Advances in Physical Education, 2022, 12, 60-74
https://www.scirp.org/journal/ape
ISSN Online: 2164-0408
ISSN Print: 2164-0386

Effectiveness of High-Intensity Games versus Moderate-Intensity Games on Cardiorespiratory Fitness and Anthropometric Variables in Children

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How to cite this paper: Reyes-Amigo, T., Palmeira, A., Martins, C., Carrasco-Beltrán, H., Gomez-Mazorra, M., Soto-Sanchez, J., Ibarra-Mora, J., & Mota, J. (2022). Effectiveness of High-Intensity Games versus Moderate-Intensity Games on Cardiorespiratory Fitness and Anthropometric Variables in Children. *Advances in Physical Education, 12,* 60-74.
https://doi.org/10.4236/ape.2022.121005

Received: December 28, 2021
Accepted: February 20, 2022
Published: February 23, 2022

Abstract

Background: Several studies have reported significant improvements in cardiorespiratory fitness (CRF) in children with high-intensity exercise. However, most research protocols focus on cycling and running. These protocols are not applicable for practical purposes in children. **Objective:** This study aims to assess the effect of an 11-week intervention using games protocols of two different intensities (high-intensity games and moderate-intensity games) on CRF and anthropometric variables in children. **Methods:** The participants included 48 schoolchildren aged between 9 to 10 years (9.48 ± 0.5 years). Children were randomized into two groups: high-intensity games (HIG) or moderate-intensity games (MIG). HIG group used relays race and small-sided games; >75% of maximum heart rate (HR_{max}). MIG group used cooperative and dynamics continued games; 60% - 74% HR_{max}. Both groups had two sessions per week for 11 weeks during physical education classes (PE). Before and after the interventions, participants completed the CRF test (20-meter shuttle run test) and measurements of anthropometric variables were taken: Body mass index (BMI), Body mass index Z-Score (BMI z-score), Waist circumference (WC), Body fat percentage (BF%) and Sum of skinfolds. **Results:** A significant time × group interaction was observed for CRF (F = 4.879, P = 0.032; ES = 0.6), between HIG and MIG. There were no significant differences time interaction between treatment groups for BMI (F = 1.158, P = 0.288), BMI z-score (F = 2.911, P = 0.095), BF% (F = 0.270, P = 0.606) and Sum of skinfolds (F = 1.481, P = 0.230). **Conclusions:** This study demonstrates that an 11-week HIG program, applied during PE classes, is more effective than MIG in the improvement of the CRF in children.

Keywords

High-Intensity Games, Children, Cardiorespiratory Fitness, Anthropometric Variables, Physical Education

1. Introduction

Regular physical activity during childhood has been demonstrated to have positive effects on health habits in adult population and to reduce incidences of cardiovascular disease, metabolic diseases and premature death (Smith et al., 2015). However, 81% of children do not meet the recommended daily physical activity—60 minutes per day of moderate-to-vigorous physical activity (Guthold et al., 2020). The evidence pointed out that the relative intensity, and not the duration of exercise, was the most important variable related to all-cause mortality (Schnohr et al., 2012). Further, studies conducted in youths showed that only vigorous physical activity was consistently associated with increased cardiorespiratory fitness (CRF) (Carson et al., 2014).

Unlike adults, children's common physical activity patterns are highly intermittent in nature, characterized by rapid changes from rest to vigorous physical activity (Malik et al., 2017). This intensity differential is of particular importance when considering that, in youth, the time spent in vigorous-intensity activity is strongly associated with many positive health outcomes, namely improved waist circumference (WC), systolic blood pressure and body mass index (BMI) (Hay et al., 2012). In this regard, short-term, high-intensity, and intermittent activities programs may be more effective for children´s health and physical fitness (Sallis et al., 1993). The main method of high-intensity activities is high-intensity interval training (HIIT). This is an exercise modality that alternates short bouts of high-intensity effort with a previously-set recovery period (Laursen & Jenkins, 2002). HIIT induces changes in a range of physiological, performance, and health-related markers in both healthy individuals and populations with some type of illness (Campbell et al., 2019; Solera-Martínez et al., 2021). Although these findings are encouraging, previous studies have been oriented to prescribe exercise with a focus on cycling and running (Baquet et al., 2010; Corte de Araujo et al., 2012;

