

Acute physiological responses to different circuit training protocols

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Aim. The purpose of present study was to compare the acute physiological responses to a circuit weight training with the responses to a combined circuit training (weight training and treadmill run).

Methods. The sample consisted of 25 individuals at an average state of training, 10 men and 15 female, between 18 and 35 year old. There were selected 60 second sets of resistance exercises to the circuit weight training (CWT). Whereas in the combined circuit training (CCT), the subjects spent 30 seconds on the same resistance exercises and 30 seconds running on the treadmill. The rest intervals between the sets lasted 15 seconds. The analysis of variance (ANOVA) with 5% significance level was utilized to the statistical analysis of the results.

Results. Comparing circuit training protocols, it was noted that CCT elicits a higher relative and absolute $\dot{V}O_2$ and energy expenditure values than CWT for both genders ($P < 0.05$). Regarding inter-gender comparison, males showed higher absolute and relative $\dot{V}O_2$ and absolute energy expenditure values for both CWT and CCT than females ($P < 0.05$). Females showed a significant greater $\% \dot{V}O_{2max}$ value for both CWT and CCT. Due to the experimental conditions used to state both circuit training bouts (CWT and CCT), the $\dot{V}O_2$ rate found was higher than the values reported by previous studies which used heavier weight lift.

Conclusion. CCT seems adequate to produce cardiovascular improvements and greater energy expenditure for both men and women, while CWT group classes are sufficient only for unfit women.

KEY WORDS: Energy metabolism - Heart rate - Exercise.

Circuit weight training (CWT) has been used to improve physical fitness since the early seven-

ties. Nowadays, there is a growing interest in CWT due to several recent studies that have demonstrated the physiological adaptations and potential health benefits of this method.¹⁻⁴ For instance, Westcott *et al.*¹ reported US Air Force physical fitness test scores improvement after the CWT.¹ Furthermore, Camargo *et al.*⁵ showed that CWT produced $\dot{V}O_{2max}$ peak and lower and upper limbs strength improvement.

A typical CWT session involves one to three sets of 10 to 12 repetitions, at 40-50%1RM. Gettman *et al.*⁶ and Wilmore *et al.*⁷ were the first to report improvements in maximal oxygen uptake ($\dot{V}O_{2max}$), strength, and body composition following CWT. Thus, other authors have tried to reveal the acute physiological strain induced by this training strategy to produce such adaptations.⁸⁻¹¹ However, the physiological stimulus reported during CWT session is usually lower than American College of Sports Medicine¹² (ACSM) recommendations for cardiovascular fitness improvement.

In fact, some studies have been conducted using similar CWT activities. Piacentini *et al.*¹³ evaluated a free weight training method (JUST PUMP[®]) and reported that this activity was performed at an intensity level below the recommended to improve aerobic capacity. Accordingly, Stanford *et al.*¹⁴ (2002) also

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demonstrated that the free weight training session (BODY PUMP®) is not a sufficient stimuli to improve cardio-vascular fitness.

The physiological strain, and consequent cardio-vascular fitness improvement, is proportional to the muscle mass recruited.¹² Therefore, free weight, multi-joint exercises seem to be an attractive way to increase training overload due to the recruitment of a larger number of agonist, antagonist, and stabilizer muscles. In addition to large muscle mass recruitment, a short rest interval between sets and exercises may also increase physiological demand during CWT.¹⁰

An alternative way to increase the physiological strain to CWT is to alternate strength and aerobic exercises. The combination of strength and aerobic exercises has been defined as compounded circuit training (CCT). For instance, Gettman *et al.*¹⁵ showed a 17% increment in $\dot{V}O_{2max}$ after 20 weeks of CCT.

Both training strategies (*e.g.* CWT and CCT) are suited for group classes and are spread across fitness centers. However, to the best of our knowledge, no study has attempted to compare the acute physiological strain produced by CWT and CCT to determine physiological strain during these sessions and confirm if they meet ACSM¹² requirements for cardio-vascular fitness improvement.

Therefore, the purpose of the present study was to compare oxygen consumption, energy expenditure, and heart rate profile between CWT and CCT in healthy men and women, and determine if both training strategies meet ACSM guidelines for cardiovascular fitness improvement.

Materials and methods

Experimental approach to the problem

A cross-over design was used to compare the physiological strain produced by both CWT and CCT. The difference between protocols was that CWT performed resistance exercises for 60 sec, while CCT executed the same resistance exercises for 30 sec combined to treadmill run during the remaining 30 sec.

