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EFEKTI INTERVALNOG TRENINGA VISOKOG INTENZITETA KOD ADOSLESCENATA

EFFECTS OF HIGH-INTENSITY INTERVAL TRAINING IN ADOLESCENTS

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Sažetak

Uvod: *Od kraja 20. veka, intervalni trening visokog intenziteta (HIIT) prvenstveno koriste sportisti, ali je u poslednjoj deceniji postao sve popularniji među opštom populacijom. Ovu strategiju treninga karakterišu navale aktivnosti visokog intenziteta, ispresecane periodima odmora ili vežbama niskog intenziteta za oporavak.*
Cilj: *Cilj ovog preglednog rada bio je da se utvrde efekti HIIT-a kod adolescenata i pokaže kako njegova primena u redovnoj nastavi fizičkog vaspitanja može doneti pozitivne promene u fizičkoj aktivnosti mladih.*
Zaključak: *Preporučuje se da nastavnici i profesori fizičkog vaspitanja uvek budu u stalnom kontaktu sa svojim učenicima kroz sistem obrazovanja i da im ukažu na značaj fizičkog i zdravstvenog vaspitanja u društvu*
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Ključne reči: *ефекти, високоинтензивно интервални тренинг, адолесценти*

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Abstract

Introduction: *Since the late 20th century, high-intensity interval training (HIIT) has primarily been used by athletes, but in the past decade, it has become increasingly popular among the general population. This training strategy is characterized by bursts of high-intensity activity interspersed with periods of rest or low-intensity exercises for recovery.*
Aim: *The aim of this systematic review was to determine the effects of HIIT in adolescents and show how its implementation in regular physical education classes can positively affect young people's activity.*
Conclusion: *It is recommended that teachers and professors of physical education always be in constant contact with their students through the education system and point out to them the importance of physical and health education in society.*

Key words: *effects, high-intensity interval training, adolescents*

Introduction

Most of children and adolescents are physically active only in regular physical education classes (PE) at school[1]. Generally, they do not receive adequate health-promoting physical activity (PA)[2,3], and school PE programs should contribute to health maintenance and disease prevention[4]. PE classes[5,6,7] or other school-based activities, such as classroom exercise[8], have been shown to induce beneficial cardiometabolic[9] and neuromuscular adaptations[8], improve health-related parameters[6,8,10]and are more enjoyable than long-duration, low-intensity exercise[11,12]. Insufficient PA[13] is associated with all risks of cardiovascular disease[14,15], increasing the risk of premature mortality[16,17]. Also, overweight and obesity, poor diet, reduced cardiorespiratory fitness, hypertension, chronic infections, and dyslipidemia are evident in youth and become persistent health problems in adulthood.[18,19,20] Childhood and adolescence are, therefore, key stages in the development and adoption of healthy habits. Although regular physical activity protects against many diseases, it is estimated that the current activity level among adolescents does not meet the recommended level of exercise[21,22]. There is a strong case for future work investigating how high-intensity interval training (HIIT) can be optimized for adolescent quality of life and mental health outcomes and an important predictor of youth cardiometabolic health[23,24]. Therefore, HIIT protocols have been introduced to obtain positive psychological responses for physically inactive adolescents, and the design of the exercises is adapted to the individual[25].

Materials and Methods

Multiple databases, such as Google Scholar, PubMed, and Web of Science, were identified. For study identification in the mentioned databases, multiple keywords (combinations are separate) were used: (adolescents, high-intensity interval training, and fitness. Two authors (R.J. and M.K.) examined the study identification and data extraction separately. Furthermore, a descriptive method was used for obtained data examination, whereas all titles, abstracts, and full-text articles were reviewed for eventual study inclusion in the systematic review. After a detailed identification process, studies were considered relevant and included only if they met the pre-defined inclusion criteria.

Inclusion criteria

Each study had to meet the following inclusion criteria: year of publication (2013-2024), full-text study published in English.

