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EFFECTIVENESS OF HIGH-INTENSITY INTERVAL TRAINING ON CARDIORESPIRATORY FITNESS AND BODY COMPOSITION IN PREADOLESCENTS: A SYSTEMATIC REVIEW

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ABSTRACT

Objective: The aim of this study is to review the published literature on the effectiveness of high-intensity interval training (HIIT) interventions on cardiorespiratory fitness and body composition in preadolescents. Method: The databases used in the study were: PubMed, SPORTDiscus and Google Scholar. We included studies published from 2005 to 2016. The included studies consider: children, examined health-related fitness outcomes, involved an intervention of ≥2 weeks, included a control or moderate intensity comparison group, or both, and prescribed high intensity activity. Results: HIIT was associated with improvements in cardiorespiratory fitness in 9 of the 10 studies. In body composition, the improvements were less evident; on body mass index (2 studies), skinfolds (1 study) and on the percentage of body fat (4 studies). Conclusion: HIIT in preadolescents could be an efficient approach for improving cardiorespiratory fitness; nevertheless, its effect on body composition is still unclear.

Key words: high-intensity interval training, preadolescents, cardiorespiratory fitness, body composition

EFECTIVIDAD DEL ENTRENAMIENTO INTERVÁLICO DE ALTA INTENSIDAD SOBRE LA APTITUD CARDIORRESPIRATORIA Y LA COMPOSICIÓN CORPORAL EN PREADOLESCENTES: UNA REVISIÓN SISTEMÁTICA

RESUMEN

Objetivo: Revisar la literatura publicada acerca de los efectos del entrenamiento interválico de alta intensidad (HIIT) sobre la aptitud cardiorrespiratoria y la composición corporal en preadolescentes. Método: Las bases de datos utilizadas en el estudio fueron: PubMed, SPORTDiscus y Google Académico. Fueron incluidos estudios publicados entre 2005 y 2016. Los estudios consideran: a niños, variables relacionadas con la condición física y la salud, intervenciones ≥ 2 semanas, un grupo control o grupo de entrenamiento comparados con HIIT; prescripción de actividades de alta intensidad. Resultados: Los efectos de HIIT sobre la aptitud cardiorrespiratoria son mostrados en 9 de los 10 estudios. En la composición corporal los efectos fueron menores; sólo tiene efectos sobre el índice de masa corporal (2 estudios), pliegues (1 estudio) y sobre el porcentaje de grasa (4 estudios). Conclusión: HIIT en preadolescentes podría ser efectivo para mejorar la aptitud cardiorrespiratoria; sin embargo, su efecto sobre la composición corporal aún no está claro.

Palabras clave: entrenamiento interválico de alta intensidad, preadolescente, aptitud cardiorrespiratoria, composición corporal

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INTRODUCTION

Physical activity presents multiple health benefits for all age groups, (Langford et al., 2015) it is a key factor in pediatric obesity (Shultz, Anner, & Hills, 2009) and cardiometabolic modifications (Donnelly et al., 1996). Therefore, physical activity during childhood and adolescence is of great importance for the public health of a country. Currently, they represent a key phase of biological and social development, laying the foundations for future adult health (Bassuk & Manson, 2014).

The recommendation of performing physical activity has not been taken into consideration by the population and the main reason is the lack of time (Zabinski, Saelens, Stein, Hayden-Wade, & Wilfley, 2003). Therefore, the effectiveness of alternative forms of physical activity needs to be considered, especially in children and adolescents (Bendiksen et al., 2014; Burgomaster, Heigenhauser, Gibala, & Kirsten, 2006; Gibala, Little, MacDonald, & Hawley, 2012; Pate, 2006). Studies have addressed this lack of time through high-intensity interval training (HIIT) programs, which decreases the required time of exercise in comparison to low intensity programs (Buchan et al., 2011). High-intensity stimuli of HIIT consider rest periods between each series (Baquet & Berthoin, 2003; Gibala et al., 2012). Several studies in adults have reported advantages of HIIT over continuous aerobic exercise at improving aerobic capacity (Keating, Machan, O'Connor, Gerofi, Sainsbury, Caterson & Johnson, 2014; Ramos, Dalleck, Tjonna, Beetham, & Coombes, 2015).

Among children and adolescents, the evidence of HIIT is limited, recent articles report that HIIT is a feasible and time-efficient approach for improving cardiorespiratory fitness and body composition in the adolescent population (Boutcher, 2011; Farah, Ritti-Dias, Balagopal, Hill, & Prado, 2014; Foster et al., 2015). The aim of this systematic review is to analyze published evidence about the effectiveness of HIIT interventions on cardiorespiratory fitness and body composition in preadolescent.

