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Energy Expenditure and Intensity of Group-Based High-Intensity Functional Training: A Brief Report

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Abstract

Background: High-intensity functional training (HIFT) may offer an attractive, time-efficient alternative to traditional aerobic exercise. However, limited information is available in the literature regarding HIFT meeting exercise guidelines for energy expenditure (improve health outcomes: ≥1000 kcal/wk; weight management: ≥2000 kcal/wk) and level of intensity (moderate:

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3–6 metabolic equivalents [METs], vigorous: ≥6 METs) elicited by this approach. Thus, the primary aim was to objectively measure energy expenditure and intensity of HIFT sessions.

Methods: Energy expenditure was assessed in 20 adults (18–50 y, 50% females). The HIFT session format included the following segments: warm-up (~5 min), exercise (~35 min), and cooldown (~5 min). Participant oxygen consumption (COSMED, L/min and mL/kg/min), heart rate (Polar RS400), and physical activity (ActiGraph GT3X+) were collected in 15-second intervals. Average kcal per minute, METs, total kcal per session, and percent maximum heart rate (HR_{max}) were calculated.

Results: METs ranged from 5.5 to 11.6 for the complete session (including warm-up and cooldown). Participant's HR_{max} was ~80% (range: 69%–100%). Average energy expenditure was ~485 kcal per session (~1400 kcal/wk). The vigorous-intensity exercise portion (~35 min) contributed to 80% of total energy expenditure.

Conclusions: HIFT has the potential to meet the recommendations for exercise to improve health outcomes.

Keywords

indirect calorimetry; exercise; accelerometer

Moderate to vigorous physical activity, primarily aerobic moderate to vigorous physical activity (eg, brisk walking/running), is endorsed by professional organizations and government agencies to reduce the risk of numerous chronic diseases, improve cardiovascular health, and manage weight.[1–5] The American College of Sports Medicine recommends at least 150 minutes per week of moderate-intensity or 75 minutes per week of vigorous-intensity aerobic activity (minimum of 1000 kcal/wk of energy expenditure), in order to improve health outcomes[3,6] and 225 minutes per week (2000 kcal/wk of energy expenditure) or more is recommended for weight loss/maintenance.[1] However, accelerometer data from the National Health and Nutrition Examination Survey indicate that only ~10% of US adults meet current physical activity recommendations.[7] Frequently reported barriers to participation in exercise include lack of time and interest in commonly prescribed activities (eg, brisk walking/running), which are perceived as repetitive and boring.[8–11] With the intention of reducing the time commitment associated with exercise, short-duration high-intensity sprint and interval training (HIIT), utilizing single modality intervals, such as cycling or running, have been shown to be effective in improving fitness and metabolic outcomes in a variety of populations.[12–14] Despite the health benefits and reduction in time to complete HIIT style exercise, adherence remains less than optimal.[15] Recent fitness trends have moved toward programs described as high-intensity functional training (HIFT), such as Tabata, CrossFit, workout videos (ie, P90x, Insanity), and group-based exercise classes, which offer a greater variety of activities compared with traditional aerobic exercise and single modality HIIT.[16]

HIFT is a type of HIIT that incorporates both resistance and aerobic training and consists of alternating short periods of intense exercise (ie, ≥77% maximum heart rate [HR_{max}]) using varied, multi-joint movements, with less-intense active recovery periods (ie, <77% HR_{max}). Although HIFT is a popular form of exercise, there is limited research regarding HIFT[17,18] and it is not commonly endorsed as a mode of meeting recommended physical activity levels or for weight management. This may be partially due to lack of information in the literature regarding objectively measured energy expenditure and level of intensity elicited by this approach.[19,20] Information on the level of energy expenditure is relevant for prescribing HIFT, particularly for weight management. Therefore, the purpose of this study was to assess energy expenditure and intensity of an ongoing, group-based HIFT session in a sample of adult volunteers.

Methods

The trial is registered with www.clinicaltrial.gov, number .

