Dear author,

Please note that changes made in the online proofing system will be added to the article before publication but are not reflected in this PDF.

We also ask that this file not be used for submitting corrections.

Science & Sports (2019) xxx, xxx—xxx

ELSEVIER

Disponible en ligne sur
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

ORIGINAL ARTICLE

Impact of a HIIT protocol on body composition and VO_2max in adolescents

Impact d'un protocole HIIT sur la composition corporelle et VO_2max chez les adolescents

D. Alonso-Fernández[a,b], R. Fernández-Rodríguez[a], Y. Taboada-Iglesias[b,c,*], Á. Gutiérrez-Sánchez[a,b]

[a] *Faculty of Science Education and Sport, University of Vigo, Campus A Xunqueira, s/n. 36005, Spain*
[b] *Education, Physical Activity and Health Research Group (Gies10-DE3), Galicia Sur Health Research Institute (IIS), Sergas-Uvigo, Spain*
[c] *Faculty of Physiotherapy, University of Vigo, Campus A Xunqueira, s/n. 36005, Spain*

Received 14 January 2019; accepted 4 April 2019

KEYWORDS
Obesity;
Physical Education;
HIIT;
Body composition;
Aerobic capacity

Summary
Objectives. — Adolescents are an increasingly sedentary population segment, which has negative repercussions on their health. The aim of the study was to analyse the effect of high-intensity interval training based on functional exercises on body fat percentage and cardiorespiratory capacity in a group of adolescents.
Methods. — An experimental pretest—posttest study was carried out, with two intervention groups, in physical education warm-ups over 7 weeks. Twenty-six schoolchildren were randomly assigned to an experimental group and to a control group. During the warm-up, the EG performed functional HIIT training and the control group the planned standardised warm-up. The HIIT workouts were based on functional bodyweight exercises with a work-to-rest ratio of 20/10s. The repeated measures ANOVA was used to analyse whether or not differences exist between the variables before and after the protocol period.
Results. — The experimental group significantly increased its cardiorespiratory capacity ($t = -5.11$, $d = 2.01$, $P < 0.001$) and significantly reduced its percentage of fat ($t = 4.05$, $d = 1.59$, $P < 0.001$). For its part, the control group only significantly increased its cardiorespiratory capacity ($t = -4.79$, $d = 1.87$, $P < 0.001$).

* Corresponding author.
E-mail address: yaitaboada@uvigo.es (Y. Taboada-Iglesias).

https://doi.org/10.1016/j.scispo.2019.04.001

Conclusions. — Functional HIIT shows the necessary potential to become a reliable strategy for countering obesity in the young population, given its impact on the reduction of body fat in the individuals involved. The short workouts mean that it can be introduced simply and frequently into physical education sessions.

MOTS CLÉS
Obésité ;
Éducation physique ;
HIIT ;
Composition corporelle ;
Capacité aérobique

Résumé
Objectifs. — Les adolescents constituent un segment de population de plus en plus sédentaire, ce qui a des répercussions négatives sur leur santé. Le but de cette étude était d'analyser l'effet d'un entraînement par intervalles de haute intensité basé sur des exercices fonctionnels sur le pourcentage de graisse corporelle et la capacité cardiorespiratoire chez un groupe d'adolescents.
Méthodes. — Une étude expérimentale pré-/post-test a été réalisée, avec deux groupes d'intervention, dans des échauffements d'éducation physique sur 7 semaines. Vingt-six écoliers ont été assignés au hasard à un groupe expérimental et à un groupe témoin. Pendant l'échauffement, le GE a effectué une formation fonctionnelle HIIT et le groupe de contrôle l'échauffement planifié prévu. Les séances d'entraînement HIIT étaient basées sur des exercices fonctionnels de poids corporel avec un rapport travail/repos de 20/10. L'Anova à mesures répétées a été utilisée pour analyser s'il existait ou non des différences entre les variables avant et après la période de protocole.
Résultats. — Le groupe expérimental a augmenté de manière significative sa capacité cardiorespiratoire ($t = -5{,}11$, $d = 2{,}01$, $p < 0{,}001$) et réduit significativement son pourcentage de graisse ($t = 4{,}05$, $d = 1{,}59$, $p < 0{,}001$). Pour sa part, le groupe de contrôle n'a augmenté que de manière significative sa capacité cardiorespiratoire ($t = -4{,}79$, $d = 1{,}87$, $p < 0{,}001$).
Conclusions. — HIIT fonctionnel montre le potentiel nécessaire pour devenir une stratégie fiable de lutte contre l'obésité chez les jeunes, compte tenu de son impact sur la réduction de la graisse corporelle chez les individus impliqués. Les séances d'entraînement courtes permettent de l'introduire simplement et fréquemment dans les séances d'éducation physique.

