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Body composition and physical fitness improve after 8 weeks of high-intensity circuit training using body weight in obese women

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Manuscript title

Body composition and physical fitness improve after 8 weeks of high-intensity circuit training using body weight in obese women

Running title

Effects of HICT using body weight in obese women

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ABSTRACT

We examined the effects of an 8-week modified high-intensity circuit training using body weight as resistance ($HICT^{BW}$) on health-related physical fitness in sedentary obese women.

METHODS:Twenty-four sedentary obese women were allocated into the $HICT^{BW}$ or a non-training control group (CG). The modified $HICT^{BW}$ was performed for 8 weeks (3 times per week). Training consisted of a 30-second workout and 10-second rest for 12 exercise poses per 1 circuit (1 circuit in the first week), with an increase of 1 circuit every 2 weeks. Body weight and body composition included skeletal muscle mass (SMM), body fat mass (BFM), body fat percentage (BF%), visceral fat area (VFA), and skeletal muscle mass to visceral fat area ratio (MFR) were measured. Physical fitness included flexibility of the lower back and hamstrings ($Flex_{LH}$), and leg and handgrip muscle strength ($Strength_{Leg}$, $Strength_{HG}$). Cardiovascular endurance included the Åstrand-Rhyming heart rate ($HR_{Åstrand}$), relative maximum oxygen uptake (relative $\dot{V}O_{2max}$), and workload.

RESULTS: All variables were obtained at baseline, week-4, and week-8. The $HICT^{BW}$ improved $Flex_{LH}$, $Strength_{Leg}$, and relative $\dot{V}O_{2max}$ from baseline to week-4 (All P<0.05). Improvements from baseline to week-8 were observed for SMM, BFM, BF%, VFA and MFR, $Flex_{LH}$, $Strength_{Leg}$, $HR_{Åstrand}$, relative $\dot{V}O_{2max}$, and workload (All p<0.05). Furthermore, the $HICT^{BW}$ elicited a higher change in SMM (+2.9%), BFM (-3.4%), BF% (-3.2%), MFR (+9.5%), $Flex_{LH}$ (+145.7%) and relative $\dot{V}O_{2max}$ (+32.3%) than the CG at week-8 (All P<0.05).

CONCLUSIONS: An 8-week modified $HICT^{BW}$ program thrice a week is an effective training modality to influence health-related physical fitness in sedentary obese women.

Keywords: High intensity circuit training- Obesity- Body composition - Muscle-to-fat ratio – Body weight resistance

Introduction

The prevalence of obesity continues to increase around the world [1] and has become a major problem in many Southeast Asian countries [2]. Obesity is one of the major risk factors for non-communicable diseases including coronary heart disease, type 2 diabetes, stroke, and cancer [3]. Sedentary behavior along with intake of an unhealthy high energy diet has been directly associated with excessive weight gain [4]. Healthcare providers offer various therapies, e.g. dietary therapy and pharmacotherapy, and physical activity and exercise guidance for people with weight management issues [5].

The American College of Sports Medicine advocates the benefits of regular exercise, with a combination of resistance and aerobic exercise for sedentary people. Whereas resistance exercise is well documented to improve musculoskeletal function, aerobic exercise can decrease fat mass and resting heart rate, and increase maximal oxygen consumption. The combination of these two exercises is known as high-intensity circuit training (i.e. HICT), and can provide more beneficial effects than performing each type of exercise separately [6, 7]. In 2013, Paoli *et al.* [7] reported that a HICT (3 times per week, 50 min per session for 12 weeks) with resistance exercise stations providing the external load (i.e. $HICT^{traditional}$) was more effective for beneficial changes of body composition and blood lipids (i.e. lipoproteins and triglycerides) in middle-aged overweight men compared to low-intensity circuit training and endurance training. In addition, Miller *et al.* [6] showed that 4 weeks of HICT for a total of 6 hours of exercise (3 times per week, 30 min per session), with a program of increasing the amount of weight lifted for each repetition during resistance exercise, improved health-related physical fitness parameters, i.e., body composition, blood profiles (i.e. cholesterol, triacylglycerol, and insulin) and work capacity in sedentary obese men.

Because of the prescribed demand for an increase in exercise intensity in a HICT^{traditional} program, there is evidence of adverse effects during the training with muscle soreness and pain being reported [8-10]. Sperlich *et al.* [10] showed that the overweight women who trained with the HICT^{traditional} program perceived more pain after the 9-week intervention than those who trained in combination with high-volume, low-intensity exercise. Consequently, the unpleasant feelings of pain caused by the high load required in the HICT^{traditional} program might discourage participation and adherence by sedentary obese women.

Instead of the HICT^{traditional} program, the HICT using only bodyweight as a form of resistance (i.e. HICT^{BW}) was firstly introduced by Klika and Jordan in 2013 [11]. It is well documented that HICT^{BW} is an accessible and applicable training modality to promote health-related physical fitness for untrained individuals. For example, Schmidt et al.(2016) [12] designed an 8-week HICT^{BW} program (3 times per week, 7 min per session) for recreationally active young men and women and reported improvement of muscle strength in men, whereas aerobic fitness was improved only in active women. In addition, our previous study found that a 4-week HICT^{BW} program (3 times per week with the volume gradually increasing from 1 circuit in week-1, 2 circuits in weeks 2 and 3, and 3 circuits in week-4, respectively) could improve cardiorespiratory fitness in sedentary women [13]. This gives rise to the question that whether the HICT^{BW} program would provide benefits in sedentary obese women. Therefore, this study aimed to examine the effects of an 8-week HICT^{BW} training program on body composition, flexibility, strength, and cardiovascular endurance in sedentary obese type I South-East Asian women.

