Original Article (short paper)

Energy expenditure and intensity of HIIT bodywork® session

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Abstract - Aim: Several programs using total body weight exercise methods have been applied in several populations especially using HIIT. The present study assessed the oxygen consumption, heart rate, and energy expenditure of a HIIT body work® session. **Methods:** Twelve male participants performed 20 minutes of a HIIT body work, consisting of 20 sets of 30 seconds of stimulation in all-out intensity, followed by 30 seconds of passive recovery. Five cycles were performed for each exercise (jumping jack, burpee, mountain climb, and squat jump). **Results:** The mean VO2 of the session was 34 ± 7 ml.kg.min-1 (80.35% of the VO2 peak obtained in the session). The energy expenditure of the session was 251±27 kcal (13±1 kcal.min-1) and 39 ± 8 kcal (75±1 kcal.min-1) during the recovery time. The heart rate values were 160±18 bpm (91% of the peak HR of the session) and 125±22 bpm (71%) in recovery. In addition, significant differences ($p<0.05$) in maximal VO2 were found between jumping jack, mountain climber, burpee and squat jump. **Conclusion:** Based on the present data, a HIIT bodywork® session presented energy expenditure as a typical high-intensity exercise profile.

Keywords: bodyweight exercise; energy expenditure; training; oxygen.

Introduction

The practice of body weight exercises first appeared on the American College of Sports Medicine (ACSM) trend list in 2013, occupying the third position[1]. Between 2014 and 2017, it remained in the 1st or 2nd position, falling to 4th place in 2018 and 5th place in the 2019[2]. While high-intensity interval training (HIIT) has only emerged in 2014 in 1st place and until the list of trends of 2019, it remains in the top 3 positions[2]. The practice of body weight exercises and HIIT are among the top 5 positions in the trend survey since 2014, showing that training with body weight and HIIT methods are directly related to the fitness world.

Additionally, the combination of whole-body exercise and high-intensity interval training methods have been investigated in the literature in acute[3-6] or chronic[7-11] study designs. Methodologically, the sessions of HIIT bodywork® consist of performing exercises only with body weight at high intensity for a predetermined time, followed by a fixed time rest interval. Although different session designs have been previously addressed[3-6,12], there still lacks information about elaboration, monitoring, progression, and characterization of the training session.

Currently, several programs using high-intensity methods have been applied in sports centers, fitness clubs, and outdoors; and have moved toward programs of group-based exercise classes. These offer a greater variety of activities and have been considered a popular strategy, due to the potential to increment fitness or weight management. Considering that energy expenditure and traditional HIIT had been the focus of several studies[13-16], however, information on the session's energy cost using body weight exercise still unclear. In 2015, Ratames, et al.[17] analysis showed the caloric cost of the squat (8.2 kcal.min^{-1}) and burpee (9.6 kcal.min^{-1}) however experiment design did not reflect a training session characterization that is realized in sports centers and fitness clubs.

Thus, considering the lack of information on energy expenditure and intensity of HIIT based on whole-body exercise, this study aimed to assess the energy expenditure and the intensity of a HIIT body work® session in healthy adult individuals.

Methods

After approval by the research ethics committee of the Federal University of Espirito Santo (N°3.733.252/2019), 12 physically active men (age 33 ± 12 years, body mass 72.83 ± 7.52 kg, height 172.83 ± 6.01 cm) voluntarily participated in the study. The Adapted International Physical Activity Questionnaire - short form (IPAQ) was used to

determine the physical activity level of subjects according to a previous study by our group[18]. The following exclusion criteria were adopted: positive clinical diagnosis of cardiometabolic and musculoskeletal diseases, smoking, and physical inactivity. The sample size was calculated to be 12 participants, by a priori analysis G * Power software (v. 3.1.9.4), for power (1 - □) of 0.95 and □ = 0.05 and effect size = 0.45.

