EFFECTS OF TABATA TRAINING ON HEALTH-RELATED FITNESS COMPONENTS AMONG SECONDARY SCHOOL STUDENTS

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Abstract:

Physical education curricula in Polish schools should include more tasks to increase physical activity. The Tabata Training Program can help regulate body weight and induce changes in body fat and physical fitness. This study aimed to determine the effects of a 10-week PE curriculum supplemented by a Tabata Training Program on health-related fitness in 16-year-old secondary school students. The study examined 187 students (66 boys and 121 girls) assigned to either a Tabata Training Program intervention or control group. The intervention lasted 14 minutes during one physical education lesson per week. *Pre*- and *post*-intervention, anthropometric measurements were taken, and each participant performed physical fitness tests to evaluate muscular strength, flexibility, speed/agility, and cardiovascular efficiency. Boys of the intervention group significantly reduced body fat (by 1.77%, $p<.05$) and increased cardiovascular efficiency (the physical efficiency index was higher by 3.61 points, $p<.05$). Girls increased cardiovascular efficiency only (the physical efficiency index increased by 5 points, $p<.001$). However, slight changes in motor parameters were observed in all the participants. The Tabata Training Program demonstrated partial effectiveness but should be individualized and sex differences should be considered.

Key words: *physical education, intervention study, exercise training, youth*

Introduction

Physical activity has comprehensive health benefits for people of all ages. Generally, young people (13–17 years old) need 60 minutes of moderate-to-high-intensity physical activity daily (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015), to which physical education (PE) classes can significantly contribute. High-intensity interval training (HIIT) can be used in these classes to help cope with and prevent obesity and overweight (Camacho-Cardenosa, et al., 2016; Costigan, et al., 2018; Delgado-Floody, Latorre-Roman, Jerez-Mayorga, Caamano-Navarrete, & Garcia-Pinillos, 2019).

Physical inactivity's growing prevalence is associated with child/adolescent overweight and obesity: about 80% of young people do not perform the minimum physical activity level recommended by the World Health Organization (WHO) (Hallal, et al., 2012). Even physically active people reduce their activity by about 10% annually during adolescence (Dumith, Gigante, Domingues, & Kohl, 2011). In Poland, the same patterns are present, where regular physical activity decline surpasses that in other European and world countries. Physical education classes should improve students' physical literacy and other skills in various sports and promote health-related physical activity through the implementation of intervention programs based on increased exercise intensity (Heath, et al., 2012). Positive correlations between the implemented high-intensity exercises and a more favorable waist-to-hip ratio (WHR), blood pressure, and body mass index (BMI) have been indicated (Carson, et al., 2014; Hay, et al., 2012).

The HIIT method, which uses a short intervention time (up to a few minutes) with vigorous-intensity exercise (at about 75% of maximum heart rate), may offer a solution (Costigan, et al., 2015). Such an intensity improves adolescents' maximum oxygen uptake and morphological features (i.e., WHR, BMI, and body fat percentage). The mentioned studies were conducted mainly in clinical conditions, instead of in natural conditions during school PE classes, and/or with rather small samples (Buchan, et al., 2011; Camacho-Cardenosa, et al., 2016; Delgado-Floody, et al., 2019). Further, studies largely used repeated sprints for the HIIT exercises, while others used a circuit-training method (Lambrick, Westrupp, Kaufmann, Stoner, Faulkner, 2016; Weston, et al., 2016) or Tabata procedure (Afyon, Mülazimoğlu, & Altun, 2018; Ekström, Ostenberg, Bjorklund, & Alricsson, 2017). In Tabata procedure, short rests between efforts are key for increasing both aerobic and anaerobic capacity in exercisers. In HIIT interval training experiments, the program is usually run one, two, or three times a week. However, results show that morphological (fat reduction) and physiological changes occur even after a single workout but also that increasing the number of weekly workouts does not significantly increase the observed changes (Chin, et al. 2020). These different strategies for achieving high intensity usually yield different results and, even when used together, do not provide a holistic solution or address both physical capacity and body weight/height components.

Therefore, our research aimed to determine the effects of a 10-week PE curriculum supplemented with the Tabata-based interval training on 16-year-olds regarding individual health-related fitness (HR-F) components, such as morphological features, cardiovascular features, muscle strength, and motor skills (divided by gender). In Poland, no studies have been conducted to date on the impact of PE lessons supplemented with HIIT on morphological and physiological parameters. Further, Poland has no recommendations for using HIIT with PE lessons, so our results may contribute to the development of PE classes that integrate HIIT. They can also be used to justify changes to Poland's PE system regarding supplementing it with various elements to improve physical performance and prevent overweight and obesity among Polish youth (Osiński & Kantanista, 2017), with no need to abandon other sports conducted during PE lessons.

We hypothesized that the introduction of a 14-minute HIIT based on the Tabata training program to one PE lesson/per week, run for 10 weeks, was sufficient to observe improvements in health indicators such as fat reduction, physical performance and motor skills performance.

Methods

Participants and procedure

The G*Power (version 3.1.) was used to calculate the *a priori* sample size. For the general linear multidimensional analysis of variance (MANOVA) with repeated measures and the interaction term, the effect size of 0.25 (medium effect size), a p-value of .05, power of 0.80, number of groups (4), and two measurements the suggested total sample size was 179 (Steyn & Ellis, 2009). This sample size was accurate (sufficient but not excessive) for proper interpretation of the results.

