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Effects of a short-term of whole-body, high-intensity, intermittent training program on morphofunctional parameters

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Short title: Whole-body, high-intensity, intermittent training on morphofunctional parameters

ABSTRACT

Background: Few studies have analyzed the application of high-intensity interval training (HIIT) using exercises with body weight among the morphofunctional parameters. **Aim:** To analyze and compare the effects of six weeks of high-intensity intermittent calisthenic training (HIICT) and moderate intensity, continuous exercise (MICT) on body composition, hypertrophy, and strength. **Materials and methods:** Twenty-five active, healthy adults were randomized in either the HIIT group (*n* = 14) or the MICT group (*n* = 11). The HIIT group performed high-intensity intermittent calisthenic training based on full body exercise. The training session involved 5 minutes of warm-up followed by 20 sets of 30 seconds all-out exercise and 30 seconds of passive recovery between sets. Jumping jack, mountain climber, burpee and squat jump were used. The MICT group performed continuous moderate running (5 minutes of warm-up followed by 20 minutes of running with intensity fixed at 80% of maximum heart rate). Training for both groups was performed three times weekly on nonconsecutive days. All subjects underwent anthropometric measurements and functional tests. Muscle thickness was also measured. **Results:** There were no significant changes observed in any anthropometric measurements in both groups. Regarding the functional tests, the analysis of the percentage changes revealed advantages of HIICT over MICT in push-ups only (p = 0.02). The muscular thickness of lower and upper limbs did not present significant differences in the pre- and post-times or between groups ($p > 0.05$). **Conclusion:** When compared to MICT, HIIT improved push-up effects, without generating significant changes in body composition and muscle thickness.

Keywords: whole-body, physical exercise, anthropometrics, muscle

INTRODUCTION

High-intensity interval training (HIIT) is characteristically composed of high-intensity stimuli interspersed by short periods of active or passive recovery, sequentially repeated in an exercise session (Gibala et al., 2014). In the last decade, HIIT has become highly popular (Thompson, 2017) mainly due to the increasing number of studies exploring its effects on different variables and populations.

The results from recent studies have shown that HIIT may be an interesting, time-efficient strategy to promote improvement in physical conditioning (Gibala et al., 2014; Naimo et al., 2015), in weight loss and body composition (Alves et al., 2017), and as a non-medicinal intervention for the treatment of certain diseases (Gibala et al., 2010; Shaban et al., 2014).

The most common HIIT protocols explored in the literature use cyclic exercises carried out in ergometry (e.g., treadmill, bicycle) with objective control of intensity (e.g.,% iVO_2max), making reproduction hard in training environments due to the high cost of equipment for training and load quantification (Gray et al., 2016).

Thus, more recently, some studies (McRae et al., 2012; Machado et al., 2017, Machado et al. 2018a, Machado et al. 2018b) have suggested the application of HIIT using exercises with body weight (burpees, mountain climb, squat and squat jumps, and others) and subjective control of intensity (i.e., subjective perception of all-out force) in order to facilitate the application of the method for the general population.

Although a previous study (McRae et al, 2012) has shown good results from a high-intensity intermittent calisthenic training program (HIICT) with regard to aerobic fitness and strength resistance, there are few studies involving this type of intervention; primarily analyzing the effects on body composition, muscle hypertrophy and strength. Thus, the aim of this study was to analyze and compare the effects of six weeks of HIICT and MICT on body composition, hypertrophy and strength.

MATERIALS AND METHODS

Participants

After the approval of the Research Ethics Committee (nº 1.738.246/2016) of *Universidade Nove de Julho*, a consent document was signed by thirty healthy adults who were physically active and independent. The following parameters were used as exclusion criteria: positive clinical diagnosis of diabetes mellitus, smoking, musculoskeletal complications and/or cardiovascular alterations confirmed by medical evaluation. During the study, five individuals (one in the HIICT group and four in MICT group) dropped out because of personal reasons not related to the study. Thus, the study was conducted with 25 physically active (1,88±1 year of practice) individuals, 14 in the HIICT group and 11 in the MICT group.