Materials and methods

Participants

In this study, sample size estimates were calculated from a previous study [13] using G*Power 3.1.9.2 analysis (Effect size: f = 1.22, Alpha = 0.05, power = 0.8, sample size = 8, critical t = 2.36, Lambda = 3.47). Therefore, 8 plus 4 participants in each group (n=12, added 50% dropout) and 24 participants in total. The study was started in May 2017 and completed in May 2018.

Twenty-four sedentary, obese type I South-East Asian women (BMI = 25-29.9 $kg \cdot m^{-2}$) [14], aged between 26 to 35 years, were selected based on their peak oxygen uptake (VO_{2peak} < 30 $mL \cdot kg^{-1} \cdot min^{-1}$) [15]. Interviews and physical activity questionnaires confirmed that participants had sedentary lifestyles by performing only activities of daily living without engaging in any other organized exercises. Exclusion criteria included musculoskeletal disorders, hypertension, diabetes, or any other known medical conditions, use of prescription medications including nutritional supplements, and smoking. Participants were instructed not to undertake any activities that differed from their usual routines and not to change their dietary habits during the study period. After the explanation of the protocols, benefits, and possible risks of the study, a written informed consent form was provided. The experimental procedure was approved by the local Ethics Committee on Human Experimentation.

Experimental design

The overall timeline of the study is illustrated in Figure 1. A familiarization session was performed within a week before data collection. The participants were randomly divided by employing a computer program into 2 groups; a $HICT^{BW}$ (n=12) and a non-training control group (n=12, CG). Baseline measurements were done within a week before assigning the participants to one of the interventions, whereas post-measurements (week-4 and week-8) were conducted within 2 days after completion of half and the complete program. Measurements were performed in the morning after a time of two hours from the same light breakfast. Participants were advised to avoid any strenuous activity for 24 hours prior to the test and avoid a heavy meal or caffeine within 2 to 3 hours of testing, and keep normal hydration status thoughout the testing session. The orders of measurements were started with physical characteristics and body composition measures, physical fitness measures, and cardiovascular endurance measures, respectively.

<u>Measurements</u>

Physical characteristics and body composition measures

Age (yrs), body weight (BW, kg), height (cm), seated resting heart rate ($HR_{Resting}$, bpm), and blood pressure (BP, mmHg) were recorded for each participant. Height and BW were measured with participants barefooted. Height was measured to the nearest 0.5 cm using a calibrated stadiometer. Body mass index (BMI) was calculated according to the formula of BW (kg) divided by the square of the body height (m).

Body composition variables were assessed using bioelectrical impedance analysis (BIA). The InBody720 (Biospace Co. Ltd., Seoul, Republic of Korea) was used to obtain body fat mass (BFM), skeletal muscle mass (SMM), body fat percentage (BF%), visceral fat area (VFA) following protocol guidelines from the manufacturer. The values for skeletal muscle mass to visceral fat area ratio (MFR) were derived from SMM values divided by VFA values. For the BIA measurements, participants were required to be in a fasted state for a minimum of 12-h. In addition, participants were barefoot, had cleaned their hands and feet and were not wearing any metal.

Physical fitness measures

The flexibility of the lower back and hamstrings ($Flex_{LH}$) was measured using a sit and reach box [16]. Participants sat with their heels firmly against the testing box. Participants kept their knees extended and placed their right hand over the left, with the long fingers even, and reached forward as far as they could by sliding their hands along the measuring board. A tape measure on the top of the measuring board indicated in centimeters how far beyond the toes each individual reached. Three trials were performed, and the average was used for data analysis.

A handgrip dynamometer (Takei A5401 Digital Hand Grip Dynamometer, Japan) was used for testing strength of the right and left hands (Rt. And Lt. $Strength_{HG}$). The participant was standing with the dynamometer in the hand of their choice and with the arm extended and slightly separated from the trunk. The grip of the dynamometer is adjusted to the size of the hand to bring the second joint of the forefinger approximately to a right angle. The participants squeezed the handles with maximal effort for 5 s. The measurement, which was recorded to the nearest 0.1 kg, was performed twice, and the highest value was retained. A 1-min break was permitted between the measurements. The values of Rt. And Lt. $Strength_{HG}$ were divided by the participant's BW to calculate the relative $Strength_{HG}$.

Maximum isometric leg muscle strength ($Strength_{Leg}$) was evaluated using a back and leg dynamometer (Takei Instruments Ltd, Tokyo, Japan) [17]. After 3 min of independent warm-up, the participant stood on a platform with the scapulae and buttocks positioned flat against the wall. Participants flexed their legs in the angle of 135 degrees. The participants' held the hand bar using a pronated grip, positioned across the thighs by adjusting the length of the chain. Next, by straightening the knees and lifting the chain of the dynamometer without leg contacted to the dynamometer's grab handle, the maximal pulling force was applied to the handle.

Maximum performance would result when the legs almost straight at the end of the lift. The test was performed three times with a 30-s rest interval and the highest value was selected.

Cardiovascular endurance measures

Cardiovascular endurance variables were evaluated using 6-min submaximal exercise testing on an ergometer (Ergomedic 828E; MONARK, Sweden) following the Åstrand-Rhyming cycle ergometer protocol [18]. The HR was continuously recorded during the test using a Polar heart rate monitor (Polar RS800CX, Polar Electro Oy, Kempele, Finland). Before the test, the HR was measured for 5 min after a 10-min rest in a sitting position. Participants were familiarized with pedaling on a cycle ergometer for 2 min. The testing started from a 10-min warm-up without load, then the initial workload was set at 50 watts and keep the cadence at 50-55 rpm for 6 min. If the HR of participants at the 6th min was lower than 120 bpm, the workload was increased, and testing was continud for 3 min. Conversely, the testing was terminated when the HR was between 120-170 bpm at the last minute, and then the values of heart rate ($HR_{Åstrand}$) and the workload at this point were recorded. Whereas, the $\dot{V}O_{2peak}$ was predicted from the Åstrand-Rhyming Nomogram and multiplied by the age-correction factors to account for the decrease in the HR_{max} with age [18].