Exclusion criteria

The studies were not included if they had been realized before 2013, published studies in other languages than English.

Results

The results of the analysed popers are showiv in Figure 1 and Table 1.

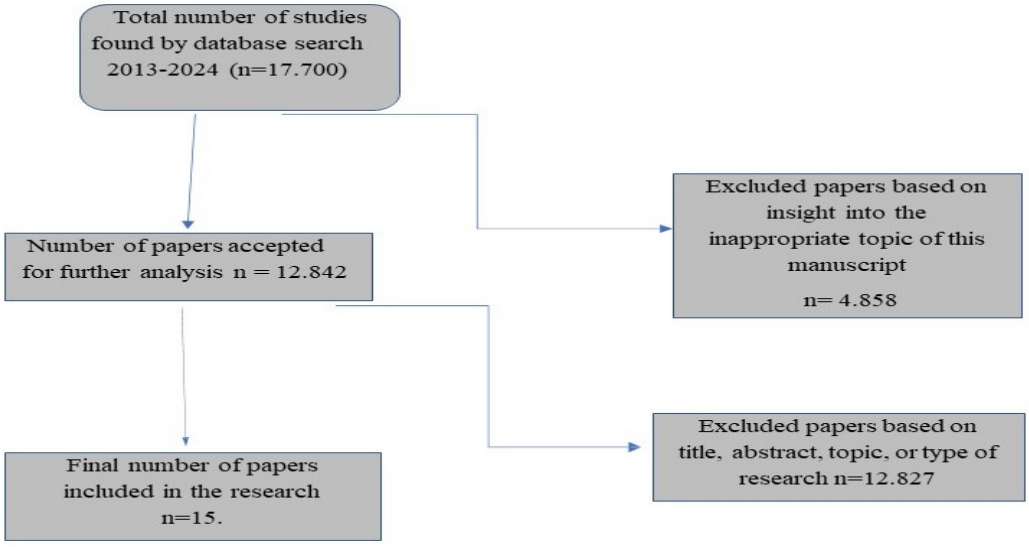

Figure 1. Flow chart of study identification

Table 1. Research on the effect of HIIT on fitness components

First author and year of publication	Examinee		Duration (weeks)	Exercise program	Measured parameters	Results	
	Age	Number and groups					
De Bourdeaudhuij et al. (2013)	10 to 12	766 girls and boys	/	E group short-term sitting exercise C group long-term sitting exercise	BMI WC	BMI E↓ WC E ↓	BMI C↑ WC C↑
Costigan et al. (2016) (5)	15,8	N-65	/	I group– aereobic exercise II group – aereobic resistance exercise III group – Control 3×HIIT per week; 8–10min	SRT MC BMI WC	I+II+III SRT MC BMI WC	SRT MC BMI WC
Muntaner-Mas et al. (2017) (2)	/	N–80 E–55 C–25	20	HIIT; 2× week on PE classes 45s exercise, 15s rest 7.5min HIIT, 2.5min rest, intensity of exercise 85%HRmax		E BMI ↑	C BMI ↑
Rey et al. (2017) (5)	14–15	N–24 Girls–14 Boys–10	5	45min HIIT, 3× недељно; diet, energy intake for girls 2000 kcal/day, for boys 2200 kcal/day; intensity of exercise >80% Hrmax	BMI W PC	Girls BMI↑ W↑ PC ↑	Boys BMI↑ W ↑ PC ↑
Larsen et al. (2018) (9)	8–10	N–295 BGG–96 CT–83 C–116	>40	HIIT; 3×40min per week; tests used to determine muscular fitness: flamingo balance test, standing long jump, 20m sprint	BM MC	BGG BM ↑ MC ↑	CT BM ↑ MC ↑
Tottori et al. (2019) (4)	/	N–56 E–28 C–28	4	(E)–3×HIIT per week/ 8–10min/4weeks	SRT ABS SLJ	(E) HIIT SRT ↑ ABS ↑ SLJ ↑	C SRT ↓ ABS ↓ SLJ ↓
Nugent et al. (2019) (4)	15,8	N–16 E–16	7	(E) HIIT; 7 weeks		(E) HIIT SP ↑	
Alonso-Fernandez et al. (2019) (4)	Adolescents	N–26 E–13 C–13	7	HIIT Tabata; 4min/8 intervals of maximum effort 20s; rest 10s	CRF BFP	(E) HIIT CRF ↑ BFP ↑	C CRF↑ BFP ↓

