Effects of Gender on Physiological Responses to Strenuous Circuit Resistance Exercise and Recovery

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Abstract

Ortego, AR, Dantzler, DK, Zaloudek, A, Tanner, J, Khan, T, Panwar, R, Hollander, DB, and Kraemer, RR. Effects of gender on physiological responses to strenuous circuit resistance exercise and recovery. *J Strength Cond Res* 23(3): 932–938, 2009—Few studies have focused upon the physiological responses to circuit weight training (CWT) in men and women, and an investigation of possible gender differences could lead to optimal exercise prescriptions and improved adaptation outcomes. The purpose of the study was to determine the effects of gender on cardiovascular and metabolic responses to CWT and consequent recovery. Ten healthy men and 10 healthy women completed an initial session to collect descriptive data and determine a 12 repetition maximum (12RM) for 6 different upper- and lower-body resistance exercises. This was followed by 2 identical sessions of a CWT protocol on 2 separate days at least 48 hours apart. The first session was used to familiarize subjects with the equipment and the testing protocol. The second session was used to determine physiological responses. Each subject performed 10 repetitions of 6 exercises for 3 circuits at a 12RM load. $\dot{V}O_2$ and respiratory exchange ratio (RER) were continuously monitored, whereas heart rate (HR) and blood pressure (BP) were taken at the end of each circuit. Across the exercise session, men revealed greater absolute and relative $\dot{V}O_2$, relative lean body mass $\dot{V}O_2$, systolic BP (SBP), RER, and recovery $\dot{V}O_2$ when compared with the female subjects. There were no differences in HR, diastolic BP (DBP), or recovery RER. The present study provides a greater insight into gender differences in cardiovascular and metabolic responses to circuit weight training. These gender differences should be taken into consideration for development of CWT protocols for men and women.

Key Words strength training, circuit weight training, oxygen consumption, energy expenditure, respiratory exchange ratio, blood pressure, heart rate

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Introduction

Several studies have examined the role of gender and how it influences physiological responses to aerobic exercise (1,3,4,5,18). During aerobic exercise, oxygen uptake ($\dot{V}O_2$), respiratory exchange ratio (RER), and systolic blood pressure (SBP) are significantly higher in men than in women (5); however, there are no significant differences in these variables with regard to gender after exercise (5). Aerobic exercise typically elicits higher SBP in men compared with women, which has been attributed to a larger heart in men and thus a greater stroke volume (3,5).

Circuit weight training (CWT) combines, in a unique fashion, the stresses of both aerobic and resistance exercise and consists of performing a predetermined set of exercises (a circuit) for a certain period of time or for 10–15 repetitions with 15–30 seconds of rest (9). Usually, multiple circuits (1–3) are performed. CWT can maintain and improve cardiovascular fitness, muscular strength, and muscular endurance (9). Understanding gender differences to circuit training may lead to improvement in protocol design to provide more effective CWT protocols. CWT has been shown to stress the cardiovascular system to a degree equal to or greater than treadmill running (10), but little is known regarding effects of gender on CWT.

A significantly higher $\dot{V}O_2$ occurs in men than in women during aerobic exercise when expressed as absolute $\dot{V}O_2$. These differences are reduced somewhat when $\dot{V}O_2$ is expressed relative to lean body mass (5), but this does not explain all of the gender differences in exercise $\dot{V}O_2$. There are minimal data concerning CWT; however, one such study has documented greater absolute $\dot{V}O_2$ in men than in women (21). For resistance exercise, the load to lean body mass ratio is usually higher in men, especially for upper-body exercise (20), which could elicit greater physiological responses. RER is also significantly higher in men during cardiovascular exercise, indicating a greater reliance on carbohydrate substrates (12,22). Women tend to have a higher rate of lipid oxidation and lower rate of carbohydrate and leucine oxidation as compared with men (15). One reason for this could be greater levels of estradiol in women. Estradiol causes an increase of intramuscular oxidation of lipids and

TABLE 1. Anthropometric data for subjects. Data represent mean ± *SEM*.

