Nuñez TP, Amorim FT, Janot JM, Mermier CM, Rozenek R, & Kravitz L. Circuit Weight Training: Acute and Chronic Effects on Healthy and Clinical Populations. J Sport Human Perf 2017; 6(1):1-21.

JOURNAL OF SPORT AND HUMAN PERFORMANCE

REVIEW OPEN ACCESS

CIRCUIT WEIGHT TRAINING: ACUTE AND CHRONIC EFFECTS ON HEALTHY AND CLINICAL POPULATIONS

Nuñez TP[1], Amorim FT[2], Janot JM[3], Mermier CM[2], Rozenek R[4], Kravitz L[2].

[1]Human Performance and Sport, Metropolitan State University of Denver, Denver, CO
[2]Health, Exercise and Sports Sciences, University of New Mexico, Albuquerque, NM
[3]Department of Kinesiology, University of Wisconsin-Eau Claire, Eau Claire, WI
[4]Department of Kinesiology, California State University, Long Beach, Long Beach CA

Correspondence to:
Tony P Nuñez
6772 W. 19th Pl. Apt 201
Lakewood, Colorado, USA, 80214
Email Address: tnunez1@msudenver.edu

ABSTRACT

Circuit weight training (CWT) involves resistance exercise movements performed in a rotational order with light loads (40-60% one-repetition maximum) using limited to no rest between exercises. This type of training has been implemented in programs involving healthy younger and older adults, as well as in programs involving clinical populations (e.g. diabetes mellitus, hypertension, cardiac disease). Acute responses to CWT demonstrate higher levels of oxygen consumption and higher heart rates compared to traditional resistance training at similar intensities. Furthermore, CWT programs are more time efficient compared to traditional resistance training. Results from investigations using this mode of training range from improvements in muscular strength and endurance, flexibility, body composition to health-related enhancements such as resting blood pressure, hemoglobin A_{1C} and aerobic capacity. The time efficiency in which these results makes circuit weight training an appealing exercise format. The incorporation of aerobic activity into circuits promotes further improvements in markers of cardiovascular health and fitness.

Keywords: Resistance training, exercise outcomes, fitness.

INTRODUCTION

The development of circuit training by R.E. Morgan and G.T. Adamson at the University of Leeds (26) can be traced back to the early 1950s. In order to maximize time and space in a gymnasium full physical education students, Morgan and Adamson implemented body weight exercises all students could perform with little to no equipment in a cyclical fashion. One of the earliest books pertaining to circuit training, written by Robert P. Sorani (26), highlighted many formats of circuit training and advantages of this type of resistance training for different populations with various health, sport and performance-related goals. Traditional circuit training is performed using body weight exercises, while circuit weight training (CWT) refers explicitly to externally loaded resistance exercises performed in a rotating format. A CWT format refers to a number of carefully selected exercises arranged sequentially and performed in a rotational order. The number of resistance exercises typically ranges from 6 to 12, and is usually performed for a specified amount of time (15 to 45 sec) or number of reps (8 to 20 reps) with limited recovery between exercises (15 to 30 sec). Intensities ranging from 40% to 60% one-repetition maximum (1-RM) are generally used for the majority of CWT protocols.

The primary focus of this current review is to provide an in-depth synopsis of the physiological and metabolic effects of CWT, as well as highlight specific health/fitness benefits resulting from participation in this type of programming. A secondary aim of this article is to detail the various training protocols from published research in order to provide readers with useful programming ideas for specific populations. This review will examine the acute and chronic effects on cardiopulmonary function, muscular fitness and body composition within the following populations: healthy, clinical and older adults.

HEALTHY POPULATIONS

Acute Cardiopulmonary Function, Muscular Fitness and Performance Outcomes

The concept of circuit training was in its developmental stages when Wilmore and colleagues (29) designed one of the first CWT studies examining energy cost. The researchers used 12 pieces of machine/cam-based strength equipment typically found in large commercial fitness settings and rehabilitation facilities. This acute study included 20 men and 20 women between 17 and 36 years of age, who had experience with both CWT and resistance training. Exercises were performed for 30 sec followed by 15 sec of rest before the next exercise was performed. Results for the 22.5 min circuit for males demonstrated an approximate mean energy expenditure of 200 kcal (±39 kcal), heart rate (HR) of 143 $b \cdot min^{-1}$ (±17 $b \cdot min^{-1}$) (~ 76% HR_{max}), and $\dot{V}O_2$ values of 20 $ml \cdot min^{-1} \cdot kg^{-1}$ (± 2 $ml \cdot min^{-1} \cdot kg^{-1}$) (~ 40% $\dot{V}O_{2max}$). Mean energy expenditure for females was 142 kcal (±22 kcal) with a HR of 148 $b \cdot min^{-1}$ (±11 $b \cdot min^{-1}$) (85.5% HR_{max}), and $\dot{V}O_2$ values of 17 $ml \cdot min^{-1} \cdot kg^{-1}$ (±2 $ml \cdot min^{-1} \cdot kg^{-1}$) (~ 45% $\dot{V}O_{2max}$). The authors concluded that the energy cost of CWT is approximately the equivalent of cycling at 18.5 $km \cdot hr^{-1}$, jogging at 8 $km \cdot hr^{-1}$ or a vigorous game of volleyball. This pioneer study initiated an extensive amount of research in the area of CWT in both the general and clinical populations.

ISSN: 2326-6333

In an effort to investigate the acute effects of different CWT protocols on cardiopulmonary function and energy expenditure, Gordon et al. (13) had 12 active male volunteers (age = 28 ±5 yr) perform two different CWT protocols of similar total duration using hydraulic exercise equipment at self-selected intensities. Results showed that 30 s work periods with 30 s rest periods elicited a significantly higher $\dot{V}O_2$ (23.4 ±3.5 ml· min^{-1}·kg^{-1}) and total energy expenditure (TEE) (9.3 ±0.3 kcal·min^{-1}) than 20 sec work periods with 60 sec rest periods ($\dot{V}O_2$ = 20.4 ±2.9 ml· min^{-1}·kg^{-1}; TEE = 8.1 ±0.3 kcal·min^{-1}). The researchers noted that the HR response to CWT (75% of HR_{max}) was disproportionately elevated as compared to oxygen uptake (40% $\dot{V}O_{2max}$) and thus not an accurate predictor of the energy demands of CWT. These results are consistent with those noted by Fleck and Dean (9), identifying a pressor response to resistance exercise. Fleck and Dean demonstrated an elevated HR compared to energy demands during common resistance exercises in both untrained and moderately trained males. Gordon et al. highlighted that heart rate response remained identical during the 60 sec and to 30 sec rest intervals between exercises despite a noticeable decrease in oxygen uptake during the 60 sec rest interval protocol. There was no physiological explanation or hypothesis in regards to the lack of change in HR response between the 30 sec and 60 sec rest intervals.

In response to the increased use of free weight CWT in group exercise classes in commercial gyms, Beckham and Earnest (3) developed a research design to examine the metabolic cost of these types of CWT classes. Light and moderate resistances were used to mimic the group exercise class structure. The circuit was performed one time utilizing the following exercises: squat, bent over row, bent leg dead lift, modified clean and press, overhead press, behind neck shoulder press, front shoulder raise and lateral shoulder raise. The number of reps performed was not specified. Instead, exercises were performed for a specified amount of time that differed between all exercises ranging between 1 and 4 min. Due to the low intensity loads used during the exercise protocols, %$\dot{V}O_{2max}$ (28.7 – 31.9% for women; 24.0 – 29.4% for men) was significantly lower than CWT oxygen consumption values reported by Wilmore et al. (44.9 – 46.8% for women; 40.2 – 45.0% for men) (29). Beckham and Earnest proposed that the light to moderate resistance used during group exercise CWT classes was not a sufficient challenge to produce an aerobic response indicative of cardiovascular (CV) improvement. For a favorable aerobic response during CWT, Beckham and Earnest suggested training at higher intensities than those used during their study.