METHOD

Literature search strategy

Articles published between January 1st, 2005 and July 21st, 2016 were analyzed. Systematic survey of the studies was conducted using the following databases PubMed, SPORTDiscus and Scholar Google. The search was conducted between July 17th and 21st, 2016. The PICO keywords used were: Population: [children or childhood or child], Intervention [high-intensity interval training or high-intensity intermittent training or high-intensity interval exercise or high-intensity aerobic training or interval aerobic training]. No comparison or outcome keywords were specified. Studies performed with children aged 6-12 and randomized designs with controlled trials [RCT] and

randomized trials were considered. Moreover, the reference lists were examined to detect studies potentially eligible for inclusion. Only articles in human and written in English were analyzed.

Criteria for inclusion and exclusion

The following inclusion criteria were selected: (a) children (6-12 years old), (b) health-related fitness outcomes (cardiorespiratory fitness and body composition), (c) involved a ≥2 week intervention, (d) included a control or moderate intensity comparison group, and (e) prescribed high- intensity activity (85–95% peak heart rate or 80–120% maximal aerobics speed). Studies focusing on diseases (except obesity), sports and reviews and papers published in conference, dissertations, thesis or in non-peer-reviewed journals were not included for review.

Data extraction

Three independent examiners searched for articles in the databases by analysis of titles, abstracts, and full papers, and assessed eligibility for inclusion of each study. Disagreements were discussed and, if unresolved, a fourth reviewer was consulted to decide whether the study should be included or excluded. Standardized worksheets were designed for data extraction such that the reviewers were able to extract information about the study characteristics, participants, study design, sample, intervention method, study duration, HIIT dose, outcomes, retention rate, instruments, and study results.

Quality of studies and risk of bias

Quality and risk of bias for all 10 studies was assessed using Quality Assessment tool for Quantitative Studies (EPHPP). A risk of bias score was awarded to each study based on item Selection Bias explicitly described. Criteria were added to create an overall risk of bias score: 1 strong (low bias), 2 moderate (moderate bias) and 3 weak (high bias).

RESULTS

Inclusion of studies

The database search yielded 387 articles in total. Of these, 320 were excluded after evaluation of titles, and 5 were duplicates, of the 62 remaining 40 were excluded by abstracts, leaving 22 articles identified as eligible. Of these, 10 studies met all inclusion criteria (Fig. 1).

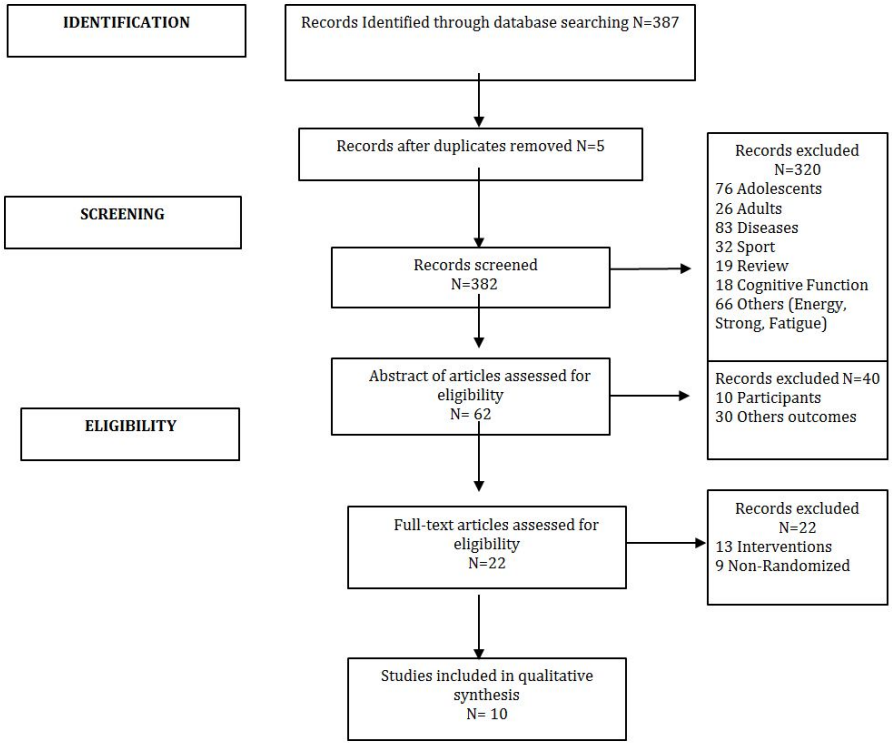

FIGURE 1. Identification flow, screening, eligibility of articles in the systematic review.