Participants

A sample of 20 volunteers (18–50 y, 50% females, 20% minorities) were recruited from ongoing, group-based HIFT classes offered at the Kirmayer Fitness facility at the University of Kansas Medical Center. All participants had completed at least one HIFT session prior to data collection. Participants completed a brief health history revealing no contraindication to exercise and provided written informed consent prior to engaging in any aspect of the study. Approval for this study was obtained from the Human Subjects Committee at the University of Kansas Medical Center (IRB number: STUDY00002608). Participants were compensated for completing the study protocol.

HIFT Sessions

Data were collected during 20 regularly scheduled group HIFT sessions. These sessions were offered daily in the morning (6:00 AM), afternoon (12:00 PM), and evening (5:30 PM). HIFT sessions were led by experienced instructors who followed similar scripted exercise routines that included a warm-up (~5 min) and cooldown (~5 min) in addition to ~35 minutes of high-intensity exercise. HIFT sessions included both resistance (kettlebells, medicine balls, and battle ropes) and cardiovascular exercise (running, stationary bikes, and rowing ergometers). All exercises were performed using self-selected pace and weight/resistance, if relevant, to complete as many repetitions as possible for each timed segment. An example of an HIFT session is presented in Table 1. HIFT classes typically consisted of 10 to 15 individuals per session.

Procedures Overview

Each participant completed a maximum of 3 separate assessments. During each HIFT sessions HR (Polar RS400; Polar Electro Inc, Kempele, Finland) and physical activity (ActiGraph GT3X+; ActiGraph, LLC, Pensacola, FL) were recorded from 2 to 3 participants. Only one portable indirect calorimeter (K4b2; COSMED, Rome, Italy) was available for this study. Therefore, energy expenditure was assessed on one participant per session over 20 total sessions. To determine if the intensity and level of activity for the HIFT session assessed in the participant using the calorimeter was representative of the group, we compared percent HR_{max} and physical activity (counts/min) in the participants wearing the calorimeter to the study and to not wearing the calorimeter. Each participant completed one session wearing an indirect calorimeter and at least one (maximum 2) additional sessions wearing only the HR monitor and ActiGraph accelerometer. Prior to each exercise session height (stadiometer, model PE-WM-60–84; Perspective Enterprises, Portage, MI) and weight were measured with participants wearing lightweight athletic clothing without shoes using a digital scale accurate to ±0.1 kg (PS6600; Befour Inc, Saukville, WI). Body mass index (BMI) was calculated as weight (kg)/height (m^2). Energy expenditure, HR, and physical activity (counts/min) outcomes were summarized both including and excluding the warm-up and cooldown periods.

Outcomes

Energy Expenditure.—Energy expenditure was assessed using a COSMED K4b2 (Pensacola, FL) indirect calorimeter. This previously validated, lightweight (~1.5 kg) open-circuit, portable indirect calorimeter measures breath-by-breath ventilation and concentration of expired oxygen and carbon dioxide.[3] The gas analyzers and flow turbine (3-L syringe) were calibrated prior to each assessment per manufacture instructions. The indirect calorimeter was attached by a harness around the individual's waist and shoulders. Expired air was directed to the gas analyzers using a facemask. To allow time for participants to acclimate to the facemask and to determine if the indirect calorimeter was functioning properly, we measured energy expenditure for ~5 minutes prior to beginning the HIFT session, with participants sitting quietly on a chair. This data were not included in the analysis. Participants wore the indirect calorimeter for the duration of the HIFT session including warm-up, high-intensity exercise, and cooldown segments. COSMED data were retrieved for analysis via serial port interface and software provided with the indirect calorimeter. The average energy expenditure was calculated from measured oxygen consumption and carbon dioxide production using the abbreviated Weir equation (energy expenditure = $(3.9 \times [VO_2] + 1.1 \times [VCO_2]) \times 1.44$). Calorimeter data were reduced to 15-second epochs, and average values were calculated over the complete HIFT session and excluding warm-up and cooldown. Metabolic equivalent (MET) levels were calculated using standard values for resting energy expenditure (3.5 mL/kg/min).