In an attempt to determine the optimal volume needed for CWT in order to elicit a CV response, Gotshalk, Berger and Kraemer (14) examined the oxygen uptake in response to CWT performed at a randomized starting point, but with exercises performed in the same order. Eleven male participants (20 ±2 yr) performed 10 exercises (bench press, leg press, latissimus pull down, seated shoulder press, biceps curl, triceps extension, knee extension, upright row, and seated back row) for 10 reps at 40% 1-RM. The protocol was completed for 4.6 circuits and oxygen uptake was analyzed throughout the entire session. Data was collected during the first six exercises to determine the extent of physiological response upon initiation of the protocol, preceded by four full circuits (4.6 circuits in total). After completing 1.6 rounds of the circuit, participants elicited a %$\dot{V}O_{2max}$ $\geq$ 50% and had a %HR_{max} > 70% both of which remained at these levels for the remainder of the circuit rounds. Comparatively, the researchers determined that exercising at an intensity of 50% $\dot{V}O_{2max}$ produced a greater HR response during CWT (mean HR ~165 $b\cdot min^{-1}$) compared to treadmill running (mean HR ~150 $b\cdot min^{-1}$). It was concluded that CWT was a suitable alternative modality for developing both strength and aerobic capacity, when performed with an intensity of at least 40% 1-RM with a volume of 4.6 rounds of 10 reps using 10 exercises.

Monteiro and colleagues (21) examined the acute differences in aerobic response and energy expenditure in trained and untrained men (n=10; age = 26.5 ±4.5 yr) and women (n=15; age = 24.5 ±6.5 yr) using either CWT or CWT combined with aerobic exercise. The CWT session consisted of the following exercises: 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 shoulder press. One set of each exercise was performed for as many reps as possible within a time period of 60 sec. Women used 2 kg weights for upper extremity exercises and 4 kg weights for the lower-body exercises, while the men used 4 kg and 6 kg weights for upper- and lower-body exercises, respectively. The combined CWT and aerobic activity session consisted of the same exercises at the same loads, but included 30 sec of running at 60% HR_{max} instead of taking 10 to 15 sec of rest between exercises. A significantly higher $\dot{V}O_2$ response for both men and women was observed during the combined CWT and aerobic exercise (women = 20.8 $ml\cdot min^{-1}\cdot kg^{-1}$; men = 23.8 $ml\cdot min^{-1}\cdot kg^{-1}$) when compared to the CWT session (women = 17.5 $ml\cdot min^{-1}\cdot kg^{-1}$; men = 20.4 $ml\cdot min^{-1}\cdot kg^{-1}$). Energy expenditure was significantly higher during the combined CWT and aerobic exercise (women = 6.3 $kcal\cdot min^{-}1$ for; men = 8.3 $kcal\cdot min^{-1}$) compared to the CWT session (women = 5.1 $kcal\cdot min^{-1}$ for; men = 7.3 $kcal\cdot min^{-1}$).

Most CWT studies have used relatively low intensities in their protocols. To determine the effect of higher intensities, Alcaraz, Sánchez-Lorente, and Blazevich (2) investigated the difference in physical performance and heart rate response between standard weight training (SWT) and CWT in 10 trained men (26 ±1.5 yr) using intensities ranging between 60 – 100% 1RM. The SWT session consisted of 5 sets of bench press with 3 min of rest between sets performed to volitional fatigue, while the CWT session completed 5 sets of bench press along with two lower body exercises (leg extension, ankle extension) with 35 sec rest between exercises and 3 min rest between circuits. Participants were split into two groups and randomly assigned to the SWT or CWT protocol for the first session and switched to the opposite protocol the following session. There were no significant differences in exercise performance as measured by maximum and average bar velocity and power, and the number of reps performed on the bench press between the CWT and SWT protocols. These results indicated that strength training can be performed in a circuit fashion without diminishing exercise performance in the primary lift (bench press). However, the CWT group did elicit statistically higher average HRs (mean = 137 $b\cdot min^{-1}$) for the entire workout compared to the SWT group (mean = 130 $b\cdot min^{-1}$). This was likely due to the HR being able to recover more readily during the SWT protocol compared to the CWT protocol. A major limitation of the study was the two protocols were very unbalanced in terms of the amount of work performed: one exercise for the SWT and three exercise for the CWT.

One of the more recent articles examining the acute effects of CWT comes from Skidmore et al. (25). Researchers examined three different training protocols using 11 recreationally active women (mean age = 34.0 ±5.5 yr) as participants; traditional circuit training (TRAD), aerobic circuit training (ACWT), and circuit training mixed with interval training (CWIT). All protocols were composed of the same three mini-circuit stations: Station A: triceps bench dip, hip bridge, prone plank; Station B: standing biceps curl, dumbbell (DB) squat, pushup; Station C: Standing DB lateral raise, DB split squat right leg, DB split squat left leg, standing DB bent-over row. Stations A, B and C were performed for 3 continuous circuits with 13 reps for each exercise (each set performed in 30 sec). Loads were determined from a 13-RM test for each exercise for all protocols (i.e., TRAD, ACWT, CWIT). During the TRAD session, participants performed each station (i.e., A, B, C) for 30 s of work with 30 sec of rest between exercises. The ACWT session involved the same stations as the TRAD protocol and also included four 2:30 min submaximal aerobic bouts on the cycle ergometer (55-65 rev·min^{-1} at 65-75% HR_{max}) alternated with the three mini-circuit stations. The CWIT workout was similar to the ACWT routine, and differed only in the performance of the cycling bout. Participants completed three 30 sec maximal effort sprint intervals [resistance set at 0.055-percent of body weight (in kg)] on the cycle ergometer followed by a 3-min active rest period on the cycle ergometer before proceeding to the next resistance exercise station. Blood lactate concentrations ([bLa]) were significantly higher at the completion of the CWIT (mean [bLa] = 6.7 mmol·L^{-1}) protocol compared to the TRAD (2.3 mmol·L^{-1}) and ACWT (4.8 mmol·L^{-1}) protocols. Estimated $\%HR_{max}$ was also significantly higher in the CWIT protocol compared to TRAD and ACWT protocols. Lastly, rating of perceived exertion was significantly higher following the CWIT protocol compared to both the TRAD and ACWT sessions.

In summary, research has shown that an acute bout of CWT can elicit suitable CV stress for improvements in CV function in the general population (13, 14, 21, 29). However, loads must be sufficient enough (≥40% 1-RM) to allow for an aerobic response indicative of CV fitness improvements, as noted by Beckham and Earnest (3). Heart rate response tends to be disproportionally elevated compared to $\dot{V}O_2$ during CWT (14, 28) and is consistent with the findings of Fleck and Dean (10) for HR responses during dynamic resistance training. It appears that combining traditional CWT with aerobic activity interspersed between resistance exercises is an effective way to elicit a greater aerobic response than with CWT alone (21, 25). Furthermore, CWT does not cause a decrement in muscular strength and power when compared to a traditional single-exercise strength protocol (2).