The HICT^{BW} program

The HICT^{BW}program was modified from Klika and Jordan [11], in ^{which} all exercise poses were adjusted by reducing the load to the joints as shown in the previous study [13]. A listing of the order of exercise poses is provided in Table 1.

Before starting the training program, the participants underwent familiarization for the exercises in 1 circuit. The training program was performed 3 times per week over 8 weeks, with the volume gradually increased from 1 circuit in week-1, 2 circuits in weeks 2 and 3, 3 circuits in weeks 4 and 5, 4 circuits in weeks 6 and 7, and 5 circuits in week-8 of training. The exercise protocol was comprised of a 5-minute warm-up, the main $HICT^{BW}$ program, and a 5-min cool-down. Each circuit consisted of a 30-s workout and 10-s rest for 12 exercise poses per 1 circuit (Table 2**)**. For the repetitions of each exercise pose, the participants were self-guided to perform as many as possible within a 30-s workout to promote pleasant feelings and engagement to activities. This routine was conducted by sports scientists for demonstration and performed in an exercising room. Attendance was taken throughout the 8 weeks. Furthermore, after a workout, the participants were routinely asked if they experienced pain, muscle soreness, unpleasant feelings, or injury from the training. Then, participant complaints and adverse events were recorded. The training was scheduled at the same time of day (5:00 pm to 6:00 pm) to reduce circadian variation. Upon completion of 4 weeks and 8 weeks of exercise training, participants repeated the same test battery for all variables measured at baseline.

During the exercise sessions, the HR was continuously measured using a Polar heart rate monitor. The HR values of each exercise pose ($HR_{Exercise\ pose}$) were used to calculate exercise intensity, which was determined as a percentage of heart rate reserve (%HRR) and calculated following the Karvonen method [19]:

Maximum heart rate (HR_{Max}) =220 – Age (in years)

$HRR = HR_{Max} - HR_{Resting}$

Exercise intensity (%HRR) = ($HR_{Exercise\ pose} - HR_{Resting}$ / HRR) x 100

Levels of exercise intensity: Very light = %HRR less than 30, Light = %HRR between 30-39, Moderate = %HRR between 40-59, and Vigorous = %HRR between 60-84 [20]

The %HRR was continuously increased from 44%HRR (moderate intensity) at week-1, 58%HRR (moderate intensity) at week-4, and reached 63%HRR (vigorous intensity) at week-8. The levels of exercise intensity are shown in Table 1.

Statistical analysis

Data for general physical characteristics are reported as the mean ±SD, and data for the rest variables are reported as the mean ±SEM). All data were confirmed to be normally distributed by the Kolmogorov-Smirnov test. A repeated-measures analysis of variance (ANOVA) was performed with 2 groups (i.e., CG versus HICT^{BW} group) x 3 times (i.e. week-0 versus week-4 versus week-8). For each variable, the values of the magnitude of the differences (F value), the significance (P), and the effect size partial eta-square (η_p^2) are shown. The Bonferroni test was used for post hoc analysis. To account for differences in all variables from week-0 to week-4 (Δ_{0-4}) and week-0 to week-8 (Δ_{0-8}), all values were expressed as percentage changes from week-0 using the formula: [(week-4 or week-8 minus week-0) and divided by week-0] multiplied by 100. Differences in %Δ_{0-4} and %Δ_{0-8} for all variables between the two groups were analyzed using the independent *t*-test. A P-value < 0.05 was considered statistically significant.

Results

Participant characteristics of both groups are shown in Table 3. At baseline, there were no differences between groups regarding all variables. The BMI values of participants were classified as obese type I [14]. In addition, the $\dot{V}O_{2peak}$ values indicated low physical fitness levels (24.9-28.6 mL·kg^{-1} ·min^{-1}) [21] and confirmed the sedentary behavior of the participants.

Participants reported no injury throughout the 8-week program. However, 4 subjects (~ 33%) complained of mild muscle pain and soreness after a workout in week-1 but the symptoms were continuously reduced in week-2, -3, and -4, and disappeared at the end of week-5. Moreover, no unpleasant feelings and dropouts were noted during the program (Table 2).

The body composition variables

As shown in Table 4, significant main effects of group x time were observed for the BFM ($F_{2,44}$ = 5.23, η_p^2= 0.19, P=0.01) and BF% ($F_{2,44}$ = 4.18, η_p^2= 0.16, P=0.02). Significant interaction effects of time were observed for the SMM ($F_{2,44}$ = 3.94, η_p^2= 0.15, P=0.027). Pair-wise comparisons indicated that the $HICT^{BW}$ had an increase in the SMM (P = 0.008) and MFR (P=0.038), as well as a decrease in the BFM (P =0.013), BF% (P =0.008), VFA (P=0.044) between week-0 and week-8, but not between week-0 and week-4. However, there were no changes in any variables from baseline to any time points in the CG (P >0.05).

The differences in percentage changes between the CG and $HICT^{BW}$ groups indicated that the $HICT^{BW}$ elicited a change in the SMM (P =0.05), BFM (P =0.009), % BF (P=0.01), and MFR (P=0.02) than the CG at week-8 ($\%\Delta_{0-8}$). However, there were no changes between groups at week-4 ($\%\Delta_{0-4}$).