Exercise protocol

All participants performed a single HIIT bodywork session consisting of 20 sets of 30 seconds stimulus (TE) with all-out intensity (as many times as possible and at a high as possible intensity), followed by 30 seconds of passive recovery (TR). Five cycles were performed for each exercise, and four exercises were performed in the following order: jumping jack, burpee, mountain climber, and squat jump. Five consecutive sets were performed for each exercise. The exercise selection and distribution were established following the criteria of alternating between an exercise considering the previous publications[3,5,6,12].

The participants were advised not to exercise or consume alcohol for 24 hours before testing. Each participant was instructed to consume 500 mL of water per hour in the 2 hours before the session, and not to consume any type of food in that period[12]. Before the start of the session, participants had measurements of their body mass, height, and resting heart rate[3]. Records of O2 consumption, energy expenditure, and heart rate were continuously assessed before, during, and after 5 minutes of the training session's end.

Energy expenditure

Maximum oxygen consumption (VO^2max) was obtained through expired gas collection during the HIIT body work session using a portable analyzer with a telemetry system (K5, Cosmed, Rome, Italy). The analyzer was calibrated according to the manufacturer. The VO2 was also measured over 5 minutes at the end of the session[19]. The VO2 was collected breath-by-breath and averaged in 10-second intervals. The VO2peak was the highest value obtained in the session[20,21]. In order to obtain the energy expenditure of the HIIT body work session, the measured O2 was converted into energy units (calorie) by a conversion factor (1 ml O^2 = 5 calories) as described elsewhere[22,23]. The same procedure was performed to calculate the energy expenditure of the recovery period. Additionally, the MET calculation was realized by the following equation: MET: VO2 ÷ 3,5 (ml/kg/min).

Heart rate

Heart rate (HR) was recorded continuously throughout the training session using Garmin HR monitors coupled with the K5 unit. The HR data were recorded every 5s. In an attempt to reduce HR recording error during training, all subjects were asked to check their HR monitors before of session and after set (~3 and 10 min). The maximal and its percentage of heart rate was estimated using the Tanaka, Monahan, and Seals equation[24].

Rate of perceived exertion

Subjects reported their rating of perceived exertion (RPE, scale 1-10), immediately at the end, and before each exercise set according to previous publications utilized in our group[3,5,12].

Statistical analysis

Data are presented as mean ± standard deviation. The Shapiro-Wilks test was used to analyze data distribution. The differences between the exercises during the training session were evaluated through repeated-measures ANOVA in conjunction with Tukey post hoc. The analyses were performed using SPSS software (v. 22; IBM, USA) with a significance level of $p < 0.05$.

Results

As described in Figure 1, relative heart rate (Panel A) and VO^2 kinetics (Panel B) at the 1st set was statistically lower than that in the other sets. Similar results were found in energy expenditures (Panel C), the energy expenditure per minute ranged from 1.05 to 14.35 $kcal.min^{-1}$n with a mean value of 12.53 ± 1.37 $kcal.min^{-1}$.

The physiological responses expressed as means of each exercise of HIIT body work session are shown in Table 1. The absolute ($p< 0.001$; $F_{(2.537, 27.91)}= 134.7$) and relative oxygen consumption ($p< 0.001$; $F_{(2.189, 24.08)}= 48.45$), and MET parameters differed ($p< 0.001$; $F_{(2.189, 24.08)}= 48.45$) between exercises, where the burpee values were higher than those in other exercises.

The total ($p< 0.001$; $F_{(2,386, 26,24)}= 47.86$) and relative ($p< 0.001$; $F_{(4.263, 46.89)}= 39.69$) energy expenditure as shown in Table 1 was higher on combined exercises (burpee and squat jump) when compared with the jumping jack. Though no differences ($p>0.05$) were found when compared with mountain climb and squat jump exercise.