The sample of participants was comprised of 187 adolescents (66 boys: age 16.24±0.34 years; 121 girls: age 16.12±0.42 years) from a preselected urban, comprehensive secondary school in Wroclaw, whose school principal responded to the invitation and consented to the study. Students were of the same sociocultural level and lived in the same geographical area (i.e., a big city of about 650,000 inhabitants). Before starting the experiment, all participants' parents provided the written informed consent. A control group (CG) and experimental group (EG) had randomly been selected from all the first-year secondary school students (six classes in total) before the school year began. All students from the three first-year classes were assigned to the EG (n=92), and all students from the other three first-year classes were included in the CG (n=95).

Participants of the EG performed a 14-minute HIIT exercise regimen based on the Tabata training program (TAP), presented as a video during one of three weekly PE lessons carried out in the fitness room. The TAP was used in the EG group for 10 weeks (from the 5th week of the school year) from 9:00 a.m. to 12:30 p.m. The remaining PE lessons were conducted according to the school's regular curriculum for the first-year secondary students. Participants of the CG followed the regular PE curriculum. The stretching or gym exercises were used instead of HIIT exercises used in the EG. Participants were instructed to maintain normal levels of their physical activity and refrain from other organized physical activities except for PE (Cvetković, et al., 2018). During the other two weekly PE lessons, both the EG and CG participated in various team sports, dance, and gym exercises.

The results of 19 EG and 26 CG participants were excluded from further analyses due to various reasons. These included the participants involved in organized physical activity (i.e., attendees of a fitness gym) or additional recreational activities during the previous six months (17 students), those who had medical contraindications for motor activity and/or those with cardiovascular/respiratory diseases (10 students), those who discontinued PE class participation (due to school or class change: nine students), and those who did not complete all the tests (nine students). No participant withdrew from the program because of fatigue or lack of interest. Therefore, 73 EG participants (girls: n=42, body height 164.89±6.08 cm; boys: n=31, body height 176.47±6.21 cm) and 69 CG participants (girls: n=47, body height 163.92±6.96 cm; boys: n=22, body height 177.13±5.98 cm) were analyzed.

The particular school was chosen since it offered a sufficient number of students and one researcher had contact to the school before the start of the study.

The project was approved by the Ethics Committee of the University of the Physical Education in Wroclaw (ECUPE No. 33/2018). All students and their legal guardians were informed in detail about the design of the study, including the potential risks and benefits, before providing their written informed consent to participate. Then all legal guardians were asked to sign a consent document prior to testing.

Intervention

During one weekly PE lesson, the EG participants performed the TAP (Fig. 1). This training aimed to improve aerobic and anaerobic efficiency, strengthen the ligamentous and muscular system, and improve resting metabolism, which should lead to gradual body fat reduction (Tabata, et al., 1996). In the current study, the TAP program was introduced in only one PE lesson per week for two reasons. First, measuring students' TAP outcomes was feasible once per week at this stage of the project. Second, the TAP implementation once a week allowed maintaining students' interest in other sports disciplines while still facilitating changes in HR-F components (Chin, et al., 2020; Logan, et al., 2016). During PE lessons, students were improving their physical literacy and other skills in various sports (e.g., volleyball, basketball, football, gymnastics, athletics, dancing, table tennis, Nordic walking). Thus, this research serves as a starting point for any further research with a larger sample size.

A PE lesson (total duration time 45 minutes) started with a standardized 10-minute warm-up of 5-minute slow jogging and 5-minute stretching (dynamic and static). The lesson's main activity was 14 minutes of TAP, which comprised three sessions, each lasting four minutes. Each session's Tabata protocol consisted of eight cycles of two exercises. The following exercises were used in the first session: push-ups and high knees. In the second session: dynamic lunges, spider crawl, and in the third: plank to push-up and side squeeze (Afyon, Mülazimoğlu, & Altun, 2018; Logan, et al., 2016; Wilke, et al., 2018). The exercises utilized were chosen because they require no or minimal exercise equipment and target several large muscle groups. Each cycle started with a maximum-intensity exercise lasting 20 seconds of as many repetitions as possible and then a 10-second active rest (low-intensity exercise) followed. There was a 1-minute break between each session during which no exercise was performed. After the TAP, the final PE lesson activity (flexibility and relaxation exercises) was performed for several minutes as a part of the regular curriculum of the subject. At the beginning and at the end of the lesson, organizational tasks were carried out and discussions on the Tabata protocol, its effects and research on Tabata training were presented.

The authors prepared the exercises (for the experimental purposes), recorded, and played them during the PE lesson on a screen so the exercise and rest times were measured accurately. To verify exercise intensity during the TAP, adolescents' maximum heart rate was determined with the formula $HR_{max} = 208 - 0.7 \times age$ (16 years) (Tanaka, Monahan, & Seals, 2001) where HR_{max} was maximum heart rate. The calculated maximum heart rate (197 bpm) was used to compute the high-intensity exercise ranging 75%–80% of maximum

