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Effects of Tabata training on physical fitness, anxiety, and depressive symptoms in middle school students: an experimental study

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Abstract

Middle school is an important period for physical and mental development. Tabata training may offer a practical approach for improving physical fitness and mental health. The present study examined the effects of an 8-week age-adapted Tabata-style high-intensity interval training with equal-duration conventional moderate-intensity training in 52 male eighth-grade students assigned by intact class (26 per group). Training was performed three times per week. Analysis using a 2 × 2 repeated-measures ANOVA identified significant interactions between group and time for the 1000-m run, vital capacity, plank hold, standing long jump, quadrant jump, triangular obstacle run, and anxiety scores (all $P < 0.05$), with greater improvements in the experimental group. The 50-m run and depression scores improved over time without significant group × time interactions. Sit-and-reach performance improved only in the control group, while trunk rotation did not change significantly. Compared with conventional training, age-adapted Tabata-style training showed relative advantages for endurance, strength, agility, and anxiety symptoms, but no additional benefit for speed, flexibility, or depressive symptoms.

Introduction

Physical and psychological development occurs rapidly during adolescence and may influence health later in life[1]. Increasing study demands, sedentary behaviour, and screen time may make it difficult for some middle school students to achieve recommended physical activity levels, while anxiety, depression, and other negative emotional symptoms are also receiving increasing attention[2]. School-based exercise should therefore consider both physical fitness and mental health within limited class time. According to the World Health Organization, mental health problems affect approximately one in seven individuals aged 10–19 years, and anxiety and depression account for an important part of the associated disease burden and functional impairment[3]. These symptoms may affect school attendance, academic performance, and social interaction and may persist into adulthood[4]. European adolescent data also suggest that greater physical activity is associated with fewer anxiety and depressive symptoms and better well-being[5]. Schools provide an organized setting for physical activity, but interventions must remain feasible in routine practice. Conventional moderate-intensity training generally provides a stable workload, although school-based intervention outcomes vary with programme design and implementation[6]. HIIT, by alternating work and recovery periods, may improve several aspects of adolescent physical fitness within a relatively short period[7]. For middle school students, however, exercise difficulty, intensity, recovery, and safety must be appropriate for age.

Tabata training is a time-efficient form of HIIT. The classic protocol alternates 20 s of intense exercise followed by a 10-s recovery period for seven or eight consecutive bouts and can stimulate both aerobic and anaerobic energy systems[8]. Because the classic Tabata protocol was not originally designed for middle school students, its exercises, intensity, recovery periods, and training volume must be adapted to students' age and the conditions of school physical education[9]. We therefore used an age-adapted Tabata-style intermittent training programme to improve feasibility in a school setting. Evidence from

HIIT studies among young people provides some support for possible effects from this type of training[10]. Improvements in cardiorespiratory fitness are relatively consistent, whereas effects on strength, speed, and body composition vary with training content, duration, and sample characteristics. Previous studies have shown that incorporating Tabata-style HIIT into physical education warm-ups can improve cardiorespiratory fitness, standing long-jump performance, and some measures of strength in adolescents. These findings support the potential use of brief HIIT in schools, but whether multiple dimensions of physical fitness improve concurrently remains unclear. The value of adolescent HIIT in school physical education extends beyond cardiorespiratory fitness. Different exercises involve rapid stretch-shortening actions of the lower limbs, core stabilization, changes of direction, and repeated brief efforts, and may therefore provide different stimuli for strength, agility, and endurance. Because training content affects physical performance in different ways, adaptations need to be understood according to the exercises used and outcome measures[11]. Tabata-style training should therefore be evaluated across multiple dimensions of physical fitness, rather than classified as effective or ineffective on the basis of a single measure, and differences among outcomes need to be understood according to the exercises performed.