Chronic Cardiopulmonary Function, Muscular Fitness, Body Composition, Health and Performance Outcomes

Wilmore and colleagues (28) followed up their first acute response study (29) with a 10-week CWT program using both men and women (specific characteristics of participants not reported). Changes in body composition, HR, maximal aerobic capacity ($\dot{V}O_{2max}$), flexibility and muscular strength were measured. The participants (age range not reported) performed the training 3 days/week for 10 weeks. Circuit exercises included bench press, sit-up, leg press, latissimus pull down, low back extension, shoulder press, knee extension, biceps curl, hamstring curl, and upright row. The circuit was performed three times for 30 s per exercise at 40 to 55% 1-RM. Each exercise was performed for as many reps as possible during the 30 sec work period. Results showed significant increases in lean body mass (1.7% for men and 1.3% for women) and treadmill time to exhaustion (24.2% for men, 23.8% for women) for both men and women. Significant increases in muscular strength in all exercises occurred in women (see Table 1). Men also had significant increases in muscular strength for shoulder press, biceps curl, latissimus pull down, and hamstring curl (see Table 1). Women demonstrated improvements in $\dot{V}O_{2max}$ (3.8%) and flexibility (1.1%), and a significant decrease (1.8%) in body fat percentage. However, the men showed no significant change in any of these variables. Wilmore et al. concluded that CWT was an efficient mode of exercise for improvements in body composition, muscular strength and endurance time to exhaustion.

Gettman et al. (11) followed up the Wilmore et al. (28) study with a 20-week CWT versus running program evaluating differences in strength, aerobic capacity, and body composition in 70 male police officers (21 to 35 year of age). The officers were split into three groups; CWT (n = 11), continuous running (RN; n = 16) and sedentary control (C; n = 15). Circuit weight training was performed for 3 days/week for 2 to 3 sets with variable reps (10-20 reps) throughout the program. Repetitions progressed from 10 to 20 per set for the first six weeks and then reduced to 15 reps per set for the remaining 14 weeks. The exercises selected were bench press, knee extension, hamstring curl, biceps curl, triceps dip, leg press, sit-up, shoulder press, latissimus pull down and upright row. The running group performed jogging (with some walking) for 3 days/week for 30 min, which was maintained at 85% maximum HR range in each session. Study results showed that CWT did not elicit significant improvements in $\dot{V}O_{2max}$, which was consistent with the findings of Wilmore and colleagues (28) in regards to males. There were no significant differences between the CWT and control group for lean body weight or fat mass. However, CWT participants experienced a significant increase in leg press strength (30.2%), $\dot{V}O_{2max}$ (2.9%), and treadmill time to exhaustion (8.9%) compared to controls. Running group participants saw significant improvements from pre- to post-test in $\dot{V}O_{2max}$ (12.7%), treadmill time to exhaustion (28.9%), fat mass (-14.1%), leg press strength (26.1%) and bench press strength (12.7%). However, only $\dot{V}O_{2max}$ and treadmill time to exhaustion in the running group was significantly greater than the CWT group at the post-test.

Gettman, et al. (12) compared the difference in physiological effects of adding running to a CWT program. Three different exercise programs were assessed over a 12-week training period: CWT with running (RUN-CWT), CWT, and a control. The running was performed for 30 sec at an intensity of 60% HR_{max} immediately after each CWT station. A submaximal Bruce protocol test was performed to estimate HR_{max}. Circuit training was performed for 3 days/week using the following exercises: squat, shoulder press, hamstring curl, bench press, leg press, biceps curl, back extension, triceps extension, sit-up, and lateral shoulder raise. Three sets of 12 to 15 reps at 40% 1-

RM were performed for each exercise. Interestingly, results showed no significant differences between the RUN-CWT and CWT groups for treadmill performance time, $\dot{V}O_{2max}$, and maximum oxygen pulse. Women from the RUN-CWT and CWT groups experienced significant improvements in treadmill time to exhaustion (1.4% and 1.0%, respectively), $\dot{V}O_{2max}$ (5.2% and 4.4%, respectively), maximum O_2 Pulse (1.4% and 1.1%, respectively), lean body weight (1.0% and 1.9%, respectively), bench press strength (6.0% and 6.0%, respectively) and leg press strength (27.0% and 20.0%, respectively) form pre- to post-test. Women in the CWT group experienced a significant increase in lean body weight (1.9%) compared to the females in the RUN-CWT group (1.0%). Men from the RUN-CWT and CWT groups also experienced significant improvements in treadmill time to exhaustion (1.5% and 1.0%, respectively), $\dot{V}O_{2max}$ (6.6% and 4.8%, respectively), O_2 Pulse max (3.8% and 2.4%, respectively), lean body weight (1.8% and 1.8%, respectively), bench press strength (14.0% and 9.0%, respectively) and leg press strength (41.0% and 31.0%, respectively) from pre- to post-test. Gettman and colleagues concluded that both RUN-CWT and CWT were similarly effective programs for improving aerobic power, muscular strength and body composition.

In order to determine the effects of combined aerobic training and circuit weight training in females, Mosher et al. (23) used a similar exercise protocol design to the Gettman et al. (12) study. Thirty-three college-aged women (age = 20.6 ±1.4 yr) were split into two groups, an aerobic CWT (n = 17) and a non-exercise control group. The aerobic CWT group performed five different modes of aerobic activity three days per week for 12 weeks. The circuit lasted 45 min, incorporating 30 activities involving five aerobic stations (treadmill, bicycle ergometer, rowing ergometer, stair climbing, airdyne bicycle) along with 25 callisthenic or weight training (Station1: twist crunches, leg flexion, shoulder press, agility shuffle and squat thrusts; Station 2: V-sit crunches, mountain climbers, back latissimus pull down, jumping jacks, hip flexors; Station 3: bicycle crunches, 2-feet hops, bench press, step bench, pushups; Station 4: chair crunches, straddle mountain climbers, front latissimus pull down, leg extension, overhead press and; Station 5: straddle crunch, leg press, chest row, flutter kicks, flys) stations. Exercise intensity for the aerobic exercise was maintained at 75 to 85% of HR_{max}, determined by a graded exercise test, and the intensity for CWT exercise was between 40 - 50% of each subject's 1-RM. Mosher et al. implemented 3-min aerobic bouts on five different pieces of cardio equipment interspersed between five 30-sec exercise stations. Significant improvements in both $\dot{V}O_{2max}$ (18.2%) and treadmill time to exhaustion (8.0%) occurred in the CWT group. Improvements in muscular strength as were seen in the bench press (20.7%), shoulder press (16.4%), latissimus pull down (13.9%), leg press (22.6%), knee extension (27.1%) and hamstring curl (22.6%). In addition, abdominal endurance improved by 44.5% following the 12-week training program. A key finding from this study was that the CWT protocol elicited improvements in maximal aerobic power as well as muscular strength and endurance in college-aged women.

In an effort to compare different types of training, Alcaraz et al. (1) examined the training adaptations resulting from high-intensity circuit training (HICT) and traditional strength training during an 8-week study with 33 healthy men (22.5 ±3.5 yr).

Alcaraz et al. defined HICT as the integration of heavy loads (>70% 1-RM) into a CWT format, rather than the typical light loads used in CWT (40 – 60% 1-RM). Two circuits of three exercises each were employed during the study. The volume during the study progressed from 3 sets for each exercise in the first week to 6 sets in the eighth week. Each exercise was performed for 6 reps at 85-90% 1-RM (or 100% 6-RM). The first circuit consisted of the following exercises: knee flexion, bench press and ankle extension. The second circuit used latissimus dorsi pull down, squat, and biceps curl. Each exercise was followed by 35 sec of rest, and the two circuits were separated by 5 min of rest. Participants in the traditional strength training group completed the same exercises for the same volume but did so in a traditional weight training format (completing all sets for one exercise before moving on to the next exercise with 3-min rest between sets). Significant improvements in strength for both the bench press (~13.6%) and squat exercise (~20.0%) occurred in the HICT group, and did not significantly differ from the traditional strength training group (~20.0% and ~21.0% respectively). Furthermore, bench press peak power at 80% of 1-RM was also significantly greater in the post-test for the HICT group (10.3%) and did not significantly differ from the traditional strength training group (13.6%). Participants in the HICT group had a significant 1.5 decrease in %-body fat (-8.1%) and a significant increase in lean mass (2.5%). However, the traditional strength training group only had a significant increase in lean mass (2.1%) but did not have a significant decrease in %-body fat.