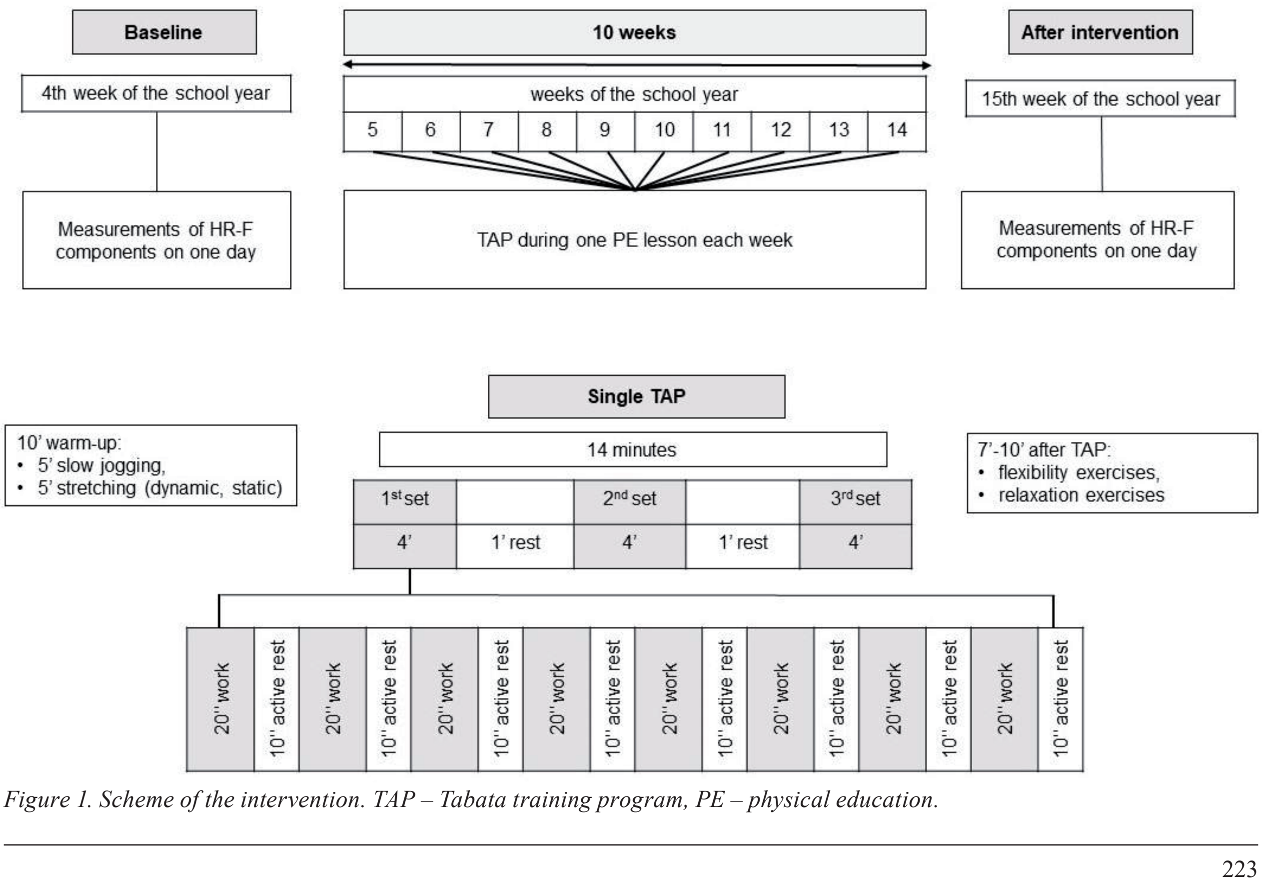

Figure 1. Scheme of the intervention. TAP – Tabata training program, PE – physical education.

heart rate (145–157 bpm). Students' heart rates were monitored during the first PE lesson with TAP using a Polar H1 heart rate monitor (Polar Electro, Kempele, Finland). The monitors were fitted to each student's chest, leveled with the xiphoid process and underneath clothing. Heart rate was displayed on the Polar H1 watch screens during TAP exercises to encourage users to maintain an adequate intensity level. The EG achieved an average of HR=155.8 bpm (±18.2; CI 121-184). In subsequent lessons of the Tabata protocol, the exercise intensity of HR measurement was similar to the intensity recorded during the first PE lesson.

Instruments

HR-F components were measured for the EG and CG *pre*- and *post*- TAP (in the 4th and 15th weeks of the school year). The tests were conducted on one day, from 8:00 a.m. to 1:00 a.m., in sports halls under the same conditions for each group. Each participant wore a T-shirt, shorts, and sports footwear. Only anthropometric measurements were conducted without sneakers.

Measurements of HR-F components

Measurements were taken *pre*- and *post*-intervention in the following order: anthropometric measurements, muscular strength and flexibility, speed and agility, and cardiovascular (physical) efficiency. Each measurement's protocol was based on HR-F measurement recommendations.

Anthropometric measurements

Two body height measurements were taken with an accuracy of 0.1 cm using anthropometers (GPM Anthropological Instruments). Body weight and body fat percentage were measured with a body composition analyzer using the InBody230 bioelectric impedance method (InBody Co. Ltd, Cerritos, CA, USA). The above data were used to calculate BMI.

Cardiovascular parameters

The physical efficiency index (PEI) that defines cardiovascular efficiency was determined using the Harvard Step Test. Participants stepped up and down on a 16.25 inch (41.3 cm) high stool at a pace of 30 cycles per minute with a metronome set at 120 bpm. The exercise continued for up to 300 seconds, unless participants' volitional exhaustion. Recovery pulse was recorded within 1.5 minutes into the recovery. Prior to each test, Polar H1 heart rate monitors were fitted to each student as per the afore-mentioned process. Resting heart rate, heart rate changes during exercise, and recovery pulse were measured. Heart rate monitors sampled participants' pulse at 5-second intervals and transmitted them to a smartwatch (Polar, Polar Electro; Kempele, Finland). PEI was calculated using the following formula (Bajaj, Appadoo, Bector, & Chandra, 2008):

$$\text{PEI} = (100 \text{ x } L)/(5{,}5 \times p)$$

where L = duration of the test in seconds, $L < 300$ seconds, and p = heart rate within 1.5 minutes after the subject stopped the test.