Characteristics of high-intensity interval training programs

The intervention programs (Table 1) used walking, (Corte de Araujo et al., 2012) some only running (Baquet et al., 2010; Gamelin et al., 2009; Lau et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz, Rosenkranz, Hastmann, & Harms, 2012), cycling (McManus, Cheng, Leung, Yung, & Macfarlane, 2005) and other different games (Lambrick, Westrupp, Kaufmann, Stoner, & Faulkner, 2015; McNarry, Lambrick, Westrupp, & Faulkner, 2015). The protocols used in the studies were heterogeneous: for example, the number of bouts ranged from 1 (Mucci et al., 2013) to 16 (Lau et al., 2015) and the frequency fluctuated from 2 (Corte de Araujo et al., 2012; Lambrick et al., 2015; McNarry et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012) to 3 (Baquet et al., 2010; Gamelin et al., 2009; Lau et al., 2015; McManus et al., 2005) sessions per week. Regarding the duration of the repetitions, were for a period of 5 seconds (Baquet et al., 2010; Gamelin et al., 2009) to 6 minutes (Lambrick et al., 2015). Recovery passive or active was between of 15 seconds (Gamelin et al., 2009; Lau et al., 2015) to 3 minutes (Corte de Araujo et al., 2012; Mucci et al., 2013). Intensity exercise was performed among 100% (Baquet et al., 2010; Gamelin et al., 2009; Lau et al., 2015; Nourry et al., 2005; Rosenkranz

et al., 2012) and 190% (Baquet et al., 2010; Gamelin et al., 2009) maximum aerobic speed (MAS), among 80% and 86% (Lambrick et al., 2015; McManus et al., 2005) maximal heart rate (MHR). The total time of the session lasted between 6 (Lau et al., 2015) and 60 minutes (Corte de Araujo et al., 2012; McNarry et al., 2015). The duration of the interventions lasted between 6 (McNarry et al., 2015) and 12 weeks (Corte de Araujo et al., 2012) (mean 7,6) (Table 1). Adherence to training programs was not reported. It is not clear the association between protocols and the results found.

TABLE 1
Main characteristics of the studies included in this review.

Study	Subjects (n) and Age (y)	Groups	Group Size	Modality /Intensity	Frequency	Recovery	Total time	Intervention duration	Quality
Corte de Araujo et al., 2012	39 obese children 8 to 12 years	HIIT TG	15 15	Walking/Running 80% peak HR. Walking/Running 100% MAS	2 sessions per week	3 minutes	30-60 minutes	12 weeks	Moderate
Baquet et al., 2010	63 children 8 to 11years	HIIT TG CG	22 22 19	Running 100-190% MAS Running 80-85% MAS	3 sessions per week	15-30 seconds 5 minutes	18-39 minutes	7 weeks	Weak
Gamelin et al., 2009	28 children 9,5 years	HIIT CG	22 16	Running 100-190% MAS	3 sessions per week	15-30 seconds	30 minutes	7 weeks	Weak
Lau et al., 2015	48 overweight children 10,4 years	HIIT TG	15 21	Running 120% MAS Running 100%MAS	3 sessions per week	15 seconds	6-8 minutes	6 weeks	Weak
McManus et al., 2005	35 children 9 to 11 years	HIIT TG CG	10 10 15	Cycling 80-85% MAS Cycling Continuous 75-85% VO_{2peak}	3 sessions per week	2 minutes 45 seconds	20 minutes	8 weeks	Moderate
McNarry et al., 2015	26 obese children 9.3 years	HIIT CG	26 10		2 sessions per week	2 minutes	40-60 minutes	6 weeks	Weak
Mucci et al., 2013	24 children 9 to 11 years	HIIT CG	9 9	Running 110-130% MAS Running 100% MAS	2 sessions per week	3 minutes	30 minutes	8 weeks	Weak
Nourry et al., 2005	24 children 9, 7 to 10 years	HITT CG	9 9	Running100-130% MAS Running 100% MAS	2 sessions per week	3 minutes	30 minutes	8 weeks	Weak
Rosenkranz et al., 2012	18 children 7 to 12 years	HITT CG	8 8	Running 100-130% MAS Running 100% MAS	2 sessions per week	Unknow Rest passive recovery	30 minutes	8 weeks	Moderate
Lambrick et al,. 215	55 children 8 to 10 years	HIIT CG	28 27	Games 86% HRmax	2 sessions per week	2 minutes	60 minutes	6 weeks	Weak

HIIT: high-intensity interval training, TG: training group, CG: control group, MAS: maximum aerobic speed, HR: Heart rate, VO_{2PEAK}: oxygen uptake.