The physical fitness variables

As shown in Table 5, significant interaction effects of group x time were observed for the $Flex_{LH}$ ($F_{2,44}$ = 7.85, η_p^2= 0.26, P=0.001) and significant interaction effects of time were observed for the $Strength_{Leg}$ ($F_{2,44}$ = 15.32, η_p^2= 0.41, P<0.0001). No significant differences were observed for Rt.- and Lt.- Relative $Strength_{HG}$ (P >0.05). Pair-wise comparisons indicated that a significant difference between groups for the $Flex_{LH}$ (P <0.046) was obtained at week-8, with the increase in the $HICT^{BW}$ greater than the CG. Moreover, the $HICT^{BW}$ displayed significant post-intervention improvements for the $Flex_{LH}$ and $Strength_{Leg}$ from week-0 to week-4 ($Flex_{LH}$ and $Strength_{Leg}$; P = 0.036 and P = 0.005, respectively) and week-0 to week-8 ($Flex_{LH}$ and $Strength_{Leg}$; P<0.0001 and P<0.0001, respectively). Whereas, there were no changes in any variables from baseline to any time points in the CG (P >0.05).

The differences in percentage changes between the CG and $HICT^{BW}$ groups indicated that the $HICT^{BW}$ elicited a greater change in the $Flex_{LH}$ than the CG at week-8 ($\%\Delta_{0-8}$) (P =0.034). However, there were no changes between groups at week-4.

<u>The cardiovascular endurance variables</u>

As shown in Table 6, significant interaction effects of group x time were observed for the relative $\dot{V}O_{2peak}$ ($F_{2,44}$ = 3.93, η_p^2= 0.15, P=0.027) and significant interaction effects of time were observed for the relative $\dot{V}O_{2peak}$ (F2,44 = 10.39, ηp²= 0.32, P=0.0001), $HR_{Åstrand}$ ($F_{2,44}$ = 5.75, η_p^2= 0.21, P=0.006) and the cycling workload ($F_{2,44}$ = 4.31, η_p^2= 0.16, P=0.020). Pair-wise comparisons indicated that the $HICT^{BW}$ induced a significant increase in the relative $\dot{V}O_{2peak}$ from week-0 to week-4 (P = 0.031) and week-0 to week-8 (P<0.0001). The $HR_{Åstrand}$ (P<0.033) and workload (P<0.011) were improved from week-0 to week-8 in the $HICT^{BW}$. Whereas, there were no changes in any variables from baseline to any time points in the CG (P >0.05). For the differences in percentage changes between groups, the $HICT^{BW}$ had a higher change in the relative $\dot{V}O_{2peak}$ than the CG at week-8 ($\%\Delta_{0-8}$) (P =0.010).

Discussion

This was the first study involving South-East Asian obese women to show that an 8-week HICT using body weight as resistance (3 days/week) was an effective training modality for improving health-related physical fitness outcomes without the report of injury. In addition, no unpleasant feelings and dropout rates of the participants were recorded during the 8-week program which could indicate the favorable affective responses and adherence to the HICT^{BW} program [22, 23].

In the present study, there were no changes in BW. This observation is similar to previous HICT studies [6, 7, 24] and may be due to the relatively short duration (i.e. 8-weeks) of the training program. However, the present study provided observations on changes in muscle mass and fat mass. After 8-weeks of HICT^{BW}, SMM was increased by 2.9 % and BFM and BF% were decreased by 3.4% and 3.2%, respectively. These changes were larger than those reported in 12 healthy middle-aged women after 14 weeks of combined resistance [3 sets of 10 repetition maximums (RM)] and aerobic training (20 min at 60%–70% of age-predicted maximal heart rate) for which a 1.4% decrease in total fat was reported [25]. Moreover, a 6-week HICT^{BW} (7 days/week, 30 s per exercise position with 10s rest) for active normal weight male and female subjects provided similar results at the end of the training program [26]. In addition, Batrakoulis *et al.* [27] demonstrated a 1.2% decrease in total fat following a 2-month new HIIT-type protocol that integrated neuromuscular training using whole-body movements with alternative portable exercise equipment in sedentary obese adults.

Noteworthy, in the present study, 4 weeks of HICT^{BW} did not change body composition variables in sedentary obese women. However, beneficial effects on body composition have been reported after 4 weeks of the HICT^{traditional} program. Miller *et al.* [6] observed an increase of lean muscle tissue by 2% and a decrease in fat tissue by 3.6% following a 4-week HICT program in 8 sedentary obese males. The larger changes in Miller's study [6] may be due to the use of high resistance exercises (at 70-80% of 1RM) and the 8-12 number of repetitions throughout the training period, whereas our study used body weight as resistance and increased the duration of exercise from 24 min to 120 min in week-8 (Table 2). Therefore, it may be due to the different training intensity that we observed the significant improvement of body composition only at week-8 but not at week-4. An increase in muscle mass might affect metabolic remodeling induced by HICT, which can result in mitochondrial biogenesis and therefore an increase in the capacity for whole-body fat oxidation [28-30]. In addition, a greater impact on subcutaneous fat loss may be due to the increased level of serum catecholamines and growth hormone responses from the HICT program [31]. Therefore, except for the benefit of being time-efficient, the modified HICT^{BW} program could have a benefit on body composition by increasing muscle mass and reducing body fat mass in obese women who trained for 8 weeks.