1. Introduction

Q2 Recent research estimates that physical exercise is the main agent to combat cardiovascular disease, which is directly linked to physical inactivity [1].

Healthy physical exercise includes a series of components to be analysed, among them, cardiorespiratory capacity, considered to be one of the essential markers of cardiovascular health [2]. Furthermore, body morphology (obesity, amount and distribution of body fat) is linked to cardiovascular and metabolic diseases [3]. The origins of these diseases emerge during childhood and adolescence [4], in the same way as behavioural patterns in relation with physical activity in childhood remain in adult life [1]. On the other hand, unlike during childhood, in adolescence an important decline in levels of physical activity occurs [5]. The repercussions of such a decline in physical activity and rise in a sedentary lifestyle are excess weight and obesity in adolescents [6], as well as a reduction in self-perceived health and wellbeing [7]. Hence the importance of intervening in the most immediate environment, in this case physical education classes (PE), as an active lifestyle at these ages will prevent the development of cardiovascular and metabolic diseases [8,9].

Studies such as the one by Ardoy et al. [10] have analysed the effects of PE sessions in the parameters mentioned above, reaching the conclusion that the time established is insufficient. Therefore, it is important to consider the effectiveness of alternative forms of exercise, fundamentally in children and adolescents [11,12]. The use of short-duration workouts such as high intensity intensive training (HIIT) can optimise the time available within the school timetable

The HIIT that consists of a training programme with short bursts of high-intensity exercise interspersed with short rest periods has been studied extensively in the last decade [12,13]. There are various different studies which underline the beneficial effects of these methods both in young people and adults [14–17], different levels of sports practice [18,19] and pathologies such as fatty liver [20].

It has been found that high-intensity exercise brings about significantly greater improvements in VO_2max as opposed to continuous moderate-intensity exercise [21–23].

Evidence also exists that these types of protocols are effective in the young and adolescent population in order to improve fitness parameters linked to health, such as aerobic capacity and the reduction in body fat percentage [18,19,24–26].

Please cite this article in press as: Alonso-Fernández D, et al. Impact of a HIIT protocol on body composition and VO_2max in adolescents. Sci sports (2019), https://doi.org/10.1016/j.scispo.2019.04.001

However, despite the huge range of studies, and now that the benefits have been confirmed, emphasis has recently been placed on the need to scientifically determine the intensity, duration and rest periods both of the sessions as well as the overall HIIT programme for each population segment [27]. This study was conceived with this aim in mind, that is, to verify the impact of HIIT based on functional exercises on the VO_2max and body fat percentage of variables in the context of PE classes in an adolescent population. In this way, we can observe the potentialities of HIIT within an educational environment in order to assess whether it could become a good strategy for countering obesity and sedentary lifestyles in the adolescent population.

2. Methods

2.1. Participants

The sample was comprised of twenty-six secondary school students of both sexes (15 boys and 13 girls) aged between 15 and 16 and from the same class, in the Autonomous region of Madrid.

They were divided up randomly into two groups. The experimental group (EG, $n = 13$) replaced the warm-ups established in the PE curriculum with the proposed functional HIIT training sessions, while the control group (CG, $n = 13$) followed the warm-up protocols established in said curriculum. The rest of each day's PE lesson was the same for both groups. Participants could not suffer from any disease or impairment preventing them from carrying out high-intensity physical exercise in order to meet the criteria for inclusion in the functional HIIT group.