McNarry et al., 2015). However, Biddle et al. (2004) and Biddle & Batterham (2015) have questioned the utility of structured activity programs for children, suggesting that the provision of such programs inadequately prepares children for the typically unstructured nature of the adult activity. Another question is the difference between moderate-intensity continuous training and HIIT, both are equally effective in improving important health parameters (e.g., CRF, insulin sensitivity, BMI) (Corte de Araujo et al., 2012). However, in recent years, several experimental studies have compared the effects of moderate-intensity continuous training and HIIT connected to these variables in children and adolescents, yet the findings were inconsistent (Corte de Araujo et al., 2012; Van Biljon et al., 2018; Yin et al., 2020).

Physical fitness during childhood has been identified as an important link among health benefits, where CRF is linked with a healthy lifestyle in children and adolescents (Cao et al., 2019). High CRF is related to lower cardiometabolic risk, especially when associated with body mass, body fat and WC reduction (Díez-Fernández et al., 2014; Lahoz-García et al., 2018). Therefore, as the number of children with low CRF gradually increases (Tomkinson et al., 2019), effective interventions targeted at promoting the development of CRF in this population are particularly important. The interventions should be designed to optimize children's enjoyment of physical activities, considering their common physical activity patterns as child-specific games or "unpredictable" sporting activities (Bendiksen et al., 2014; Brøgger et al., 2013). In this regard, high-intensity games interventions may be positive for the health and fitness of children, yet more experimental work is needed to establish the optimal volume, activities and safety of vigorous exercise in conferring improvement on CRF and anthropometric variables (Lambrick et al., 2015).

Therefore, the main purpose of this study is to assess the effect of an 11-week intervention using two different intensity games (high-intensity and moderate-intensity games) on CRF and anthropometric variables (BMI, Body mass index z-score (BMI z-score), WC, Body fat percentage (BF%) and Sum of skinfolds) in children.

2. Methods

2.1. Participants

Forty-four children (16 boys and 32 girls) volunteered to participate in the study. The participants were students recruited through emails and meetings with parents and teachers from an elementary school in Valparaíso, Chile. The students' age ranged from 9 - 10 years (9.48 ± 0.5 years), with a sexual maturity stage Tanner 1 - 2 (Tanner & Whitehouse, 1976). Parent/guardian consent and child agreement were obtained before the start of the intervention. Ethical approval was granted for this study by a bioethics committee (01/2017). The participants selected were not part of any regular exercise-training program. Volunteers were excluded if they presented any type of chronic pediatric disease, cardiovascular or metabolic disease (except for obesity), or any orthopedic limitation. Participants whose attendance was lower than 95 percent (%), who failed to attend the first or second measurement, and/or presented a negative response to training were excluded. The initial number of volunteers was 66 (23 boys and 43 girls) and the final analysis was carried out with 48 participants (32 girls, 16 boys) because 11 children were already part of a regular exercise-training program and 7 presented a form of chronic pediatric disease. All participants remaining completed the study and there were no negative effects after the interventions. Children were randomly assigned and divided into two groups: a high-intensity games (HIG) group and a moderate-intensity games (MIG) group, using simple randomization procedures (Lim & In, 2019). As a result of the randomization process, the HIG group consisted of 25 children (7 boys, 18 girls) and the MIG group consisted of 23 (9 boys and 14 girls) (**Figure 1**).

In the present study, a power analysis was performed (G * Power 3; Heinrich-Heine-Universität, Düsseldorf, Germany) to calculate the adequate sample size (F-test, effect size = 0.25, α error = 0.05, power = 0.80). According to this calculation, 24 participants were required.