Although previous studies suggest that HIIT can be implemented in schools, the available evidence has several limitations directly relevant to this study. First, most studies have focused on cardiorespiratory fitness, body composition, and metabolic outcomes, with fewer comprehensive assessments of flexibility, strength, speed, agility, and endurance[12]. Second, findings on anxiety, depression, and other psychological outcomes following physical activity programs delivered in schools are inconsistent, and effects differ among intervention types[13]. Some school-based studies have assessed cardiorespiratory fitness, cognition, and mental health together, but have included few measures of other fitness components, and their findings may have been affected by intervention adherence[14]. We therefore examined changes associated with interval training across several dimensions of physical fitness as well as anxiety and depressive symptoms among adolescents. Previous studies have also differed substantially in training format, work-to-rest ratio, intervention duration, and control conditions[15]. The terms HIIT and Tabata consequently do not denote identical training stimuli. The classic Tabata protocol is very intense and cannot be transferred directly to a general middle school population. Rather than replicating the classic 20-s work/10-s rest protocol, we retained its core features of brief high-intensity effort, repeated intervals, and high exercise density, but extended each work period to 30 s and controlled training load using phase-specific heart-rate targets and changes in exercise selection. Thus, the intervention was a Tabata-style HIIT programme adapted for school physical education, and the findings apply primarily to this specific training arrangement. The psychological effects of exercise depend on both the training mode and the context in which it is delivered[16]. School-based exercise also involves social factors such as peer interaction, teacher organization, and task experience, so its psychological effects cannot be attributed to exercise intensity alone[17]. Evidence remains inconclusive as to whether exercise intensities produce consistent differences in psychological outcomes. For general school populations in particular, short-term changes in questionnaire scores should not be

interpreted as clinical treatment effects. It is nevertheless important to determine whether different training formats produce different symptom changes over the same exercise duration.

We therefore assessed physical fitness and symptoms of anxiety and depression within the same intervention framework and used conventional moderate-intensity training of equal duration as an active control. The aim was not to determine whether exercise was better than no exercise, but whether an age-adapted Tabata-style programme produced greater pre-to-post changes in selected physical and psychological outcomes within similar training time available at school. We report outcomes with and without significant interactions to avoid generalizing the effects of Tabata training from statistically significant results alone. The present research examined changes following an 8-week age-adapted Tabata-style HIIT and equal-duration conventional moderate-intensity training on multidimensional physical fitness and symptoms of anxiety and depression in male eighth-grade students, and tested whether changes over time differed between the two training conditions.

Methods

Participants

The research protocol was approved by the Sports Science Ethics Committee of Shandong Sport University (approval no. 2026095). Participants were 52 boys aged 13–14 years from two parallel eighth-grade classes at the Affiliated Middle School of Shandong Normal University. Inclusion criteria were good health, no known cardiopulmonary disease or other contraindication to exercise, no severe sports injury during the previous year, and the ability to complete the prescribed training. Students were excluded if they had a long-term exemption from physical education for medical reasons or a health condition that could affect their participation in the study or completion of the assessments. Before the experiment, the researchers explained the purpose of the research, its procedures, possible risks, and right to withdraw to all students and their guardians. Written informed consent was obtained from the students' guardians, and assent was obtained from the students before their participation.All methods were performed in accordance with the relevant guidelines and regulations.

Study design and intervention development

The study followed a controlled pretest-posttest design. The experimental and control groups comprised two parallel eighth-grade classes, with 26 students in each intact class. A 1-week pilot phase preceded the formal intervention to familiarize participants with the exercises, assessment procedures, and exercise load. This was followed by an 8-week intervention performed three times per week. The experimental group completed age-adapted Tabata-style HIIT, whereas the control group completed conventional moderate-intensity training of equal duration. Both groups underwent the same assessments of physical fitness together with anxiety and depression symptoms both before and following the intervention. Intervention by intact class was chosen to fit normal school organization and

to avoid contamination that could occur if students in the same class received two different programmes. Because participants were not individually randomized, the study was treated as a non-randomized controlled pretest-posttest design, and between-group differences were interpreted cautiously because of possible class-level effects[18]. Both groups completed the baseline and post-intervention assessments according to the same schedule, with the intervention period also occurring over the same time frame, to reduce potential effects of season, school scheduling, and assessment timing[19]. The primary statistical evidence was the group × time interaction, which was used to determine whether changes over time were different between the two groups. Relative effectiveness was not inferred solely from within-group pre-post comparisons.

The training programme and outcome measures were developed and refined using previous evidence and expert consultation[20]. Fourteen experts in physical education, exercise physiology, youth physical conditioning, sports rehabilitation, nutrition, and related fields advised on training load, exercises, outcome measures, and evaluation criteria. The consultation aimed to improve the feasibility of the programme in middle schools and to screen candidate outcome measures, exercises, training loads, and evaluation criteria. Particular consideration was given to exercise safety, facility and equipment requirements, difficulty of class organization, test repeatability, and the sensitivity of measures to changes in middle school students' physical fitness. Expert opinion was used to refine the protocol, not to replace empirical evaluation. Intervention effects were determined from participants' pre- and post-intervention data and group x time interactions.

