JOURNAL OF SPORTS SCIENCES
2021, VOL. 39, NO. 5, 496–502
https://doi.org/10.1080/02640414.2020.1829362

Routledge
Taylor & Francis Group

PHYSIOLOGY AND NUTRITION

Effects of descending or ascending stair exercise on body composition, insulin sensitivity, and inflammatory markers in young Chinese women with obesity: A randomized controlled trial

Bik Chu Chow [a,b], Shuoqi Li [c,d], Xiangui Zhu [a,c], Jiao Jiao [a], Binh Quach [b], Julien S. Baker [b] and Haifeng Zhang [c,e]

[a]Dr. Stephen Hui Research Centre for Physical Recreation and Wellness, Hong Kong Baptist University, Hong Kong, China; [b]Department of Sport and Physical Education, Hong Kong Baptist University, Hong Kong, China; [c]Physical Education College, Hebei Normal University, Shijiazhuang, China; [d]School of Health Sciences, University Sains Malaysia, Kota Bahru, Malaysia; [e]Hebei Provincial Key Lab of Measurement and Evaluation in Human Movement and Bio-Information, Hebei Normal University, Shijiazhuang, China

ABSTRACT

We examined the effects of descending (DSE) or ascending (ASE) stair exercise on body composition, insulin sensitivity, and inflammatory markers in young Chinese women with obesity. Thirty-six participants were randomly assigned into three groups DSE, ASE and a control group. The DSE and ASE groups performed three sessions of stair walking per week for 12 weeks with a gradual increase in repetitions. Following the exercise interventions, body composition related variables obtained by Dual-energy X-ray absorptiometry scans significantly decreased. Abdominal fat decreased in the DSE group only. Moreover, Insulin sensitivity improved significantly 3.5-fold in the DSE group compared with ASE group (insulin: −33.2% vs. −9.8%, homoeostasis model assessment for insulin resistance: −35.6% vs. −10.8%). Pro-inflammatory factors showed significant decreases in tumour necrosis factor-α (TNF-α) (−39.9% vs. −23.2%) for both intervention groups. The reduction in TNF-α concentrations in the DSE group was significantly different compared to the other two groups. Interleukin-6 significantly decreased in both exercise protocols. Our results show that 12-weeks induced stair walking improved body composition parameters in Chinese females with obesity. The results also demonstrate the superiority of the DSE protocol for improving insulin sensitivity. These findings may be attributable to the decreases observed in TNF- α levels.

ARTICLE HISTORY
Accepted 23 September 2020

KEYWORDS
Descending stair exercise; ascending stair exercise; body composition; insulin sensitivity; obesity

Introduction

The beneficial effects of exercise have been widely reported in reducing obesity and the risk of diseases, such as type-2 diabetes, cardiovascular disease and symptoms associated with the metabolic syndrome (Pasanen et al., 2017; Pedersen & Saltin, 2015). In the past decade, the morbidity of obesity-related diseases has been increasing throughout the world, particularly in women (Kim & Hartzema, 2020; Ng et al., 2014). Therefore, it seems appealing to promote and examine exercise interventions for the prevention and treatment of obesity-related pathologies in females (Pasanen et al., 2017; Thompson et al., 2013). In general, an exercise involving walking and running up and down, on a slope or stairs can be categorized into two different types of contraction, eccentric and concentric (Thompson et al., 2013). Eccentric exercise such as descending stair exercise (DSE), requires less metabolic and cardiovascular demand, and induces less fatigue than concentric type training used for ascending stair exercise (ASE) (Chavanelle et al., 2014; Penailillo et al., 2014; Thompson et al., 2013). DSE has been suggested as a feasible exercise prescription modality for people susceptible to chronic diseases, especially adult populations with obesity (Julian et al., 2018). The integration of DSE into individual daily habits, offers an alternative and feasible choice for individuals with obesity who may find difficulty in adhering to conventional exercise training regimes(Chen et al., 2017).

At present, research relating to the effects of DSE and ASE on body composition parameters remains underresearched and underexplored. It has been reported previously that eccentric exercise is effective in reducing whole body, abdominal and intramuscular adipose tissue of the thigh (Marcus et al., 2008; Mueller et al., 2009). However, other studies have found no significant effects on decreasing abdominal fat and intermuscular thigh adipose tissue (Jacobs et al., 2014; Marcus et al., 2009). These outcomes suggest that current research findings on the impact of eccentric training on body composition variables are inconsistent.