Musculoskeletal component parameters

To determine the musculoskeletal component parameters, hand muscular strength (HST) measurement, 30-second sit-up test (abdominal muscular strength) and sit-and-reach test (SRT; flexibility) were used. All the tests were performed according to the Eurofit guidelines (Adam, Klissouras, Ravazzolo, Renson, & Tuxworth, 1988). The Eurofit tests demonstrate very good test-retest reliability and validity (Tomkinson, et al., 2018).

HST was measured using the handgrip strength test via a hydraulic hand dynamometer (Baseline, FEI, Irvington, NY, USA). The dynamometer was sized to the individual with its spine parallel to the performer's thumb. The participant gripped the have demonstrated (with or without chalk, as desired) with a neutral wrist and squeezed it for 3–5 seconds. Any dynamometer *pumping* was considered a failed trial because it seemed to cause a falsely high reading, and the test was repeated. The better score of two trials was recorded for each hand.

The 30-second sit-up test measured the number of sit-ups with the hands placed at the side of the head, knees bent at 90º, and feet securely held by a partner. A full sit-up was defined as touching the knees with the elbows and returning shoulders to the ground. A total number of correctly performed sit-ups during 30 seconds was recorded. During the tests, the evaluators announced remaining time at the 10-, 20-, and 30-second marks. No other verbal encouragement other than counting the repetitions aloud was given during the test. Each participant performed the test once.

In the SRT, participants sat on the ground with straight legs against a standard reach box with 23 cm marked at the feet level. They were instructed to bend smoothly forward and sustain the extreme reach position for two seconds. The better score of two trials was recorded.

Motor component

The 4x10 m shuttle run test (agility) and the vertical jump test (VJT) were used to determine the motor component.

The 4x10 m shuttle run was performed according to Ortega, Ruiz, Castillo, and Sjöström, (2008). Two parallel lines were drawn on the floor 10 m apart. Participants ran as fast as possible from the starting line to the other line and returned to the starting line, crossing each line with both feet every time. The researcher stood at the starting line and stopped the stopwatch when participants crossed the line with one foot. The time taken to complete the test was recorded to the nearest tenth of a second. Participants wore sportswear and performed the test twice with a 5-minute rest, and the best time was selected.

Vertical jumping ability was assessed using the static vertical jump procedures in the VJT. In the VJT, a static position with a 90° knee flexion angle was maintained for two seconds before a jump attempt without any preparatory movement (Pereira, et al., 2018). All jumps were executed with the hands on the hips. Three attempts at each jump were performed, interspersed by 15-second intervals. Jumps were performed on a g-force tracker (Vert Jump; VERT, Fort Lauderdale, USA) with the obtained flight time (t) used to estimate the height of the rise of the body's centre of gravity (h) during the vertical jump (i.e., $h=gt^2/8$, where g=9.81 m/s^2). The best attempt was analyzed.

All measurements met HR-F guidelines. The scientific rationale for the selection of all the tests used, including their reliability for young people, have been previously verified (Bajaj, et al., 2008; Ortega et al., 2008, 2011).

Data analysis

The Shapiro-Wilk test was used to evaluate data distribution normality; all the data were normally distributed. Descriptive data were presented as mean ± standard deviation and skewness. General linear multidimensional analysis of variance (MANOVA) with repeated measures was used to evaluate the statistical significance of changes between the *pre*- and *post*-intervention measurement and the differences in all measurements between the EG and CG (boys and girls). Three factors were controlled for: *gender*, *intergroup differentiation* (EG vs CG), and *intervention* (repeated measures factor). We used Wilk's Λ and η_p^2 to interpret multidimensional statistical results. When statistically significant differences were observed, ANOVA with detailed comparisons of *post-hoc* tests (Tukey's HSD tests) was used. Statistical significance was set at α=.05. We used Statistica version 13.0 (StatSoft Polska, Cracow, Poland) for data analysis.

Results

Descriptive statistics of variables for the EG and CG *pre*- and *post*- intervention are presented in Table 1 and Table 2.

The pre-intervention MANOVA showed no statistically significant variation (group x gender interaction effect; Λ=.87, F=1.3, p=.20, η_p^2=.13) between the EG and CG (both boys and girls). Thus, the groups had a similar initial level in terms of body composition and aerobic and motor performance.

The MANOVA with repeated measures confirmed statistically significant changes in the variables following 10 weeks of the intervention (Λ=.43, F= 12.500, p=.000, η_p^2=.566). The *intervention* factor explained 57% of parameter variability. There was a statistically significant interaction of the first order of the *intervention* and *intergroup differentiation* factors (Λ=.77, F=2,800, p=.001, η_p^2=.228), meaning both factors were modified by their interaction and produced different results between the EG and CG. To identify the gender subgroups that showed differences in individual variable results, the second-order interaction of *intervention*, *intergroup differentiation*, and *gender* factors was analyzed. This interaction was statisti-

Table 1. Changes in body composition, aerobic performance, and motor performance before and after the 10-week intervention in boys; data are M±SD, skewness