Psychological outcome measures

We assessed anxiety using the Chinese version of the Beck Anxiety Inventory (BAI). The BAI contains 21 questions scored from 0 to 3, giving a total score ranging from 0 to 63; higher scores reflect more severe anxiety symptoms[21]. We evaluated depressive symptoms with the Chinese Beck Depression Inventory (BDI). It also consists of 21 questions, with each question scored from 0 to 3 and provides an overall score of 0–63, with a higher score indicating greater depressive symptoms[22]. Total BAI and BDI scores were analysed as continuous variables to examine how symptoms changed from before to after the intervention; they were not used for clinical diagnosis. At both assessment points, researchers administered the questionnaires using standardized instructions. Because the participants were students from a general school population, total scores were retained as continuous measures, and participants were not classified as having or not having anxiety or depression using a single cut-off. This approach enabled direct comparison of mean changes in symptom scores between groups without interpreting short-term score fluctuations as changes in clinical diagnostic status.

Outcome selection and protocol refinement

Two Delphi consultation rounds were carried out to select and improve the outcome measures, training exercises, and evaluation criteria. Fourteen experts participated in both rounds. The expert authority

coefficient was Cr = 0.871, while items were retained when their mean rating was > 3.5 and coefficient of variation was < 0.25. Detailed results can be found in Supplementary Table S1.

Intervention and experimental procedures

The study took place at the Affiliated Middle School of Shandong Normal University between 4 March to 11 May 2026. It lasted 9 weeks, comprising a 1-week pilot phase and an 8-week formal intervention. The pilot phase familiarized participants with the exercises, training pace, and assessment procedures and allowed the training organization to be adjusted according to actual performance. During the formal intervention, sessions were held three times per week on Monday, Wednesday, and Friday afternoons. Both groups trained at the same school site and used the same assessment venue and equipment. The pilot phase was not included in the 8-week intervention and was used primarily for exercise instruction and adaptation to the training load. During the pilot phase, researchers observed participants performing high-knee running, jumps, lateral movements, and core-stability exercises, and standardized exercise cues and training pace. After the formal intervention began, both groups followed the prescribed frequency of three sessions per week. All sessions were conducted under routine school physical activity conditions. Researchers monitored exercise technique and immediate responses during training. If a participant experienced clear discomfort, the session was stopped and the participant was observed as needed.

The 52 participants were assigned by intact class to the experimental or control group (n = 26 each). Before the formal intervention, both groups completed baseline assessments of physical fitness, BAI scores, and BDI scores. The experimental group performed age-adapted Tabata-style HIIT, whereas the control group received conventional moderate-intensity training for the same duration. Following the 8-week intervention, both groups underwent post-intervention assessments under procedures and conditions consistent with those used at baseline. Baseline characteristics and principal outcomes are shown in Table 1. Each experimental-group training session included a 10–15-min warm-up, 11–12 min of core training, and a 10-15-min cool-down. The core component followed an age-adapted Tabata-style interval structure with eight exercises. Each exercise lasted 30 s and was followed by a 10-s rest period. Two circuits were completed, with 30 s of rest between circuits. Exercise content was changed every 2 weeks, and intensity was progressively adjusted by training phase. Target intensity was 70–80%, 75–85%, 80–90%, and 75–85% of maximum heart rate across the four successive phases. Heart rate was monitored during training to assess exercise load. Exercise content and workload are detailed in Table 2.

The term age-adapted Tabata-style training refers to a school-based modification of the classic Tabata structure. Instead of the classic 20-s work and 10-s recovery periods, we used 30-s work and 10-s recovery periods so that students could establish a relatively complete movement rhythm within each exercise bout. Total volume was controlled using two circuits and 30 s of recovery between circuits. Exercises varied across phases but consistently involved whole-body movement, jumping, rapid stretch-shortening actions of the lower limbs, and core stabilization. Phase-specific heart-rate targets prevented an excessively high load at the start of the intervention. Training intensity increased gradually from the

adaptation phase, peaked during the intensive phase, and was reduced moderately during the consolidation phase. The control group completed conventional school-based moderate-intensity fitness training. Training frequency and core training duration were similar to those of the experimental group, but the control programme did not use a Tabata-style high-intensity interval structure. The content and workload are detailed in Table 3. To improve comparability, the groups were matched as closely as possible for training venue, time, duration, equipment, and organization, except for the core training mode. Attendance, exercise completion, and training load were recorded throughout the intervention. The same procedures and conditions were used for all physical fitness and psychological assessments before and after the intervention.

Table 1
Baseline characteristics and outcome measures of the participants before intervention.