Subjects

The sample consisted of 10 males and 15 females. They were healthy and had to be resistance trained

TABLE I.—Female (N.=15) and men (N.=10) characteristics.

	Female	Male
Age (yr)	24.2±6.6	26.4±4.7
Height (cm)	164.8±7.0	173.7±5.5
Weight (kg)	57.6±5.2	71.2±7.1
BMI (kg/m ²)	20.9±1.3	23.3±1.3
Fat %	22.8±4.7	9.8±3.5
Free fat mass (kg)	44.4±4.7	64.1±5.5
Fat mass (kg)	13.8±3.4	6.9±2.5
$\dot{V}O_{2max}$ (L/min)	2.2±0.4	3.3±0.4
$\dot{V}O_{2max}$ (mL/kg/min)	37.1±5.1	46.6±5.5
HR _{max} (bpm)	185.8±12.3	192.4±7.9

for at least six months. Training frequency was at least three times per week. Subjects that were under medication that could either influence cardiorespiratory response or exercise performance were excluded. The study was approved by the University's ethic committee and all subjects signed an informed consent form before participation. Average and standard deviation of anthropometric and cardiorespiratory data are presented in Table I.

$\dot{V}O_{2max}$ testing

The $\dot{V}O_{2max}$ was determined through a modified Astrand treadmill protocol up to exhaustion.¹⁶ Individuals were instructed and stimulated to run until exhaustion. Criteria for $\dot{V}O_{2max}$ achievement was reach age-predicted maximal heart rate and respiratory exchange ratio (RER) >1.0. An Aerosport (Medical Graphics - VO2000 – USA) gas analyzer was used. Heart rate was measure by a telemetric monitor (S610 - Polar, Finland). Physiological variables were recorded in 15 sec intervals averages.

Measurement of work $\dot{V}O_2$, energy cost and heart rate

$\dot{V}O_2$ was measured during both interventions (CWT and CCT). In brief, expired gases analyzed for percent oxygen and carbon dioxide on Aerosport (Medical Graphics - VO2000 – USA) gas analyzer. Analyzer was calibrated prior to each test using Micro Scholander apparatus. The energy equivalent of 1 L of oxygen was assumed to be 5 kcal, so net energy expended from oxidative processes was calculated by multiplying $\dot{V}O_2$ by 5. Heart rate was measure by a telemetric monitor (S610 - Polar, Finland). Physiological variables were recorded in 15 sec intervals averages.

TABLE II.—Training session description.

CWT		CCT		
Warm-up	10 min	Warm-up	10 min	
Main part	10 min	Main part	10 min	
Exercises		Exercises		Treadmill
Squat	60"	Squat	30"	30"
Push up	60"	Push up	30"	30"
Right leg lunge with biceps curl	60"	Right leg lunge with biceps curl	30"	30"
Bent over row	60"	Bent over row	30"	30"
Left leg lunge with biceps curl	60"	Left leg lunge with biceps curl	30"	30"
Upright row with squat	60"	Upright row with squat	30"	30"
Wide squat with military press	60"	Wide squat with military press	30"	30"
Cool down	5 min	Cool down		5 min

Exercise protocol

Both exercise protocols (CWT and CCT) followed a typical training sessions, 10 min of warm up, 10 min of main part, and 5 min of cool down. The data were collected during the main part of the lesson (10 min). Warm up consisted of a 5 min treadmill walk/jogging ($60\%HR_{max}$), followed by upper and lower limbs stretching exercises. The main part in the CWT condition consisted of eight exercises that emphasize the large muscle groups (squat, push up, right leg lunge with biceps curl, bent over row, left leg lunge with biceps curl, upright row with squat, wide stance squat with military press) (Table II). Each resistance exercise was performed for 60 sec with 2 and 4 kg for females and with 4 and 6 kg for males, for upper and lower limbs, respectively.¹⁷ The rationale to choose the workloads used for each exercise was based in the study conducted by Beckham and Earnest,¹⁷ which suggested that moderate to high loads are required to improve cardiovascular fitness. Exercises were the same in CCT but exercise duration was divided in 30 s for the resistance exercise and 30 sec for the treadmill run, totalizing 60 sec. In order to compare both protocols, the time of work was equalized as recommended by Getman *et al.*¹⁵ From 10 to 15 seconds were allowed between exercises for both conditions. The performance pace was set at 140 bpm by a CD music, and running speed was selected to elicit and/or maintain at least $60\%HR_{max}$ for both genders. Cool down consisted of light stretching for the exercised muscle groups. Exercise bout sessions were at least 48 hours apart.