2.2. Outcomes

Procedures: Prior to starting the study, all subjects were introduced to the staff who carried out the study and all the experimental procedures, and were subsequently tested on two different days on their school premises. On the first day, anthropometric measures, height and body mass, were measured with a wall stadiometer and a balance model SECA 703 (were obtained to calculate the BMI), BMI (kg/m^2) and BMI z-score (De Onis & Lobstein, 2010) were calculated with the Software AnthroPlus. WC was measured using a Lufkin tape, model

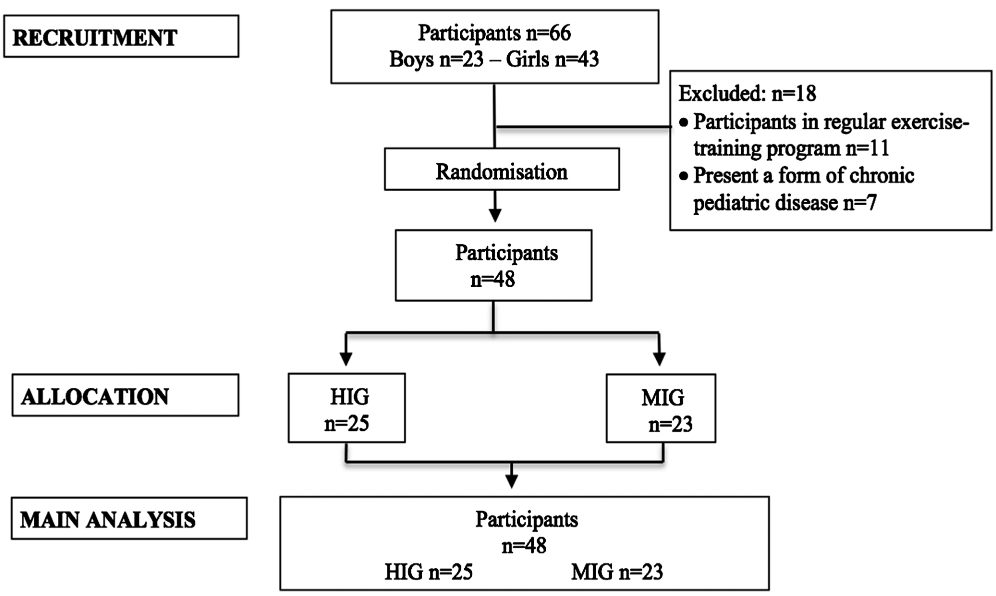

Figure 1. CONSORT flow chart for randomised. HIG, high-intensity games group; MIG, moderate-intensity group.

W606P, in the horizontal plane, midway between the inferior margin of the ribs and the superior border of the iliac crest in deep expiration (Mederico et al., 2013). To measure BF%, the tricipital fold and the subscapular fold were assessed using a Lange Skinfold Caliper, model 102-602 L (Minneapolis, USA) by applying Slaughter's formula (Slaughter et al., 1988). The Sum of skinfolds variable was obtained from the result of the sum of the tricipital, subscapular and calf folds. The sexual maturity was assessed according to the pubertal development stage of the participants, pictures of Tanner's five stages were used. All participants were requested to self-evaluate their pubertal development showing them pictures of Tanner's stages and asking them to identify in which stage they thought they were. This procedure was explained by a pediatrician who supervised all the procedures, which were performed respecting the privacy of the participants and promoting their comfort level during the evaluation. The process was carried out individually and independently in a specially assigned room. Each participant was classified in one of Tanner's five stages described for both sexes (Matsudo & Matsudo, 1994; Tanner & Whitehouse, 1976).

On the second day, CRF was measured with a 20 meters shuttle run test (Leger et al., 1988). Subjects were required to run back and forth a 20-meter course, and had to touch the 20-meter line at the same time that a sound signal was emitted from a prerecorded tape. The frequency of the sound signals increases in such a way that running speed is increased by 0.5 km/h each minute from a starting speed of 8.5 km/h. The test stops when the subject is no longer able to follow the set pace. The last announced stage number or the equivalent maximal aerobic speed is then used as the maximum oxygen uptake (VO_{2max}) index, by applying Leger's formula (Leger et al., 1988).