	Height (in.)	Weight (kg)	Age (y)	Body fat
Men	179.47 (5.19)	86.33 (14.32)	23.40 (1.64)	14.82 (4.96)
Women	166.55 (3.38)	72.61 (19.60)	23.80 (5.47)	25.44 (6.30)

TABLE 2. Twelve repetition maximum loads (kg) for men and women. Data represent mean ± *SEM*.

	Leg press	Pec dec	Leg extention	Lat pull-down	Leg curl	Upright row
Men	320 (49.4)	94.5 (7.7)	92.5 (7.2)	217.5 (13.9)	114.0 (11.2)	98.0 (6.6)
Women	102.5 (23.4)	29.5 (3.2)	67.5 (30.1)	109.0 (7.6)	58.0 (7.0)	52.5 (4.0)

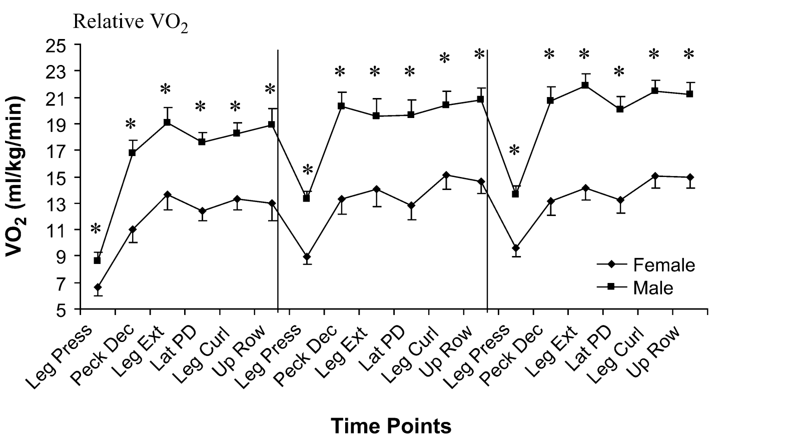

Figure 1. Male and female relative $\dot{V}O_2$ during circuit strength training exercises. Values are expressed as mean ± *SEM*. *Denotes significant difference between genders.

is also responsible for the greater oxidation of lipids during exercise (12).

Whereas many studies have investigated these variables in response to cardiovascular exercise and various resistance exercises, to our knowledge, they have not been examined collectively and in a controlled fashion during resistance CWT and during recovery from CWT. The purpose of this study was to investigate gender differences in cardiovascular and metabolic responses during CWT and recovery. From previous research demonstrating gender differences in cardiovascular responses to aerobic exercise and resistance exercise, we hypothesized that male participants would reveal greater SBP, RER, absolute and relative $\dot{V}O_2$, as well as greater total energy expenditure than the women during CWT. Additionally, we hypothesized that men would have greater BP, $\dot{V}O_2$, and RER after exercise.

METHODS

Experimental Approach to the Problem

The study consisted of 3 parts: session 1 for baseline testing, session 2 for subject familiarization, and session 3 for assessment. Cardiorespiratory and metabolic responses of men and women to CWT in session 3 were compared.

Subjects

Ten healthy men and 10 healthy women between the ages of 18 and 35 years were recruited for the present investigation. All of the subjects had a minimum of 1 year of strength training experience, and most had 2 or more years of experience. A health-history questionnaire was used to screen participants. Subjects were excluded if they met any of the following criteria: (a) history of hypertension, (b) cardiovascular disease, (c) pulmonary disease, (d) neuroendocrine disease, (e) metabolic diseases, (f) exercise-limiting injuries, (g) anabolic steroid use, and (h) special diets. Subjects were recruited from a university student population. All subjects