Study design

This study followed an experimental design, using a two group, random selection, pre- and post-test approach. All anthropometric measurements for body composition, muscular thickness and strength were assessed at baseline and after six weeks of training.

Anthropometric measures

Height was measured using a Cardiomed (WCS model- Brazil) stadiometer, with an accuracy of 115/220 cm. The measurement was performed with the cursor at an angle of 90°, with the patient standing with their feet together, in contact with the stadiometer. The subjects were instructed to stay in inspiratory apnea, with their head parallel to the ground. The total body mass was measured by a calibrated Filizola electronic scale (Personal Line Model 150- Brazil) with a 100g scale and a maximum capacity of 150 kg.

Skinfold thickness was used to predict body fat. The following skinfold thicknesses were measured three times in a rotation system and the median was used: triceps, supra iliac and thigh for women; and chest, abdominal and leg for men. Measurement precision was evaluated as proposed by Marks et al. (1989). Fat percentage calculations were performed by using generalized equations proposed by Jackson et al. (1989) and the body density equation proposed by Siri (1960). From these data, absolute and relative fat mass (FM) and free fat mass (FFM) were also calculated. Circumference of the waist was also measured.

All anthropometric measurements were performed before and after six weeks of training protocols (72 hours before the first training sessions and 72 hours after the last).

Muscle thickness measure

Ultrasonography was used to obtain measurements of muscle thickness (MT). The reliability and validity of ultrasound in the determination of MT has been reported to be very high when compared to the gold standard magnetic resonance (REEVES et al., 2004). A trained technician performed all tests using a portable ultrasound imaging unit (Bodymetrix, BodyMetrix, BX2000, IntelaMetrix, Inc., Livermore, CA, USA). Water soluble transmission gel (100 Aquasonic Ultrasound Transmission Gel, Parker Laboratories, Inc., Fairfield, NJ, USA) was used at each measurement location and an ultrasound wave of 2.5 MHz was applied perpendicular to the skin in relation to the place of measurement.

When the image quality was considered satisfactory, it was saved to obtain muscle thickness dimensions by measuring the distance from the subcutaneous adipose tissue and underlying muscle interface to the muscle-bone interface according to the protocol of ABE et al. (2000) and Schoenfeld et al. (2015). Measurements were made on the right side of the body on both the elbow flexors (on the anterior medial line of the arm, midway between the shoulder and the elbow joint on front of the arm or on the area of greatest circumference of the biceps) and on the thigh (on the anterior medial line of the thigh midway between the patella and the hip). MT was analyzed before and after six weeks of training protocols.

Functional fitness measures

Muscle endurance was evaluated by the 1 minute abdominal test and by the arm flexion test according to protocols described by Pollock and Wilmore (1993). The horizontal impulsion test was used as an indicator of muscle power. Each subject performed three trials, and the highest value was recorded (Matsudo, 1987). Flexibility was measured by the sit-and-reach test (Heyward, 2004)

All measurements were performed before and after six weeks of training protocols (72 hours before the first training sessions and 72 hours after the last).

Training protocols

Both groups performed the protocols three times weekly, on nonconsecutive days, for six weeks. The HIICT group performed high-intensity intermittent calisthenic training based on full body exercise according to Machado et al., (2017). Their training session involved 5 minutes of warm-up followed by 20 sets with 30 seconds of all-out exercise and 30 seconds of passive recovery between sets. Jumping jack, mountain climber, burpee and squat jump were used in the protocol.

The MICT group performed continuous moderate running. Their training session involved 5 minutes of warm-up followed by 20 minutes of running at an intensity fixed at 80% of maximum heart rate (HR). HR was recorded continuously throughout the training session using Polar HR monitors (Polar Oy, Finland). The HR data were recorded every 5 seconds and the information was downloaded to a mainframe computer using Polar Advantage Software.