The muscle-to-fat ratio (MFR), representing the ratio of skeletal muscle mass to the visceral fat area, is negatively associated with metabolic syndrome in obesity [32] and type 2 diabetes [33]. The present study obtained an increased MFR value following the 8-weeks HICT^{BW} which might indicate a beneficial effect of the training program on reducing the risk of developing cardiovascular disease in an obese population. In addition, Paoli *et al.* [7] suggested that HICT using resistance exercise machines (3 times per week, 50 min per session for 12 weeks) was more effective on blood lipid profiles in healthy overweight men than endurance training or low-intensity circuit training. Recently, Sepehrirad *et al.* [34] reported the metabolic benefits of an 8-week HICT^{BW} protocol in elderly women with metabolic syndrome and suggested that the program would be effective for health improvement in this specific population. According to the results of the present study, an 8-week HICT^{BW} has positive effects on body composition by increasing the muscle-to-fat ratio. In addition, it might be considered a safe and suitable training program for the sedentary obese female population to prevent the development of non-communicable diseases.

The obesity-associated reduction in the range of motion for particularly trunk segments can lead to functional task limitations [35, 36]. A significant increase in flexibility and leg muscle strength was obtained within a 4-week HICT^{BW} training compared to baseline data. Interestingly, the present study observed a 146% increase in flexibility of the trunk and legs after 8 weeks of HICT^{BW}, which was larger than the 7% increase in the control group who only participated in the habitual activity. The substantial increase in flexibility can most likely be related to the synergistic effects of the training program where each exercise pose was encouraged to perform with a full range of motion as well as a negatively relationship between BF% and flexibility where the lower BF% following exercise training could result in the higher flexibility [37]. Furthermore, we showed a 41.6% increase in leg muscle strength from pre- to post-HICT^{BW}. The increase in strength may have occurred through increased motor unit firing rate, recruitment of motor units, and the synchronization of motor units [38]. Taken together, the present study provided evidence for the beneficial effects of an 8-week modified HICT^{BW} program on physical fitness parameters including flexibility and strength of back and leg muscles in sedentary obese women. The majority of the modified HICT^{BW} program has focused predominantly on the lower limbs and has, therefore, potential implications to improve functional capacity (e.g., walking, stairs negotiation, and rising from a chair or bed), prevent the risk of joint pathologies (e.g. knee and hip osteoarthritis) and consequently improve quality of life in obese women. However, for grip strength, the present study is consistent with that of previous studies [12, 26] which showed that HICT^{BW} had no effect. It is possible that the pose of HICT^{BW} might not be intense enough to generate meaningful muscle recruitment of hand muscles, especially in female participants [12].

Cardiovascular fitness is a modifiable risk factor, with improvements directly linked with reduced mortality and improved health status [39]. Recently, the use of interval-based training programs to stimulate improvements in cardiovascular health, requiring less time than traditional exercise has received increased attention in clinical populations [40]. The present study demonstrated an increase of 8 $mL \cdot kg^{-1} \cdot min^{-1}$ (~32%) in relative $\dot{V}O_{2peak}$ values after 8 weeks of HICT^{BW} compared to the control group. In addition, a significant increase in peak oxygen consumption (~18%) occurred as early as 4 weeks of training compared to baseline and could indicate a high impact of the modified HICT^{BW} program on aerobic fitness adaptation. Similarly, the adaptations to cardiovascular endurance following HICT^{BW} obtained in obese individuals was not different than those in healthy individuals. We reported an 18% increase in $\dot{V}O_{2peak}$ from pre- to week-4 HICT^{BW} in sedentary normal weight women [13]. The increase of VO_{2peak} can result from both peripheral and central adaptations. Repeated fluctuations of O_2 consumption between each cycle (1 cycle in week 1 to 5 cycles in week 8) may have been required to improve muscular oxidative capacity [41] by increasing mitochondrial biogenesis in the trained muscles [42]. High-intensity exercise has also been shown to improve stroke volume and cardiac output, thereby improving oxygen delivery [43] . The present study demonstrated a 5% decrease in $HR_{Åstrand}$ and a 25% increase in cycling workload after 8 weeks of HICT^{BW}. Cardiovascular fitness such as $\dot{V}O_{2peak}$, has been reported to improve in overweight women who regularly practice functional HICT but with perception of pain [10]. Interestingly, our data demonstrate that whereas the modified HICT^{BW} appears to have greater improvements in peak oxygen uptake, the perception of muscle pain is attenuated as training proceeds and disappeared at week-5 of the program. Therefore, an 8-week modified HICT^{BW} elicits an improvement in cardiovascular fitness with less perception of muscle pain.

Limitations

The present study has the following limitations. Firstly, the lack of gold standard methods, i.e. DXA, for assessing body composition. However, the BIA provides reliable single-measure body composition estimates [44], and seems to be more convenient than DXA in the research settings, since it is quick, easily transported, no need to be done by a specialist, and a low-cost device. Secondly, we did not use any tools or questionnaires to measure pain and risk of injury.

However, after exercising, we did ask the subjects routinely if they have pain, muscle soreness, unpleasant feelings, or experienced injury from the training and responses were recorded. Finally, we did not monitor habitual dietary intake or physical exercise outside of the study, although participants regularly reported no change in their normal dietary intake and were aware that no additional activity was allowed throughout the study period.

Conclusions

The 8-week modified high-intensity circuit training using body weight as resistance thrice a week is an effective training modality to influence health-related physical fitness components in sedentary obese women. Although there was no change in body weight, the $HICT^{BW}$ program seems to be more efficient in the long term to gradually reduce fat mass and increase muscle mass. Short-term improving flexibility, leg muscle strength, and VO_{2peak}, following the program may be necessary for the sedentary population to ensure the body can perform normal daily tasks. In addition, an increase in cardiovascular endurance with less perception of muscle pain could, in turn, elicit pleasant feelings and adherence to the program. Overall, the modified $HICT^{BW}$ program can be a safe training modality with the exercise being practical and providing quickly benefical adaptations (except body composition) in sedentary obese women.

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Figure 1: The timeline and main outcome variables of this study.