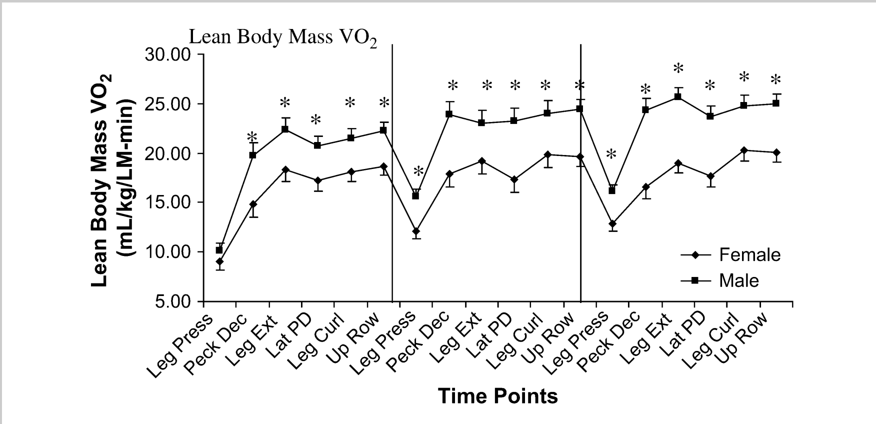

Figure 2. Male and female lean body mass $\dot{V}O_2$ during circuit strength training exercises. Values are expressed as mean ± *SEM*. *Denotes significant difference between genders.

gave written informed consent, and all experimental procedures were approved by the Southeastern Louisiana University Institutional Review Board.

Experimental Procedures

Session 1: Baseline Testing. During the first session, resting heart rate (HR), BP, height, weight, and body composition for each subject were determined. Body composition was obtained via a 7-site skinfold assessment using equations from Jackson and Pollock (16). Each subject then performed a light warm-up on a stationary leg ergometer followed by a light stretch to increase blood flow to different tissues. A 12 repetition maximum (12RM) for each exercise was then determined. Whereas some CWT research has used loads of 40–60% 1RM, other research have used 8–12RM loads (17). We deemed a 12RM load (approximately 67% 1RM) as optimal to demonstrate gender differences in response to CWT for two reasons. First, there seems to be more variability in number of repetitions that can be completed for men and women at lower workloads, e.g., greater variability at 40 vs. 60% $\dot{V}O_2$ (13). Second, we expected greater loading to elicit greater physiological responses, which would provide greater ability to compare gender differences yet not be too great to prevent subjects from completing the 3 circuits (which was verified from piloting the protocol before study onset).

Determination of the 12RM load was accomplished using a modified version of a previously documented protocol (8) in which the subjects lifted 1 to 2 sets at a load of 70–80% of a 12RM followed by a 3- to 5-minute rest. Subsequently, the subjects were instructed to lift their perceived 12RM load to failure. If the subject could lift the weight more than 12 times, more weight was added and a new attempt was made 3–5 minutes later. This was continued until the subject reached his or her 12RM.

Session 2 and 3: Familiarization and Assessment. Session 2 and 3 were identical. Session 2 was used as a familiarization session for the CWT protocol, and session 3 was used for assessment. Before each exercise session, the portable metabolic system (ParvoMedics, TrueMax 2400, Sandy, Utah) was calibrated with gases of known composition. Resting HR and BP were first recorded followed by a light warm-up. Heart rate was determined by telemetry (Polar, E30, Woodbury, N.Y.), and BP was determined using a mercury sphygmomanometer on a rolling stand (Trimline, PyMaH, Raritan, N.J.) The warm-up consisted of two parts: (a) a general warm-up consisting of 5 minutes of pedaling a stationary leg ergometer (Monark, 828E, Vansbro, Sweden) at a low resistance (50 watts), which is recommended before resistance exercise to increase blood flow to tissues and increase muscle temperature (14) and (b) 2 minutes of static stretching of major muscle groups. This was followed by 5 minutes of rest in

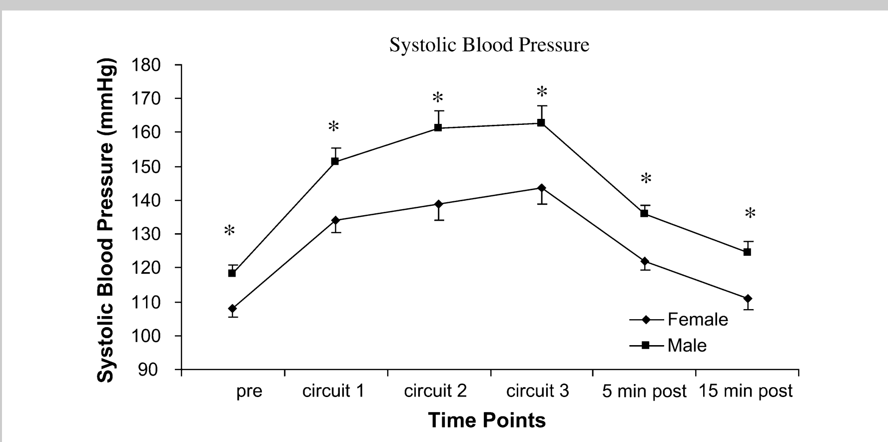

Figure 3. Male and female systolic blood pressure (SBP) during and after circuit strength training exercises. Values are expressed as mean ± *SEM*. *Denotes significant difference between genders.