Statistical Analyses

Initially, the Shapiro-Wilk test was performed to verify the normality of the data. The ANOVA for repeated measurements was used to compare the intergroup and intragroup responses after the training period. The Mauchly sphericity test was applied and corrected, when necessary, by Greenhouse-Geissenger. When the F-test was significant, the analysis was supplemented by the Bonferroni multiple-comparison test. These data are presented as mean and standard deviation. The Mann-Whitney test was used to verify if there was significant intergroup difference in the variation (percentage delta) of the physiological responses to the different training methods. Data are presented as median and interquartile range. $P \leq 0.05$ level was accepted. The Hedges G approach was used to calculate the effect size. The effect size is displayed with its respective 95% confidence interval.

RESULTS

The volunteers of the MICT group had a mean age of 28.7 ± 4.9 years and height of 1.7 ± 0.1 meters. In the HIICT group, mean age and height were, respectively, 28.3 ± 6.8 years and 1.7 ± 0.1 meters.

The participants did not present injuries as a result of the workout during or after exercise sessions. Table 1 shows the anthropometric variables and functional test results. There was no significant difference in any variable measured (*p*> 0.05) for all measurements) after training protocols in both groups.

Table 1. Morphofunctional alterations in HIICT and MICT groups after 6 weeks of training.

Parameters	HIICT		MICT	
	Before	**After**	**Before**	**After**
Body mass (kg)	72.1 ± 9.5	70.7 ± 10.4	71.7 ± 9.6	72.1 ± 11
BMI (kg/m^2)	25.3± 2,2	24.8±1.8	25.2±1.7	25.4 ± 2.1
Fat body (%)	29.7 ± 8.7	29.6 ± 8.2	30.8 ± 11.1	29.7 ± 11.8
Lean mass (kg)	48.5 ± 9.8	49.4 ± 9.8	49.6 ± 10.5	50.1 ± 9.1
Fat mass (kg)	21.2 ± 6	21.3 ± 5.4	22 ± 9	21.9 ± 11
Waist circumference (cm)	78.4 ± 7.2	76.8 ± 6.2	80.3 ± 4.3	79.6 ± 4
Sit and reach (cm)	24 ± 6.4	28 ± 5.7	24.5 ± 11.1	26.9 ± 10.2
Abdominal (rep)	36.5 ± 10.2	39.5 ± 10.8	33.8 ± 6	36 ± 6.5
Horizontal jump (min)	1.6 ± 0.3	1.7 ± 0.3	1.8 ± 0.4	1.7 ± 0.4
Push-ups (rep)	27.8 ± 13.9	34.3 ± 12.8	22.3 ± 11.7	22.8 ± 9.6

Values expressed in mean± DP of high-intensity intermittent calisthenic training (HIICT) and moderate-intensity continuous training (MICT). BMI: body max index.

Table 2 demonstrates the Median and Inter Quartile Interval (IQR) of changes and groups effect size calculation after 6 weeks of training. Only push-ups (*p* = 0.02) showed a significant change in HIICT group (ES= -0.47) compared to the MICT group (ES= -0.04). The other variables did not present a significant difference between groups.

Table 2. Median and inter quartile interval (IQR) of changes and effect size calculation groups after 6 weeks of training.

Parameters	HIICT		MICT	
	Median (IQR)	ES (CI 95%)	Median (IQR)	ES (CI 95%)
Bodymass (kg)	-1.8 (3.9)	0.11 (-3.8 – 4.0)	-1.2 (4.7)	-0.08 (-4.0 – 3.9)
BMI (kg/m^2)	-1.8 (3.9)	0.24 (-0.5 – 0.9)	-1.2 (-1.8)	-0.11 (-0.8 – 0.6)
Fat body (%)	-1.9 (25.8)	0.01 (-3.1 – 3.1)	0 (21.8)	0.09 (-4.6 – 4.8)
Leanmass (kg)	2.7 (8.5)	-0.08 (-3.5 – 3.4)	-1.3 (8.2)	-0.04 (-4.1 – 4.0)
Fat mass (kg)	1.8 (20.2)	-0.01 (-1.9 – 1.9)	-1.3 (12.2)	0.01 (-4.1 – 4.2)
Waistcircumference (cm)	-1.9 (2.9)	0.23 (-2.2 – 2.7)	-0.6 (1.3)	0.16 (-1.5 – 1.8)
Sitandreach (cm)	10.2 (12,8)	-0.64 (-2.8 – 1.6)	5.2 (11.1)	-0.21 (-4.6 – 4.2)
Abdominal (rep)	4.6 (20.2)	-0.28 (-4.1 – 3,5)	6 (11.4)	-0.33 (-2.9 – 2.2)
Horizontal jump (min)	2.3 (11.6)	-0.27 (-0.4 – 0.14)	6 (11.4)	0.22 (0.04 – 0.4)
Push-ups (rep)	12.2 (21.1)*	-0.47 (-5.4 – 4.4)	5.8 (13.3)	-0.04 (-4.5 – 4.4)