The same test procedure was applied for the assessments at the end of the intervention period.

All measurements were performed by members of the research team, who were specially trained, under standardized conditions. The same investigator performed the pre-and the post-test measurements. To avoid circadian variation in the parameters, the remeasurements after the observation period were performed at the same time each day. To rule out external influences, parents were instructed that their children had to abstain from consuming caffeinated beverages and also refrain from intensive physical activity for 12 hours prior to the test day.

2.3. Intervention

A 2-week pilot trial with children (n = 32; mixed ethnicity, aged 9 - 10 years) from a school different from the one the current study was carried out in, showed that children could repeatedly perform HIG and MIG for the time allotted.

Throughout the 11-weeks intervention period, both the HIG and MIG took part in regular physical education (PE) classes of 45 minutes twice a week. The HIG and MIG were conducted by a qualified PE teacher who was specifically trained in these types of activities.

The HIG intervention was characterized by a vigorous interval regimen and consisted of different relays race (Ketelhut et al., 2020) and collaboration and opposition in small-side games (Bendiksen et al., 2014; Halouani et al., 2014) at an intensity level set at >75% of their predicted maximum heart rate (HR_{max}) (Brøgger et al., 2013). Our goal is to provide a variety of different tasks and activities were perceived to be more enjoyable during each session. Each session started with a 6-minute warm-up and ended with a 6-minute cool-down and 5-minutes class feedback. The main protocol comprised 2 HIG blocks lasting 12 minutes with a 4-minutes recovery between the blocks. Within the HIG blocks there were games intervals lasting from 5 minutes interspersed with 2 minutes of passive rest (Lambrick et al., 2015) (**Table 1**). During the intervals, the children were verbally cheered to provide maximal or near-maximal efforts.

The MIG intervention was characterized by continuous exercise and consisted of cooperative and dynamic continuous games at an intensity level set at 60% - 74% of their predicted HR_{max} (Bendiksen et al., 2014; Reyes-Amigo et al., 2021). Each session started with a 5-minute warm-up and ended with a 5-minute

Table 1. HIG and MIG intervention.

Groups	Content	Activities description	Times
HIG	Warm-up	Joint mobility - jogging	6 min
	Games	Block I: Relays race	12 min (2 × 5 min active/2 min of passive rest)
		Passive rest	4 min
		Block II: C-O SSG	12 min (2 × 5 min active/2 min of passive rest)
	Intensity	>75% HR_{max}	
	Cool-down	Stretching	6 min
	Feedback	Verbal feedback	5 min
MIG	Warm-up	Joint mobility - jogging	5 min
	Games	Block I: CCG	14 min (2 × 6 min 30 s active/1 min of passive rest)
		Passive rest	2 min
		Block II: Groups dynamics	14 min (2 × 6 min 30 s active/1 min of passive rest)
	Intensity	60% - 74% HR_{max}	
	Cool-down	Stretching	5 min
	Feedback	Verbal feedback	5 min

HIG, High-Intensity Games; MIG, Moderate-Intensity Games; min, minutes; s, seconds; C-O SSG, cooperative–opposition small-sided games; CCG, cooperative continues games; HR_{max}, Maximal heart rate.

cool-down plus 5-minute class feedback. The main protocol comprised 2 MIG blocks lasting 14 minutes with a 2-minute recovery between the blocks. Within the MIG blocks, there were games intervals lasting from 6 minutes to 30 seconds interspersed with 1 minute of passive rest (Reyes-Amigo, 2015) (**Table 1**). Heart rate (HR) was monitored continuously throughout each HIG and MIG. Using the Tanaka formula ($HR_{max} = 208 - 0.7 \times age$), which is valid in child population in Latin America (Machado & Denadai, 2011). The exercise intensity was documented using an HR monitor (Cardiac frequency monitor M400 POLAR, Finland) (McNarry et al., 2015; Van Biljon et al., 2018).