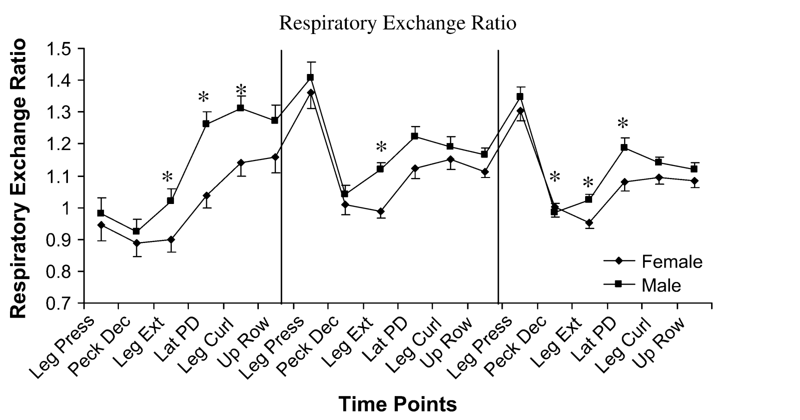

Figure 4. Male and female respiratory exchange ratio (RER) during circuit strength training exercises. Values are expressed as mean ± *SEM*. *Denotes significant difference between genders.

proceeded to the next exercise. The portable metabolic cart was moved from station to station with the subject to allow for continuous $\dot{V}O_2$ assessment for sequential 30-second intervals. After completing each of the circuits, subjects rested briefly in a seated position while HR and BP were recorded. All circuits were completed with the same order of exercises at the same speed and with the same work-to-rest ratio. Subjects were instructed not to alter the acceleration of the load and to perform each exercise using smooth, steady movements. Again, HR and BP were recorded at the end of each circuit, whereas $\dot{V}O_2$ and RER were continuously recorded. After completing the 3 circuits, subjects recovered in a seated position while metabolic measures were continuously collected. At 5 and 15 minutes after exercise, HR and BP were determined.

a seated position, during which a mouthpiece and headgear from the metabolic system were adjusted for each subject in the first 2 minutes followed by $\dot{V}O_2$ and RER measurements for the next 3 minutes before exercise onset. After gathering pre-exercise metabolic measures, subjects began the first circuit of machine-based resistance exercises that started with leg presses, followed by a pec deck (pectoral fly), leg extension, lat pull-down, leg curl, and upright row exercises (leg press; Body Masters Corp., LXp 740, Rayne, La; leg curl; Quantum Fitness Corp., QIS-8030, Stafford, Tex; leg ext, lat pull-down, pec deck, and upright row; Body Masters Corp., Masters Trainer II). Subjects lifted their predetermined 12RM weight 10 times to a regulated (metronome) cadence to standardize the work completed and to maintain a 1:1 work-to-rest ratio. Subjects completed 20 seconds of resistance exercise (1 set) followed by 20 seconds of rest and then

Statistical Analyses

Cardiovascular and metabolic data were analyzed to compare changes over time and between genders using repeated-measure analysis of variance (ANOVA) with time and gender as the main factors. $P \leq 0.05$ was deemed significantly different. *t*-tests were applied where appropriate. For absolute, relative, as well as relative lean mass $\dot{V}O_2$ the values analyzed were those collected after each exercise in the circuit and at every 3-minute time point during recovery. Data are presented as mean ± *SEM*.