With respect to the anthropometric characteristics before the intervention, no significant differences existed between the groups before the intervention, although in the CG, average height and body weight were slightly higher (2.36% and 2.71% respectively).

The school gave its consent to carry out the study, as did the parents and legal guardians, who signed an informed consent document relating to the physical education sessions, which explained the type of submaximal effort tests that the students would be doing. Given the type of study and the techniques it uses, this research respected all of the ethical procedures for data collection and Organic Law 15/1999 on personal data protection as well as the precepts of the Declaration of Helsinki.

2.2. Design

An experimental pretest—posttest design with two intervention groups in a PE class was used. The functional HIIT training programme and standardised PE session warm-ups were defined as an independent variable for the EG and GC, respectively. As a dependent variable, and in order to determine the effects of both training sessions, weight and body composition were evaluated using the bioelectric impedance analysis (BMI and body fat percentage). The body fat mass (FM) was calculated from the body fat percentage (FM = (% of body fat × weight)/100) and the fat free mass (FFM) a through the formula: FFM = weight − FM. The aerobic capacity was evaluated via an indirect test, the 20-m cardiorespiratory endurance test.

2.3. Instruments

A Tanita MC 980 MA (Tanita Corp, Tokyo, Japan), with four electrodes and a ''Holtex'' tallimeter (Tanita Institute Contract Study, 2004) [28] was used to evaluate body composition VO_2max was estimated using the Course-Navette test [29]. The result of this test enables us to validly and reliably predict VO_2max [30].

Participants were asked not to make any changes to their eating or physical activity habits in order to prevent the results from being conditioned by diet or exercise external to the intervention. However, these possible contaminating variables were controlled before and after the intervention via a PAR-Q questionnaire [31] on physical activity habits and a record of weekly eating habits (Software Nutriber 1.1.1), with no significant changes detected between the evaluations.

2.4. Procedure

The study was carried out over 9 weeks. Week 1 was given over to the preliminary preparation of the GE participants (initial preparation and learning the different exercises), and both groups did the pretest. The posttest was carried out in week 9. Over the 7 weeks of training, prior to the main part of the PE sessions, which was similar for both groups, the EG did 14 functional HIIT training sessions (two sessions per week), while the CG did the 14 ordinary scheduled warm-ups (two sessions per week).

The EG intervention programme, based on functional HIIT training, is made up of high-intensity intermittent efforts based on the Tabata method [32]. It consists of a 4-minute workout block where eight 20-second intervals of maximal effort are alternated with 10-second rest periods. The proposed exercises are based on functional bodyweight exercises, that is, using one's own bodyweight, and involves multiple articulations and muscle groups. Previously, participants will run continuously for 4 minutes and stretch for 1 minute. The organisation and order of the proposed exercises can be seen in Fig. 1.

The structure of the functional HIIT protocol intervention for the EG was set out in the following way (Table 1).

All the participants were asked to do the high-intensity exercises by increasing the speed of the movements over the 20 seconds that each workout interval lasted. The intensity was controlled using heart rate monitors and a subjective perception of effort (SPE) scale after each training session. A researcher supervised each session during the PE classes to guarantee that the workouts were homogenous and their intensity was controlled.

2.5. Statistical analysis

The data was reviewed, its normality ensured via the Shapiro-Wilk test, and homoscedasticity checked using the Levene test. The Greenhouse-Geisser correction was used when the sphericity assumption was violated ($P < 0.05$ for

Please cite this article in press as: Alonso-Fernández D, et al. Impact of a HIIT protocol on body composition and VO_2max in adolescents. Sci sports (2019), https://doi.org/10.1016/j.scispo.2019.04.001