Outcome measure	Experimental group	Control group	t value	P value
Sit-and-reach (cm)	6.8 ± 3.2	6.5 ± 3.1	0.40	0.691
Trunk rotation test (degrees)	85 ± 5.2	86 ± 5.1	-0.81	0.420
1000-m run (s)	290 ± 13.5	288 ± 14.1	0.61	0.544
Vital capacity (mL)	2850 ± 320	2820 ± 310	0.39	0.699
Plank hold (s)	68 ± 10.3	66 ± 10.8	0.77	0.444
Standing long jump (cm)	195 ± 12.6	193 ± 13.2	0.61	0.546
50-m run (s)	8.4 ± 1.9	8.6 ± 1.7	-0.46	0.645
Quadrant jump (repetitions)	37 ± 3.5	36 ± 3.4	1.14	0.257
Triangular obstacle run (s/lap)	26.8 ± 2.9	26.4 ± 2.8	0.72	0.473
BAI score	18.6 ± 3.2	18.2 ± 3.4	0.48	0.632
BDI score	17.5 ± 3.0	17.1 ± 3.2	0.51	0.614

Table 2
Experimental-group Tabata training programme across the 8-week intervention.

Training phase	Exercises	Training parameters	Exercise intensity
Adaptation phase, weeks 2–3	1. Jumping jacks; 2. High-knee running in place; 3. Butt kicks with both legs; 4. Lateral shuffles; 5. Quick steps in place; 6. Jumping jacks; 7. Plank hold; 8. Russian twists	30 s per bout, 2 circuits; 10-s rest between exercises; 70 s per exercise; total session time, 670 s (11 min)	70–80% of maximum heart rate
Progression phase, weeks 4–5	1. Jumping jacks; 2. High-knee running in place; 3. Butt kicks with both legs; 4. Lateral shuffles; 5. Crossover jumps; 6. Z-shaped shuttle runs; 7. Tuck jumps; 8. Rapid vertical jumps	30 s per bout, 2 circuits; 10-s rest between exercises; 70 s per exercise; total session time, 670 s (11 min)	75–85% of maximum heart rate
Intensive phase, weeks 6–7	1. Crossover jumps; 2. Z-shaped shuttle runs; 3. Tuck jumps; 4. Rapid vertical jumps; 5. Lateral jumps; 6. Crossover steps; 7. Tuck jumps; 8. Rapid vertical jumps	30 s per bout, 2 circuits; 10-s rest between exercises; 70 s per exercise; total session time, 670 s (11 min)	80–90% of maximum heart rate
Consolidation phase, weeks 8–9	1. Lateral jumps; 2. Crossover steps; 3. Tuck jumps; 4. Rapid vertical jumps; 5. Butt kicks with both legs; 6. Lateral shuffles; 7. Z-shaped shuttle runs; 8. Crossover-step combinations	30 s per bout, 2 circuits; 10-s rest between exercises; 70 s per exercise; total session time, 670 s (11 min)	75–85% of maximum heart rate

Experimental condition control

Table 3
Control-group conventional moderate-intensity training programme across the 8-week intervention.

Week	Training content	Sets	Within-set rest (s)
Week 2	6-min aerobic endurance run; bodyweight squats, 10 repetitions x 3 sets; lateral side steps, 1 min x 2 sets	1	60
Week 3	50 m x 4 sets (2-min rest between sets); squat jumps, 15 repetitions x 2 sets; vertical jumps, 15 repetitions x 2 sets; lateral retreat steps, 1 min x 2 sets	1	60
Week 4	Plank holds totalling 3 min; push-ups; zigzag runs x 3 sets; Z-shaped shuttle runs x 3 sets; followed by 4 min of variable-pace running	1	60
Week 5	200-m + 400-m + 600-m runs (2-min rest between sets); semicircular movement runs, 1 min x 2 sets	1	60
Week 6	6-min aerobic endurance run; bodyweight squats, 10 repetitions x 3 sets; lateral shuffles, 1 min x 2 sets	1	60
Week 7	50 m x 4 sets (2-min rest between sets); squat jumps, 15 repetitions x 2 sets; vertical jumps, 15 repetitions x 2 sets; lateral crossover steps, 1 min x 2 sets	1	60
Week 8	Plank holds totalling 3 min; push-ups; zigzag runs x 3 sets; Z-shaped shuttle runs x 3 sets; followed by 4 min of variable-pace running	1	60
Week 9	200-m + 400-m + 600-m runs (2-min rest between sets); fan-shaped change-of-direction movements, 1 min x 2 sets	1	60
Total training time: 360 + 105 + 150 + 60 = 675 s (11 min)			

To improve comparability, the groups were matched as closely as possible for training venue, equipment, time, core training duration, and organization, except for the training mode. The same outcome measures and assessment procedures were used before and after the intervention. Attendance, training duration, exercise completion, and heart rate were recorded to assess intervention implementation.