Shortly following the Alcaraz et al. (1) study, Paoli and colleagues (24) examined physiological adaptations following 12 weeks of HICT, low-intensity circuit training (LICT) and endurance training (ET) in middle-aged overweight men. The researchers recruited 58 participants (61 ±3.3 yr) for the study and were split into one of the three previously stated groups (n = 19, n = 19, n = 20, respectively). The variables examined during the study were body composition (fat mass and lean body mass), blood pressure (systolic and diastolic [DBP]), cholesterol (total, low-density lipoproteins [LDL-c], high-density lipoproteins [HDL-c]), and triglycerides. Participants in the ET group performed aerobic exercise on a cycle ergometer 3 days/week for 40-50 min per session at 50% heart rate reserve (HRR). Participants in the LICT group performed 8 min of aerobic exercise on the cycle ergometer at 50% HRR, followed by a circuit style resistance training routine for 3 circuits of four exercises (latissimus pull down, chest press, lateral shoulder raise and leg press) at 15 repetition maximum. Sixty sec of rest were given between circuit exercises. Participants in the HICT group also performed aerobic exercise on the cycle ergometer, but performed two bouts of 1 min at 75% HRR and 3 min at 50% HRR. Following the cycle ergometer, the same circuit format was performed; however, unlike the LICT, the HICT performed a “Rest-Pause” lifting style, where participants utilized a 6 RM load for each exercise. The exercise was performed for 6 reps at the 6 RM, paused for 20 sec, performed 2 more reps at the 6 RM, paused for 20 sec and performed 1-2 reps at the 6 RM. Results demonstrated significantly greater improvements in the HICT group compared to the LICT and ET groups for all of the following variables: fat mass (-17.5%), lean body mass (4%), DBP (-7%), total cholesterol (-9.5%), HDL-cholesterol (10%), LDL-cholesterol (-16%) and triglycerides (-15%).

In order to further investigate the effects on blood lipids, Miller et al. (20) recruited 8 obese men (34 ±12.1 yr) to participate in a 4-week HICT program that met three days/week using the following seven exercises: squat, bench press, partial curl-up, dead lift, burpee, bent over row and shoulder press. Exercise loads were selected to allow for 8 to 12 reps with minimal rest between exercises and progressed or modified according to this repetition range. Each exercise session lasted for approximately 30 min. The following variables were analyzed pre- and post-training: resting HR, systolic and diastolic blood pressure, total cholesterol, triglycerides, HDL-c, LDL-c, blood glucose and insulin, insulin resistance, beta-cell function, %-body fat and lean body mass. Following the 4-week HICT program, participants saw significant improvements in measures of CV function such as resting HR (-16.0%) and systolic blood pressure (-5.5%). Participants also demonstrated significant improvements in %-body fat (-1.6% from baseline) but did not significantly increase lean body mass. Fasting blood cholesterol (-10%) and circulating triacylglycerol (-22.4%) also exhibited significant improvements and there were trends for significant improvements in blood insulin (-19.1%; p = .06), insulin resistance (-18.9%; p = .07) and beta-cell function (-18.2%; p = .06).

In review, CWT elicits a significant improvement in aerobic power; however, not to the same extent as traditional aerobic training (11-12, 23). An exception to these findings come from Wilmore and colleagues (28), who did not show significant improvements in $\dot{V}O_{2max}$ in men, but did in women, following a 10-week CWT study. Improvements in aerobic power tend to be greater when integrating CWT with aerobic exercise stations (between exercises or circuits) (12, 23), which is consistent with studies comparing acute aerobic responses ($\dot{V}O_2$ and HR) to traditional CWT and combined CWT with aerobic exercise (21, 25). Other CV variables, such as resting HR and blood pressure have also been shown to improve following HICT in as little as 4 weeks (1, 20). All studies assessing CWT have shown improvements in muscular strength and endurance (11-12, 23, 29) in the general population. Improvements in body composition (increases in lean body mass and decreases in fat mass) in women (23, 28) and men (11, 20) have also been shown following CWT. Furthermore, HICT appears to be the most time-efficient way of improving physiological variables (DBP, total cholesterol, HDL-c, LDL-c and triglycerides) associated with risk for CV disease (24).

ISSN: 2326-6333

Table 1. Chronic Physiological Benefits of Circuit Weight Training and High-Intensity Circuit Training for Healthy Populations

Investigator(s)	Measured Variable(s)	n	Age, years (mean ± SD)	%-Change
Blood Markers				
Miller et al. (2014)	Total cholesterol Triacylglycerol	8	34.3 ± 12.1	-10.0% -22.4%
Cardiovascular				
Wilmore et al. (1978)	Treadmill time to exhaustion $\dot{V}O_{2max}$	50	NR	23.8 – 24.2% 3.8% for women only
Gettman et al. (1978)	Treadmill time to exhaustion	41	29.7 ± NR	8.9% change
Gettman, Ward, and Hagan (1982)	Treadmill time to exhaustion $\dot{V}O_{2max}$ MaxO_2Pulse	77	35.9 ± 5.8	1.0 – 1.5% 4.4 – 6.6% 1.1 – 3.8%
Mosher et al. (1994)	Treadmill time to exhaustion $\dot{V}O_{2max}$	33	20.6 ± 1.4	8.0% 18.2%
Miller et al. (2014)	Resting heart rate Systolic blood pressure	8	34.3 ± 12.1	-16% -5.5%
Muscular Strength and Endurance				
Wilmore et al. (1978)	*Muscular strength*: Shoulder press Bench press Upright row Biceps curl Lat pull down Leg press Hamstring curl	50	NR	 6.9 – 8.8% 14.0% 6.1% 8.1% 10.6 – 20.5% 50.0% 5.6-21.8%
Gettman, Ward, and Hagan (1982)	*Muscular strength*: Bench Press Leg Press	77	35.9 ± 5.8	 6.0 – 14% 20.0 – 41.0%
Mosher et al. (1994)	*Muscular strength*: Bench Press Shoulder Press Lat Pull Down Leg Press Knee Extension Hamstring Curl *Muscular endurance:* Abdominal	33	20.6 ± 1.4	 20.7% 16.4% 13.9% 22.6% 27.1% 22.6% 44.5%
Flexibility				
Wilmore et al. (1978)	Sit-Reach Test	50	NR	1.1% for women only
Body Composition				
Wilmore et al. (1978)	Lean body mass Fat mass	50	NR	1.3 – 1.7% -1.8%
Gettman, Ward, and Hagan (1982)	Lean body mass	77	35.9 ± 5.8	1.8%
Miller et al. (2014)	Percent-body fat	8	34.3 ± 12.1	-1.6%

Abbreviations: Percent-Change from baseline (%-Change); Maximal oxygen consumption ($\dot{V}O_{2max}$); Maximal Oxygen Pulse (MaxO_2Pulse); Not Reported (NR)