Effects of high-intensity interval training on cardiorespiratory fitness

Cardiorespiratory fitness was determined by tests on treadmill (Baquet et al., 2010; Corte de Araujo et al., 2012; Gamelin et al., 2009; Lambrick et al., 2015; McNarry et al., 2015), cycle ergometer (McManus et al., 2005; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012) or field test (Yo-Yo intermittent test) (Lau et al., 2015).

The studies showed that the group performing high-intensity exercises increased cardiorespiratory fitness (Baquet et al., 2010; Corte de Araujo et al., 2012; Gamelin et al., 2009; Lambrick et al., 2015; McManus et al., 2005; McNarry et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012) and in a single study the HIIT group not present any changes (Table 2) (Lau et al., 2015). As for the results of HIIT and the training group, both groups increased their cardiorespiratory fitness in three studies (Baquet et al., 2010; Gamelin et al., 2009; McManus et al., 2005) and a single study none of the groups presented changes (Lau et al., 2015). The control group in 6 studies, it has been shown to decrease its yield (Baquet et al., 2010; Lambrick et al., 2015; Lau et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012) and in 3 studies there is a slight increase in cardiorespiratory fitness (Gamelin et al., 2009; McManus et al., 2005; McNarry et al., 2015).

TABLE 2
Results cardiorespiratory fitness.

Study	Measure Outcome	Control Group		Effect %	Training Group		Effect %	HIIT		Effect %	Comparison other groups
		Pretest	Posttest		Pretest	Posttest		Pretest	Posttest		
*Corte de Araujo et al., 2012	Cardiorespiratory fitness ml/kg/min	—	—	—	—	—	—	—	—	—	HIIT and the training group increased their cardiorespiratory fitness.
Baquet et al., 2010	Cardiorespiratory fitness ml/kg/min	50.6	42.2	-16.6	50.1	53.6	+6.9	51.6	54.1	+4.8	HIIT and the training group increased their cardiorespiratory fitness, however the control group reduced it.
	MAS km/h	10.8	8.5	-21.3	10.8	11.7	+8.3	11.3	12.1	+7.1	
Gamelin et al., 2009	Cardiorespiratory fitness ml/kg/min	36.2	36.7	+1.38	_	_	_	51.6	54.1	+4.8	HIIT increased their cardiorespiratory fitness, however the control group keep it the same.
Lau et al., 2015	Cardiorespiratory fitness MAS km/h	10.9	10.8	-0.92	10.9	10.9		10.9	10.9		Both groups show no changes.
McManus et al., 2005	Cardiorespiratory fitness ml/kg/min	44.7	45.4	+1.5	47.0	50.7	+7.8	45.5	50.7	+11.4	HIIT, training group and control group increased their cardiorespiratory fitness. Control group has the lowest increase.
McNarry et al., 2015	Cardiorespiratory fitness ml/kg/min	20.3	20.5	+0.98	_	_	_	18.1	19.3	+6.6	HIIT increased their cardiorespiratory fitness, however the control group keep it the same
Mucci et al., 2013	Cardiorespiratory fitness ml/kg/min	39.77	38.81	-2.42	_	_	_	39.6	45.1	+13.8	HIIT increased their cardiorespiratory fitness, however the control group reduced it.
Nourry et al., 2005	Cardiorespiratory fitness ml/kg/min	36.8	36.6	-0.45	_	_	_	37.4	43.2	+15.5	HIIT increased their cardiorespiratory fitness, however the control group keep it the same.
Rosenkranz et al., 2012	Cardiorespiratory fitness ml/kg/min	33.1	30.4	-8.1	_	_	_	23.6	29.4	+24.5	HIIT group increased their cardiorespiratory fitness, however the control group reduced it.
Lambrick et al., 2015	Cardiorespiratory fitness ml/kg/min	55.4	54.9	-0.91	_	_	_	51.4	54.3	5.6	HIIT group increased their cardiorespiratory fitness, however the control group reduced it.