Physical fitness measurements

Physical fitness measurements were carried out both before and following the formal training period across flexibility, endurance, strength, speed, and agility domains. The sit-and-reach and trunk rotation tests were used to evaluate flexibility. Endurance-related outcomes were assessed using the 1000-m run and vital capacity. The plank hold was used to measure strength, and the standing long jump, speed using the 50-m run, and agility using the quadrant jump and triangular obstacle run. All assessments followed standardized procedures and requirements at the same venue, and identical methods and conditions were used before and after the intervention. Each measure represented a prespecified dimension of physical fitness, and findings were interpreted in relation to performance on the specific test. The sit-and-reach and trunk rotation tests assessed flexibility or mobility in different directions. The

1000-m run and vital capacity described endurance-related performance. The plank hold and standing long jump assessed core endurance and lower-limb explosive power, respectively. The 50-m run assessed short-distance speed, whereas the quadrant jump and triangular obstacle run emphasized rapid footwork, changes of direction, and body control. Field-based fitness assessment in young people should use standardized, feasible, and evidence-based procedures[23]. The same test order, venue, and organization were used at both assessment points to reduce bias arising from procedural differences.

Statistical analysis

The data were organized in Microsoft Excel and then examined with SPSS 26.0. Continuous data are presented as mean ± standard deviation (M ± SD). Baseline values were compared between the two groups. Intervention effects were examined with a 2 × 2 repeated-measures ANOVA, including group (experimental and control) and time (before and after the intervention). Time and group effects, as well as their interaction, were examined. The group × time interaction was the principal effect of interest because it showed whether pre-to-post changes differed across the two training conditions. Simple-effects analyses were conducted when the interaction was statistically significant. All analyses were two-sided, with $\alpha = 0.05$ used as the threshold for statistical significance. Time was included as the within-subject factor, whereas group was included as the between-subject factor. A main effect of time indicated an overall change across all participants, whereas a main effect of group indicated an overall difference between groups. The group × time interaction directly tested whether the magnitude of change differed between groups. When a significant time effect occurred without a significant group × time interaction, it indicated only an overall change in both groups. Between-condition differences were interpreted using simple-effects analyses only when the interaction was significant [24].

Results

Flexibility outcomes

Table 4 summarizes the principal physical fitness and mental health outcomes before and after the intervention, and Fig. 1 visualizes the pre-to-post changes. Statistical inference was based on the repeated-measures ANOVA. Significant interactions were concentrated in measures of endurance, strength, agility, and anxiety symptoms, indicating that the relative effects of age-adapted Tabata-style training were outcome specific.

Table 4
Pre- and post-intervention outcomes and group × time interaction effects.

Outcome	Experimental pre	Experimental post	Control pre	Control post	Group × time
Sit-and-reach (cm)	6.8 ± 3.2	6.5 ± 3.5	6.5 ± 3.1	8.2 ± 3.3□	F = 5.195,P = 0.027
Trunk rotation test (degrees)	85.0 ± 5.2	85.0 ± 4.8	86.0 ± 5.1	86.0 ± 4.9	F < 0.001,P = 1.000
1000-m run (s)	290.0 ± 13.5	255.0 ± 12.8□□	288.0 ± 14.1	270.0 ± 13.2□	F = 22.464,P < 0.001
Vital capacity (mL)	2850.0 ± 320.0	3200.0 ± 330.0□□	2820.0 ± 310.0	2980.0 ± 320.0□	F = 12.689,P = 0.001
Plank hold (s)	68.0 ± 10.3	105.0 ± 12.1□□	66.0 ± 10.8	74.0 ± 11.2□	F = 94.574,P < 0.001
Standing long jump (cm)	195.0 ± 12.6	213.0 ± 11.5□□	193.0 ± 13.2	201.0 ± 12.3□	F = 9.053,P = 0.004
50-m run (s)	8.4 ± 1.9	7.5 ± 1.4□	8.6 ± 1.7	8.0 ± 1.2□	F = 0.485,P = 0.489
Quadrant jump (repetitions)	37.0 ± 3.5	46.0 ± 3.2□□	36.0 ± 3.4	38.0 ± 3.3□	F = 60.924,P < 0.001
Triangular obstacle run (s)	26.68 ± 2.57	23.86 ± 2.29□□	26.74 ± 2.61	25.92 ± 2.43	F = 12.35,P = 0.001
BAI score	18.6 ± 3.2	10.2 ± 2.5□□	18.2 ± 3.4	16.5 ± 3.1□	F = 65.738,P < 0.001
BDI score	17.5 ± 3.0	10.4 ± 2.3□	17.1 ± 3.2	10.3 ± 2.8□	F = 0.153,P = 0.698