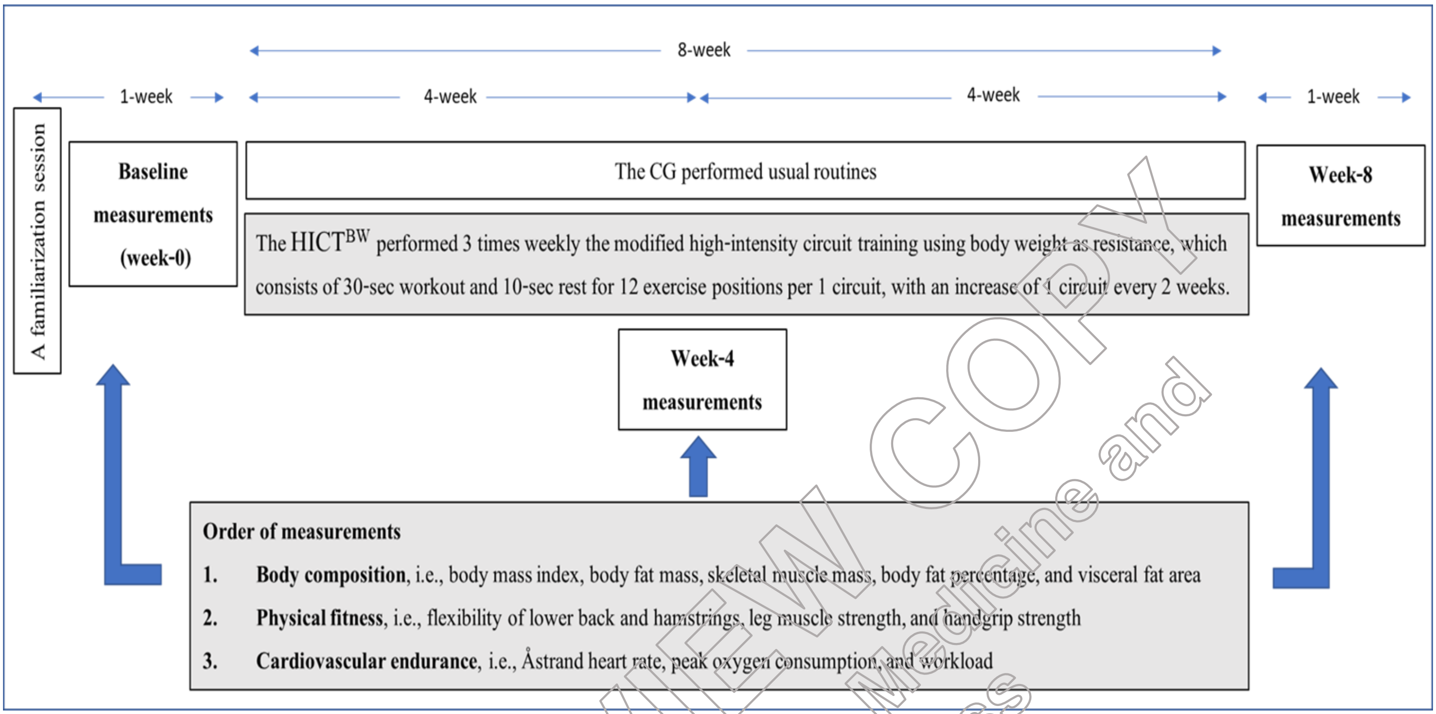


TABLE 1: Exercise intensity (%HRR) of modified high-intensity circuit training exercise using body weight ($HICT^{BW}$) program at week-0, week-4, and week-8.

Pose #	$HICT^{BW}$	Exercise Intensity (%HRR)*		
		Week- 0	Week- 4	Week- 8
1	Step Jacks	Very light	Moderate	Moderate
2	Wall sit	Light	Moderate	Moderate
3	Wall push-up	Light	Moderate	Moderate
4	Sit-ups hand reach	Light	Moderate	Moderate
5	Step-up onto step aerobics	Moderate	Moderate	Vigorous
6	Half squat	Moderate	Vigorous	Vigorous
7	Bend knee Triceps dip on chair – Half bottom	Moderate	Vigorous	Vigorous
8	Plank with Knee	Moderate	Moderate	Vigorous
9	Hop	Moderate	Moderate	Vigorous
10	Split squats	Moderate	Vigorous	Vigorous
11	Plank rotation	Moderate	Vigorous	Vigorous
12	Side plank	Moderate	Vigorous	Vigorous
	Total	**Moderate**	**Moderate**	**Vigorous**

* % Hearth rate reserve (%HRR) was calculated from values following Karvonen method. [24]

Exercise intensity (%HRR) = (Heart rate of each exercise pose – Resting HR) / HRR x100

Levels of exercise intensity [21]: Very light: %HRR= <30, Light: %HRR = 30-39, Moderate: %HRR = 40-59, and Vigorous: %HRR = 60-84

TABLE 2: Details of the modified high-intensity circuit training using body weight ($HICT^{BW}$) program for 8 weeks (3 times per week) and the percentage of muscle pain and soreness, unpleasant feelings, and dropout rates in the program, n=12 for $HICT^{BW}$ group.

Week	Circuit	Warm-up (minutes)	Exercise duration (minutes)	Cool-down (minutes)	Total training duration per week (minutes)	Muscle pain and soreness (%)
1	1	5	~ 8	5	24	33
2-3	2	5	~16	5	48	16
4-5	3	5	~24	5	72	8
6-7	4	5	~32	5	96	0
8	5	5	~40	5	120	0

1 circuit = 12 exercise poses, 30 sec of workout per pose with a 10-sec rest interval, approximately 8 min per circuit.