Plavsic et al. (2020)	13 to 19	N-44	12	E E – HIIT + nutrition C – nutrition K	BMI SBP MHR RHR	BMI ↑ SBP ↑ MHR ↑ RHR ↑	BMI ↑ SBP ↑
Ketelhut et al. (2020)	/	N-46 E-22 C-24	12	E group – first 20min of class HIIT C group – regular PE class	AFT CSP PSP APV	AFT ↑ PSP ↑ CSP ↑ APV ↑	
Fang et al. (2021) (3)	/	N-56 E-28 C-28	4	E group- HIIT; Cgroup- moderate intensity training	CF(E) ME(C)	E CF↑	C ME↑
Bogataj et al. (2021)	15.5	N-48 E-24 C-24	8	E group- 3× week HIIT and nutrition C group – regular PE class	BC CMJ YYT	BC↑↑↑ CMJ↑↑↑ YYT↑↑↑	BC↑ CMJ↑ YYT↑
Bossman et al. (2022)	11 to 15	N-121 E- 121	6	3 types of HIIT, 2xweek	BC	E BC↑	
Petrušič et al. (2022)	12 to 14	N-59	12	E group – games program (football, basketball, handball, volleyball) C group – PE classes	CMJ CMJPA SQJ MBT ABS YYT	E in relation to C CMJ (p<0.001) MBT (p<0.001) ABS (p=0,030) CMJPA (p<0.001) YYT (p=0,004)	
Popowczak et al. (2022)	Students	N-187 Boys 66 Girls- 121	10	E group-boys HIIT C group- girls, regular PE class	F S CE BF	E group – reduction of body fat and an increase in cardiovascular efficiency C group – increase in cardiovascular efficiency	

N – total number of participants; E – experimental group; C – control group; SRT – shuttle run test; ABS – abs; SLJ – standing long jump; SP – swimming performance; CRF – cardiorespiratory fitness; BFP – body fat percentage; BF- body fat; SBP – systolic blood pressure; CF – cardiorespiratory fitness; ME – muscular endurance; BMI – body mass index; S – speed; BC – body composition; MC – muscular condition; WC – weist circumference; W – weight; BGG- ball game group; PC – physical condition; CT – circuit training; BM – bone mineralization; MC – muscular condition; MHR – maximum heart rate; RHR – resting heart rate; AFT – aerobic fitness test; CSP – central systolic pressure; PSP – peripheral systolic pressure; APV – aortic pulse velocity; BC– body composition; CMJ – counter movement jumo; MBT – medicine ball test; YYT – yo-yo test; ТАК – тест аеробне кондиције; F – flexibility; CE – cardiovascular efficiency; SQJ- squat jump

Discussion

The aim of the study[26] was to identify subgroups of children based on whether they had moderate or vigorous-intensity PA (MVPA) and length of sitting time and to investigate differences in body mass index (BMI), waist circumference, and prevalence of overweight between these subgroups. A sample of 766 children aged 10 to 12 (52.9% girls, 11.6 ± 0.8 years) participated in this study. Children wore accelerometers to measure MVPA and sitting time. Cluster analysis revealed four clusters in both gender groups showing an unhealthy pattern (low MVPA/long sitting), a healthy pattern (high MVPA/short sitting), a low mixed pattern (low MVPA/short sitting), and a moderate to a high degree of mixedness (moderate to high MVPA/moderate sitting). In girls, the high MVPA/short-term sitting group had significantly lower BMI ($p \leq 0.05$), lower waist circumference ($p \leq 0.01$), and the lowest percentage of overweight ($p \leq 0.10$) compared to the other three clusters. In boys, both clusters with higher activity levels had significantly lower BMI ($p \leq 0.001$) and waist circumference ($p \leq 0.001$) than the two low-activity clusters, regardless of sitting time. The authors conclude that engaging in more MVPA and less sitting time is associated with a more favorable weight status among girls