Individuals with obesity have an increased risk of developing insulin resistance, which is associated with the development of metabolic diseases such as type 2 diabetes and cardiovascular disease (Pedersen & Saltin, 2015). Eccentric exercise training has been found to be more beneficial than concentric exercise for improving insulin sensitivity. This has been quantified using the homoeostasis assessment model for insulin resistance (HOMA-IR), oral glucose tolerance tests and glycosylated haemoglobin measurements in elderly men (TCC Chen et al., 2017), middle-aged subjects (Zeppetzauer et al., 2013) and untrained young healthy women respectively (Paschalis et al., 2011). Chen et al. (Chen et al., 2017) studied elderly women with obesity who

CONTACT Haifeng Zhang zhanghaifeng@hebtu.edu.cn Physical Education College, Hebei Normal University, China

performed either a DSE or ASE twice a week for 12 weeks. They found similar improvements in body composition, but the DSE group showed greater improvements in insulin sensitivity. However, Chen et al. may have provided more meaningful results if accurate measures of body composition were used e.g., Dual-energy X-ray absorptiometry, (DEXA) instead of bioelectrical impedance (Johnstone et al., 2014; Lemos & Gallagher, 2017). Obesity-induced chronic inflammation plays a crucial role in the mechanisms of insulin resistance (Debnath et al., 2016). Chronic inflammation results in increases in biochemical inflammatory markers, such as interleukin-6 (IL-6) and tumour necrosis factor-α (TNF-α) in subjects with obesity, and are usually 2–3 times higher than individuals who are non obese (Mathur & Pedersen, 2008). Studies have shown that long-term regular exercise can significantly reduce IL-6 and TNF-α concentrations in populations with obesity and that eccentric exercise may be a better alternative than concentric exercise (Zeppetzauer et al., 2013).

To our knowledge, there have been minimal studies investigating the effects of DSE and ASE involving young females with obesity as participants. The present study aimed to examine the effects of DSE and ASE on body composition and insulin sensitivity in young Chinese women with obesity, with body fat percentages > 30%. In addition, fasting blood was also collected pre- and post-intervention to evaluate any changes in insulin sensitivity and the inflammatory factors TNF-α and IL-6. We hypothesized that participants involved in the DSE protocol would have improved body composition values, insulin sensitivity and levels of inflammation compared to those in the ASE and control groups post-intervention.

Methods

Participants

Participants were inactive female college students who did not participate in any regular physical activity. The subjects were recruited via posters placed on campus and internet mailing on the university web site. Body composition parameters were determined by DEXA scanning prior to the exercise interventions. A total of 36 female participants with obesity were recruited for the study in accordance with the following inclusion criteria: 1) body fat percentage > 30%; 2) stable body weight within 2 kg in the past three months; 3) no exercise or regular physical activity; 4) no history of metabolic syndrome, cardiovascular disease, or disorders of the bones, muscles and joints. All participants completed informed consent forms prior to data collection and ethical approval was obtained from the University Ethical Research Committee.

Experimental design and procedures

Thirty-six participants were randomly assigned into three groups: a DSE group, an ASE group and a control (CON) group (n = 12, each group) (**Figure 1**). Both the DSE and ASE groups completed a 12-week supervised intervention training protocol three times per week, while the CON received no training. During the experimental period, all participants were asked to maintain their daily activity levels and avoid any

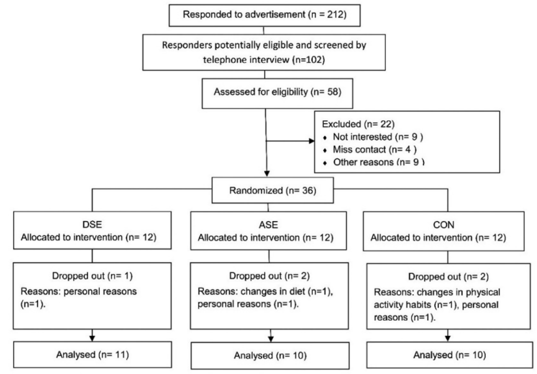

Figure 1. Distribution of study participants. Descending stair exercise group (DSE) ascending stair exercise group (ASE)) and control group (CON).

changes in eating habits. The participants in the CON group attended check-up visits every week to report their daily dietary intake and physical activity levels. Any changes in body composition and blood biochemistry pre-training and following the 12-week intervention were compared between the three groups.

Figure 2 Outlines the protocol used for the two exercise interventions. Subjects performed either a DSE or ASE intervention following guidelines from a previous study (Chen et al., 2017). Considering the diurnal variation problems related to standard exercise performance, each exercise session was performed between the hours (h) of 5:00–9:00 p.m. This was done to prevent diurnal variation compromising the accuracy of the results obtained. Prior to data collection, all participants were fully familiarized with testing procedures and the testing environment. The training stairway used for the intervention comprised of 4 floors with 24 steps per floor. Therefore, each repetition of descending or ascending stair exercise included 96 steps with a height of 15 cm/step (i.e. each repetition = 4 floors × 24 steps). After each repetition of the DSE or ASE protocol, participants used an elevator to return back to the starting point and immediately started the next repetition. The time taken to complete the DSE or ASE exercise protocols was 96 seconds (s). The time taken to take the lift, on exercise completion of 1 repetition, and return to the starting point for the next repetition was approximately 55 s. This time period equates to a work/rest recovery period of 96/55 s or a 1 to 0.57 work recovery ratio. The work recovery ratios remained the same when the exercise duration increased.