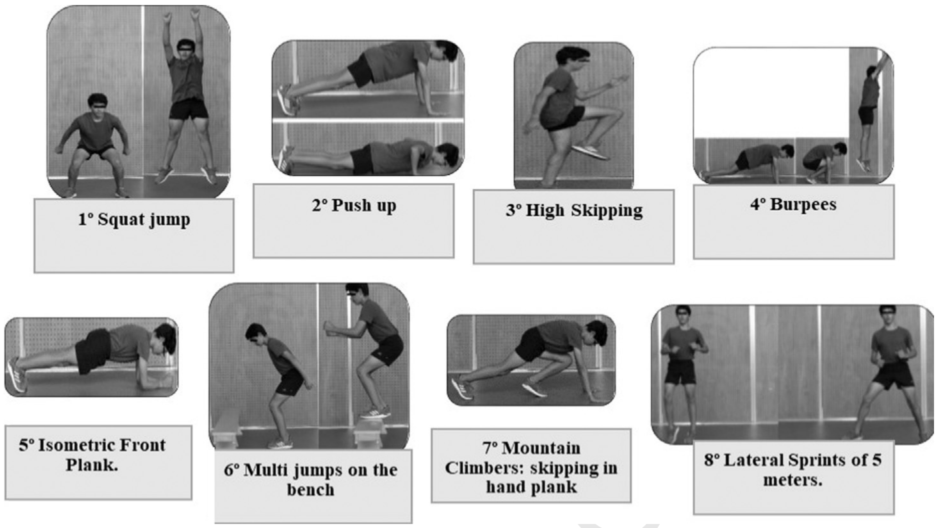

Figure 1 Organisation of HIIT training exercises in the EG (4-minute Tabata Block).

Table 1 Scheduling and workload of the HIIT method for the EG.

	''Tabata'' Blocks	No. of Exercises	Total HIIT time, minutes
Week 1	1 Tabata Block	8	4
Weeks 2 and 3	1 Block + 2 first exercises from the Block	10	5
Weeks 4 and 5	1 Block + 4 first exercises from the Block with a 1-minute rest period	12	6
Weeks 6 and 7	2 complete Blocks with a 1-minute rest period between the two	16	8

Mauchly's sphericity test). Changes in the dependent variables over time were compared between the groups by a repeated measures ANOVA (2 groups × 2 time points: pretest and posttest). A post hoc t-test with Bonferroni correction to determine the significant differences between pairwise comparisons was used. Significance was set at $P < 0.05$ and, where necessary, Cohen's d was added to establish effect size measure, where the values 0.2, 0.5 and 0.8 represent small, medium and large differences, respectively [33].

3. Results

The feeding control turned out to be effective. There were no changes in the daily consumption of total calories or in the proportion of nutrients (proteins, lipids or carbohydrates) (Table 2).

Table 3 shows the results obtained bearing in mind the different variables measured in the sample of subjects.

Weight was not affected by the HIIT protocol, $F(1.5–12.61) = 0.27$; $P > 0.05$, $\eta_p^2 = 0.02$. No significant changes at the end of the 7-week experimental phase were noticed either in the EG ($t = –1.87$; $P > 0.05$) or in the CG ($t = 0.32$; $P > 0.05$).

In the same way, BMI was not affected by the functional HIIT protocol, $F(1.05–12.63) = 0.36$; $P > 0.05$; $\eta_p^2 = 0.03$. No significant changes at the end of the 7-week experimental phase were observed either in the EG ($t = 1.17$; $P > 0.05$) or in the CG ($t = 1.28$; $P > 0.05$).

However, for its part, body fat percentage was affected by the functional HIIT protocol, $F(1.07–12.80) = 7.35$; $P < 0.05$; $\eta_p^2 = 0.58$. With regard to the pairwise comparisons derived from the Post hoc analysis, in the EG there was a significant reduction in body fat percentage between the pretest and the posttest ($t = 4.05$; $d = 1.59$; $P < 0.001$). However, the CG did not show significant differences in relation with this variable ($t = –0.13$; $P > 0.05$).