CLINICAL POPULATIONS

Acute Cardiopulmonary Function, Muscular Fitness and Safety Outcomes

Butler et al. (6) examined CV function and safety in response to an acute bout of CWT in 13 men (57 ±10 yr) with cardiac disease (4 with single-vessel, 8 with two-vessel and 1 with three-vessel coronary artery disease). A crossover design was used to compare the effect of CWT on CV responses to that of walking on a treadmill. Heart rate, blood pressure (BP), and echocardiogram inspecting segmental left ventricular wall motion were examined. Abnormal left ventricular lateral wall motion is associated with ischemia during exercise, thus detriments to the left ventricular lateral wall motion would be indicative of contraindicated exercise. Lateral wall motion was measure on a five-point numerical rating system: 3 = hyperkinetic, 2 = normal, 1 = hypokinetic, 0 = akinetic, and -1 = dyskinetic. Participants performed two circuits of eight exercises (chest fly, lateral shoulder raise, biceps curl, shoulder press, upright row, chest press, latissimus pull down, triceps extension) for ten reps between 40% and 60% 1-RM, with 60 sec of rest between exercises. The CWT protocol was compared to 35 min of continuous treadmill exercise at 85% HR_{max}. No differences were found for HR between the CWT protocol (33 ±4 $b \cdot min^{-1}$ increase from rest) and the treadmill exercise (39 ±3 $b \cdot min^{-1}$ increase from rest), and there was a higher systolic BP response during the treadmill exercise (149 ±6 mm Hg; 37 mm Hg increase from rest) compared to the CWT protocol (127 ±6 mm Hg; 7 mm Hg increase from rest). There was a positive and significant improvement in lateral wall motion during CWT (2.35 ±0.14) compared treadmill exercise (2.04 ±0.13). Butler and colleagues suggest that CWT may be less demanding on left ventricular myocardial oxygen consumption compared to aerobic exercise performed at 85% HR_{max}. Moreover, no new area of wall-motion abnormalities developed during circuit weight training. However, four left ventricular segments in two patients developed a new wall-motion abnormality during aerobic exercise. Butler et al. concluded that CWT is a safe form of training for patients with cardiac disease.

In another effort to determine the safety of CWT in cardiac patients, DeGroot and colleagues (7, 8) compared two work-to-rest ratios with two intensities; 30 sec work interval at 40% 1-RM with 30 sec of rest; 30 sec work interval at 40% 1-RM with 60 sec of rest; 30 sec work interval at 60% 1-RM with 30 sec of rest; and a 30 sec work interval at 60% 1-RM with 60 sec of rest were used to determine the optimal workload in 9 cardiac patients (63 ±7.5 yr) following an acute bout of CWT. Using the same sample, the researchers examined the following variables (which were published in two different studies): energy expenditure, blood lactate [BLa^-] and heart rate response. Results showed much lower energy cost (2.98-3.81 $kcal \cdot min^{-1}$) compared to the previous study by Wilmore et al. (28) who reported an energy cost of ~6.0-9.0 $kcal \cdot min^{-1}$. This was expected, since cardiac rehabilitation patients start at much lighter resistance exercise loads compared to those used by apparently-healthy participants as in previous studies. Furthermore, participants in the DeGroot et al. study had a higher mean age (63.3 ±7.5 yr) compared to all other studies previously cited. Energy expenditure during resistance exercise tends to decrease as we age and may explain the lower energy cost reported during the current study (18). Also, DeGroot and colleagues only had patients perform six

ISSN: 2326-6333

exercises (bench press, latissimus pull down, shoulder press, hamstring curl, triceps extension and knee extension) while Wilmore et al. (28) had participants perform 10 exercises which may have contributed to the lower energy expenditure. The response of BLa^- concentration to the protocols was significantly elevated when using 60% 1-RM (mean [bLa] = ~7.5 mmol·L^{-1}) as compared to 40% 1-RM (mean [bLa] = ~4.7 mmol·L^{-1}). Blood lactate concentration was also significantly greater following 40% 1-RM with 30 sec rest (mean [BLa^-] = ~5.5 mmol·L^{-1}) compared to 40% 1-RM with 60 sec rest (mean [BLa^-] = ~4.5 mmol·L^{-1}). There was no significant difference in mean [bLa] between the 60% 1-RM with 30 sec of rest and 60% 1-RM with 60 sec of rest protocols (8). The levels of mean [bLa] for all protocols ranged from 4.20 to 8.45 mmol·L^{-1}, and the researchers determined these BLa^- concentrations to be safe in regards to corresponding exercise intensity for cardiac patients performing CWT. However, a conservative approach for the initial exercise prescription in these populations should be used in order to maintain exercise compliance.

Though not many acute research studies have been done to assess the safety of CWT in clinical patients (6-8), all have determined that loads between 40-60% 1-RM appear to be safe for cardiac rehabilitation patients. Furthermore, these loads are in conjunction with rest intervals between 30 and 60 sec, as well as using between six to eight exercises for the circuit. Butler and colleagues (6) hypothesized that CWT may be more effective for improving lateral wall motion compared to aerobic exercise performed at similar intensities. Energy expenditure tends to be much lower in cardiac rehabilitation patients due to lower exercise intensities; however, the main goal of implementing CWT in this population is to improve overall physical fitness (muscular strength, aerobic capacity), making caloric expenditure a secondary concern.

Chronic Cardiopulmonary Function, Muscular Fitness, Body Composition, Health and Safety Outcomes

Harris and Holly (15) performed a CWT training study in 26 pre-hypertensive males (mean age = 32.1 yr). Ten participants were randomly assigned to the exercise (CWT) group and 16 were assigned to a non-exercise control group. Participants performed CWT 3 days/week for 9 weeks using three groups of exercises: Group 1: biceps curl, triceps extension; Group 2: bench press, abdominal curl, latissimus dorsi pull down, seated back row; Group 3: knee extension, leg press, hamstring curl, calf raise. Exercises were performed for 3 sets of 20 to 25 reps at 40% 1-RM. Following 9 wks of CWT, participants improved 1-RM in bench press (12.3%), leg press (53.0%) and increased lean body mass (2.2%). Participants also displayed an increase in $\dot{V}O_{2max}$ during maximal arm ergometry (7.8%). Additionally, volunteer males demonstrated a significant decrease in diastolic blood pressure (-4.7%). All outcome measures were significantly improved from pre- to post-test as well as significantly different from the non-exercise control.

Kelemen et al. (17) observed improvements in CV endurance similar to those found by Harris and Holly (15) following a CWT program in 43 males (55 ±8.5 yr) with known coronary artery disease between the ages of 35 and 70 yr. Patients were randomly assigned to either a CWT (n = 20) or control group (n = 23). Control group patients engaged in a walk/jog mixed with volleyball program, while patients in the CWT group performed the same walk/jog program with CWT. Safety between the two programs was determined by any complications that took place while participating in the study. The CWT program was performed for 3 days/week for 10 weeks and utilized the following exercises: vertical chest fly, biceps curl, shoulder press, high pulley row, low pulley row, bench press, hamstring curl, knee extension, sit-up and leg raises. Each exercise was performed for 2 sets of 10 to 15 reps at 40% 1-RM. The walk/jog program was performed after the CWT program (or after volleyball for the control group) at 85% HRmax as determined by a graded exercise test (GXT) on a treadmill. Following the training participants demonstrated improvements in aerobic function (10.8%) based on a timed treadmill walking test, as well as a decrease in body fat (-7.2%). Improvements in strength for chest fly (26.9%), shoulder press (17.0%), hamstring curl (27.0%), knee extension (52.0%), low pulley row (26.6%) and bench press (6.0%) were also observed. The walk/jog combined with volleyball group saw significant improvements in leg curl (19.0%) strength, 0.5% decrease in body fat (-2.3%) and handgrip (1.1%) strength. There was no difference in complications due to exercise for participants in the walk/jog and volleyball nor CWT group. It was concluded that CWT was a safe and effective intervention in cardiac rehabilitation programs and superior to a walk/jog combined with volleyball program.