Heart Rate.—Heart rate was assessed by a Polar (RS400; Polar Electro Inc.) HR monitory. HR during HIFT sessions was recorded in 15-second epochs and downloaded to a computer for analysis. Exercise intensity was calculated as percent of estimated HR_{max} (220 – age [y]).

Physical Activity.—Physical activity was assessed by an ActiGraph GT3X + (ActiGraph LLC) portable triaxial accelerometer (3.8 ×3.7 × 1.8 cm, 27 g), which records accelerations from ~0.05 to 2.0 g with a frequency response from 0.25 to 2.50 Hz reflected as activity counts per minute. Accelerometers were worn on an elastic belt over the nondominant hip. The data collection interval was set at 15 seconds. Data were downloaded using ActiGraph software and processed using a custom SAS program developed by our research group.

Analysis

Participant characteristics and physiological responses to the HIFT sessions were summarized by means and SDs or percentages, as appropriate. Two sample *t* tests for continuous variables and chi-square tests for categorical variables were used to assess differences between males and females. To account for clustering within each session and repeated assessments on the same individual, we used multilevel generalized linear mixed random effect models (SAS version 9.4, PROC MIXED; SAS Institute Inc, Cary, NC) to examine differences in percent HR_{max} and physical activity (counts/min) between those wearing versus not wearing the calorimeter. Covariates included were sex, race, and ethnicity. Statistical significance was determined at .05 alpha level, and all analyses were performed using SAS (version 9.4; SAS Institute Inc).

Results

Twenty-one individuals attended the orientation session and provided informed consent to participate. Of these potential participants, 20 decided to participate in the study. Due to technical problems with the calorimeter or time constraints of the HIFT sessions, calorimeter data were not obtained during warm-up for one female or during cooldown for 2 males. Available data for all eligible participants were included in the final analyses. The characteristics of the 20 participants (10 males, 10 females, and 20% minorities) are presented in Table 2. The mean age was ~31 years, with 90% of males and 30% of females under the age of 30. Compared with males, the females were significantly older ($P < .05$). Approximately, 50% of males and 30% of the females were classified as overweight/obese (BMI ≥ 25 kg/m^2).

Duration/Intensity

The average length of the complete HIFT sessions was ~44 minutes. MET values ranged from 5.5 to 11.6 for the complete session and 7.0 to 14.9 during the high-intensity exercise segment. There were no significant differences in METs between males and females for the complete session and excluding warm-up and cooldown ($P > .05$). In the total sample, participant's percent HR_{max} was ~80% (range: 69%–100%) throughout the complete session (including warm-up and cooldown) and ranged from 72% to 100% during the high-intensity exercise segment (Figure 1). In males, HR_{max} throughout the entire session ranged from 74% to 85% and 75% to 87% during the high-intensity exercise segment. Similarly, in females, HR_{max} throughout the entire session ranged from 69% to 98% and ranged from 72% to 100% during high-intensity exercise segment.

Energy Expenditure

The average exercise energy expenditure for the complete session (including warm-up and cooldown segments) was ~485 kcal (Table 3). The exercise portion (~35 min) contributed 80% of total exercise energy expenditure. In both the complete session and excluding warm-up and cooldown, energy expenditure response differed by sex (complete session: males 552 [71] kcal, females 418 [69]; $P < .001$; excluding warm-up and cooldown males: 442[54] kcal, females: 334 [62]). There was individual variability in total exercise energy expenditure within males (complete session: 452–671 kcal/session; excluding warm-up and cooldown: 352–522 kcal/session) and females (complete session: 315–543 kcal/session; excluding warm-up and cooldown: 245–422 kcal/session; Figure 2).