Variables	Experimental group		Control group	
	Pre	Post	Pre	Post
BW [kg]	65.24±13.67, 1.41	63.81±11.81, 1,43	65.69±10.89, 0.85	66.87±11.34, 0.93
BMI [points]	20.90±3.92, 1.67	20.44±3.19, 1.33	20.89±2.96, 1,10	21.21±3.10, 1,17
WHR	0.83±0.06, 1.44	0.81±0.05, 1.53	0.82±0.05, 1.55	0.82±0.06, 1.44
FAT%	15.67± 7.03, 1.22	13.90±6.14*, 1.02	14.78±6.74, 1.89	14.11±7.38, 1.68
PEI [points]	42.96±4.23, 0.68	46.57±4.27*, 1.51	43.41±4.03, 0.03	43.84±2.20, -0.60
HST [kgF]	44.61±7.90, 0.57	44.71±7.40, 0.27	42.10±7.24, 0.48	44.05±7.57, 0.54
AbS (n)	26.19±3.58, -0.14	27.48±3.73, -0.19	26.38±3.58, -0.98	30.10±5.08†, 0.28
Flex (n)	21.58±7.53, -0.64	23.29±8.29, -0.45	23.95±8.59, -0.04	25.98±8.57, -0.14
Ag [s]	10.08±0.55, 0.79	10.25±0.78, 0.88	9.92±0.81, 1.63	10.05±1.11, 1.23
VJ [cm]	57.35±9.43, -0,55	54.35±8.37, 0.04	55.62±7.65, 0.25	55.21±9.39, -0.33

Note. *Pre* – the first examination before the intervention, *post* – the second examination after 10 weeks of the intervention, BH – body height, BW – body weight, BMI – body mass index, WHR – waist-hip ratio, FAT% – fat percentage, PEI – physical efficiency index, HST – handgrip strength test, AbS – abdominal strength, Flex – flexibility, Ag – agility, VJ – vertical jump, *post-hoc* Tukey's test results: * p≤.05, # p<.01, †p<.001.

Table 2. Changes in body composition, aerobic performance, and motor performance before and after the 10-week intervention in girls; data are M±SD, skewness

Variables	Experimental group		Control group	
	Pre	Post	Pre	Post
BW [kg]	56.08±7.48, 0.68	56.22±7.71, 0.69	57.27±12.23, 1.63	57.43±12.26, 1.61
BMI [points]	20.57±1.93, 0.07	20.62±2.01, -0.01	21.24±3.83, 1.68	21.30±3.87, 1.63
WHR	0.85±0.05, 0.65	0.85±0.05, 0.41	0.85±0.05, 1.01	0.86±0.07, 1.22
FAT%	26.72±4.92, 0.57	26.57±5.23, 0.34	28.77±6.14, 0.56	27.81±7.46, 1.14
PEI [points]	42.17±5.47, 0.61	47.17±5.10†, 0.58	44.34±5.58, 0.10	43.50±3.77, 0.52
HST [kgF]	31.31±4.28, 0.28	31.86±4.66, -0.09	32.09±6.23, 1.42	33.28±6.66, 0.94
AbS (n)	19.29±4.79, 0.22	23.26±4.27†, -0,68	20.57±3.55, 0.19	22.49±3.65#, -0.22
Flex (n)	27.20±6.06, 0.14	28.80±6.13*, -0.13	26.28±6.85, -0.32	28.39±8.09†, -0,76
Ag [s]	11.42±0.78, 0.42	11.56±0.70, 0.72	11.24±0.78, 0.77	11.43±0.74, 0.43
VJ [cm]	41.64±6.63, 0.17	41.83±6.77, 0.64	43.32±5.93, 0.69	43.14±6.46, 0.53

Note. *Pre* – the first examination before the intervention, *post* – the second examination after 10 weeks of the intervention, BH – body height, BW – body weight, BMI – body mass index, WHR – waist-hip ratio, FAT% – fat percentage, PEI – physical efficiency index, HST – handgrip strength test, AbS – abdominal strength, Flex – flexibility, Ag – agility, VJ – vertical jump, *post-hoc* Tukey's test results: * p≤.05, # p<.01, †p<.001.

cally significant (Λ=.81, F=2.30, p=.01, η_p^2=.19) and indicated differentiation in individual parameters between the four subgroups.

A series of ANOVAs identified variables that contributed to the changed *post*-intervention measurement (Table 1**,** Table 2). The comparison of results *pre*- and *post*- intervention revealed statistically significant effects of TAP on body fat percentage and physical fitness improvement in EG boys, who reduced body fat by 1.77% (p<.05). They significantly improved their PEI score by 3.61 points (p<.05, Table 1). Among EG girls, there was a statistically significant improvement (by 5 points) in physical capacity (p<.001, Table 2). Interestingly, motor ability test results also improved in some groups: abdominal muscle strength in EG girls (by 3.97, p<.001), CG girls (by 1.92, p<.01), and CG boys (3.72, p<.001). Changes also occurred in girls' flexibility; in EG girls, flexibility was improved by 1.6 cm (p=.04) and by 2.11 cm in CG girls (p<.001).

Discussion and conclusions

The study was mainly expected to achieve effects related to body weight and its components and the cardiovascular system. Detailed analysis of *post-hoc* tests confirmed a significant reduction of body fat and physical capacity improvements in EG boys and girls versus CG peers.

Similar results were obtained by Engel, Engel, Ackermann, Chtourou, and Sperlich (2018), who found improvements in certain aerobic and anaerobic performance variables in athletes aged 8–18 years following a HIIT training protocol. Favorable changes in aerobic and anaerobic capacity development in young female volleyball players were documented by Afyon et al. (2018) following six weeks of TAP participation. Furthermore, Cvetković et al. (2018) observed an insignificant reduction in body fat and a physical performance improvement in 11 to 13-year-old boys after their participation in a 12-week HIIT training program. In 14-year-olds in PE classes, Racil et al. (2016) found reduced body fat and improvement in maximal oxygen uptake and maximal aerobic speed following 12 weeks of HIIT or moderate-intensity interval training programs. Additionally, Camacho-Cardenosa et al. (2016) compared changes in 11-year-olds following a HIIT program and found increased fat mass percentage in the CG. However, there was no significant increase in body fat in the EG, which can be considered a positive result.