As shown in Table 1, although the values found for perceived exertion (9.51 ± 0.34) and relative heart rate (89.42 ± 7.15 %) of overall session may classify as an intense exercise program. The values of perceived exertion ($p< 0.001$; $F_{(3.44)}= 32.01$), absolute ($p< 0.001$; $F_{(1.674, 18.42)}= 92.71$) and relative ($p< 0.001$; $F_{(3.406, 37.47)} = 41.33$) heart rate of jumping jack were lower than other exercises. As expected, the total numbers differed around exercises ($p< 0.001$; $F(_{2.111, 23.22)}= 59.04$).

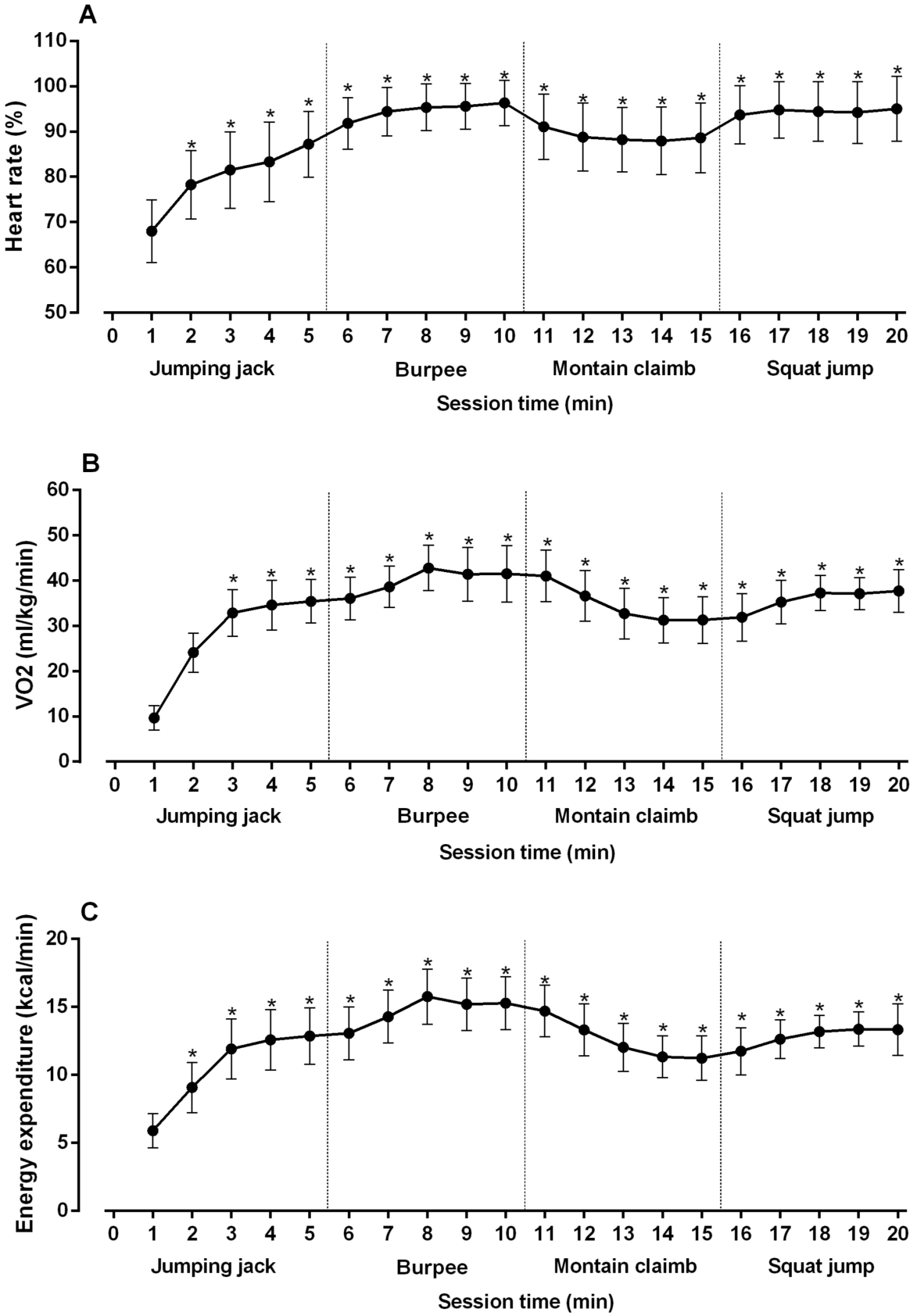

Figure 1 - Values expressed as mean ± standard deviation for % maximal heart rate (Panel A), VO2 (Panel B) and energy expenditure (Panel C). *indicate statistical differences ($p < 0.05$) from the first set.