aged 10 to 12. MVPA appears to be most important for body weight, while sitting is less relevant. In a study[27], the authors indicate that current PA and fitness levels among adolescents are low, which increases the risk of chronic diseases. The authors conducted a pilot randomized study on 65 students with an average age of 15.8 years, divided into three groups. The first group followed an aerobic exercise program, the second group followed an aerobic and resistance exercise program, and the third was a control group. The program consisted of three weekly HIIT sessions (8–10 min) held during physical education classes or lunch. Measurements were taken at the beginning and end of the exercise to detect changes in cardiorespiratory function (shuttle run test), muscle fitness (push-ups, long jump tests), body composition (body mass index (BMI)), waist circumference, and motivation for physical activity (questionnaire). Current physical activity and fitness levels among adolescents are low, which increases the risk of chronic diseases. This study indicates the need to include HIIT during mandatory PE classes to improve cardiorespiratory function and body composition among adolescents. On the other hand, the goal of the study[28] was to integrate the new HIIT method into a traditional physical education unit. The study was conducted on 80 subjects divided into two groups: an experimental group consisting of 55 subjects and a control group (25) of subjects for 5 months, twice a week in physical education classes. The program consisted of a circuit of 10 stations, each performing HIIT. Three students were at each station and stayed together for all 10 stations, exercising simultaneously. They started at one station and moved clockwise for the remaining 9. The exercise time was 45s, with a 15s rest period. The total duration of the program was 7.5 min of HIIT and 2.5 min of rest. The optimal intensity was 85 HRmax. By analyzing the results obtained, the authors indicate an improvement in body composition. The authors conclude that it is a priority to include methodological strategies during physical education classes to achieve adequate intensity. The proposed method shows a positive trend in improving health in schoolchildren, although future research is necessary to confirm or refute the results obtained. In the study[29,] the authors examined the effects of HIIT and diet in 24 obese adolescents over five weeks. Fourteen girls and ten boys (aged 14-15) participated in a pediatric rehabilitation center. The intensity of the HIIT was above 80% of the maximum heart rate (HR) and above six kilocalories per minute. The average energy intake was 2000 kcal/day (17% protein, 33% fat and 50% carbohydrates) for girls and 2200 kcal/day (17% protein, 30% fat and 53% carbohydrates) for boys. The study was conducted through three training sessions per week over five weeks, 45 minutes of different interval training consisting of playing basketball, running, cycling, and non-contact boxing and kickboxing with a similar 10-minute warm-up followed by different rest periods. The three types of training were performed: (a) in three sets of 10 min / three min passive rest in a three-on-three basketball game; (b) in two sets of three min work / three min passive rest and running at a free cadence for a maximum distance; and (c) in three sets of eight min repetitions of 10 seconds of hitting the bag / 20 seconds of passive rest. Measurements were taken before and after the intervention, including Body composition (BMI, weight, body fat percentage), physical self-perception and physical fitness (6 min walk and work), and related physiological responses (HR peak and blood lactate concentration). Significant improvements were found in body composition, physical condition and physical fitness (endurance, activity level, sports competence and appearance). This five-week HIIT program combined with diet is an effective means of improving body composition, physical condition, and physical fitness in obese adolescents, with the effects on physical fitness being greater in girls. The authors investigated[30] the effects of HIIT on musculoskeletal fitness in school children aged 8–10 years. The study included 295 Danish children, divided into small groups: a ball game group (n=96, four schools, five classes); a circuit training group (n=83, four schools, four classes); and a control group (n=116, two schools, five classes). The study lasted over 10 months, with 3×40 min/week of exercise. X-rays and absorptiometry scans were used to determine bone mineral density, bone mineral content, and body mass. The following tests were used to determine muscular fitness: flamingo balance, standing long jump, and 20m sprint. The results indicate that 3×40 min/week of HIIT including ball games or circuit training throughout the school year improves bone mineralization and several aspects of muscle fitness in children aged 8–10 years. Well organized physical education classes can positively contribute to the development and health of musculoskeletal fitness in school children.