Statistics

Means and standard deviation were computed for all variables measured during CWT and CCT exercise sessions for both genders. Shapiro-Wilk was used to test data normality. Then, a set of two way ANOVAs for repeated measures was used for each dependent variable to test for differences between exercise protocols and gender.

A one-sample, two-tailed, t-test ($P<0.05$) was used to compare the mean relative HR and $\dot{V}O_2$ values, measured during CWT and CCT, with ACSM criteria for improving cardiovascular fitness in healthy individual,¹⁰ $50-85\% \dot{V}O_{2max}$ and $60-90\% HR_{max}$. Significance level was set at $P<0.05$, for both analyses.

Results

Table III shows dependent variable values in CWT and in CCT bouts for both genders. Comparing circuit training protocols, it was noted that CCT promoted a higher relative ($mL \cdot kg^{-1} \cdot min^{-1}$) and absolute ($L \cdot min^{-1}$) $\dot{V}O_2$ and energy expenditure values than CWT for both genders ($P<0.05$). Regarding inter-gender comparison, males showed higher absolute and relative $\dot{V}O_2$ and absolute energy expenditure ($kcal \cdot min^{-1}$) values for both CWT and CCT than females ($P<0.05$). Females showed a significant greater $\% \dot{V}O_{2max}$ value for both CWT and CCT. It is noteworthy that both genders did not reach the minimum $\% \dot{V}O_{2max}$ recommended by ACSM¹² criteria during CWT protocol. On the other hand, $\%HR_{max}$ values were within the recommended range by ACSM¹² for both circuit protocols and genders.

TABLE III.—Physiological responses to CWT and CCT sessions.

Gender	Parameters	Training session	
		CWT	CCT
Female	$\dot{V}O_2$ (L·min ⁻¹)	1.0±0.2	1.3±0.3*
	$\dot{V}O_2$ (mL·kg ⁻¹ ·min ⁻¹)	17.5±2.8	20.8±2.8*
	% $\dot{V}O_{2max}$	47.2±5.9	59.8±7.8*
	HR (bpm)	141.2±14.6	141.7±14.3
	%HR _{max}	76.0±7.6	76.4±7.5
	EE (kcal·min ⁻¹)	5.1±1.2	6.3±1.3*
Males	EE (kcal·kg ⁻¹ ·h ⁻¹)	5.3±1.2	6.5±1.3*
	EE (kcal·kg(FFM) ⁻¹ ·h ⁻¹)	6.9±1.1	8.5±1.8*
	$\dot{V}O_2$ (L·min ⁻¹)	1.5±0.1°	1.7±0.3°*
	$\dot{V}O_2$ (mL·kg ⁻¹ ·min ⁻¹)	20.4±2.0°	23.8±2.8°*
	% $\dot{V}O_{2max}$	43.6±3.9°	46.9±8.7°
	HR (bpm)	145.5±19.9	137.4±11.2
	%HR _{max}	75.7±9.2	71.4±4.4
	EE (kcal·min ⁻¹)	7.3±0.8°	8.3±1.2°*
EE (kcal·kg ⁻¹ ·h ⁻¹)	6.2±0.8	7.0±1.1*	
EE (kcal·kg(FFM) ⁻¹ ·h ⁻¹)	6.8±0.8	7.8±1.1*	

*Significant difference between CWT and CCT (P<0.05); °significant difference between males and females (P<0.05).

Discussion

The purpose of this study was to compare oxygen consumption, energy expenditure, and HR profile between circuit weight training (CWT) and combined circuit weight training (CCT) in healthy men and women. A secondary aim was to determine if both training strategies met ACSM guidelines for cardiovascular fitness improvement. The main findings of the present study were 1) CCT imposed a higher physiological strain than CWT; 2) women needed a higher fraction of the $\dot{V}O_{2max}$ to execute similar protocols, due to a lower aerobic power than men; and 3) CWT session produced lower oxygen cost than the recommended by the ACSM.¹²