The minute-by-minute percent HR_{max} values across the HIFT session are shown in Figure 1. Percent HR_{max} was not significantly different for the participant wearing the calorimeter (80.4 [6.2]) and the other participants (77.6 [8.4], $P = .13$, Table 4) for the total session or when segmented by exercise (calorimeter: 82.6 [6.1], other participants: 79.9 [8.8], $P = .13$). Similar to the percent HR_{max} data, mean activity counts per minute were not significantly different for the participant wearing the calorimeter (582 [128] counts/min) and other participants (570 [172]) ($P = .98$) for the total session or when segmented by exercise (calorimeter: 686 [164], other participants: 626 [210]) ($P = .38$).

Discussion

The results from the present study indicate that the mean energy expenditure, assessed by the indirect calorimeter, for group-based HIFT sessions (including warm-up and cooldown) was 485 (97) kcal per session (10.8 [2.1] kcal/min). During the high-intensity exercise segment, energy expenditure was 388 (79) kcal per session (11.1 [2.3] kcal/min). Results from the limited number of studies, where energy expenditure of HIFT exercise was measured by a calorimeter, have varied.[19,20] For example, Brisebois[19] reported the mean energy expenditure during a 60-minute CrossFit session in 30 adults (age 19–44 y, 50% females) was 326 to 693 kcal per session (7.5 [1.8] kcal/min). Porcari et al[20] recorded energy expenditure in 12 males and females following a 40-minute boot-camp exercise video. Results showed that subjects expended an average 392 kcals per session (9.8 kcal/min). The differences between our results and those of others are likely due to the variation in the type and intensities of exercises performed during the sessions. Furthermore, in the present study, there were noticeable variations in energy expenditure within and between males and females. Sex differences in energy expenditure was ~134 kcal per session (3 kcal/min). In males, energy expenditure ranged from 452 to 671 kcal per session and 315 to 543 kcal per session in females. These differences are expected due to differences in body weight and higher levels of lean mass in males. It is important to consider and account for these variations when developing targeted exercise interventions to ensure energy expenditure is at the necessary level to elicit health benefits for all individuals. Further research is needed to confirm our results and to identify the most optimal type of group exercise sessions that would maximize energy expenditure while increasing compliance.

On average, the MET levels were 9.1 and 7.7 in males and females, respectively, which represent exercise being performed at a high-intensity level according to the American College of Sports Medicine (high: >6 METs).[4] Similarly, mean percent HR_{max} was 78% and 83% in males and females, respectively, exceeding the percent HR cutoff for high-intensity exercise (>77% HR_{max}).[7] Other high-intensity training protocols found results similar to the current study. For example, acute CrossFit sessions were shown to average ~6 METs[19] and boot-camp workouts average 77% HR_{max}.[20] Together these results indicate that HIFT type workout sessions exceed the American College of Sports Medicine guidelines of intensity for improving health outcomes.[3]

With the promise of HIFT meeting the recommended levels of physical activity while decreasing the time burden of exercise, randomized control trials are needed to assess their effectiveness on health-related outcomes. To date, only 2 studies have assessed changes in health outcomes from HIFT with conflicting results.[17,18] For example, Kliszcewicz et al[17] found that acute bouts of HIFT showed improvements in glucose, insulin, epinephrine, and norepinephrine similar to those reported with continuous aerobic exercise, whereas Heinrich et al[18] showed no improvements in BMI or body composition following 8 weeks of HIFT. This finding of no changes in weight would be consistent with the results in the present study of energy expenditure less than the ~2000 kcal per week necessary to produce clinically meaningful weight loss.[1,2,22] However, this result of no changes in weight loss could be contributing to the short duration of the intervention and studies with longer durations and powered to detect changes in health-related outcomes are warranted. Though, previous research utilizing high-intensity single modality intervals (eg, cycling or running) has been shown to be equally effective as continuous training in improving fitness (VO_2 max),[23,24] resting metabolic rate,[25] metabolic biomarkers,[26–28] and body composition,[26,29] more research is needed to see if HIFT elicits the same effects. Furthermore, with the challenge of individuals completing the recommended minutes of exercise on a weekly basis, perhaps the self-selected intensity levels, exercise variance, or novelty of HIFT may be more appealing compared with the single modality HIIT or traditional aerobic exercise (ie, walking/running).