In a study[31], the researches investigated the effects of a HIIT program on physical fitness and intelligence in children. This study involved 56 subjects, divided into an experimental and a control group. The experimental group performed three HIIT training sessions of 8 to 10 min per week for 4 weeks. Before and after the study, 20m running, sit-ups, and long jumps were assessed as a test of physical fitness. The findings of the study suggest that HIIT has positive effects on physical fitness indicators such as cardiorespiratory endurance and muscular endurance. The effect of HIIT was tested in 16 female swimmers with an average age of 15.8 years for seven weeks, and an improvement in swimming performance was shown in the experimental group that practiced HIIT[32]. In their study[33], the authors analyzed the effect of HIIT based on functional exercises on body mass index and cardiorespiratory capacity in adolescents. The study, which lasted over 7 weeks, involved 26 adolescents randomly divided into an experimental and a control group. The experimental group showed a significant increase in cardiorespiratory capacity and a significant decrease in body fat percentage. The control group showed only a significant increase in cardiorespiratory capacity. The training was based on the Tabata method. It consisted of 4 min of training, with 8 intervals of maximal effort, each interval lasting 20 s, followed by a 10 s rest period. The authors conclude that HIIT protocols represent a promising way to reduce body fat percentage and improve cardiorespiratory fitness, as well as support adolescents to reduce their sedentary lifestyle through physical education classes. The aim of the study[34] was to compare the effects of high-intensity interval training (HIIT) and dietary advice on cardiometabolic biomarkers, hormonal parameters, and cardiorespiratory fitness in adolescent girls with obesity. Adolescent girls with obesity (n=44, ages 13-19) were randomly assigned to two groups: an experimental group that performed HIIT and received dietary advice (n=22), and a control group that received only dietary advice (n=22). The study lasted 12 weeks. The concentration of inflammatory biomarkers, biochemical and hormonal tests, oral glucose tolerance test, cardiorespiratory fitness, PA level and diet were assessed. Both groups had significant improvements in body mass index (BMI), BMI standard deviation, body fat percentage, and systolic blood pressure. Positive effects on waist circumference, waist/height, diastolic blood pressure, CRP, maximal heart rate, and resting heart rate were observed only after the diet+high-intensity interval training program. There was no significant change in maximal oxygen uptake, lipid profile, and hormonal parameters between groups after intervention. Dietary advice reduced BMI, body fat, and systolic blood pressure in obese adolescent girls. In the study[35], the authors aimed to determine the effectiveness of HIIT at school on aerobic fitness and hemodynamic parameters in 46 students divided into an experimental (n=22) and a control group (n=24). During the 3-month exercise program period, students in both groups had regular physical education classes twice a week. The experimental group had HIIT during the first 20 min of physical education class. In addition to the aerobic fitness test, peripheral and central systolic blood pressure and aortic pulse wave velocity were measured. Significant differences in the effects of HIIT in the experimental group were noted for aerobic fitness ($p=0.007$), peripheral systolic blood pressure ($p=0.038$), central systolic blood pressure ($p=0.041$), and aortic pulse wave velocity ($p=0.031$). HIIT has shown positive effects on aerobic fitness and hemodynamic parameters in children. The aim of the research[36] was to examine the effect of HIIT over four weeks in 56 soccer players and showed improvements in cardiorespiratory fitness in the group of soccer players who trained with a HIIT program, while the group who worked with a moderate-intensity training program showed improvements in muscular endurance. In their study[37], the authors investigated the effects of HIIT and diet on body composition and physical fitness in obese adolescent girls (48) divided into two groups: an experimental group (24 subjects aged 15.5± 0.7 years) who received HIIT and a diet program led by a nutritionist at school; and a control group (24 subjects aged 15.7± 0.6 years) who maintained their usual activities in physical education classes. HIIT consisted of 10 sets of bodyweight exercises three times a week for eight weeks. The experimental group participated in a nutrition program led by a nutritionist twice a week. In addition to the body composition assessment, the subjects performed a prepared squat jump (CMJ), a medicine ball throw as a strength test, and a Yo-Yo test. The results show that there was a statistically significant difference between the groups in the javelin throw test ($p<0.001$) and the Yo-Yo test ($p=0.024$). A significant improvement was obtained in the