In order to improve cardio-respiratory function, it is imperative to monitor physiological strain induced by acute training variables (e.g. intensity, volume, and work to rest interval). The ACSM recommends strain intensities between 50-85% $\dot{V}O_{2max}$ to promote cardiorespiratory system improvement, which corresponds to approximately 60-90%HR_{max}.¹² In the present study, CWT produced a strain intensity of 47% $\dot{V}O_{2max}$ and 76%HR_{max}, and 43% $\dot{V}O_{2max}$ and 76%HR_{max} for females and males, respectively (Table II). In agreement, Wilmore *et al.*⁸ reported values of 45% $\dot{V}O_{2max}$ and 70%HR_{max} for males and 50% $\dot{V}O_{2max}$ and 80%HR_{max} for females during CWT protocol. Beckham and Earnest¹⁷ also used a free weight CWT

protocol and reported values of 30% $\dot{V}O_{2max}$ and 65%HR_{max} to male and 32% $\dot{V}O_{2max}$ and 62%HR_{max} to female. Gotshalk *et al.*¹¹ described values from 39% to 53% $\dot{V}O_{2max}$ and from 71% to 87%HR_{max} among trained male. In another study, Ballor *et al.*¹⁸ reported intensities of 53% $\dot{V}O_{2max}$ and 153 bpm corresponding to 87%HR_{max} in CWT performed with hydraulic resistance.

A study conducted by Stanford *et al.*¹⁴ evaluated the energy expenditure, HR and $\dot{V}O_2$ of a BODY PUMP® workout. They showed that the $\dot{V}O_2$ during a BODY PUMP® session (14.8 mL·kg⁻¹·min⁻¹) was less than the $\dot{V}O_2$ achieved in previous CWT studies.^{8, 18-21}. In accordance to these data, Piacentini *et al.*¹³ also found that JUST PUMP® workout was performed at an intensity level below the recommended to improve aerobic capacity. It is noteworthy that BODY PUMP® was primarily designed to improve muscular endurance rather than cardiorespiratory fitness.

Despite the similarity, there are several differences between CWT and BODY PUMP®. For instance, a standard BODY PUMP® workout involves 9 tracks, each one isolating particular muscle groups, over 50 minutes. Furthermore, during one track an individual completes almost 100 repetitions. By comparison, CWT typically requires 20-30 minutes to complete the workout, involving 1-3 sets of 8-12 repetitions for each exercise. Therefore, individuals perform less repetitions with a greater total workload during CWT than during a BODY PUMP® session. Previous studies have shown that the more load lifted, the higher is the aerobic requirement of the circuit.^{21, 22}

Although, there are many studies reporting HR and $\dot{V}O_2$ during CWT, only a few used free weight CWT protocol. The free weight CWT protocol adopted in the present study produced a higher $\dot{V}O_2$ (17.5-20.4 mL·kg⁻¹·min⁻¹) for both women and men than the value reported by Stanford *et al.*¹⁴ The higher aerobic requirement of the present CWT protocol might be associated with the selection of compound exercises.

It seems that the free weight CWT protocol adopted, using compound exercises with upper and lower limbs, produced a greater physiological strain than the strain reported by previous studies that used PUMP workouts.^{13, 14} Furthermore, the data presented herein indicate that CWT seems to be adequate only for untrained women who have lower aerobic power.

On the other hand, free weight CCT elicited values of 59% $\dot{V}O_{2max}$ and 76%HR_{max}, and 47% $\dot{V}O_{2max}$ and

71%HR_{max} for females and males, respectively (Table III). Therefore, CCT protocol seems appropriate for cardiovascular fitness improvement for both females and males.

Overall CCT produced higher energy expenditure than CWT. Moreover, males had higher energy expenditure than females in both CWT and CCT (7.3 vs 5.1 kcal·min⁻¹, and 8.3 vs 6.3 kcal·min⁻¹, respectively) (Table III). Beckhan and Earnest,¹⁹ reported that caloric expenditure was also significantly higher for male (4.9 kcal·min⁻¹) than for female (3.6 kcal·min⁻¹). In line with Phillips and Ziuraitis,²³ evaluating calorie expenditure through 8 exercises, with one set of 15RM, with two minutes interval between sets, found 3.4 and 5.6 kcal·min⁻¹ to female and male respectively. Wilmore *et al.*⁸ reported results were higher, 9.0 and 6.1 kcal·min⁻¹ for male and female, respectively, suggesting that this difference was due to differences in body composition. Nevertheless, differences among studies in caloric expenditure may also be related to strain intensity during exercise,¹⁰ which depends on the intervals between exercises and amount of weight to be lifted.^{21, 23} Ordway *et al.*²⁴ reported a linear increase in $\dot{V}O_2$ with increasing exercise loads. Thus, it seems important that fitness instructors match exercise load between genders to produce similar relative energy expenditure between genders in group classes.

Conclusions

As conclusion, CCT seems to be an adequate training strategy to produce cardiovascular improvements and greater energy expenditure for both men and women, while CWT is a moderate stimulus only for unfit women.

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