The FM was affected by HIIT protocol, $F(1.04–12.53) = 0.22$, $P < 0.05$, $\eta_p^2 = 0.02$. The pairwise comparisons derived from the analysis Post hoc show a significant decrease in the FM between the pretest and the posttest in the EG ($t = 3.75$, $d = 1.23$, $P < 0.001$). However, there were no significant differences of this variable in the CG ($t = –0.12$, $P > 0.05$).

Also the FFM was affected by the HIIT protocol, $F(1.15–13.84) = 2.03$, $P < 0.05$, $\eta_p^2 = 0.15$. In the pairwise comparisons derived from the Post hoc analysis, the EG shows a significant increase in the FFM between the pretest and the posttest ($t = –4.15$, $d = 1.23$, $P < 0.001$). However, the CG did not show significant differences in this variable ($t = 0.33$, $P > 0.05$).

And, finally, VO_2max was also affected by the functional HIIT protocol, $F(1.17–14.04) = 3.39$; $P < 0.05$; $\eta_p^2 = 0.32$. In the pairwise comparisons derived from the post hoc analysis, the EG shows a significant increase in VO_2max between the pretest and the posttest ($t = –5.11$; $d = 2.01$; $P < 0.001$), which also occurs in the CG ($t = –4.79$; $d = 1.87$; $P < 0.001$).

Q5 **Table 2** Changes in diet in the EG and the CG between the pretest and the posttest (average ± SD).

Variables	EG: HIIT (n = 13)			CG: traditional warm-up (n = 13)		
	Pretest	Posttest	% Change	Pretest	Posttest	% Change
Kcal/day	2534.1 ± 427.5	2613.3 ± 558.2	3.13	2446.8 ± 667.7	2591.6 ± 472.4	5.92
Proteins/day (%)	16 ± 4	16 ± 3	0	17 ± 2	16 ± 3	−1
Lipids/day (%)	40 ± 6	41 ± 7	1	39 ± 7	41 ± 6	2
Carbohydrates/day (%)	44 ± 8	43 ± 6	−1	44 ± 9	43 ± 8	−1

EG: experimental group; CG: control group; SD: standard deviation.
* $P < 0.05$ vs Pretest.

Table 3 Changes in weight, BMI, body fat, Fat Mass, Fat-Free Mass and VO_2max in the EG and the CG between the pretest and the posttest (average ± SD).

Variables	EG: HIIT (n = 13)			CG: traditional warm-up (n = 13)		
	Pretest	Posttest	% Change	Pretest	Posttest	% Change
Weight	58.02 ± 5.48	58.55 ± 5.38	0.91	59.65 ± 8.55	59.48 ± 7.67	−0.28
BMI	20.51 ± 2.27	20.33 ± 2.22	−0.88	19.99 ± 2.71	19.74 ± 2.34	−1.25
Body fat	22.02 ± 6.79	20.3 ± 6.55*	−7.81	19.6 ± 6.33	19.66 ± 6.73	0.3
Fat Mass	12.76 ± 3.90	11.87 ± 3.79*	−6.97	11.79 ± 4.63	11.83 ± 4.81	0.34
Fat-Free Mass	36.00 ± 8.95	38.25 ± 8.59*	6.25	40.05 ± 9.58	39.81 ± 8.68	−0.59
VO_2max (ml/kg/min)	42.91 ± 6.91	47.29 ± 7.72*	10.21	40.68 ± 8.44	43.54 ± 9.61*	7.03

BMI: body mass index; VO_2max: maximum oxygen uptake; EG: experimental group; CG: control group; SD: standard deviation.
* $P < 0.001$vs Pretest.

4. Discussion

The purpose of this research was to evaluate the effects of a functional HIIT training programme on aerobic capacity and body composition in a group of adolescents. After applying the 14-session programme to a group of schoolchildren, during the warm-ups in PE classes, the most important results point to reductions in body fat percentage values, fat mass and increases in participants' fat free mass and VO_2max.