2.4. Statistical Analysis

The normal distribution of the data was checked using the Kolmogorov-Smirnov test. Differences in subject characteristics between groups were determined using independent Samples t-test in the baseline. The Chi-Square test was used to compare the distribution between the study groups in sex and sexual maturation. Levene's test was used to check the homogeneity of variance. Paired t-tests were used to compare, mean HR and heart rate peak (HRpeak) between HIG and MIG. Repeated-measure analysis 2 × 2 with the covariate WC (ANCOVA) was used to determine the main effects and the interaction effects between groups (HIG and MIG) over time (pre and post-test). A significant difference was observed in WC at the baseline; therefore, the analysis was adjustments to this pre-value.

The effect size (ES) was calculated using Cohen's d test. Effect sizes of less than 0.4 represented a small difference, where 0.41 - 0.7 and greater than 0.7 represented a moderate or a large difference respectively (Delgado-Floody et al., 2018). The threshold for significance was set at $P < 0.05$. Data were analyzed with Statistical Package for the Social Sciences (SPSS v.25) software.

3. Results

Forty-eight participants completed all the interventions. No adverse events were reported. Children randomized to HIG and MIG groups had a 94% attendance: 16 of the 17 sessions available.

Table 2 shows characteristics of the participants at baseline. All variables were not statistically significant between the groups at baseline, except WC (HIG, 63.62 ± 6.67 cm vs. MIG, 68.22 ± 9.73, $P > 0.04$). Chi-Square analysis shows no difference in the proportion of boys and girls in the studied groups (Chi-Square = 0.414, $P > 0.05$), nor in differences in relation to maturation status (Chi-Square = 0.882, $P > 0.05$).

During the 11-week intervention program, HIG presented a significantly higher mean HR when compared to the MIG (153 ± 11.05 bmp vs. 129 ± 12.5 bmp; $P = .001$; ES = 0.2). The HRpeak was also significantly higher HIG when compared to MIG (196 ± 12.1 bmp vs 184 ± 16.8 bmp; $P = .001$; ES = 0.1) (**Table 3**).

Table 2. Physical characteristics data in mean (±SD) for HIIG and MIG groups in baseline.

Variables	HIIG [n (25)]		MIG [n (23)]		P
	Mean	SD±	Mean	SD±	
Age (years)	9.48	0.50	9.52	0.51	0.77
Height (cm)	138.16	6.22	138.60	6.11	0.80
Weight (kg)	37.89	6.99	41.21	10.04	0.23
CRF ($VO2_{max}$ $ml \cdot kg^{-1} \cdot min^{-1}$)	44.85	3.53	44.84	3.74	0.87
BMI ($kg \cdot m^{-2}$)	19.73	2.49	21.28	4.05	0.15
BMI z-score (BMI/E)	1.20	0.73	1.65	1.03	0.09
WC (cm)	63.62	6.67	68.22	9.73	0.04*
BF%	26.86	5.42	29.25	6.99	0.21
Sum of Skinfolds (mm)	50.12	15.86	60.10	25.65	0.17

CRF, cardiorespiratory fitness; BMI, body mass index; BMI z-score, body mass index z-score; WC, waist circumference; BF%, percentage of body fat; *, significant ($P < 0.05$)

Table 3. Comparison of measures of exercise intensity (HR) between HIG and MIG.

Variables	HIG		$\%HR_{max}$	MIG		$\%HR_{max}$	P	ES
	Mean	SD±		Mean	SD±			
HR (bmp)	153	11.1	78	129	12.5	65	0.001*	0.2
HRpeak (bmp)	196	12.1	99	184	16.8	93	0.001*	0.1

HR, Heart rate; HRpeak, heart rate peak; HIG, High-Intensity Games; MIG, Moderate-Intensity Games; *, significant ($P < 0.05$).