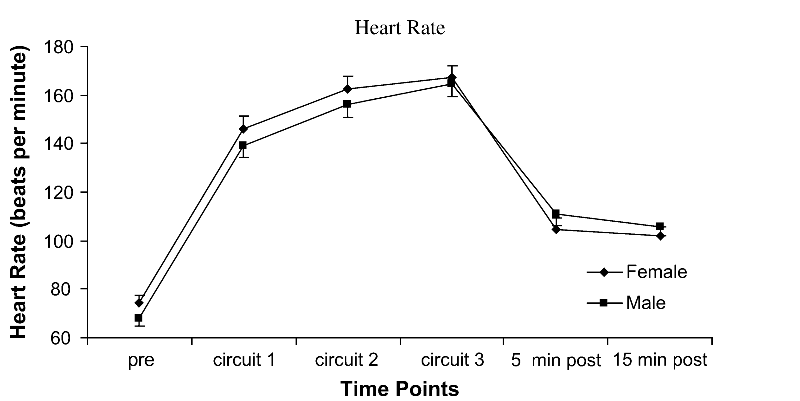

Figure 5. Male and female heart rate (HR) during and after circuit strength training exercises. Values are expressed as mean ± *SEM*.

Results

Between genders, there were no significant differences in weight or age; however, height and body fat differed significantly (Table 1). Men were significantly stronger than women (Table 2). For both genders, there was significant time effect for absolute $\dot{V}O_2$ (L·minute^{-1}), relative $\dot{V}O_2$ (ml·kg^{-1}·minute^{-1}), lean mass $\dot{V}O_2$ (ml·kg^{-1} of lean mass per minute), RER, and SBP ($P < 0.05$). During CWT, men had a significantly higher absolute $\dot{V}O_2$ (L·minute^{-1}) than women ($P < 0.05$; data not shown).

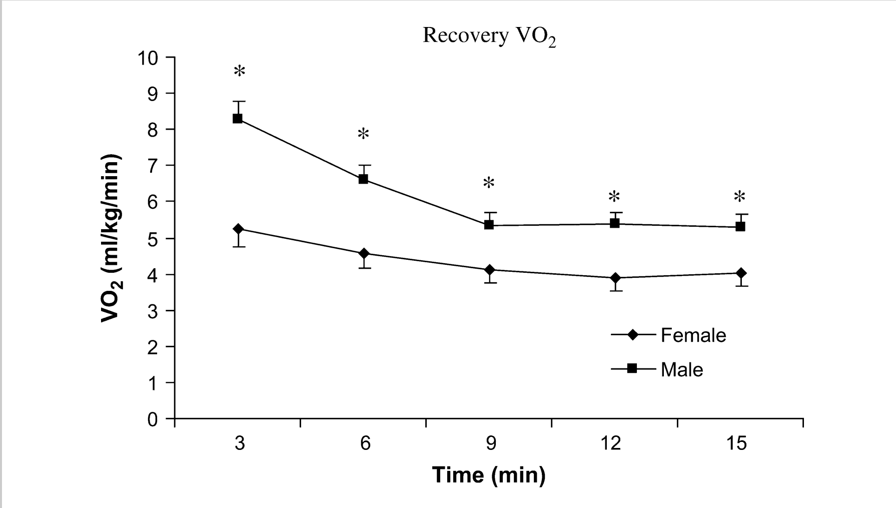

Figure 6. Male and female recovery $\dot{V}O_2$ after circuit strength training exercises. Values are expressed as mean ± *SEM*. *Denotes significant difference between genders.

These differences still existed for relative $\dot{V}O_2$ (ml·kg^{-1}·minute^{-1}) (Figure 1). When relative $\dot{V}O_2$ was compared to lean body mass $\dot{V}O_2$, significant time, gender, and interaction effects were also observed. Moreover, the rate of change in lean mass $\dot{V}O_2$ (ml·kg^{-1} of lean mass per minute) was different in men compared with women (Figure 2). Peak metabolic equivalent (MET) levels for men and women were 5.6 and 3.8 METs, respectively. Total energy expenditure and energy expenditure per kilogram of lean mass (820 ± 68.27 vs. 473 ± 25.35 kJ: 10.97 ± 0.71 vs. 8.99 ± 0.42 kJ·kg of lean mass) was greater for men than women, respectively. There was also a significant time, gender, and interaction effect for RER. Men produced higher RERs throughout the CWT, and the rate of change was different for gender (Figure 3).