The analysis showed a significant group × time interaction for the sit-and-reach test (F = 5.195, P = 0.027). Further analysis indicated that the value measured after the intervention was higher than the baseline value in the control condition (P = 0.009), while the experimental group showed no clear change (P = 0.640). Post-intervention values did not differ significantly between the two groups (P = 0.067). No significant effects of time, group, or their interaction were found for the trunk rotation test (all P > 0.05). Mean sit-and-reach performance changed from 6.8 ± 3.2 cm to 6.5 ± 3.5 cm in the experimental group and increased from 6.5 ± 3.1 cm to 8.2 ± 3.3 cm in the control group. Trunk rotation performance remained essentially stable in both groups: 85.0 ± 5.2 degrees and 85.0 ± 4.8 degrees in the experimental group, and 86.0 ± 5.1 degrees and 86.0 ± 4.9 degrees in control participants. Thus, these flexibility outcomes failed to show any consistent advantage for participants in the experimental group.

Endurance outcomes

For the 1000-m run, significant effects were observed for time ($F = 218.344$, $P < 0.001$) and group ($F = 4.389$, $P = 0.041$), together with a significant group × time interaction ($F = 22.464$, $P < 0.001$). Completion time decreased for participants in each group (both $P < 0.001$), with better post-intervention performance observed in the experimental condition than in the control condition ($P < 0.001$). For vital capacity, significant effects were found for time ($F = 89.237$, $P < 0.001$) and group ($F = 11.452$, $P = 0.001$), while the interaction ($F = 12.689$, $P = 0.001$) also reached statistical significance. Values increased from baseline to post-intervention in both groups (both $P < 0.001$), and post-intervention values were higher in the experimental group than in the control group ($P = 0.001$). Mean 1000-m run time decreased from 290.0 ± 13.5 s to 255.0 ± 12.8 s in the experimental group and from 288.0 ± 14.1 s to 270.0 ± 13.2 s in the control group. Vital capacity increased from 2850.0 ± 320.0 mL to 3200.0 ± 330.0 mL in the experimental group and from 2820.0 ± 310.0 mL to 2980.0 ± 320.0 mL in the control group. Both endurance-related outcomes improved over time in the two groups, but the amount of change was greater for participants in the experimental condition.

Strength outcomes

For the plank hold, time ($F = 227.720$, $P < 0.001$), group ($F = 41.196$, $P < 0.001$), and interaction effects ($F = 94.574$, $P < 0.001$) were significant. Both groups improved (both $P < 0.001$), and the experimental group showed greater post-intervention performance ($P < 0.001$). For the standing long jump, the effects of time ($F = 61.200$, $P < 0.001$), group ($F = 5.941$, $P = 0.018$), and the group × time interaction ($F = 9.053$, $P = 0.004$) were significant. Participants in both groups improved (experimental, $P < 0.001$; control, $P = 0.003$), with better performance after the intervention observed for the experimental group ($P < 0.001$). Both measures of strength therefore demonstrated clear interactions between group and time.

Speed outcome

In the 50-m run, only the effect of time was significant ($F = 12.115$, $P = 0.001$); the effects of group ($F = 0.940$, $P = 0.337$) and group × time interaction ($F = 0.485$, $P = 0.489$) were not significant. Completion time decreased in both groups (experimental, $P = 0.010$; control, $P = 0.045$), but the difference between groups after the intervention was not significant ($P = 0.157$). Thus, speed improved over time in both groups, but the magnitude of improvement did not differ significantly between conditions.