Table 1 - Physiological responses of HIIT body work® session.

Parameters	Jumping jack	Burpee	Mountain climber	Squat jump	Overall session
VO2 (L.min-1)	1.51 ± 0.27a (1.33 - 1.68)	2.98 ± 0.37b (2.67 - 3.14)	2.50 ± 0.33c (2.28 - 2.71)	2.60 ± 0.29c (2.41 - 2.78)	2.38 ± 0.28 (2.20 - 2.56)
VO2 (ml.kg.min-1)	27.33 ± 3.97a (24.82 - 29.84)	40.09 ± 4.70b (37.10 - 43.08)	34.59 ± 5.12c (31.34 - 37.85)	35,87 ± 3.91c (33.38 - 38.36)	34.47 ± 3.82 (32.04 - 36.90)
MET	7.80 ± 1.13a (7.09 - 8.52)	11.45 ± 1.34b (10.60 - 12.31)	9.88 ± 1.46c (8.95 - 10.81)	10.25 ± 1.11c (9.53 - 10.96)	9.85 ± 1.09 (9.15 - 10.54)
TEE (Kcal)	50.65 ± 8.05a (47.82 - 56.57)	73.55 ± 8.83b (67.94 - 79.16)	62.60 ± 8.20c (57.39 - 67.81)	64.24 ± 6.54c (60.08 - 68.40)	251.05 ± 27.26 (236.20 - 269.00)
EE (Kcal.min-1)	10.46 ± 2.96a (9.56 - 11.31)	14.71 ± 1.03b (13.59 - 15.83)	12.52 ± 1.47c (11.48 - 13.56)	12.85 ± 0.68c (12.02 - 13.68)	12.63 ± 2.24 (11.81 - 13.45)
Heart rate (bpm)	145.10 ± 11.37a (137.90 - 152.40)	167.30 ± 10.13b (160.90 - 173.70)	163.80 ± 8.68b (158.30 - 169.30)	169.00 ± 13.19b (160.60 - 177.40)	161.30 ± 10.11 (154.90 - 167.70)
Heart rate (%)	79.67 ± 7.27a (72.73 - 83.57)	94.69 ± 1.74b (84.40 - 95.78)	88.93 ± 1.24b (82.98 - 93.36)	94.43 ± 0.51b (84.32 - 97.82)	89.42 ± 7.15 (81.27 - 92.47)
RPE (0-10 scale)	7.45 ± 1.02a (6.80 - 8.09)	9.53 ± 0.37b (9.29 - 9.77)	9.55 ± 0.68b (9.11 - 9.98)	9.75 ± 0.34b (9.53 - 9.96)	9.51 ± 0.34 (9.29 - 9.73)

Values expressed as mean ± standard deviation (lower and upper 95% of confidence interval). MET = metabolic equivalent; TEE= total energy cost; EE = energy cost; RPE= rate of perceived exertion. Different letters indicate statistical differences ($p < 0.05$).

Discussion

The energy expenditure found in this study was 12.63 kcal. min^{-1}, which is similar to values observed in a Crossfit study[25] and corresponding to high intensity, as recommended by the ACSM - exercises performed above 6 METS are considered as intense[26]. Similarly, both the heart rate data of the present study (86.87%) and previous reports[3-5], as well as in studies with boot camp, naval rope, jumps, and circuit training, all agree that it attains values above those proposed (85% of maximum predicted HR) by ACSM for high-intensity exercise (85% of predicted maximum HR)[28-30].