SBP was significantly higher in men during CWT (Figure 4). There was a significant time effect for HR (Figure 5) and diastolic BP (DBP; data not shown), but no significant differences were observed between HR and DBP with regard to gender. Heart rate maximum (HRmax) was predicted using the method of Tanaka et al. (19), and there was no difference between male and female percentages of HRmax throughout the exercise trial (e.g., values for men vs. women for circuits 1, 2, and 3 were 73 vs. 76%, 81 vs. 85%, and 86 vs. 87%, respectively).

There was a significant time effect for recovery RER (data not shown), but no significant differences were found with regard to gender. Significant gender differences were observed for recovery $\dot{V}O_2$ (ml·kg^{-1}·minute^{-1}; Figure 6).

Discussion

The major findings of the study were that the men responded with significantly higher $\dot{V}O_2$, RER, and SBP than the women during CWT, but there were no gender differences for HR and DBP. Additionally, recovery $\dot{V}O_2$ and SBP were significantly higher in men, but there were no gender differences for recovery RER, HR, and DBP. Total energy expenditure was greater in men than women. The $\dot{V}O_2$ and energy expenditure data remained significant whether expressed relative to body weight or to lean body mass. These results were consistent with our hypotheses.

Only limited data are available concerning gender and physiological responses to CWT; moreover, previous gender-comparison studies have not reported BP responses to CWT (1,18,21). To our knowledge, the present study is the first to compare the acute effects of gender on cardiovascular (HR and BP) and metabolic VO_2 and RER) responses to CWT and recovery while carefully controlling for repetition number and relative loading. It is also the first CWT study to demonstrate greater SBP, higher $\dot{V}O_2$ and energy expenditure relative to lean body mass, and higher RER in men compared with women while controlling for repetition number and relative loading.

Men have greater maximal cardiac output, stroke volume, ejection fraction, and hemoglobin values that contribute to greater $\dot{V}O_{2max}$. However, these differences are reduced but not lost when $\dot{V}O_{2max}$ is expressed relative to lean body mass (6,18). Our $\dot{V}O_2$ CWT data were in agreement with previous aerobic exercise studies that have documented greater exercise $\dot{V}O_2$ in men (3,6). Deschenes et al. (6) noted greater $\dot{V}O_2$ during cycling in men than women, expressed both relative to both body mass and lean body weight. Similar to our CWT findings, there were no gender differences in $\dot{V}O_2$ during recovery. Exercise $\dot{V}O_2$ was higher in men than in women in the present investigation. These data are consistent with other data in the study in that HR and DBP of the men and women were similar, but SBP was higher in the men. This suggests that men had higher stroke volume that produced greater O_2 delivery and $\dot{V}O_2$. Muscle mass in men was responsible for a portion of the greater $\dot{V}O_2$ during exercise in men vs. women because expression in milliliters per kilograms of lean body mass per minute reduced but did not eliminate the $\dot{V}O_2$ milliliters per kilograms of lean body mass per minute gender difference. Other factors, such as heart size and hemoglobin levels, may explain some of the $\dot{V}O_2$ gender differences.

In one CWT study that compared gender responses, men revealed greater relative $\dot{V}O_2$ (ml·kg^{-1}·minute^{-1}) during exercise, which was similar to our findings, but $\dot{V}O_2$ relative to lean mass was not reported, and the number of repetitions varied per set (20). In another CWT study, men and women completed two different trials in which either a light weight (1.4 kg for men and women) or a moderate weight (5.9 kg for women and 10.5 kg for men) was used. Greater absolute, but not relative $\dot{V}O_2$ values were reported in men, and no gender differences were reported for HR or RER during the light resistance trial (1). These data were likely affected by standard loading regardless of muscular strength.

Data from our study differed from a previous study (18) that measured physiological responses to a variation of CWT known as "body pump" exercise in which relative $\dot{V}O_2$ values were similar in men and women. In that investigation, subjects performed approximately 100 repetitions per muscle group during 9 tracks (circuits) using either 1.0-, 2.5-, or 5-kg plates. Oxygen uptake levels were lower than in the present study and were likely affected by use of much smaller loads. Moreover, lack of gender differences in relative $\dot{V}O_2$ was probably caused by the smaller loads, as well as unspecific loading of muscle and variation in the number of repetitions performed.

