-142.

Nugroho, S., Nasrulloh, A., Karyono, T. H., Dwihandaka, R., & Pratama, K. W. (2021). Effect of intensity and interval levels of trapping circuit training on the physical condition of badminton players. Journal of Physical Education and Sport, 21, 1981-1987.

Olson, M. (2013). Tabata interval exercise: energy expenditure and post-exercise responses. Med Sci Sports Exerc, 45, S420.

Paton, C. D., & Hopkins, W. G. (2005). Combining explosive and high-resistance training improves performance in competitive cyclists. The Journal of Strength & Conditioning Research, 19(4), 826-830. https://doi.org/10.1519/00124278-200511000-00017

Pyne, D. B., Saunders, P. U., Montgomery, P. G., Hewitt, A. J., & Sheehan, K. (2008). Relationships between repeated sprint testing, speed, and endurance. The Journal of Strength & Conditioning Research, 22(5), 1633-1637. https://doi.org/10.1519/JSC.0b013e318181fe7a

Ryman Augustsson, S., Bersås, E., Magnusson Thomas, E., Sahlberg, M., Augustsson, J., & Svantesson, U. (2009). Gender differences and reliability of selected physical performance tests in young women and men. Advances in Physiotherapy, 11(2), 64-70. https://doi.org/10.1080/14038190801999679

Sarkar, S., Chatterjee, S., & Dey, S. K. (2019). Effect of 8 weeks high intensity interval training on maximum oxygen uptake capacity and related cardio-respiratory parameters at anaerobic threshold level of indian male field hockey players. European Journal of Physical Education and Sport Science.

Scribbans, T. D., Edgett, B. A., Vorobej, K., Mitchell, A. S., Joanisse, S. D., Matusiak, J. B. L., Parise, G., Quadrilatero, J., & Gurd, B. J. (2014). Fibre-specific responses to endurance and low volume high intensity interval training: striking similarities in acute and chronic adaptation. PloS One, 9(6), e98119. https://doi.org/10.1371/journal.pone.0098119

Spencer, M. R., & Gastin, P. B. (2001). Energy system contribution during 200-to 1500-m running in highly trained athletes. Medicine and Science in Sports and Exercise, 33(1), 157-162. https://doi.org/10.1097/00005768-200101000-00024

Støren, Ø., Helgerud, J., Johansen, J.-M., Gjerløw, L.-E., Aamlid, A., & Støa, E. M. (2021). Aerobic and anaerobic speed predicts 800-m running performance in young recreational runners. Frontiers in Physiology, 12, 672141. https://doi.org/10.3389/fphys.2021.672141

Sumpena, A., & Sidik, D. Z. (2017). The impact of tabata protocol to increase the anaerobic and aerobic capacity. IOP Conference Series: Materials Science and Engineering, 180(1), 12189. https://doi.org/10.1088/1757-899X/180/1/012189

Tabata, I., Nishimura, K., Kouzaki, M., Hirai, Y., Ogita, F., Miyachi, M., & Yamamoto, K. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO2max. Medicine and Science in Sports and Exercise, 28, 1327-1330. https://doi.org/10.1097/00005768-199610000-00018

Terada, S., Kawanaka, K., Goto, M., Shimokawa, T., & Tabata, I. (2005). Effects of high-intensity intermittent swimming on PGC-1α protein expression in rat skeletal muscle. Acta Physiologica Scandinavica, 184(1), 59-65. https://doi.org/10.1111/j.1365-201X.2005.01423.x

Thomassen, M., Christensen, P. M., Gunnarsson, T. P., Nybo, L., & Bangsbo, J. (2010). Effect of 2-wk intensified training and inactivity on muscle Na+-K+ pump expression, phospholemman (FXYD1) phosphorylation, and performance in soccer players. Journal of Applied Physiology, 108(4), 898-905. https://doi.org/10.1152/japplphysiol.01015.2009

Thompson, M. A. (2017). Physiological and biomechanical mechanisms of distance specific human running performance. Integrative and Comparative Biology, 57(2), 293-300. https://doi.org/10.1093/icb/icx069

Thompson, P. (2009). Run! Jump! Throw!:| bthe Official IAAF Guide to Teaching Athletics. International Association of Athletics Federations.

Tjønna, A. E., Leinan, I. M., Bartnes, A. T., Jenssen, B. M., Gibala, M. J., Winett, R. A., & Wisløff, U. (2013). Low-and high-volume of intensive endurance training significantly improves maximal oxygen uptake after 10-weeks of training in healthy men. PloS One, 8(5), e65382. https://doi.org/10.1371/journal.pone.0065382

Tong, T. K., McConnell, A. K., Lin, H., Nie, J., Zhang, H., & Wang, J. (2016). "Functional" Inspiratory and Core Muscle Training Enhances Running Performance and Economy. Journal of Strength and Conditioning Research, 30(10), 2942-2951. https://doi.org/10.1519/JSC.0000000000000656

Trapp, E. G., Chisholm, D. J., Freund, J., & Boutcher, S. H. (2008). The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women. International Journal of Obesity, 32(4), 684-691. https://doi.org/10.1038/sj.ijo.0803781

Usha S Nair, G. M. (2017). Effect of Tabata training on body composition and aerobic capacity of swimmers. International Journal of Applied Research, 3(8), 901-904.

Vaara, J. P., Kyröläinen, H., Niemi, J., Ohrankämmen, O., Häkkinen, A., Kocay, S., & Häkkinen, K. (2012). Associations of maximal strength and muscular endurance test scores with cardiorespiratory fitness and body composition. The Journal of Strength & Conditioning Research, 26(8), 2078-2086. https://doi.org/10.1519/JSC.0b013e31823b06ff

Viana, R. B., de Lira, C. A. B., Naves, J. P. A., Coswig, V. S., Del Vecchio, F. B., & Gentil, P. (2019). Tabata protocol: a review of its application, variations and outcomes. Clinical Physiology and Functional Imaging, 39(1), 1-8. https://doi.org/10.1111/cpf.12513

Viana, R. B., Naves, J. P. A., de Lira, C. A. B., Coswig, V. S., Del Vecchio, F. B., Vieira, C. A., & Gentil, P. (2018). Defining the number of bouts and oxygen uptake during the "Tabata protocol" performed at different intensities. Physiology & Behavior, 189, 10-15. https://doi.org/10.1016/j.physbeh.2018.02.045

Williams, K. R., Cavanagh, P. R., & Ziff, J. L. (1987). Biomechanical studies of elite female distance runners. International Journal of Sports Medicine, 8(S 2), S107-S118. https://doi.org/10.1055/s-2008-1025715

Yapici-Oksuzoglu, A. (2020). The effects of theraband training on respiratory parameters, upper extremity muscle strength and swimming performance. Pedagogy of Physical Culture and Sports, 24(6), 316-322. https://doi.org/10.15561/26649837.2020.0607