Aerobic activity (treadmill running, rowing, cycling, stair climbing, combined arm/leg ergometry) and CWT were used to determine the effectiveness of combining these modalities on cardiorespiratory fitness, body composition, muscular strength, glucose regulation and lipid/cholesterol levels in a group of 10 males with insulin-dependent diabetes mellitus (IDDM) (22) and 11 gender-match, non-diabetic (ND) controls. Participants trained for 12 weeks using a circuit-style format, five stations with five strength exercises (using 25 different upper and lower body resistance training exercises), each circuit was preceded with a 3-min aerobic bout. The researchers reported the IDDM males had significant increases in lean body mass (3.5%), VO_2max (10.5%), average overall muscular strength (23.6%), and HDL-cholesterol levels (11.9%). Significant decreases were reported for fat mass (-5.2%), fasting blood glucose (-5.7%), LDL-cholesterol (-12.1%) and hemoglobin A_{1c} (12.4%), a marker for glycemic regulation. Participants in the ND group demonstrated similar improvements in maximal aerobic capacity (12.0%) and overall muscular strength (23.2%), but did not experience significant improvements in the blood marker variables except for HDL-cholesterol (13.5%). The key finding from this study was that the combined aerobic and strength training circuit style program elicited similar improvements in fitness and greater improvements in glycemic control compared to a ND group performing the same exercise protocol.

Dunstan and colleagues (9) examined the effects of an 8-week CWT program with participants with non-insulin-dependent diabetes mellitus (NIDDM) compared to a non-exercise control group (50.7 ±2.1 yr). Unlike the Mosher et al. (21) study that used apparently healthy participants as a non-exercise control, Dunstan and colleagues used NIDDM as the control (n = 10) to better match the CWT (n = 11) group. Participants performed exercise three non-consecutive days per week for 60 min per day using the following 10 exercises: leg extension, bench press, leg curl, dumbbell biceps curl, behind neck pull down, calf raise, dumbbell overhead press, seated row, triceps extension, and abdominal curls. Exercises were performed between 50 and 55% 1-RM for two sets for the first two weeks and three sets for weeks 3 through 8. All participants performed pre- and post- anthropometric measurements, blood pressure, self-blood glucose monitoring (SBGM) and blood analysis (serum glucose, insulin, and hemoglobin A_{1C}). There was no change in mean serum glucose and insulin from baseline in both groups; however, there was a significant increase in total serum insulin area under the OGTT curve from baseline to post-intervention for the non-exercise control group compared to the CWT group (exact values not provided). There was a relative decrease in total serum glucose are under the OGTT curve from baseline to post-intervention for the CWT group compared to an increase in the non-exercise control group (exact values not provided). Self-monitored blood glucose showed a relative maintenance in the CWT group while the non-exercise control experience a significant increase in SMBG following the 8-week intervention. The results of the study demonstrated that CWT has merit as a suitable form of exercise for the management of NIDDM. Although the findings did not demonstrate significant decreases in all blood analysis (mean serum glucose and insulin) it did negate any deterioration effects of NIDDM.

Ten years later, Kang and colleagues (16) determined that CWT improves glycemic control in females with a similar condition to the sample used by Dunstan and colleagues (9) (type 2 diabetes mellitus; T2DM). Fifteen (51.1 ±1 yr) postmenopausal women completed the 12-week study. Participants were randomized into two groups: walking exercise (WE) or CWT. Both groups performed the same quantity of exercise: 60 min, 3 days/week, for 12 weeks. The WE group walked at 60% of HRR while the CWT group combined stair climbing, stationary cycling and 5 resistance exercises (latissimus pull down, abdominal crunch, hamstring curl, knee extension, and biceps curl). All resistance exercises were performed for 3 sets of 12 reps and maintained 60% of HRR to match the WE group intensity. The following variables were analyzed pre- and post-exercise: body composition, VO_2max, hemoglobin A_{1C}, insulin, and glucose. Following the training, the CWT group showed a significant decrease in body weight (-2.6%), 2.1% decrease in body fat percentage (-7.7%), increase in muscle mass (7.0%) and an increase in VO_{2max} (7.9%). Participants in the WE group saw significant improvements in body weight (-2.8%) and a 1.0% decrease in body fat percentage (-3.3%); however, these values were significantly lower than the CWT group. Hemoglobin A_{1C} and fasting blood glucose significantly improved in the CWT group (-8.8% and -5.5%, respectively), while the WE group did not experience a significant change in these markers. However, resting blood insulin significantly improved in both groups, with the WE group (-60.2%) experiencing a more significant improvement compared to the CWT group (-17.9%). It is important to note that resting blood insulin was significantly higher in the WE group compared to the CWT group at baseline (17.04 and 13.45 $\mu U \cdot dl^{-1}$, respectively). Kang and colleagues demonstrated that CWT is suitable for improving blood glucose and insulin, as well as a lifestyle marker, such as hemoglobin A_{1C} after 12 weeks of training. Interestingly, insulin saw greater improvements following a walking program compared to CWT, but may have been due to higher insulin values in the WE group.

Maiorana et al. (18) combined CWT with aerobic activity during an 8-week training study with 13 male (60 ±2 yr) patients suffering from chronic heart failure. Participants were randomized into either an 8-week exercise or non-exercise period. Following the 8 weeks, participants switched into the opposite condition. Participants performed CWT 3 days/week using the following exercises: leg press, left hip extension, right hip extension, chest exercises (not specified), shoulder flexion, seated abdominal crunch, and hamstring curl. Exercise intensity started at 55% 1-RM and increased to 65% 1-RM by week 4, while cycle ergometry and treadmill walking commenced at 60% peak HR and increased to 85% peak HR by week 6. Peak HR was determined by a submaximal GXT on a cycle ergometer. The combination of aerobic training (eight 45-sec bouts on a cycle or treadmill) and CWT (15 reps for 1 to 3 sets depending on tolerance) increased the aerobic response in terms of relative (11.4%) and absolute $\dot{V}O_{2max}$ (10.5%), as well as a significant decrease in HR response after exercising at 60 watts (-11.1%) and 80 watts (-10.7%) during the post-GXT starting at 20 watts and increasing 20 watts every 3 min.

Resistance training is essential for maintaining bone mineral density and bone mass especially in post-menopausal women. Thus, Brentano et al. (5) investigated the physiological adaptations to strength and CWT in 28 postmenopausal women (mean age not presented) with bone loss. Participants were divided into three groups; strength training (ST) (n=10), CWT, (n= 9), and control, (n=9). The CWT group performed 24 weeks of training for 3 days/week. Ten exercises (leg press, hip abduction, hip adduction, knee extension, chest fly, reverse fly, biceps curl, triceps extension, sit-up, low back extension) were performed for 2 to 3 sets of 10 to 20 reps at 45-60% 1-RM with little to no rest between exercises. The ST group performed the same exercises for 2 to 4 sets of 6 to 20 reps at 45-80% 1-RM with 2-min rest between sets. For both groups, a new 1-RM test was performed every 8 weeks and matched with the same relative intensity for the exercise. Both the ST and CWT groups improved in $\dot{V}O_{2max}$ (~20.0%), treadmill time to exhaustion (~20.0%) and dynamic upper-body (~30.0%) and lower-body (~35.0%) strength compared to the control. Neither group demonstrated a significant change in bone mineral density (BMD). Brentano and colleagues determined that both CWT and traditional ST improved both strength and CV fitness in post-menopausal women; however, BMD saw slightly greater improvements (non-significant) in the ST group and CWT may not be the most suitable option for improving BMD.