*HIIT: high-intensity interval training, *: doses not present numerical results, %: percentage, -: percentage decrease, +: percentage increment*

Effects of high-intensity interval training on body composition

Body composition was assessed using three methods: bioelectrical impedance (Corte de Araujo et al., 2012; Lambrick et al., 2015; McNarry et al., 2015). Dual-energy x-ray absorptiometry (DXA) (Rosenkranz et al., 2012) and skinfolds (Lau et al., 2015; Nourry et al., 2005). The other studies only report measurements of body composition with body mass index (BMI) (Baquet et al., 2010; Gamelin et al., 2009; McManus et al., 2005; Mucci et al., 2013), the studies analyzed show that the group that performing high intensity exercises improves indicators of body composition (Corte de Araujo et al., 2012; Lambrick et al., 2015; Lau et al., 2015; McNarry et al., 2015; Nourry et al., 2005; Rosenkranz et al., 2012). In three studies, there was no significant improvement in body composition indexes (Baquet et al., 2010; Gamelin et al., 2009; Mucci et al., 2013). As for the results of HIIT and the training group in an article, none of the groups presented significant modifications (Baquet et al., 2010) in another article both groups improved (Corte de Araujo et al., 2012) and in an article alone HIIT group positively modified the result of the sum of skinfolds (Lau et al., 2015). In relation to the control group in all analyzed articles that present data increase the percentage of fat, body weight or BMI (Baquet et al., 2010; Gamelin et al., 2009; Lambrick et al., 2015; Lau et al., 2015; McNarry et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012) and in a single study decreases their fat percentage (Table 3) (Nourry et al., 2005).

TABLE 3
Results body composition.

Study	Measure Outcome	Control Group		Effect %	Training Group		Effect %	HITT		Effect %	Comparison other groups
		Pretest	Posttest		Pretest	Posttest		Pretest	Posttest		
Corte de Araujo et al., 2012	BMI (kg/m2) Body Fat (%)	—	—	—	30 37	29 36	-3.34 -2.71	32 38	30 37	-6.25 -2.64	Both groups decrease BMI and body fat.
Baquet et al., 2010	BMI (kg/m2) Body mass (kg)	18.5 36.2	18.2 37	-1.6 +1.3	17.9 33.5	18.1 34.7	+1.1 +3.5	17.5 35	17.6 35	+0.57	Control group presents a slight decrease, Training group increases BMI and body mass, and not changes group HIIT.
Gamelin et al., 2009	Body Mass (kg)	36.2	36.7	+1.3	_	_	_	35.5	36.4	+2.5	Both groups increase body mass.
Lau et al., 2015	BMI (kg/m2) Sum of skinfolds (mm)	24.8 56.1	25.2 60.4	+1.61 +7.66	22.8 53.9	22.9 53.3	+0.43 -1.12	23.7 59.5	23.9 51.3	+0.84 -13.7	Control group presents a increase BMI and sum of skinfolds, training group not changes in BMI but a slight decrease in sum of skinfolds. HIIT shows a small decrease in BMI and a significant decrease in the sum of skinfolds.
McNarry et al., 2015	BMI (kg/m2)	17.0	17.1	+0.5	_	_	_	23.7	23.6	-0.4	Both groups do not present change.
Nourry et al., 2005	Body Fat (%) Body mass (kg)	16.4 39.0	15.9 39.9	-3.1 +2.3	—	—	—	19.0 34.6	17.5 35.7	-7.9 +3.1	Control group presents a decrease in body fat and increase y body mass HIIT shows a decrease in body fat and a increase in body mass.
Rosenkranz et al., 2012	BMI (kg/m2) Body Fat (%)	13.6 15.7	18.3 21.6	+34.5 +37.5	—	—	—	19.5 22.2	18.1 20	-7.1 -9.9	Control group presents a increase BMI and body fat. HIIT shows a decrease in BMI and body fat.
Mucci et al., 2013	Body mass (kg)	43	44	+2.3	_	_	_	33.1	33.8	+2.1	Both groups increase body mass.
Lambrick et al., 2015	BMI (kg/m2) Body Fat (%)	19.5 23.1	19.5 24.3	+5.1	—	—	—	20.5 25.9	20.5 25.1	-3.1	The control group showed no change in BMI but an increase in body fat. HIIT does not but a slight decrease in body fat.