An experienced researcher used a stopwatch to record the interval time of each exercise repetition during the exercise

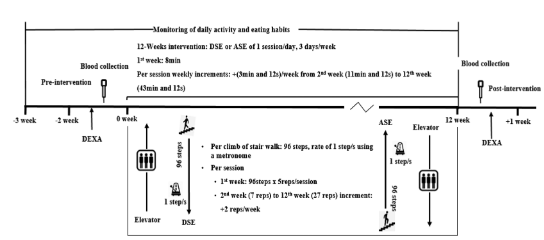

Figure 2. Design and time course of the experiment. Note: DSE, descending stair exercise; ASE, ascending stair exercise; DEXA, Dual-energy X-ray absorptiometry.

period. The cadence of descending or ascending exercise was set at 1 s per step. The exercise duration regime lasted 8 minutes (min) in the 1st week and increased to 43 min and 12s in the 12th and final week. This was an increase of 2 repetitions/week, (3 min and 12s)/week. A metronome provided audio signals to control the stair walking speed. A heart rate (HR) monitor (Polar, Finland) was used to record exercise HR and a Borg scale was used to determine participants' rate of perceived exertion (RPE) during the exercise interventions.

Measurements

A daily diary for self-reported physical activity was used for estimating habitual energy expenditure during the 3-week pre-intervention period and during the 12-week intervention period. Total energy expenditure was estimated based on metabolic equivalents (METs) reported in the Compendium of Physical Activities (Ainsworth et al., 2011). During the same period, the diets of each participant were recorded daily to estimate caloric intake. A dietician provided commentary on the recorded values to avoid errors in caloric estimations. Dietary advice was provided to the participants by the dietician if the maintenance of the weekly caloric intake was violated. Energy expenditure was not calculated directly for any of the exercise protocols during the exercise interventions.

During their first lab visit, body mass (BM) was measured using a calibrated weighing scale with an accuracy of 0.100 g with the individuals positioned barefoot and wearing minimum clothing. Height was measured using a calibrated stadiometer with a precision of 0.1 cm. Body mass index (BMI) was calculated using the formula BMI = kg/m^2 where kg is the person's weight in kilograms and m^2 is their height in metres squared. Body composition was determined twice, pre and post the 12-week exercise intervention. DEXA (General Electric lunar DPX-NT, USA) was used to measure body fat percentage, whole-body fat mass, trunk fat mass, abdominal fat mass, lower limb fat mass and lower limb muscle mass. Regional demarcations were adjusted by a trained technologist according to the guidelines provided (Zhang et al., 2017). Briefly, the trunk region was inclusive of the bottom of the neckline to the top of the pelvis, excluding the upper limbs. The abdominal region included the pelvic region to 20% of the distance between the pelvic cut and the bottom of the neckline, excluding the arms. Intraclass correlation coefficients (ICCs) between two scans were >0.98. DEXA scanning and data analysis were performed in a single-blinded manner by an experienced researcher.

Values for fasting blood glucose, insulin, HOMA-IR, IL-6 and TNF-α were obtained one week prior and 48 h post 12 weeks of exercise following completion of the last exercise intervention. All blood samples were taken in avoidance of the menses phases of the participants, and specific timing was obtained from individual subject diaries. The participants were told to avoid vigorous exercise, smoking, alcohol, coffee consumption and any medication for 48 h in advance of testing. They were asked to fast for 8 h the night before and they arrived at the laboratory at 8:00 a.m. Following an explanation of procedures subjects, in a comfortable seated position, provided pre-exercise fasted venous blood samples that were collected using a 5 ml vacuum tube. The same procedures and conditions were observed after the 12-week exercise intervention. Blood samples were incubated for 30 min and centrifuged at 3000 rpm for 15 min. The serum was then divided into 0.5 ml EP tubes for further analysis. Serum glucose was estimated using an automatic chemistry analyser (Genesys 5, SPECTRONIC, USA) with testing kits (Nanjing Jiancheng Bioengineering Institute, China). Serum insulin, IL-6, and TNF-α concentrations were analysed using enzyme-linked immunosorbent assay kits (Shanghai Jingkang Biosmart, China) in conjunction with an enzyme-labelled instrument (Elx800, Biotek, USA). HOMA-IR was calculated as fasting insulin ($\mu U{\cdot}mL^{-1}$) multiplied by fasting glucose ($mmol{\cdot}L^{-1}$)/22.5. The coefficient of variation (CV) of each sample was: insulin: 1.48%; glucose/HOMA-IR: 2.97%; IL-6: 4.44%; TNF-α: 5.16%.