Along this line of results, Heydari, et al. [24] obtained significant reductions in body fat percentage in adolescents with a 12-week HIIT protocol, somewhat similar to what Balbasi, Shabani and Nazari obtained [34] with a 3-week protocol in the same population type. The review by Costigan et al. [25] on HIIT and adolescents underlines this training method's capacity to obtain significant results insofar as body fat percentage reduction is concerned. However, other studies have not obtained this type of result: Camacho Cardenosa et al. [26], after subjecting a group of adolescents who were good at sports to an 8-week HIIT protocol, obtained results showing that their body fat percentage stayed at the same level and was not reduced. It would appear that the findings of scientific literature in recent years corroborates the trend that this variable is sensitive to the use of the HIIT method in the adolescent population but, according to our criteria, it is highly influenced by the level of intensity developed by the subjects during the training protocol. Being an ''intensive'' method, it is necessary to control this intensity, in order to ensure that subjects reach a high enough threshold in their workouts as, if the intensity is too low, the expected benefits will not be obtained.

In the same way, Amaro et al. (2018)[35] establish other factors that influence fat tissue, such as the type of fat, and noted that the concentration of irisin myokine is benefited by the HIIT exercise protocols, favoring a more vascularized and active adipose tissue.

This incidence on the body composition derived from the HIIT training is also supported by observing the significant reductions in fat mass and the significant increase in the fat free mass of the individuals belonging to the control group. These results follow a similar trend provided by the results of previous studies in similar populations [36]. The significant increase in FFM may also reflect important metabolic adaptations resulting in enhanced insulin sensitivity [37].

Secondly, in this study the functional HIIT method is also shown to be the workout that improves participants' cardiorespiratory capacity. This circumstance had been observed in previous studies [18,19,22,38]. Corte de Araujo et al. [39] studied improvements in this variable by comparing HIIT training to a traditional endurance method, obtaining improvements in VO_2max in both in a population of young obese people, but with a substantially lower session duration time: the HIIT session lasts 70% less than an endurance training session.

In this way, the HIIT method, with a more condensed workout volume, obtains health benefits for schoolchildren, as Camacho-Cardenosa et al. point out [26]. This could help remedy a current problem: actual PE class time remains limited (2 50-minute sessions per week), making it difficult to find content that can positively influence a healthy physical condition in students due simply to an objective lack of time.

Please cite this article in press as: Alonso-Fernández D, et al. Impact of a HIIT protocol on body composition and VO_2max in adolescents. Sci sports (2019), https://doi.org/10.1016/j.scispo.2019.04.001

The results obtained enable us to be optimistic with regard to how HIIT can help us modify students' physical condition just by replacing the traditional warm-up with one based on our protocol with functional bodyweight exercises, without influencing the rest of the content it is also necessary to cover in PE classes throughout the year. Given that the workouts are short, they can be introduced into PE classes regularly without interfering with other curricular content provided in this subject, as they only take up the time given over to the warm-up.

Recent studies in professional athletes detected that this type of training increases levels of anxiety and fatigue [40], for that reason in future research it would be important to analyze the psychological factors such as mood, and the possible effect of the HIIT program on them. On the other hand, it would be interesting to study if a single session of HIIT weekly during the rest of the course could consolidate a maintenance of the impacts obtained in body composition and VO_2max of adolescents.