Limitations

There are several limitations to this study. This study was limited to healthy individuals who had experience with HIFT sessions making the generalizability of the results limited. There are a variety of HIFT programs and exercise regimens and results from this study cannot be applied to other forms of HIFT. Furthermore, energy expenditure was derived by evaluating a variety of different exercises completed in random order resulting in an inability to assess energy expenditure separated by individual exercises. Additionally, the sample size was small and consisted of participants across the BMI spectrum, so specific energy expenditure in overweight/obese individuals cannot be evaluated. Finally, participants only wore the calorimeter device during one energy expenditure assessment, it is possible participants could have felt uncomfortable wearing this apparatus during the full session, potentially altering their movement patterns and corresponding physiological responses. However, this is doubtful as there were no differences in HR_{max} or physical activity (counts/min) found between those wearing the calorimeter and the other participants in the session.

Conclusions

In summary, the present study contributes to the limited literature on objectively measured energy expenditure of group-based high-intensity training. Energy expenditure during the 44-minunte HIFT session appears to be ~485 kcals for the total sample (including warm-up and cooldown). HIFT sessions have the potential to fall within the exercise intensity and duration ranges recommend for cardiovascular fitness by the American College of Sports Medicine and Physical Activity Guidelines for Americans.[3] Finally, this study could have implications for planning exercise interventions, however, future trials should be designed and powered to determine the long-term effect of HIFT on health-related outcomes.

Practical Application

On average, MET values exceeded 6 METs during ~33 minutes (75%) of the ~44-minute session (including warm-up and cooldown). Consistent with the MET values observed, on average, percent HR_{max} exceeded 77% during ~28 minutes (66%) of the ~44-minute session (including warm-up and cooldown). These results suggest that implementing group-based HIFT at least 3 days per week would result in an average ~84 minutes per week of vigorous-intensity exercise and ~1500 kcal per week of energy expenditure, which would satisfy the Physical Activity Guidelines for Americans recommendation of 75 minutes per week of vigorous-intensity physical activity (1000 kcal/wk energy expenditure).[3,6,30] This is of public health importance as HIFT has potential to be a time efficient mode of exercise to meet current cardiovascular fitness guidelines. However, previous research has shown that an energy expenditure of ~2000 kcal per week or greater is necessary for weight management.[1,2,22] Our findings suggest that group-based HIFT (including warm-up and cooldown) would need to be performed for 162 minutes per week for males and 215 minutes per week for females to elicit an energy expenditure of 2000 kcal per week. Donnelly et al[2] reported males required ~155 minutes per week (~31 min/session 5 d/wk) and females required ~240 minutes per week (~48 min/session 5 d/wk) to achieve the 2000 kcal per week energy expenditure. However, HIFT is typically prescribed no more than 3 days per week and sessions usually last ~45 minutes (135 min/wk), thus the current findings do not support the recommended time or energy expenditure required for weight management benefits. However, the use of alternating HIFT sessions with traditional continuous aerobic exercise (brisk walking/running) may provide variety for individual routines to reduce boredom. Further research on frequency, dose, and long-term health benefits of HIFT is warranted.

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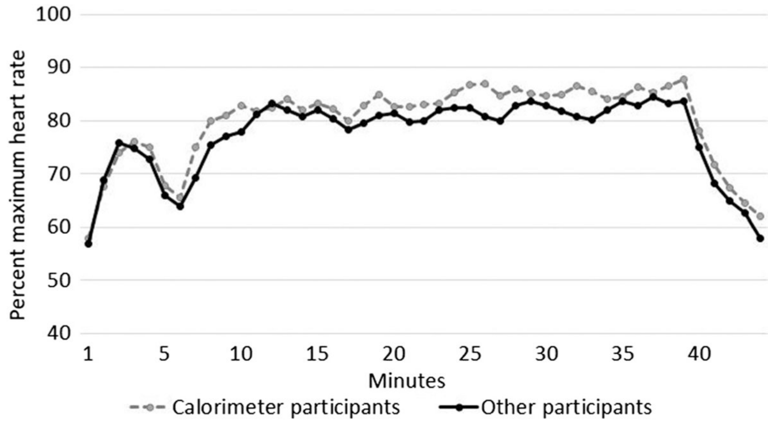

Figure 1 —.
Percent maximum heart rate (minute-by-minute) by participants wearing the calorimeter versus other participants.