Regarding CRF, Table 4 shows that there is no time effect on the CRF average from pre- to post-intervention. Nevertheless, a significant time × group interaction was observed for CRF (F = 4.879, $P = 0.032$; ES = 0.6), where HIG had increased the CRF from pre- to post-intervention, while the MIG CRF remained similar.

Concerning anthropometric variables, when comparing BMI from both groups, no significant time effects were observed. Also, the BMI did not change as a result of the intervention, because time x group was not significant (F = 1.158, $P = 0.288$). When looking exclusively at pre-and post-intervention comparisons, no significant time effects were found for BMI z-score. Either was observed significant differences in the time x group (F = 2.911, $P = 0.095$) (Table 4).

As indicated in Table 4, there is not a time effect on the BF% average, from baseline to post-intervention. Regarding the result of time x group, there are not significant differences in the interaction for BF% (F = 0.270, $P = 0.606$).

According to Table 4, there is a time effect on the Sum of skinfolds average, representing a reduction on Sum of skinfolds from baseline to post-intervention on both groups as a whole (F = 9.851, $P = 0.001$). Nevertheless, there is no significant time × group interaction (F = 1.481, $P = 0.230$). This result is similar to

Table 4. Participant description at baseline and post-intervention assessments for children randomized to the HIG and MIG conditions.

Variables		HIIG [n (25)]		MIG [n (23)]		Time		Time X Group		ES
		Mean	SD±	Mean	SD±	F	P	F	P	
CRF ($VO2_{max}$)	Baseline	44.85	3.53	44.84	3.74					
	Post	46.30	3.84	44.03	3.22	0.575	0.452	4.879	0.032*	0.6
BMI ($kg*m^{-2}$)	Baseline	19.73	2.49	21.28	4.05					
	Post	20.37	2.47	21.66	4.08	2.034	1.61	1.158	0.288	0.3
BMI z-score	Baseline	1.20	0.73	1.65	1.03					
	Post	1.39	0.76	1.68	0.97	3.604	0.064	2.911	0.095	0.3
BF%	Baseline	26.86	5.42	29.25	6.99					
	Post	25.65	5.36	28.51	7.38	0.611	0.438	0.270	0.606	0.3
Sum of Skinfolds (mm)	Baseline	50.12	15.86	60.10	25.65					
	Post	47.54	13.74	51.43	17.16	9.851	0.001	1.481	0.230	0.2

CRF, cardiorespiratory fitness ($VO2_{max}$ $ml \cdot kg^{-1} \cdot min^{-1}$); BMI, body mass index; BMI z-score, body mass index z-score; WC, waist circumference; BF%, percentage of body fat; *, significant ($P < 0.05$).

the one obtained in the BF%.

4. Discussion

The main purpose of this study was to assess the effect of an 11-week intervention using two games of different intensities (HIG and MIG) on CRF and anthropometric variables in children. Children were selected as the specific subjects of this study because short-term programs of high-intensity activities have shown to be safe and effective on children's physical fitness and health (Pozuelo-Carrascosa et al., 2018).

HR analysis revealed significant differences in the peak HR between the HIG and the MIG. Additionally, the mean HR throughout the HIG program was significantly higher than the mean HR during the MIG intervention. This result shows a connection to the structured intermittent exercise of HIG which is more effective in increasing intensity in comparison to continuous activity (Bendiksen et al., 2014; Brøgger et al., 2013).

This study demonstrated that HIG can produce improvements on CRF, which is significantly different from the one seen for the MIG. A possible explication for this is that children are capable of exercising near their HRpeak in intervals for about four minutes with 2 - 3 minutes recovery without high levels of fatigue for a long time (Selmi et al., 2020). In addition, the use of playful activities may have enhanced the motivation to sustain the high intensity (Ketelhut et al., 2020). The evidence shows that the longer vigorous or high-intensity physical activity is carried out, the greater the positive effect on CRF (Cao et al., 2019).