5. Conclusions

This study has observed how two groups of adolescents who formed a part of the same PE class, in which only the warm-up phase (standardised or functional HIIT) differed, obtained a significant difference in the reduction of body fat percentage, which could make it a promising strategy for combating obesity and sedentary lifestyles in children and adolescents from within the education system itself.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Martínez V, Sánchez M. Relación entre actividad física y condición física en niños y adolescentes. Rev Esp Cardiol 2011;61:108–11.
[2] Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. JAMA 2009;301(19): 2024–35.
[3] Bouchard C, Shepard R. Physical activity, fitness and health: the model and key concepts. In: Bouchard C, Shephard RJ, Stephens T, editors. Physical activity, fitness and health: International proceedings and consensus statement. Champaign, IL: Human Kinetics Publishers; 1994. p. 11–20.
[4] Dwyer T, Sun C, Magnussen CG, Raitakari OT, Schork NJ, Venn A, et al. Cohort profile: the International Childhood Cardiovascular Cohort (i3c) Consortium. Int J Epidemiol 2013;42(1): 86–96.
[5] Cossio-Bolaños M, Viveros-Flores A, Castillo-Retamal M, Vargas-Vitoria R, Gatica P, Gómez-Campos R. Patrones de actividad física en adolescentes en función del sexo, edad cronológica y biológica. Nutr Clín Diet Hosp 2015;35(2):41–7.
[6] Kurdaningsih SV, Sudargo T, Lusmilasari L. Physical activity and sedentary lifestyle towards teenagers' overweight/obesity status. Int J Community Med Public Health 2016;3(3):630–5.
[7] Martínez-López EJ, Hita-Contrera F, Moral-García JE, Grao-Cruces A, Ruiz JR, Redecillas-Peiró MT, et al. Association of low weekly physical activity and sedentary lifestyle with self-perceived health, pain, and well-being in a Spanish teenage population. Sci Sports 2015;30(6):342–51.
[8] Resaland GK, Anderssen SA, Holme IM, Mamen A, Andersen LB. Effects of a 2-year school-based daily physical activity intervention on cardiovascular disease risk factors: the Sogndal school-intervention study. Scand J Med Sci Sports 2011;21(6):122–31.
[9] Twig G, Yaniv G, Levine H, Leiba A, Goldberger N, Derazne E, et al. Body-mass index in 2.3 million adolescents and cardiovascular death in adulthood. N Engl J Med 2016;374:2430–40.
[10] Ardoy D, Castillo M, Chillón R, España V, Fernández J, Ortega F, et al. Improving physical fitness in adolescents through a school-based intervention: the EDUFIT study. Rev Esp Cardiol 2011;64(6):484–91.
[11] Bendiksen M, Williams CA, Hornstrup T, Clausen H, Kloppenborg J, Shumikhin D, et al. Heart rate response and fitness effects of various types of physical education for 8- to 9-year-old schoolchildren. Eur J Sport Sci 2014;14(8):861–9.
[12] Gibala MJ, Little JP, MacDonald MJ, Hawley JA. Physiological adaptations to low-volume, high-intensity interval training in health and disease. J Physiol 2012;590(5):1077–84.
[13] Alonso-Fernández D, Lima-Correa F, Gutiérrez-Sánchez A, Abadía-García de Vicuña O. Effects of a high-intensity interval training protocol based on functional exercises on performance and body composition in handball female players. J Human Sport Exerc 2017;12(4):1186–98.
[14] Emberts T, Porcari J, Dobers-tein S, Steffen J, Foster C. Exercise intensity and energy expenditure of a Tabata workout. J Sports Sci Med 2013;12:612–3.
[15] Farah BQ, Ritti-Dias RM, Balagopal P, Hill JO, Prado WL. Does exercise intensity affect blood pressure and heart rate in obese adolescents? A 6-month multidisciplinary randomized intervention study. Pediatr Obes 2014;9(2):111–20.
[16] Foster C, Farland CV, Guidotti F, Harbin M, Roberts B, Tuuri A, et al. The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. J Sports Sci Med 2015;14:747–55.
[17] Ramos JS, Dalleck LC, Tjonna AE, Beetham KS, Coombes JS. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: a systematic review and meta-analysis. Sports Med 2015;45(5):679–92.
[18] Sheykhlouvand M, Gharaat M, Khalili E, Agha-Alinejad. The effect of high-intensity interval training on ventilatory threshold and aerobic power in well-trained canoe polo athletes. Sci sports 2016;31(5):283–9.
[19] Ramírez JM. Speed-endurance training effect on aerobic capacity of basketball players. Sci sports 2018;33:183–4.
[20] Fakhredin S, Rahmati M, Gollop ND, Mirnasuri R. The effects of high intensity interval training on the levels of liver enzymes associated with non-alcoholic fatty liver and selected anthropometric indices in obese men. Sci sports 2019;34:59–60.
[21] Alonso-Fernández D, Fernández-Rodríguez R, Gutiérrez-Sánchez A. Effect of a HIIT programme vs. Extensive Continuos Training on inexperienced individuals. Apunts. Educación Física y Deportes 2017;130:84–94.
[22] Baker J, Buchan D, Cooper S, Ollis S, Shield J, Young J. High intensity interval running enhances measures of physical fitness but not metabolic measures of cardiovascular disease risk in healthy adolescents. BMC Public Health 2013;13:498.
[23] Nybo L, Sundstrup E, Jakobsen MD, Mohr M, Hornstrup T, Simonsen L, et al. High-intensity training versus traditional exercise interventions for promoting health. Med Sci Sports Exerc 2010;42(10):1951–8.
[24] Heydari M, Freund J, Boutcher SH. The effect of high-intensity intermittent exercise on body composition of overweight young males. J Obes 2012:1–8. Q3