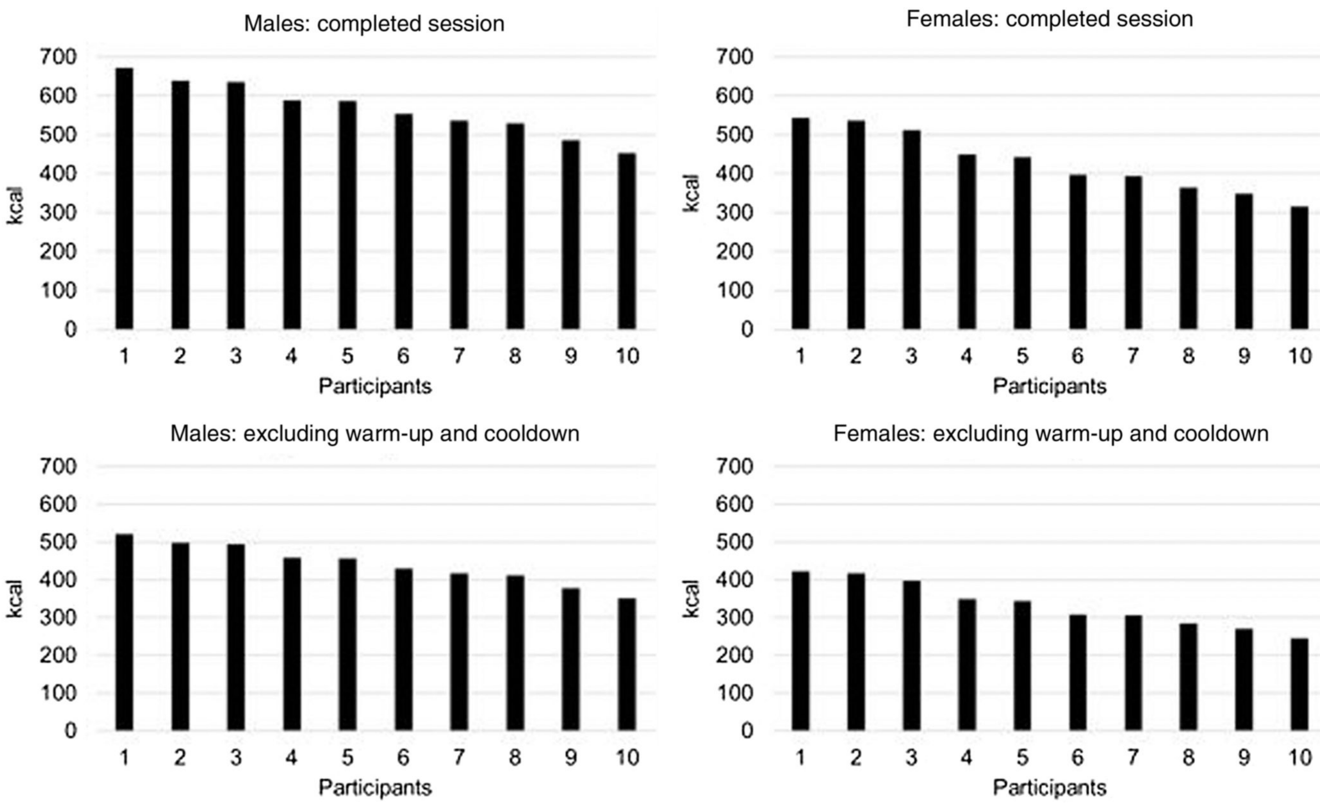

Figure 2 —.
Individual variation in energy expenditure by sex.