TABLE 3: Participant's physical characteristics in the control (CG) and $HICT^{BW}$ groups.

Variables	CG (n=12)	$HICT^{BW}$ (n=12)
Age (years)	32±3	31±2
Height (cm)	160±5	159±5
BW (kg)	68.4±7.7	70.4±8.2
BMI (kg/m^2)	26.7±3.0	27.9±2.5
Waist circumferences (cm)	87.5±2.1	90.3±2.3
Waist to hip ratio	0.87±0.05	0.89±0.04
Systolic blood pressure (mmHg)	111±9	117±11
Diastolic blood pressure (mmHg)	77±7	81±7
Resting heart rate (bpm)	78±7	76±4
$\dot{V}O_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	25.2±2.7	24.5±3.7

BW = Body weight; BMI = Body Mass Index; kg = kilogram; m^2 = square meter; cm = centimeter; bpm = beat per minute; mmHg = millimeters mercury; $\dot{V}O_{2peak}$ = peak oxygen uptake; mL = milliliter; min = minute. The data is expressed as means ± SD.

TABLE 4: Body composition variables, consisting of body weight (BW), skeletal muscle mass (SMM), body fat mass (BFM), body fat percentage (BF%), visceral fat area (VFA) and skeletal

muscle mass to visceral fat area ratio (MFR) at week-0, week-4 and week-8 in the control (CG) and HICT^{BW} groups.

Variables	CG					HICT^{BW}				
	Week- 0	Week- 4	$\%\Delta_{0-4}$	Week- 8	$\%\Delta_{0-8}$	Week- 0	Week- 4	$\%\Delta_{0-4}$	Week- 8	$\%\Delta_{0-8}$
BW (kg)	68.4 (2.2)	68.8 (2.3)	+0.7 (0.5)	69.2 (2.4)	+1.2 (0.6)	70.4 (8.2)	70.4 (2.3)	+0.1 (0.5)	70.0 (2.2)	-0.4 (0.7)
SMM (kg)	23.8 (0.8)	23.9 (0.8)	+0.6 (0.9)	23.9 (0.8)	+0.6 (0.9)	23.7 (0.8)	24.0 (0.7)	+1.0 (0.5)	24.3 (0.6) *	+2.9 (1.1) [a]
BFM (kg)	24.9 (1.5)	25.2 (1.5)	+1.0 (0.9)	25.5 (1.6)	+2.3 (1.3)	27.0 (1.8)	26.6 (1.6)	-1.2 (1.3)	26.0 (1.4) *	-3.4 (1.8) [a]
BF% (%)	36.2 (1.3)	36.3 (1.3)	+0.1 (1.0)	36.6 (1.3)	+1.0 (1.1)	38.0 (1.4)	37.5 (1.3)	-1.3 (1.0)	36.7 (1.1) *	-3.2 (1.4) [a]
VFA (cm^3)	80.6 (4.2)	77.7 (4.6)	-3.2 (2.8)	79.8 (3.8)	-0.1 (2.4)	90.4 (4.7)	88.8 (5.4)	-2.2 (1.7)	85.2 (4.4) *	-5.3 (2.0)
MFR ($kg.cm^{-3}$)	0.31 (0.09)	0.32 (0.10)	+5.2 (4.0)	0.31 (0.06)	+0.3 (2.7)	0.27 (0.06)	0.28 (0.08)	+3.7 (2.0)	0.29 (0.02) *	+9.5 (3.1) [a]

Values are given as mean (SEM). n=12 for each group. %Δ0-4 = percentage change from week-0 to week-4 and %Δ0-8 = percentage change from week-0 to week-8. *, significant within group change from week-0 ($p < 0.05$) (Repeated ANOVA; $p < 0.05$). [a], significant of $\%\Delta_{0-8}$ between CG and HICT^{BW} (Independent t-test; $p < 0.05$).

TABLE 5: Physical fitness variables, consisting of flexibility of lower back and hamstrings (Flex $_{LH}$), leg muscle strength (Strength$_{Leg}$), and right and left relative handgrip strength (Rt. And Lt. Relative Strength$_{HG}$) at week-0, week-4 and week-8 in the control (CG) and HICT^{BW} groups**.**