High-intensity intermittent calisthenic training (HIICT) and moderate-intensity continuous training (MICT). Effect size (ES). *Differences between HIICT and MICT (p= 0.02).

The thickness of both the elbow flexors (Figure 1A) and extensors (Figure 1B) showed no significant difference in pre- and post-times after HIICT (EF= -0.25 for biceps and -0.14 and for triceps) and MICT (EF= -0.46 and -0.04 for biceps and triceps, respectively) protocols and no difference in the comparison between groups (p> 0,05 in both occasions). For the thickness of the quadriceps muscles, neither rectus femoris (Figure 1C) nor vastus lateralis (Figure 1D) presented significant differences at pre- and post- times (HIICT: EF= -0.23 04) for rectus femoris and -0.15 for vastus lateralis; MICT: EF= -0.11 and -0.04 for rectus femoris and vastus lateralis, respectively) or between the groups (*p*>0,05) for rectus femoris and for vastus lateralis).

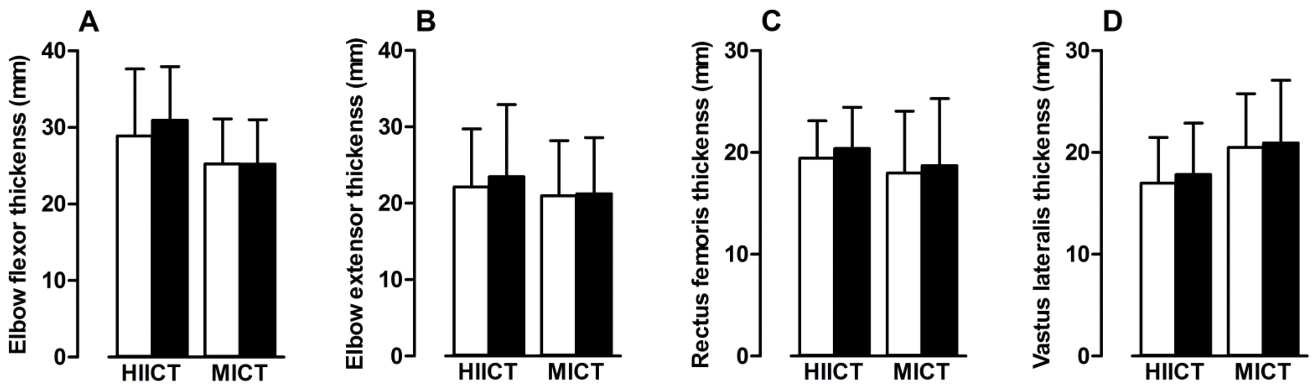

Figure 1. Values expressed in mean ± DP of high-intensity intermittent calisthenic training (HIICT) and moderate-intensity continuous training (MICT) before and after 6 weeks of training.

DISCUSSION

The present study compared the effects of six weeks of HIICT and MICT on body composition, muscle thickness and maximum strength. The initial hypothesis expected to find superior results in the HIICT group, due to the characteristics of intermittent stimuli, greater intensity and greater metabolic stress. The hypothesis was confirmed in part.

There were no significant changes observed in body mass, percentage of fat, lean mass, fat mass and waist circumference in either group when the means between the pre- and post-intervention periods were compared. Also, no differences were observed in the means of these variables between the groups.