In summary, the evidence shows that CWT is an effective exercise strategy for combatting many clinical diseases (5, 9, 15-18, 22). Improvements such as decreases in DBP (15), insulin (16), hemoglobin A_{1C} (22), body weight and percent-body fat, as well as increases in functional capacity (5, 15-18, 22) and muscular strength and endurance are experienced in individuals with hypertension, IDDM, and a chronic heart condition following 8 to 12 weeks of CWT. However, eliciting improvements in BMD in post-menopausal women may be best with traditional ST and not CWT (5). Results from studies using participants with NIDDM/T2DM indicate that CWT seems to be a suitable intervention for combatting the negative side effects of the fastest growing disease in the world (9, 16).

Table 2. Chronic Physiological Benefits of Circuit Weight Training in Clinical Populations

Investigator(s)	Measured Variable(s)	*n*	Age, years (mean ± SD)	%-Change
Blood Markers				
Kang et al. 2009	HbA_{1C} Resting blood glucose Resting blood insulin	15	51.1 ± 1.0	-8.8% -5.5% -17.9%
Cardiovascular				
Harris and Holly (1987)	$\dot{V}O_{2max}$ Blood Pressure	26	32 ± 5.7	7.8% -4.7%
Kelemen et al. (1986)	Treadmill time to exhaustion	43	55 ± 8.5	10.8%
Maiorana et al. (2000)	$\dot{V}O_{2max}$	13	60 ± 2.0	11.4%
Brentano et al. (2008)	Treadmill time to exhaustion $\dot{V}O_{2max}$			20.0% 20.0%
Kang et al. 2009	$\dot{V}O_{2max}$	15	51.1 ± 1.0	7.9%
Muscular Strength and Endurance				
Harris and Holly (1987)	*Muscular Strength*: Bench Press Leg Press	26	32 ± 5.7	 12.3% 53.0%
Kelemen et al. (1986)	*Muscular Strength*: Bench Press Chest Fly Shoulder Press Hamstring Curl Knee Extension Low Pulley Row	43	55 ± 8.5	 6.0% 26.9% 17.0% 27.0% 52.0% 26.6%
Mosher et al. (1998)	*Muscular Strength*: MVC_7	10	17 ± 1.2	 23.6%
Brentano et al. (2008)	*Muscular Strength*: Upper-body Lower-body	28	NR	 ~30.0% ~35.0%
Body Composition				
Harris and Holly (1987)	Lean body mass	26	32 ± 5.7	2.2%
Kelemen et al. (1986)	Fat mass	43	55 ± 8.5	-7.2%
Mosher et al. (1998)	Lean body mass Fat mass	10	17 ± 1.2	3.5% -5.2%
Kang et al. (2009)	Body weight Percent-body fat Lean body mass	15	51.1 ± 1.0	-2.6% -7.7% 7.0%

Abbreviations: Percent-Change from baseline (%-Change); Maximal oxygen consumption ($\dot{V}O_{2max}$); Average of Seven Maximal Voluntary Contractions (MVC_7); Hemoglobin A_{1C} (HbA_{1C}); Not Reported (NR)

OLDER ADULT POPULATIONS

The only CWT study to our knowledge to use healthy older adults (n=18, 8 men, 10 women; 68 ±5 yr) was done by Takeshima and colleagues (27). Participants were considered sedentary, but were free of signs and symptoms of disease, and were not taking medications for any CV, metabolic or pulmonary diseases. Each participant performed a stage GXT on a cycle ergometer in which metabolic gases, HR, RPE and blood lactate were collected every minute during the test. The training exercise protocol consisted of 12 30-sec strength exercises integrated with 30 sec of aerobic activity (marching with arm movements). Every 4 weeks the researchers progressively overloaded all resistance exercises (resistance dial between 1 and 6; set at “2” for weeks 0-4, “3” for weeks 5-8 and “4” for weeks 9-12) during the 12-week program. Participants in the exercise group were compared to a non-exercise control. Results showed no significant decreases in body mass for either the exercise or sedentary groups. There was a significant decrease in skinfold thickness (-16%) in the exercise group and a non-significant increase in the control group (6.16%). A significant increase in HDL-cholesterol (10.9 $mg \cdot dL^{-1}$) was also found in the exercise group, but no differences were observed between groups for LDL-cholesterol. The older adults in the exercise group improved in aerobic capacity (29%) determined by $\dot{V}O_2$ at the lactate threshold, as well as peak $\dot{V}O_2$ (15%) during an exercise test.

Bocalini and colleagues (4) examined the effects of 12 weeks of CWT in 69 elderly (67.9 ±9 yr) women, 18 of which were obese as defined by a body mass index (BMI) greater than 30 $kg \cdot m^{-2}$. The participants were split into three distinct groups based on BMI: normal, overweight and obese. All groups had a training and control subgroup. Exercise sessions were performed for 50 min per day, three days per week. The following 12 exercises were used: knee flexion, front shoulder raise, lateral shoulder raise, straight-arm latissimus pull down, shoulder rotation, squat, biceps curl, triceps extension, calve raise, push-up, abdominal crunch and hip extension. All exercises were performed for 45 sec with 40 sec of rest between exercises and intensity was maintained at 70% of the target heart rate [as determined using the Karvonen equation: .70·(maximal HR – resting HR) + resting HR]. Results showed that participants taking part in training in the obesity group had the largest improvements from baseline in body weight (-8.0%), %-body fat (-20.7%), fat mass (-52.6%) and lean body mass (8.6%). Significant improvements also occurred in participants taking part in training in the overweight group for body weight (-4.5%), %-body fat (-10.0%) and fat mass (-15.0%); however, no significant improvements occurred in any anthropometric variables for the normal weight group. We can conclude that CWT is a viable option for decreasing body weight and %-body fat in overweight and obese elderly women, while eliciting improvements in lean body mass.

DISCUSSION

Circuit weight training is a time efficient and effective way of implementing RT programs into healthy and clinical populations. Research indicates that CWT is a safe and effective program for individuals with cardiac disease and other clinical disorders (e.g., hypertension, diabetes mellitus). Improvements in both strength and aerobic capacity ($\dot{V}O_{2max}$) are evident when the appropriate loads are used. Body composition improvements as observed with

ISSN: 2326-6333

increases in lean mass and decreases in fat mass are also evident following CWT in general and clinical populations. In clinical populations meaningful decreases in resting blood pressure, heart rate and hemoglobin A_{1c} have been shown. The time efficiency in which results are attained following CWT are advantages as compared to traditional resistance training. Lastly, the ability to integrate various aerobic activities into CWT provides further improvements in markers of CV health. Although there has been some research investigating the acute response of the integration of CWT and HIIT (CWIT) (25), training studies examining the chronic adaptations between this CWIT and traditional CWT have yet to be performed. An integration of CWT and HIIT may be the most time efficient form of exercise to improve both muscular strength and aerobic capacity.

The results of this review reveal that CWT is a sufficient means of eliciting an acute aerobic response while maintaining muscular strength, power and endurance. Training studies examining CWT have proven that these acute responses can lead to improvements in aerobic capacity and muscular strength and endurance. Furthermore, decreases in body fat and increases in lean body mass have also been shown following CWT. Utilizing rest periods as “aerobic” stations between circuit exercises may be the most effective way of improving aerobic capacity when implementing CWT into an exercise program. There appears to be a compromise when implementing CWT into a training program, meaning exercisers may be able to make some improvements in both muscular strength and cardiovascular endurance but not optimize either. It is still important to perform muscular strength and aerobic endurance in isolation to optimize these types of improvements and implement CWT for more time-efficient workouts (shorter in duration to stimulate both muscular strength and aerobic endurance). The combination of CWT with integrated aerobic bouts (in between circuits) appears to elicit the greatest improvements in aerobic endurance.