Concerning recovery from aerobic exercise in the present study, women exhibit a greater decrease in mean arterial pressure (MAP) compared with men. These findings may be because women have relatively greater reduction in cardiac output and less of an increase in total peripheral resistance after exercise (3). In the present CWT study, women demonstrated significantly lower SBP (Figure 5) and MAP during recovery (data not shown), but there was no difference in the rate of decrease during recovery.

An important finding was the greater energy expenditure per kilogram of lean mass in men compared with women, which was different from previous findings (21). One difference in the present study compared with the previous investigation was that our subjects worked at a greater workload (67% 1RM vs. 40% 1RM in the previous study), which could explain the disparate results. The gender difference in our study was consistent with demonstrable differences in $\dot{V}O_2$ per kilogram of lean mass.

The RER values were high for both genders, which indicate a significant carbohydrate contribution to energy expenditure. Previous studies have revealed that women exhibit lower RERs as compared to their male counterparts during sustained aerobic exercise. This is attributed to greater circulating estradiol, which would lead to more lipid metabolism and a lower RER in women (5,10). In a study by Hamadeh et al. (12), estrogen supplementation in men resulted in a decrease in RER, carbohydrate oxidation, and leucine oxidation. It also led to an increase in lipid oxidation in men similar to that observed in women. Consistent with these data, men in the present study revealed higher RER values during exercise than women. These findings are different from the findings of no gender differences in RER from a CWT reported previously (1), but again, the use of standard loading regardless of strength may have affected their findings. Other studies have not reported the RER responses to CWT in men and women (18,21).

Recovery $\dot{V}O_2$ was significantly higher in men than in women. It can be assumed that because men consumed more O_2 than women during the CWT, then recovery $\dot{V}O_2$ (especially the fast component) would be higher and therefore would take a little longer to reach resting $\dot{V}O_2$. Data from our lab have previously demonstrated that inclusion of recovery $\dot{V}O_2$ (excess postexercise oxygen consumption) is very important in determining total caloric cost from CWT exercise (11). Although we only measured $\dot{V}O_2$ for 15 minutes of recovery, it has been demonstrated that most of the excess postexercise oxygen consumption from CWT occurs during the first 10–15 minutes after exercise (11).

A factor that could have affected the gender differences is the load lifted relative to lean body mass (20). We compared the load to lean body mass ratios for the men and women, and indeed, men lifted a higher load per kilogram of lean body mass, especially for upper-body exercises. This could have contributed to the greater $\dot{V}O_2$ and RER responses in men compared with women.

A limitation of the study is that the women were tested without regard for the phase of their menstrual cycle. However, data from several previous studies suggest that effects of menstrual cycle phase were minimal. Although it has been shown that there is significantly greater postexercise hypotension in the early follicular phase as compared with the late follicular and midluteal phases of the menstrual cycle, the phase differences were relatively small (7). Whereas the phase of the menstrual cycle influences muscle glycogen use and glucose turnover during moderate-intensity endurance exercise, gender has a greater overall effect (6). Moreover, there are data suggesting that cyclic variations in estrogen and progesterone do not affect systemic lipolysis and systemic nonesterfied free fatty acids (15). Another limitation is that RER was used to determine energy expenditure, and RER values were greater than 1 for most of the 3 circuits; this was induced by increased H^+ buffering and ventilation that reduced the accuracy of energy expenditure determination. It should be noted, however, that this was fairly consistent for men and women, and thus, it is likely that this did not affect the findings of gender differences in energy expenditure.

In summary, physiological responses during CWT are affected by gender with significantly higher $\dot{V}O_2$, RER, and SBP responses in men than women during CWT, but there are no gender differences in HR and DBP. These gender differences are likely explained to a large degree by differences in load to muscle mass ratio, sex hormone levels, and stroke volume. Moreover, $\dot{V}O_2$ and SBP are significantly higher in men during CWT recovery, but there is no difference in recovery RER, HR, and DBP.

Practical Applications

The present study provides greater insight into gender differences in both cardiovascular and metabolic responses to

CWT, a training method that provides some cardiovascular and strength benefits. Future studies should consider investigating gender differences with regard to different muscle loads and rest-to-work ratios. Data from the study suggest that gender differences should be considered when developing CWT protocols for moderately fit individuals.

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