Indeed, the current result is in line with other intervention studies that lasted 6 weeks or more, comparing high and moderate-intensity activities (Cao et al., 2019; McNarry et al., 2015; Mucci et al., 2013). For example, McNarry et al., (2015) showed improvement in the CRF in 6 weeks and Garcia-Hermoso et al., (2016) by 12 weeks of high-intensity exercise intervention. These results are different from other research that have found similar results connected to an increase of the CRF between high-intensity and moderate-intensity (Corte de Araujo et al., 2012; Van Biljon et al., 2018). Nevertheless, recent evidence shows that high-intensity intervention is more effective, therefore the evidence has shown high intensity to be an important aspect for improving children's CRF (Cao et al., 2019; Eddolls et al., 2017). Moreover, among the existing studies, improvements in CRF are shown if the intensity level is above 70% HR_{max} (Baquet et al., 2010; Strong et al., 2005). In this regard, the current study correlates with the evidence in the number of weeks of intervention and the intensity. However, it does not correlate with the type of activities, since most of the existing studies follow a rigid structure (cycling-running) (Reyes-Amigo et al., 2017), which may not be adequate for children, considering the typically unstructured nature of their physical activity (Biddle & Batterham, 2015). Although there are few studies on this line studies (Brøgger et al., 2013; Ketelhut et al., 2020; Lambrick et al., 2015), the current study demonstrated that high-intensity games (relays race and small-sided games) have a significant effect on CRF in children, while other studies show that these activities are associated to a better enjoyment in childhood (Howe et al., 2010).

Regarding anthropometric variables, no significant differences were observed between HIG and MIG during the intervention in BMI, BMI z-score, BF%, and Sum of skinfolds. These results are in line with reviews that revealed little evidence to suggest that high-intensity activities can elicit significant improvements in body composition (Garcia-Hermoso et al., 2016). However, other studies have reported significant improvements in BMI, Sum of skinfolds and BF% associated with a medium-to-large effect size following a 6 to 8 weeks intervention when compared with moderate-intensity activities or control group (Lau et al., 2015; Rosenkranz et al., 2012). Another review indicates that 7 weeks or more of high-intensity exercise can change anthropometric variables (Eddolls et al., 2017). This shows a similarity with the results from Lau et al. (2015) and Rosenkranz et al. (2012), but it is not in line with our results. The difference between high and moderate intensity is still unclear. In regards to the change in the anthropometric variables, further research should be conducted to compare the long-term effects of high and moderate-intensity exercise in children (Yin et al., 2020) and should further analyse the high-intensity protocol, aiming to compare different work and recovery durations to better understand the efficiency of the method in children and adolescents (de Menezes-Junior et al., 2020).

The role of ecological designs could potentially validate that the game-based intervention in children increased social interaction and enjoyment, and mimic their usual patterns of play (Lambrick et al., 2015). The intervention was also carried out in the children's schools, and the school environment is considered highly important when implementing physical activity strategies for children (Greier et al., 2020).

Our data and previous studies (Ketelhut et al., 2020; Martínez-Vizcaíno et al., 2021) suggest that high-intensity games intervention, focused on playful activities and children's enjoyment, is sustainable because it is implemented using the school facilities, in a controlled setting and does not modify the school curriculum. These characteristics are considered strengths of this study and lay the foundation for the following research.

5. Limitations

We did not control for diet during the intervention, we were unable to determine the influence of dietary habits on anthropometric variables changes between HIG and MIG groups. This is important in the results of the anthropometric variables.

6. Conclusion

This study demonstrates that an 11-week HIG program, applied during PE classes, is effective in the improvement of the CRF in children, when compared to MIG. Finally, according to the obtained results, the utility and contribution of this study is the practical application of embedding high-intensity games within the school setting, especially in PE classes, offering a time-efficient strategy for the strict school timetable.

Acknowledgements

The authors thank the participants of the present study for volunteering their time and effort. Additionally, this study was financially supported by Research Centre in Physical Activity, Health and Leisure (CIAFEL) (FCT UID/DTP/00617/2020), Sports Faculty of the University of Porto, Portugal.

Trial registration: "clinicaltrials.gov". Identifier: NCT038500.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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