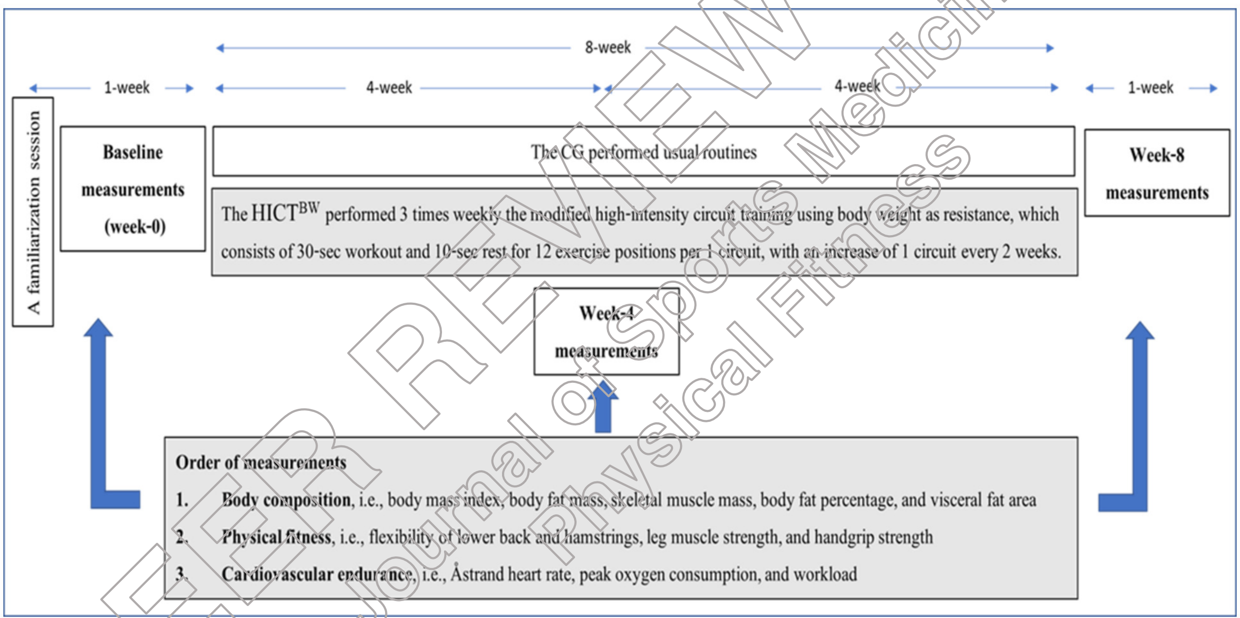
Variables	CG					HICT^{BW}				
	Week- 0	Week- 4	%Δ_{0-4}	Week- 8	%Δ_{0-8}	Week- 0	Week- 4	%Δ_{0-4}	Week- 8	%Δ_{0-8}
Flex$_{LH}$ (cm)	8.0 (2.2)	6.0 (2.3)	-21.9 (35.7)	7.6 (2.6)	+7.0 (30.8)	8.5 (1.9)	11.7 (1.4) *	+84.9 (51.1)	14.7 (1.4) *	+145.7 (65.5)[a]
Strength$_{Leg}$ (kg)	90.9 (4.9)	105.2 (5.2)	+16.1 (3.4)	103.1 (7.2)	+18.1 (6.5)	91.8 (7.1)	112.3 (8.5) *	+24.4 (5.6)	121.6 (7.8) *	+41.6 (16.5)
Rt.- Relative Strength$_{HG}$ (kg/kg BW)	0.40 (0.03)	0.42 (0.03)	+3.8 (3.0)	0.42 (0.03)	+5.1 (4.3)	0.41 (0.02)	0.41 (0.02)	-3.1 (2.8)	0.42 (0.02)	-0.3 (3.5)
Lt.- Relative Strength$_{HG}$ (kg/kg BW)	0.35 (0.02)	0.36 (0.02)	+4.6 (3.1)	0.37 (0.02)	+8.0 (4.3)	0.36 (0.02)	0.35 (0.02)	-1.5 (5.1)	0.37 (0.2)	+1.3 (3.9)

Values are given as mean (SEM). BW, body weight. n=12 for each group. %Δ_{0-4} = percentage change from week-0 to week-4 and %Δ_{0-8} = percentage change from week-0 to week-8. *, significant within group change from week-0 ($p < 0.05$) (Repeated ANOVA; $p < 0.05$). [a], significant of %Δ_{0-8} between CG and HICT^{BW} (Independent t-test; $p < 0.05$).

TABLE 6: Cardiovascular endurance consisting of heart rate ($HR_{Åstrand}$), relative maximum oxygen consumption (Relative $\dot{V}O_{2max}$), and work load (Load) were recorded following Åstrand's protocol [19] for the submaximal test in the control (CG) and $HICT^{BW}$ groups**.**

Variables	CG					$HICT^{BW}$				
	Week- 0	Week- 4	$\%\Delta_{0-4}$	Week- 8	$\%\Delta_{0-8}$	Week- 0	Week- 4	$\%\Delta_{0-4}$	Week- 8	$\%\Delta_{0-8}$
$HR_{Åstrand}$ (bpm)	136 (2)	132 (2)	-2.7 (2.1)	132 (2)	-2.9 (1.9)	139±3	133±3	-4.7 (1.5)	132 (2) *	-4.8 (1.5)
VO_{2max} ($mL.kg^{-1}.min^{-1}$)	26.9 (1.3)	28.4 (1.3)	+8.2 (6.3)	28.7 (1.2)	+9.7 (6.6)	24.5 (1.4)	28.1 (1.1) *	+18.1 (7.6)	32.0 (1.5)*	+32.3 (6.3) [a]
Load (kp)	1.0 (0.2)	1.1 (0.2)	+4.2(4.2)	1.1 (0.2)	+8.3 (5.6)	1.1 (0.1)	1.2 (0.1)	+8.3 (5.6)	1.3 (0 .1) *	+25.0 (11.5)

Values are given as mean (SEM). n=12 for each group. $\%\Delta_{0-4}$ = percentage change from week-0 to week-4 and $\%\Delta_{0-8}$ = percentage change from week-0 to week-8. *, significant within group change from week-0 ($p < 0.05$) (Repeated ANOVA; $p < 0.05$). [a], significant of $\%\Delta_{0-8}$ between CG and $HICT^{BW}$ (Independent t-test; $p < 0.05$).


8-week
1-week
4-week
4-week
1-week
A familiarization session
Baseline measurements (week-0)
The CG performed usual routines
The HICT^BW performed 3 times weekly the modified high-intensity circuit training using body weight as resistance, which consists of 30-sec workout and 10-sec rest for 12 exercise positions per 1 circuit, with an increase of 1 circuit every 2 weeks.
Week-8 measurements
Week-4 measurements
Order of measurements
1. Body composition, i.e., body mass index, body fat mass, skeletal muscle mass, body fat percentage, and visceral fat area
2. Physical fitness, i.e., flexibility of lower back and hamstrings, leg muscle strength, and handgrip strength
3. Cardiovascular endurance, i.e., Åstrand heart rate, peak oxygen consumption, and workload