To our knowledge, few studies have investigated the energy expenditure in exercise sessions that used only bodyweight[17,28]. The total energy expenditure of 251.05 ± 27.26 kcal or 12.63 ± 2.24 kcal.min^{-1} found in this study was similar to those in other high-intensity modalities[17,23,27-31]. Using the burpee exercise, Ratamess, Rosemberg, Klei et al.[17] showed that 10s all-out repetitions, with a 2-minutes interval, resulted in an expenditure of approximately 9.6 ± 1.kcal.min-1. Brisebois[25] reported that the mean energy expenditure during a 60-minute CrossFit session in 30 adults was 693 kcal (7.5 kcal.min^{-1}). Porcari, Hendrickson, Foster et al.[27] demonstrated that 40 minutes boot-camp exercise results in 392 kcal (9.8 kcal.min^{-1}) per session. Willis, Szabo-Reed, Ptomey et al.[31] evaluated an energy expenditure of HIIT session of 45 minutes and found an energy expenditure of 552 ± 71 kcal. Finally, with the naval rope, Fountaine and Schmidt[28] using a 1:3 protocol for 10 minutes found an energy expenditure of 9.79 kcal.min^{-1}. In agreement with these previous studies, our data and converge in a typical high-intensity exercise profile.

In addition, the differences found between exercises are important for practical applications. To the best of our knowledge, there is no information about the exercise influences on metabolic outcomes. Accordingly, our results indicated that patterns (jumping jack and mountain climb) and combined (burpee and squat jump) exercises exhibit different physiological and psychological responses between exercises[3,12]. Collectively, this information allows an exercise selection in a training session to be applied to important pedagogical strategies to address exercise program elaboration for individual subjects with diverse functional fitness needs.

Certain information should be highlighted as important determinants of the energy expenditure of exercise sessions, such as the exercises used, the session duration, and the sample gender. The differences between genders were clarified by Willis et al. study[31], which showed an energy expenditure difference of ∼134 kcal per session (3 kcal.min^{-1}). In addition, different exercises cause different physiological demands, even at equal intensities[34,35] as in the case of naval rope vs. exercises that use the only bodyweight. In a recent publication by our group[10], using the same experimental design as that in the present study, with 3 weekly sessions for a period of 6 weeks, no significant differences in body composition parameters were observed. These findings may be consistent with the results of the present study, showing that the energy expenditure required for weight loss is approximately 2000 Kcal per week[36,37]. However, it is important to mention that the program duration, the training progression, and the energy intake control may have influenced their results.

Although studies have found favorable outcomes in morpho-functional parameters for HIIT training using treadmills and cycle ergometers ∼when compared with moderate-intensity exercise[38-43], studies have also shown similarity in aerobic capacity[44,45], biochemical parameters[46,47] and weight loss[40,48,49] when compared high and moderate-intensity exercises. Hence,

the complete details of HIIT training vs. moderate-intensity training remains to be further clarified.

Briefly, some important points present in this study should be clarified by other investigations. Firstly, corresponding to the heart rate and O^2 kinetics, our results were similar to other studies using a different HIIT design[49]. Furthermore, the exercise changes in HR and caloric cost are in concordance with prepositions to address the differences in training pattern and combined exercise as suggested to our group[3,12].

Additionally, some important limitations are present in this study. The sample was limited to healthy individuals who had experience with HIIT bodywork sessions, the maximal oxygen uptake was not evaluated, together these points limit the generalization of the results. There is a large variety of HIIT applications on programs and exercise regimes, and the results from this study cannot be applied to other forms of exercise session design. Additionally, the sample size was small and consisted of eutrophic participants, so the specific energy expenditure in overweight/obese individuals cannot be speculated. The maximal test should also be applied to confirm the % HR kinetics during the exercise session.

Conclusion

In summary, the energy expenditure during the 20 minutes of a single HIIT bodywork session appears to be ~250 Kcal as a typical high-intensity exercise profile. Future trials should be designed to determine the long-term effect on health-related outcomes and be applied in different populations.

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