Circuit weight training appears to be safe for cardiac rehabilitation patients and has proven to be effective for improving blood pressure in borderline hypertensive patients and hemoglobin A_{1C} in individuals with insulin-dependent diabetic mellitus. More recent research in the area of high-intensity circuit training has also proven to be safe for individuals who are obese and have dyslipidemia. This progression of CWT leads to large improvements in total cholesterol, low-density lipoproteins, high-density lipoproteins and triglycerides, as well as improvements in body composition.

ACKNOWLEDGEMENTS

The authors would like to thank their colleagues who provided feedback on this review. There were/are no professional relationships with companies or manufacturers identified in this review. The the findings of the review are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

1. Alcaraz PE, Perez-Gomez J, Chavarrias M, and Blazevich AJ. Similarity in adaptations to high-resistance circuit vs. traditional strength training in resistance-trained men. Journal of

Strength & Conditioning Research. 2011; 25: 2519-2527.
2. Alcaraz PE, Sánchez-Lorente J, and Blazevich AJ. Physical performance and cardiovascular responses to an acute bout of heavy resistance circuit training versus traditional strength training. Journal of Strength & Conditioning Research. 2008; 22: 667-671.
3. Beckham SG and Earnest CP. Metabolic cost of free weight circuit weight training. Journal of sports medicine and physical fitness. 2000; 40: 118-125.
4. Bocalini DS., Lima LS., de Andrade S., Madureira A., Rica RL., dos Santos RN., Serra AJ., Silva Jr. JA., Rodriguez D., Figueira Jr. A and Pontes Jr. FL. Effects of circuit-based exercise programs on the body composition of elderly obese women. Clinical Interventions in Aging. 2012; 7: 551-556.
5. Brentano MA, Cadore EL, Da Silva EM, Ambrosini AB, Coertjens M, Petkowicz R, Viero I, and Kruel LFM. Physiological adaptations to strength and circuit training in postmenopausal women with bone loss. Journal of Strength & Conditioning Research. 2008; 22: 1816-1825.
6. Butler RM, Beierwaltes WH, and Rogers FJ. The cardiovascular response to circuit weight training in patients with cardiac disease. Journal of Cardiopulmonary Rehabilitation and Prevention. 1987: 7; 402-409.
7. DeGroot DW, Quinn TJ, Kertzer R, Vroman NB, and Olney WB. Circuit weight training in cardiac patients: determining optimal workloads for safety and energy expenditure. Journal of Cardiopulmonary Rehabilitation and Prevention. 1998: 18; 145-152.
8. DeGroot DW, Quinn TJ, Kertzer R, Vroman NB, and Olney WB. Lactic acid accumulation in cardiac patients performing circuit weight training: implications for exercise prescription. Archives of physical medicine and rehabilitation. 1998: 79; 838-841.
9. Dunstan DW, Puddey IB, Beilin LJ, Burke V, Morton AR, and Stanton KG. Effects of a short-term circuit weight training program on glycaemic control in NIDDM. Diabetes Research and Clinical Practice. 1998: 40; 53-61.
10. Fleck SJ and Dean LS Resistance-training experience and the pressor response during resistance exercise Journal of applied physiology. 1987: 63; 116-120.
11. Gettman LR, Ayres JJ, Pollock ML, and Jackson A. The effect of circuit weight training on strength, cardiorespiratory function, and body composition of adult men. Medicine and science in sports. 1977: 10; 171-176.
12. Gettman LR, Ward P, and Hagan RD. A comparison of combined running and weight training with circuit weight training. Medicine and science in sports and exercise. 1981: 14; 229-234.
13. Gordon NF, Kohl HW, Villegas JA, Pickett KP, Vaandrager H, and Duncan JJ. Effect of Rest Interval Duration on Cardiorespiratory Responses to Hydraulic Resistance Circuit Training. Journal of Cardiopulmonary Rehabilitation and Prevention. 1989: 9; 325-330.
14. Gotshalk LA, Berger RA, and Kraemer WJ. Cardiovascular responses to a high-volume continuous circuit resistance training protocol. Journal of Strength & Conditioning Research. 2004: 18; 760-764.

15. Harris KA and Holly RG. Physiological response to circuit weight training in borderline hypertensive subjects. Medicine and science in sports and exercise. 1987: 19; 246-252.
16. Kang S, Woo JH, Shin KO, Kim D, Lee H, Kim YJ and Yeo NH. Circuit resistance exercise improves glycemic control and adipokines in females with type 2 diabetes mellitus. Journal of Sports Science and Medicine. 2009: 8; 682-688.
17. Kelemen MH, Stewart KJ, Gillilan RE, Ewart CK, Valenti SA, Manley JD, and Kelemen MD. Circuit weight training in cardiac patients. Journal of the American College of Cardiology. 1986: 7; 38-42.
18. Maiorana A, O'Driscoll G, Cheetham C, Collis J, Goodman C, Rankin S, Taylor R, and Green D. Combined aerobic and resistance exercise training improves functional capacity and strength in CHF. Journal of applied physiology. 2000: 88; 1565-1570.
19. Manini TM. Energy expenditure and aging. Ageing research reviews. 2010: 9; 1-11.
20. Miller MB, Pearcey GEP, Cahill F, McCarthy H, Stratton SBD, Noftall JC, Buckel S, Basset FA, Sun G, Button DC. The effect of a short-term high-intensity circuit training on work capacity, body composition, and blood profiles in sedentary obese men: a pilot study. Biomedical Research International. 2014: 1-10.
21. Monteiro AG, Alveno DA, Prado M, Monteiro GA, Ugrinowitsch C, Aoki MS, and Picarro IC. Acute physiological responses to different circuit training protocols. Journal of Sports Medicine and Physical Fitness. 2008: 48; 438-442.
22. Mosher PE, Nash MS, Perry AC, LaPerriere AR, and Goldberg RB. Aerobic circuit exercise training: effect on adolescents with well-controlled insulin-dependent diabetes mellitus. Archives of physical medicine and rehabilitation. 1998: 79; 652-657.
23. Mosher PE, Underwood SA, Ferguson MA, and Arnold RO. Effects of 12 Weeks of Aerobic Circuit Training on Aerobic Capacity, Muscular Strength, and Body Composition in College-Age Women. Journal of Strength & Conditioning Research. 1994: 8; 144-148.
24. Paoli A, Pacelli QF, Moro T, Marcolin G, Neri M, Battaglia G, Sergi G, Bolzetta F, and Bianco A. Effects of high-intensity circuit training, low-intensity circuit training and endurance training on blood pressure and lipoproteins in middle-aged overweight men. Lipids in health and disease. 2013: 12; 1-8.
25. Skidmore BL, Jones MT, Blegen M, and Matthews TD. Acute effects of three different circuit weight training protocols on blood lactate, heart rate, and rating of perceived exertion in recreationally active women. Journal of Sports Science and Medicine. 2012: 11; 660-668.
26. Sorani RP. Circuit training. Wm. C. Brown, 1966.
27. Takeshima N, Rogers ME, Islam MM, Yamauchi T, Watanabe E, and Okada A. Effect of concurrent aerobic and resistance circuit exercise training on fitness in older adults. European journal of applied physiology. 2004: 93; 173-182.
28. Wilmore JH, Parr RB, Girandola RN, Ward P, Vodak PA, Barstow TJ, Pipes TV, Romero GT, and Leslie P.

Physiological alterations consequent to circuit weight training. Medicine and science in sports. 1977: 10; 79-84.
29. Wilmore JH, Parr RB, Ward P, Vodak PA, Barstow TJ, Pipes TV, Grimditch G, and Leslie P. Energy cost of circuit weight training. Medicine and science in sports. 1977: 10; 75-78.

ISSN: 2326-6333