Therefore, the present study confirms the importance of HIIT protocols in physical activity aimed to reduce adolescents' body fat and improve their physical capacity. Regarding body composition (BMI or fat mass percentage), these changes may be minor, which may be because total energy expenditure is limited during interval training (Cvetković, et al., 2018). However, the HIIT training effect size may depend on training sessions frequency (Weston, et al., 2014). In the current study, Tabata exercises were used during one out of three weekly PE lessons, since the aim was to attract students' interest to this physical activity that can complement regular programs implemented in schools. Moreover, a short-term, intense exercise can cause positive changes in HF-R components in students. Furthermore, male adolescents respond more quickly and to a greater extent to external factors, like the high-intensity training used in our study (Silva, Rodrigues, Clemente, Bezerra, & Cancela Carral, 2019); in girls, however, body fat is more stable (Pulit, Karaderi, & Lindgren, 2017). No changes in girls' body fat might also have depended on their exercise involvement.

Boys tend to be more motivated during physical exercise. Girls after puberty are reluctant to start and fully engage in physical activity (Whitehead & Biddle, 2008). Despite PEI improvements observed in girls, this could have translated into insignificant body fat changes.

Because of the TAP, changes also occurred in EG girls in motor tests measuring abdominal strength and flexibility. However, similar changes occurred in CG girls. Therefore, it is not possible to state that Tabata exercises were critical to developing abdominal strength and flexibility, because changes could have come from different activities performed by all the first-year secondary schoole students in other PE classes.

Both groups of boys showed an improvement in strength after 10 weeks, despite the fact that significant changes occurred only in abdominal strength of CG. It may be a proof of the different pace of strength development in young boys. At the same time, it is difficult to identify the factors of power development, which may be largely determined by the sexual maturation of peasants (García-Baños, Rubio-Arias, Martínez-Aranda, & Ramos-Campo, 2020).

TAP has proved very safe for young people implementing the PE program. No one has reported any adverse effects or injuries resulting from participation in this form of exercise (Weston, et al., 2014).

A study limitation is that participants were local youths; students from other geographical locations may have different physical fitness characteristics/ preferences and be involved in other forms of physical activity. Therefore, similar studies are needed in different countries to evaluate TAP's usefulness during PE lessons in improving physical fitness and preventing overweight and obesity. Furthermore, participants' motor activity in their free time was not monitored (apart from *pre*- and *post*- intervention instructions).

Another important factor involves controlling for sexual maturation, which could have affected our results' consistency with previous studies. Sexual maturation can greatly affect metabolic outcomes, so considering puberty's effect on metabolism is important for results' validity (Camacho-Cardenosa, et al., 2016).

Moreover, research on the effectiveness of intervention interval protocols included in PE classes should also consider nutritional aspects.

The study was limited to a 10-week exercise intervention because *pre*- and *post*- measures needed to be completed during one school term. Future research could investigate effects of HIIT dose-response over a longer duration or with a higher weekly frequency (Zapata-Lamana, et al., 2019). Moreover, similar studies are needed to evaluate the sustainability of the intervention. It is also necessary to consider individual variability when determining exercise intensity and average HR (HR max) during HIIT exercises.

In conclusion, we found the program used in the study to be effective, but it should be individualized to consider sex differences. For example, exercise to increase muscle mass is a common motivator for boys to exercise, but they act as a motivation barrier to girls' activity (Casey, Mooney, Smyth, & Payne, 2016). In addition, excessive sweating during exercise can discourage girls from doing them (Cowley, et al., 2021). Moreover, individual monitoring of the heart rate in real time during exercise would allow for immediate response in case of intensity reduction. This would increase the effectiveness of the intervention program. The hypothesis was partially confirmed. The TAP improved physical fitness and reduced body fat, but only in boys; in girls, only physical capacity was improved. It is necessary to examine why changes did not occur in girls' body fat. Second, the sustainability of the induced changes is worth analyzing, making it advisable to repeat the tests after a certain time. However, PE classes are not enough to reduce obesity among school-age populations. Therefore, familiarizing young people with HIIT protocols and opportunities to perform this training during daily life may contribute to their decision of doing it in their free time, which may offer a viable solution to counter youth overweight and obesity.

This study's findings show that adding TAP to a PE program can produce positive changes in youth physical fitness and help reduce body fat. Exercise frequency may affect the magnitude of changes in HR-F components. In this context, schools may consider implementing a variety of physical activities and between-lesson breaks to promote physical fitness. A significant advantage is the exercises' availability as well as the fact that a large group can simultaneously perform such high-intensity exercises even in small rooms. Another advantage is that this training is inexpensive and easy to introduce.

References

Adam, C., Klissouras, V., Ravazzolo, M., Renson, R., & Tuxworth, W. (1988). *The Eurofit Test of European physical fitness tests*. Council of Europe.

Afyon, Y.A., Mülazimoğlu, O., & Altun, M. (2018). The effect of 6 weekly Tabata training on some physical and motor characteristics on female volleyball players. *European Journal of Physical Education and Sport Science, 5*(5), 223-229. doi: 10.46827/ejpe.v0i0.2169

Bajaj, A., Appadoo, S., Bector, C., & Chandra, S. (2008). Measuring physical fitness and cardiovascular efficiency using Harvard step test approach under fuzzy environment. *Administrative Sciences Association of Canada, 29*(2), 129-143.