Agility outcomes

For the quadrant jump, significant effects were identified for time ($F = 150.444$, $P < 0.001$) and group ($F = 33.670$, $P < 0.001$), along with a significant group × time interaction ($F = 60.924$, $P < 0.001$). Participants in both groups improved after the intervention, with a larger change found in participants from the experimental group. For the triangular obstacle run, time had a significant effect ($F = 38.42$, $P < 0.001$), and the group × time interaction was also significant ($F = 12.35$, $P = 0.001$), whereas the group effect was not significant ($F = 3.71$, $P = 0.061$). The experimental group improved from baseline ($P < 0.001$) and performed better than the control group after the intervention ($P = 0.002$), whereas participants in the control group showed no significant pre-to-post change ($P = 0.078$). Quadrant-jump repetitions increased from 37.0 ± 3.5 to 46.0 ± 3.2 in the experimental group and from 36.0 ± 3.4 to 38.0 ± 3.3 in the control

group. Triangular obstacle-run time decreased from 26.68 ± 2.57 s to 23.86 ± 2.29 s in the experimental group and from 26.74 ± 2.61 s to 25.92 ± 2.43 s in the control group. Both agility outcomes showed larger changes from before to after the intervention among participants in the experimental condition.

Anxiety symptoms

For BAI scores, time ($F = 149.387$, $P < 0.001$), group ($F = 17.343$, $P < 0.001$), and interaction effects ($F = 65.738$, $P < 0.001$) were significant. BAI scores declined in both groups (experimental, $P < 0.001$; control, $P = 0.010$), while the experimental group had lower scores following the intervention ($P < 0.001$). The significant interaction indicated a greater reduction in anxiety symptoms in the experimental condition.

Depressive symptoms

For BDI scores, only the effect of time was significant ($F = 327.673$, $P < 0.001$); neither the group effect ($F = 0.145$, $P = 0.705$) nor the group × time interaction ($F = 0.153$, $P = 0.698$) reached significance. BDI scores decreased in both groups (both $P < 0.001$), and post-intervention scores did not differ significantly between the groups ($P = 0.884$).

Discussion

The present research examined changes following an 8-week age-adapted Tabata-style HIIT and equal-duration conventional moderate-intensity training on physical fitness and symptoms of anxiety and depression in male eighth-grade students. Significant interactions between group and time were mainly observed in the 1000-m running test, vital capacity, plank hold, standing long jump, quadrant jump, triangular obstacle run, and BAI scores. Thus, the relative advantages of Tabata training were outcome specific and did not extend to every physical or psychological measure. This pattern is consistent with previous evidence that the effects of HIIT depend jointly on training content, dose, and outcome measure[25]. For flexibility, the sit-and-reach test showed a significant interaction, but only the control group improved significantly, whereas the experimental group did not. The trunk rotation test showed no significant change. Sustained static stretching can improve range of motion and flexibility[26], whereas the present Tabata programme emphasized rapid and explosive movements and provided relatively little targeted flexibility stimulus. For strength and speed, improvements in plank-hold time and standing long-jump distance were significantly greater in the experimental group. The Tabata programme included core stabilization, jumping, and rapid stretch-shortening exercises that closely matched the demands of the core-endurance and lower-limb explosive-power tests. In contrast, both groups improved significantly in the 50-m run, but the group x time interaction was not significant. Both agility measures, the quadrant jump and triangular obstacle run, showed significant interactions and greater improvements in the experimental group. Repeated multidirectional jumps, rapid changes of direction, and reacceleration after braking in the Tabata programme corresponded to the foot speed, shifts in centre of mass, and directional control required by these tests. This finding is consistent with pooled evidence that plyometric training improves change-of-direction performance in adolescents[27]. For endurance, improvements in 1000-m run time and vital capacity were significantly greater in the experimental group.

Alternating high-intensity exercise with brief recovery imposes a substantial cardiorespiratory load, and pooled evidence on HIIT in children and adolescents identifies cardiorespiratory fitness as one of its more consistent benefits[28]. Mental health outcomes showed different patterns. BAI scores decreased in both groups, with a significantly greater decrease observed in participants from the experimental condition, providing preliminary experimental evidence that school-based Tabata-style training may reduce anxiety symptoms. However, earlier studies examining how HIIT affects anxiety symptoms are inconsistent[29], and the mechanisms require further investigation. BDI scores showed only an effect of time, while the interaction between group and time was not significant, suggesting similar changes in depressive symptoms in the two groups.

Overall, compared with equal-duration conventional moderate-intensity training, age-adapted Tabata-style training showed relative advantages for endurance, strength, agility, and anxiety symptoms, but not for speed, flexibility, or depressive symptoms. In school physical education, Tabata-style training may therefore be suitable as a supplementary module targeting specific fitness outcomes rather than as a single replacement for conventional training. This study has several limitations. The sample included only 52 boys aged 13–14 years, restricting generalizability. Assignment by intact class and the absence of a non-exercise control group prevent exclusion of class-level differences, shared participation, or general effects of exercise and school routine. The intervention lasted 8 weeks and did not include long-term follow-up, so persistence of the effects remains unknown. Future studies should include larger and more diverse samples, use more rigorous allocation procedures, and incorporate longer follow-up and measures of potential mechanisms[30].

Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Author contributions

All authors contributed to the conception and design of the study, data acquisition or interpretation, manuscript drafting or critical revision, approved the final manuscript, and agree to be accountable for the work.

Competing interests

The authors declare no competing interests.

Additional information

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Figures

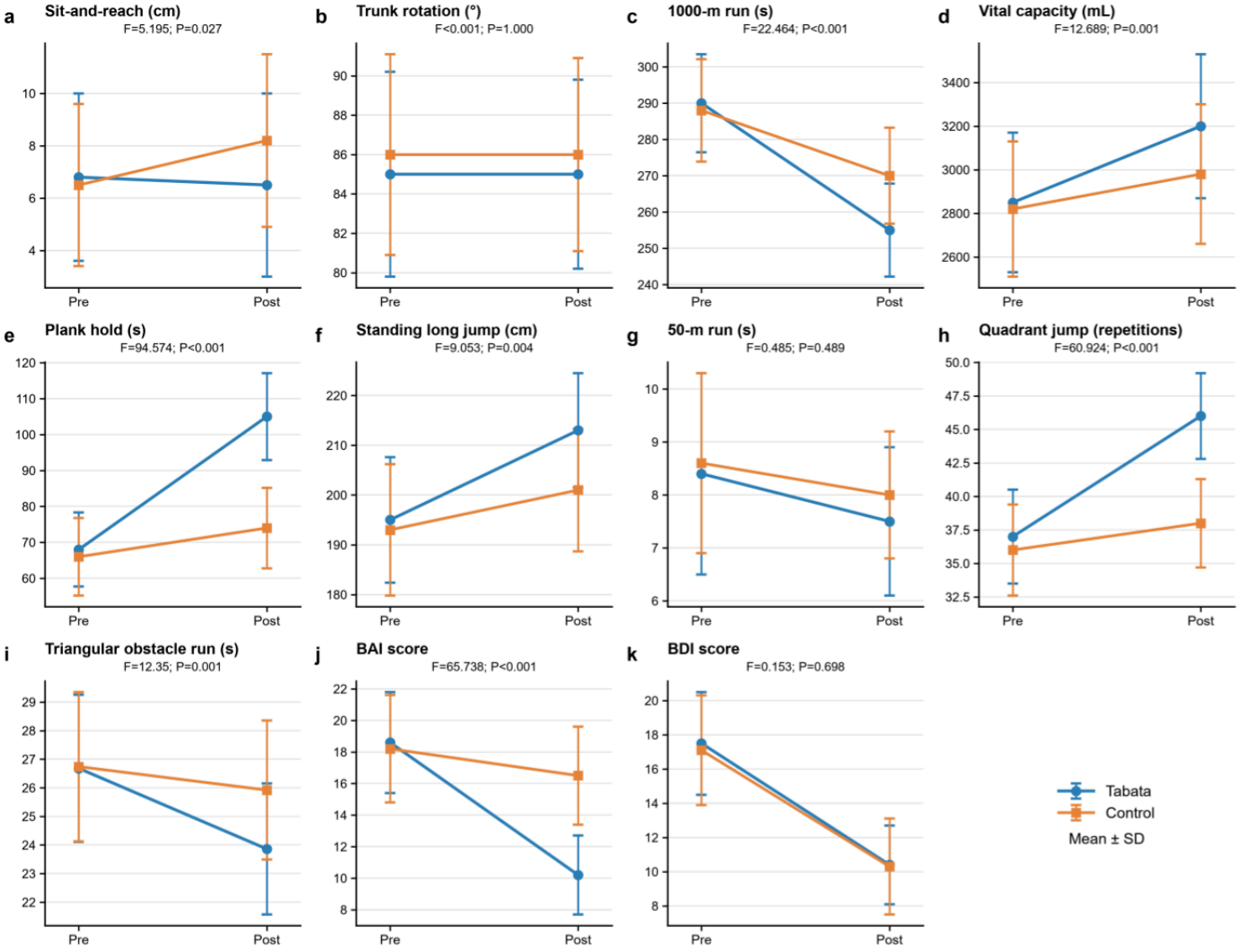


Figure 1

Changes in physical fitness and psychological outcomes from pre- to post-intervention.