Table 1

Sample HIFT Session

Warm-up segment: 8–10 reps each (duration = ~5 min)
Knee pulls
Cradle walk
Straight-leg kick
Standing hip opener
Thoracic rotations
Wall push-ups
Body weight squats
Shuffles
1 court/track lap (walk/run)
High-intensity exercise segment (duration = ~35 min)
Circuit 1: (as many rounds as possible in 5 min)
10 squats
10 push-ups
10 calories burn on stationary bike
Break (~2–3 min)
Circuit 2: (as many rounds as possible in 5 min)
10 deadlifts
10 TRX rows
10 calories burn on stationary rowing machine
Break (~2–3 min)
Circuit 3: (as many rounds as possible in 10 min)
20 battle rope slams
10 (each side) lateral ball tosses
20 walking lunges
10 burpees
Cooldown: full-body static stretch (duration = ~5 min)

Abbreviation: HIFT, high-intensity functional training.

Table 2

Sample Characteristics

Variable	Total sample (n = 20)	Males (n = 10)	Females (n = 10)
Age, y[a]	31.4 (9.2)	26.4 (4.8)	36.3 (10.0)
Weight, kg	75.0 (16.0)	79.3 (12.8)	70.6 (18.2)
BMI, kg/m^2	25.4 (5.4)	24.7 (3.9)	26.1 (6.7)
Minorities n, %	4 (20.0)	2 (20.0)	2 (20.0)

Abbreviation: BMI, body mass index. Note: Values are expressed as mean (SD) unless otherwise stated.

[a]Significantly different between males and females ($P < .05$).

Table 3

Physiologic Responses to an HIFT Session (n = 20)

	Duration, min	Energy expenditure, kcal/min[a,b]	Energy expenditure, total kcal[a,b]	METs	Heart rate, bpm	Percent HR_{max}
Total sample						
Complete session	43.9 (2.0)	10.8 (2.1)	485 (97)	8.5 (1.4)	151.5 (11.9)	80.4 (6.2)
Excluding warm-up and cooldown	35.6 (2.0)	11.1 (2.3)	388 (79)	8.7 (1.6)	156.0 (12.1)	82.7 (6.1)
Males						
Complete session	43.5 (2.2)	12.3 (1.6)	552 (71)	9.1 (1.0)	151.5 (7.4)	78.3 (4.0)
Excluding warm-up and cooldown	35.2 (1.7)	12.5 (1.8)	442 (54)	9.2 (1.3)	156.0 (7.0)	80.6 (3.8)
Females						
Complete session	44.2 (1.8)	9.3 (1.5)	418 (69)	7.9 (1.5)	151.4 (15.6)	82.6 (7.5)
Excluding warm-up and cooldown	35.9 (2.4)	9.6 (1.8)	334 (62)	8.1 (1.7)	155.6 (15.8)	84.9 (7.3)

Abbreviations: bpm, beats per minute; HR_{max}, maximum heart rate. Note: Values are expressed as mean (SD) unless otherwise stated.

[a]Complete session significantly different between males and females ($P < .001$).

[b]Excluding warm-up and cooldown significantly different between males and females ($P < .001$).

Table 4

Intensity and Physical Activity by Calorimeter Participants and Other Participants

	Calorimeter participants		Other participants			
	Intensity, % HR_{max}	**Physical activity, counts/min**	**Intensity, % HR_{max}**	**Physical activity, counts/min**	***P* for intensity**	***P* for physical activity**
Complete session	80.4 (6.2)	582 (128)	77.6 (8.4)	570 (172)	.13	.98
Excluding warm-up and cooldown	82.6 (6.1)	686 (164)	79.9 (8.8)	626 (210)	.13	.38

Abbreviation: HR_{max}, maximum heart rate. Note: Values are expressed as mean (SD) unless otherwise stated.