Buchan, D.S., Ollis, S., Thomas, N.E., Buchanan, N., Cooper, S.M., Malina, R.M., & Baker, J.S. (2011). Physical activity interventions: Effects of duration and intensity. *Scandinavian Journal of Medicine and Science in Sports, 21*(6), e341-e350. doi: 10.1111/j.1600-0838.2011.01303.x

Camacho-Cardenosa, A., Brazo-Sayavera, J., Camacho-Cardenosa, M., Marcos-Serrano, M., Timón, R., & Olcina, G. (2016). Effects of high intensity interval training on fat mass parameters in adolescents. *Revista Espanola de Salud Publica, 21*(90), e1-e9.

Carson, V., Rinaldi, R.L., Torrance, B., Maximova, K., Ball, G.D.C., Majumdar, S.R., Plotnikoff, R.C., Veugelers, P., Boulé, N.G., Wozny, P., McCargar, L., Downs, S., Daymont, C., Lewanczuk, R., & McGavock, J. (2014). Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. *International Journal of Obesity, 38*(1), 16-21. doi: 10.1038/ijo.2013.135

Casey, M., Mooney, A., Smyth, J., & Payne, W. (2016). 'Power, regulation and physically active identities': The experiences of rural and regional living adolescent girls. *Gender and Education*, *28*(1), 108-127. doi: 10.1080/09540253.2015.1093098

Chin, E.C., Yu, A.P., Lai, C.W., Fong, D.Y., Chan, D.K., Wong, S.H., Sun, F., Ngai, H.H., Yung, P.S.H., & Siu, P.M. (2020). Low-frequency HIIT improves body composition and aerobic capacity in overweight men. *Medicine and Science in Sports and Exercise, 52*(1), 56-66. doi: 10.1249/MSS.0000000000002097

Costigan, S.A., Eather, N., Plotnikoff, R.C., Taaffe, D.R., & Lubans, D.R. (2015). High-intensity interval training for improving health-related fitness in adolescents: A systematic review and meta-analysis. *British Journal of Sports Medicine, 49*(19), 1253-1261. doi: 10.1136/bjsports-2014-094490

Costigan, S.A., Ridgers, N.D., Eather, N., Plotnikoff, R.C., Harris, N., & Lubans, D.R. (2018). Exploring the impact of high intensity interval training on adolescents' objectively measured physical activity: Findings from a randomized controlled trial. *Journal of Sports Sciences, 36*(10), 1087-1094. doi: 10.1080/02640414.2017.1356026

Cowley, E.S., Watson, P.M., Foweather, L., Belton, S., Thompson, A., Thijssen, D., & Wagenmakers, A.J.M. (2021). "Girls Aren't Meant to Exercise": Perceived influences on physical activity among adolescent girls—The HERizon Project. *Children*, *8*(1), 31. doi: 10.3390/children8010031

Cvetković, N., Stojanović, E., Stojiljković, N., Nikolić, D., Scanlan, A.T., & Milanović, Z. (2018). Exercise training in overweight and obese children: Recreational football and high-intensity interval training provide similar benefits to physical fitness. *Scandinavian Journal of Medicine and Science in Sports, 28*(Suppl 1), 18-32. doi: 10.1111/sms.13241

Delgado-Floody, P., Latorre-Roman, P., Jerez-Mayorga, D., Caamano-Navarrete, F., & Garcia-Pinillos, F. (2019). Feasibility of incorporating high-intensity interval training into physical education programs to improve body composition and cardiorespiratory capacity of overweight and obese children: A systematic review. *Journal of Exercise Science and Fitness, 17*(2), 35-40. doi: 10.1016/j.jesf.2018.11.003

Dumith, S.C., Gigante, D.P., Domingues, M.R., & Kohl, H.W. (2011). Physical activity change during adolescence: A systematic review and a pooled analysis. *International Journal of Epidemiology, 40*(3), 685-698. doi: 10.1093/ije/dyq272

Ekström, A., Ostenberg, A.H., Bjorklund, G., & Alricsson, M. (2017). The effects of introducing Tabata interval training and stability exercises to school children as a school-based intervention program. *International Journal of Adolescent Medicine and Health, 31*(4), 20170043. doi: 10.1515/ijamh-2017-0043

Engel, F.A., Ackermann, A., Chtourou, H., & Sperlich, B. (2018). High-intensity interval training performed by young athletes: A Systematic review and meta-analysis. *Frontiers in Physiology, 9,* 1012. doi: 10.3389/fphys.2018.01012

García-Baños, C., Rubio-Arias, J. Á., Martínez-Aranda, L. M., & Ramos-Campo, D. J. (2020). Secondary-school-based interventions to improve muscular strength in adolescents: A systematic review. *Sustainability*, *12*(17), 6814. doi:10.3390/su12176814

Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet, 380*(9838), 247-257. doi: 10.1016/s0140-6736(12)60646-1

Hay, J., Maximova, K., Durksen, A., Carson, V., Rinaldi, R.L., Torrance, B., Ball, G.D.C., Majumdar, S.R., Plotnikoff, R.C., Veugelers, P., Boulé, N.G., Wozny, P., McCargar, L., Downs, S., Lewanczuk, R., & McGavock, J (2012). Physical activity intensity and cardiometabolic risk in youth. *Archives of Pediatrics and Adolescent Medicine, 166*(11), 1022. doi: 10.1001/archpediatrics.2012.1028