In our view, some factors may have contributed to these results observed in the anthropometric variables. The main one is the short duration of the training protocol (6 weeks).In their systematic review study, Kessler et al. (2012) concluded that short-term HIIT protocols (≤ 10 weeks) are weakly effective in promoting significant changes in anthropometric variables, and there is a need for longer-term interventions for this goal (≥ 12 weeks). In addition, when analyzing the results of seven studies comparing conventional HIIT with continuous moderate intensity exercise, the authors observed similar results among the interventions, corroborating the present findings. Other studies also did not demonstrate superiority of conventional HIIT versus MICT in body composition variables (Dias et al., 2017, Schubert et al., 2017; Zhang et al., 2017). It is worth mentioning that the degree of the effect observed in HIICT in the variables of body weight and waist circumference was superior, which indicates a possible potential for promoting significant changes in these variables in the long term.

Specifically in the HIICT group, McRae et al. (2012) also did not observe changes in body composition variables after four weeks of intervention. As in our study, the duration of the intervention was also short, which may explain the results.

Regarding the functional tests, although the analysis of the inter- and intragroup averages did not show significant alteration, the analysis of the percentage changes revealed advantages of HIICT over MICT only in push-ups. These results are likely due to the specificity of the motor gestures applied during the HIICT protocol, because Burpee works with similar movements to that applied in the physical test. Considering the relevance of the different manifestations of muscular strength for functional aptitude and performance in several daily situations (La Scala Teixeira et al., 2017), slight increases in these variables, even if it is not significant, may present important clinical effects.

In the sit-and-reach abdominal flexion tests, no significant and relevant effects were observed in any groups, likely due to the lack of specificity in the interventions. For gains in flexibility, it is necessary to explore movements at large amplitudes (Morton et al., 2011), a characteristic that was not present in any exercise performed in the groups. Regarding the abdominal flexion test, although the HIICT has contemplated integrated exercises with characteristics that stimulate the activation of the core muscles (La Scala Teixeira et al., 2017), the counter-resistant trunk flexion movement was not explored in any exercise.

As far as muscle thickness is concerned, to the best of our knowledge, this is the first study to analyze the adjustments of this variable against the HIICT program. Although the percentage changes and the effect size were slightly higher in the HIICT, especially in the upper limb muscles, intra- and intergroup analysis did not reveal statistically significant differences.

Although HIICT is a training method with a high metabolic stress demand (Gist et al., 2014) and metabolic stress is one of the factors that contribute to muscle hypertrophy (Schoenfeld, 2010), one of the characteristics that seems to be necessary to promote higher levels of hypertrophy in low weight training (e.g., body weight) is the execution of series until concentric failure (Nóbrega and Libardi, 2016). In our HIICT protocol, although the exercises were performed all-out, the 30-second stimulus time was not sufficient for the subjects to achieve concentric failure in sets.

In addition, it should be noted that the sample subjects, although active, were untrained. In untrained subjects, muscle hypertrophy seems to become more evident after a few weeks of training. In the initial phase (<8 weeks), the adaptations observed with greater emphasis are of a neuromuscular order, contributing to the increase in strength manifestation (Narici et al., 1996), as observed in the present study in the percentage changes of the horizontal jump and push-up. Thus, mainly considering the percentage changes and the analysis of the effect size in the different variables investigated, it is necessary to carry out more long-lasting studies (≥ 8 weeks) involving HIICT, in order to verify its effect over time.

The application of high-intensity interval training using body weight is advancing towards occupying a prominent role among major fitness trends worldwide (Thompson, 2017). The data from our study show that even though there were no differences in body composition between the groups (maybe due to the short duration of the protocol used), the HIIT method using body weight seems to be an efficient strategy to promote changes just on push-up. Some limitations in the study were present, such as a relatively small sample size and experimental time, which do not allow for further generalizations. Therefore, future research in this area should consider the association between training progression, diet/dietary restriction, and non-physically active subjects, as well as assessing functional fitness parameters.

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