anthropometric test (p=0.004) and in the CMJ (p=0.001). This study showed that an 8-week school-based HIIT intervention and a dietary intervention, three times a week, can improve body composition, as well as muscle and physical aerobic performance in overweight adolescent girls. A study[38] in which 121 students aged 11 to 15 years at a high school in Baden-Württemberg (Germany) were tested confirmed the excellent effects of training on the aerobic fitness of adolescents in a relatively short time. The students had three different forms of HIIT training that differed in duration and content (4×4 HIIT, 12×1 HIIT, circuit), twice a week for 6 weeks (10-12 training sessions). Strength and endurance performance were determined before and after the intervention. The results confirmed that all three HIIT programs led to significant improvements in aerobic fitness ($p<0.001$). The authors[39] determined the effects of a twelve-week program of high-intensity indoor games on physical fitness in girls aged 12–14 years. The study was conducted on 59 adolescent girls aged 13.2 ± 0.3 years, randomly assigned to an experimental group that participated in a games program (football, basketball, handball, and volleyball) and a control group that participated only in mandatory physical education classes. Physical fitness was assessed using standardized tests: prepared squat jump (CMJ), free-arm squat jump (CMJ free arms), squat jump (Squat Jump), overhead medicine ball throw, 30s sit-ups, and the Yo-Yo test to assess recovery speed. There was a significant difference between groups for the standing long jump ($p<0.001$), overhead medicine ball throw ($p<0.001$), 30-s sit-ups ($p=0.030$), free-arm squat jump (CMJ) ($p<0.001$), and Yo-Yo recovery test ($p=0.004$). The results of this study indicate that after-school play significantly improved adolescent PA and fitness compared to adolescent girls who received regular physical education (PE). The authors believe that just two additional training sessions per week are enough to lead to significant changes in physical fitness in adolescent girls.

The authors conducted a study[40] on 187 students (66 boys and 121 girls), divided into two groups: an experimental group that followed a 10-week physical education curriculum supplemented with Tabata training and a control group attending classic physical education class. The intervention lasted 14 min during one physical education class per week. Before and after the intervention, anthropometric measurements were taken, and each participant was tested with tests to assess muscle strength, flexibility, speed/agility, and cardiovascular efficiency. In the experimental group, boys experienced a significant decrease in body fat (by 1.77%, $p<0.05$) and an increase in cardiovascular efficiency ($p<0.05$). Girls only increased cardiovascular efficiency ($p<0.001$). However, small changes in motor parameters were observed in all participants. The Tabata training program has shown partial effectiveness but needs to be individualized and pay attention to gender differences.

Conclusion

Physical activity plays a major role in maintaining health and improving quality of life. Adolescents who practice HIIT have improved cardiorespiratory fitness, aerobic and muscular endurance, and strength. The proven health benefits of regular physical activity in adolescents are reduced body fat, reduced risk of cardiovascular and metabolic diseases, and reduced anxiety and depression. Performing HIIT is very simple and does not require special conditions. This is a circumstance for all educational institutions to make an effort and provide appropriate requisites for the well-being of their students. It is recommended that physical education teachers and professors always be in constant contact with their students through the education system and point out the importance of physical and health education in society.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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