Heath, G.W., Parra, D.C., Sarmiento, O.L., Andersen, L.B., Owen, N., Goenka, S., Montes, F., & Brownson, R.C. (2012). Evidence-based intervention in physical activity: Lessons from around the world. *The Lancet, 380*(9838), 272-281. doi: 10.1016/s0140-6736(12)60816-2

Lambrick, D., Westrupp, N., Kaufmann, S., Stoner, L., & Faulkner, J. (2016). The effectiveness of a high-intensity games intervention on improving indices of health in young children. *Journal of Sports Sciences, 34*(3), 190-198. doi: 10.1080/02640414.2015.1048521

Logan, G.R., 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 and Science in Sports and Exercise, 48*(3), 481-490. doi: 10.1249/mss.0000000000000799

Ortega, F.B., Artero, E.G., Ruiz, J.R., Espana-Romero, V., Jimenez-Pavon, D., Vicente-Rodriguez, G., Moreno, L.A., Manios, Y., Beghin, L., Ottevaere, C., Ciarapica, D., Sarri, K., Dietrich, S., Blair, S.N., Kersting, M., Molnar, D., Gonzalez-Gross, M., Gutierrez, A., Sjostrom, M., & Castillo, M.J. (2011). Physical fitness levels among European adolescents: The HELENA study. *British Journal of Sports Medicine, 45*(1), 20-29. doi: 10.1136/bjsm.2009.062679

Ortega, F.B., Ruiz, J.R., Castillo, M.J., & Sjöström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity, 32*(1), 1-11. doi: 10.1038/sj.ijo.0803774

Osiński, W., & Kantanista, A. (2017). Physical activity in the therapy of overweight and obesity in children and adolescents. Needs and recommendations for intervention programs. *Journal of Mother and Child 21*(3), 224-234. doi: 10.34763/devperiodmed.20172103.224234

Pereira, L.A., Nimphius, S., Kobal, R., Kitamura, K., Turisco, L.A.L., Orsi, R.C., Cal Abad, C.C., & Loturco, I. (2018). Relationship between change of direction, speed, and power in male and female national Olympic team handball athletes. *Journal of Strength and Conditioning Research, 32*(10), 2987-2994. doi: 10.1519/jsc.0000000000002494

Pulit, S.L., Karaderi, T., & Lindgren, C.M. (2017). Sexual dimorphisms in genetic loci linked to body fat distribution. *Bioscience Reports, 37*(1), BSR20160184. doi: 10.1042/bsr20160184

Racil, G., Coquart, J.B., Elmontassar, W., Haddad, M., Goebel, R., Chaouachi, A., Amri, M., & Chamari, K. (2016). Greater effects of high- compared with moderate-intensity interval training on cardio-metabolic variables, blood leptin concentration and ratings of perceived exertion in obese adolescent females. *Biology of Sport, 33*(2), 145-152. doi: 10.5604/20831862.1198633

Silva, B., Rodrigues, L., Clemente, F., Bezerra, P., & Cancela Carral, J. (2019). Motor competence and body composition in young adults: An exploratory study. *Obesity Medicine, 14,* 100087. doi: 10.1016/j.obmed.2019.100087

Steyn, H.S., & Ellis, S.M. (2009). Estimating an effect size in one-way multivariate analysis of variance (MANOVA). *Multivariate Behavioral Research*, *44*(1), 106-129. doi: 10.1080/00273170802620238

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*(10), 1327-1330. doi: 10.1097/00005768-199610000-00018

Tanaka, H., Monahan, K.D., & Seals, D.R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37*(1), 153-156. doi: 10.1016/S0735-1097(00)01054-8

Tomkinson, G.R., Carver, K.D., Atkinson, F., Daniell, N.D., Lewis, L.K., Fitzgerald, J.S., Lang, J.J., & Ortega, F.B. (2018). European normative values for physical fitness in children and adolescents aged 9–17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *British Journal of Sports Medicine*, *52*(22), 1445-1456. doi: 10.1136/bjsports-2017-098253

Weston, K.L., Azevedo, L.B., Bock, S., Weston, M., George, K.P., & Batterham, A.M. (2016). Effect of novel, school-based high-intensity interval training (HIIT) on cardiometabolic health in adolescents: Project FFAB (Fun Fast Activity Blasts)—An exploratory controlled before-and-after trial. *PLoS One, 11*(8), e0159116. doi: 10.1371/journal.pone.0159116

Weston, K.S., Wisløff, U., & Coombes, J.S. (2014). High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: A systematic review and meta-analysis. *British Journal of Sports Medicine, 48*(16), 1227-1234. doi: 10.1136/bjsports-2013-092576

Whitehead, S., & Biddle, S. (2008). Adolescent girls' perceptions of physical activity: A focus group study. *European Physical Education Review, 14*(2), 243-262. doi: 10.1177/1356336x08090708

Wilke, J., Kaiser, S., Niederer, D., Kalo, K., Engeroff, T., Morath, C., Vogt, L., & Banzer, W. (2018). Effects of high-intensity functional circuit training on motor function and sport motivation in healthy, inactive adults. *Scandinavian Journal of Medicine and Science in Sports*, *29*, 144-153. doi: 10.1111/sms.13313

Zapata-Lamana, R., Cigarroa Cuevas, I., Fuentes, V., Soto Espindola, C., Parrado Romero, E., Sepulveda, C., & Monsalves-Alvarez, M. (2019) HIITing health in school: Can high intensity interval training be a useful and reliable tool for health on a school-based environment? A systematic review. *International Journal of School Health*, *6*(3), 1-10. doi: 10.5812/intjsh.89829

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