[25] Costigan SA, Eather N, Plotnikoff RC, Taaffe DR, Lubans DR. High-intensity interval training for improving health-related fitness in adolescents: a systematic review and meta-analysis. Br J Sports Med 2015;49(19):1253—61.

[26] Camacho-Cardenosa A, Brazo-Sayavera J, Camacho-Cardenosa M, Marcos-Serrano M, Timón R, Olcina G. Efecto de un protocolo de entrenamiento interválico de alta intensidad sobre masa grasa corporal en adolescentes. Rev Esp de Salud Pública 2016;90.

[27] Reyes-Amigo T, Gómez M, Gallardo M, Palmeira A. Effectiveness of high-intensity interval training on cardiorespiratory fitness and body composition in preadolescents: a systematic review. Eur J Hum Mov 2017;39:32—47.

[28] Tanita Institute Contract Study. Algorithm development for estimating visceral fat rating. Heymsfield. S.B. MD. Columbia University College of Physicians and Surgeons; 2004.

[29] Gastón C, Jeremías D. Test Course Navette de 20 metros con etapas de un minuto. Una idea original que perdura hace 30 años. Apunts. Med Esport 2014;183:93—103.

[30] García GC, Secchi JD. Test course navette de 20 metros con etapas de un minuto. Una idea original que perdura hace 30 años. Apunts. Med Esport 2014;49(183):93—103.

[31] Herazo-Beltran AY, Dominguez-Anaya R. [The reliability of a questionnaire regarding Colombian children's physical activity]. Rev Salud Publica (Bogota) 2012;14(5):802—9.

[32] Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, et al. Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO_2max. Phys Fitness Performance 1996;28(10):1327—30.

[33] Cohen J. Statistical power analysis for the behavioural sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum; 1988.

[34] Balbasi F, Shabani R, Nazari M. Effect of high-intensity interval training on body composition and bioenergetic indices in boys — futsal players. Phys Educ Students 2016;5(42): 42—8.

[35] Amaro P, Souza BK, Corrêa A, Oliveira FM, Barbosa CO, Gonçalves RC. Effect of exercise on concentrations of Irisin in overweight individuals: a systematic review. Sci Sports 2018;34:80—9.

[36] Heydari M, Freund J, Boutcher H. The effect of high-intensity intermittent exercise on body composition of overweight young males. J Obes 2012;2012:1—8.

[37] Burgomaster KA, Hughes SC, Heigenhauser GJF, Bradwell SN, Gibala MJ. Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. J Appl Physiol 2005;98(6):1985—90.

[38] Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, et al. Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 2009;15(5):731—8.

[39] Corte de Araujo AC, Roschel H, Picanco AR, do Prado DM, Villares SM, de Sa Pinto AL, et al. Similar health benefits of endurance and high-intensity interval training in obese children. PLoS One 2012;7:1—8.

[40] Selmi O, Ben W, Zouaoui M, Azaiez F, Bouassida A. High intensity interval training negatively affects mood state in professional athletes. Sci Sports 2018;33(4):151—7.

Please cite this article in press as: Alonso-Fernández D, et al. Impact of a HIIT protocol on body composition and VO_2max in adolescents. Sci sports (2019), https://doi.org/10.1016/j.scispo.2019.04.001