HIIT: high-intensity interval training, BMI: body mass index, %: percentage, -: percentage decrease, +: percentage increment

Methodological quality of studies

The overall quality (EPHPP) of the studies analyzed was weak. Seven studies were considered of weak quality (Baquet et al., 2010; Gamelin et al., 2009; Lambrick et al., 2015; Lau et al., 2015; McNarry et al., 2015; Mucci et al., 2013; Nourry et al., 2005) and three moderate (Corte de Araujo et al., 2012; McManus et al., 2005; Rosenkranz et al., 2012). Out of the 10 studies analyzed (EPHPP) in respect of risk of bias, one article was moderate (Corte de Araujo et al., 2012) and nine weak (Baquet et al., 2010; Lambrick, Stoner, Grigg, & Faulkner, 2016).

DISCUSSION

HIIT is based on short bouts of high intensity exercise as an alternative approach to achieve the health benefits delivered when performing physical activity in a short period of time (Burgomaster et al., 2006). HIIT in adolescents can significantly improve cardiorespiratory fitness, BMI, and decrease body fat percentage, in comparison to moderate intensity training and non-training control group conditions (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015). However, in preadolescents, evidence is not clear enough when comparing HIIT to other forms of exercise (Racil et al., 2016). In this review, HIIT programs were consistently associated with an improvement in the cardiorespiratory fitness. On the other hand, body composition results are very inconsistent in BMI and body mass, however body fat shows a decrease in most studies.

Regarding cardiorespiratory fitness, HIIT has the potential to improve cardiorespiratory fitness in preadolescents. For this study, 10 articles were analyzed and 9 of them (Table 2) reported a significant increase in cardiorespiratory fitness (Baquet et al., 2010; Corte de Araujo et al., 2012; Gamelin et al., 2009; Lambrick et al., 2015; McManus et al., 2005; McNarry et al., 2015; Mucci et al., 2013; Nourry et al., 2005; Rosenkranz et al., 2012). Only one did not present a significant increase (Lau et al., 2015). This result is consistent with other reviews (Buchheit & Laursen, 2013; Costigan et al., 2015; Dobbins, Husson, Decorby, & LaRocca, 2013; Garcia-Hermoso et al., 2016). Therefore there is enough evidence to conclude that children and adolescents must engage in vigorous physical activity to improve their cardiorespiratory fitness. HIIT can be accomplished in a short period of time and the results are similar or better on cardiorespiratory fitness compared to traditional endurance training (Dobbins et al., 2013).

The body composition data showed that HIIT, in comparison with other training programs or non-exercise groups (Table 3), can enhance body composition in children (Logan, Harris, Duncan, & Schofield, 2014). Nevertheless, in this review only 3 studies showed a decrease of BMI through

HIIT (Corte de Araujo et al., 2012; Gamelin et al., 2009; McNarry et al., 2015) and one showed a decrease in the sum of skinfolds (Lau et al., 2015). Other studies showed not significant effect in reducing body fat with HIIT (Table 3) (Baquet et al., 2010; Corte de Araujo et al., 2012; Nourry et al., 2005; Rosenkranz et al., 2012). However, 3 studies in HIIT showed a decrease in fat mass percentage (Corte de Araujo et al., 2012; Nourry et al., 2005; Rosenkranz et al., 2012). The effect of HIIT is considerably larger than the effect of other interventions on body composition in young people (Dobbins et al., 2013) but its real effectiveness in preadolescent body composition is still unclear (Garcia-Hermoso et al., 2016).

Limitations

The main limitation of the study was that several types of HIIT programs were implemented. In addition, different instruments to perform measurements were used. Although the studies addressed the same topic, the heterogeneity of the variables reduces the strength of the conclusions generated. Other limitations of the study were: not examining cardiometabolic effects of HIIT, not performing meta-analysis, and weak quality of studies.

CONCLUSIONS

According to the studies analyzed, it is still unclear which HIIT protocol produces benefits for preadolescents' health. Future research should examine the effects of various HIIT interventions to determine the optimum strategy to produce health benefits. Also, the minimum duration and frequency of HIIT bouts must be determined if it is to be used as an alternative to physical activity recommendations in children. Literature should scientifically determine the intensity, duration of exercise, and rest bouts, as well as total duration of the session and the program. Exercise intensity measurements must also be stated and easily translated to practice by the subjects.

Researches should explicitly show the differences between the HIIT intervention group and the control or traditional endurance-training group, since the scale of HIIT difference to other exercise modalities is of great interest for the public health.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no identifiable children data appear in this article.

Right to privacy and informed consent. The authors declare that no identifiable children data appear in this article.

Conflicts of interest

The authors have no conflicts of interest to declare.

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