Statistical analysis

The sample size was estimated based on an effect size of 1.91, an α-level of 0.05, and a power (1-β) of 0.08 as outlined in a previous study (Chen et al., 2017). For a possible difference in the concentrations of HOMA-IR between the groups using G*Power, calculations indicated that 6 participants per group were necessary. Considering a possible drop out rate of 20% a sample size of 12 participants per group was recruited. Statistical analysis was performed using IBM SPSS version 25.0 (IBM Corp, Armok, NK, USA). The Shapiro-Wilks normality test was used to investigate if the data were normally distributed. A two-way analysis of variance (ANOVA) with repeated measures was used to assess any differences in body composition and blood variables between time points and within and across groups. Post-hoc analyses using the Bonferroni Test for identification of simple main effects were performed when a significant interaction was detected. Statistical significance was set at $P < 0.05$. All values are reported as means ± Standard Deviations (SD).

Results

All measures at baseline for the DSE, ASE, and CON groups were not significantly different (**Table 1**). The final number of participants completing all tests and interventions were 31 female participants; DSE (n = 10), ASE (n = 11), CON (n = 10). Five participants dropped out due to changes in diet and physical activity habits (n = 2), or personal reasons (n = 3).

The mean HR and RPE for the DSE group (108.6 ± 5.8, 10.3 ± 1.5) were significantly lower than the ASE group (145.5 ± 3.1, 13.5 ± 0.6) during the intervention. The two exercise groups spent the same amount of time performing each exercise and similar mean exercise interval time (DSE: 54.1 ± 16.4 s, ASE: 55.5 ± 16.1 s). There were no significant differences in the average daily energy intake for a 3-week pre-intervention and during the 12-week intervention period ($P > 0.05$).

Following the 12-week intervention, a significant ($P < 0.01$) reduction in body mass, BMI, body fat percentage, whole-body fat mass, trunk fat mass and lower limb fat mass was observed for the two exercise groups with no significant difference for the mean values in **Figure 3** ($P > 0.05$). Abdominal fat mass in the DSE group was significantly lower than the pre-exercise

Table 1. Pre- and post-intervention average (± SD) values for body composition and blood parameters for DSE, ASE, and CON. DSE, descending stair exercise; ASE, ascending stair exercise; CON, control group; HOMA-IR, Homoeostasis model assessment for insulin resistance; IL-6, Interleukin-6; TNF-α, Tumour necrosis factor-α. *Significantly (*P* < 0.05) different from pre values.

	DSE		ASE		CON		ANOVA p value		
Variables	pre	post	pre	post	pre	post	group	time	interaction
Age (years)	19.9 ± 0.9	-	19.7 ± 0.9	-	19.4 ± 0.5	-	-	-	-
Height (cm)	162.3 ± 6.1	-	165.0 ± 2.9	-	161.0 ± 6.3	-	-	-	-
Body mass (kg)	65.2 ± 6.4	62.7 ± 6.8*	65.9 ± 4.3	63.0 ± 4.9*	64.3 ± 7.5	65.0 ± 6.7	0.962	0.000	0.001
BMI (kg·m^{-2})	24.8 ± 2.6	23.8 ± 2.7*	24.2 ± 1.1	23.1 ± 1.4*	24.8 ± 1.7	25.1 ± 1.9	0.374	0.000	0.000
Body fat percentage (%)	43.7 ± 4.2	41.5 ± 4.4*	43.6 ± 2.1	41.1 ± 2.7*	43.0 ± 4.3	43.3 ± 4.4	0.888	0.001	0.009
Whole-body fat mass (kg)	27.0 ± 5.0	25.2 ± 5.3*	27.2 ± 2.9	24.9 ± 4.3*	26.5 ± 3.8	27.1 ± 4.2	0.903	0.000	0.001
Trunk fat mass (kg)	13.9 ± 2.9	13.0 ± 3.1*	14.6 ± 1.6	13.4 ± 1.5*	13.9 ± 2.5	14.3 ± 2.7	0.811	0.008	0.009
Abdominal fat mass (kg)	2.1 ± 0.5	1.9 ± 0.5*	2.2 ± 0.3	2.0 ± 0.2	2.1 ± 0.4	2.1 ± 0.5	0.745	0.017	0.116
Lower limbs fat mass (kg)	9.8 ± 1.8	9.2 ± 2.0*	9.5 ± 1.5	8.6 ± 1.4*	9.5 ± 1.8	9.7 ± 1.8	0.747	0.000	0.001
Lower limbs muscle mass (kg)	12.4 ± 1.3	12.3 ± 1.1	12.7 ± 1.3	12.5 ± 1.2*	12.4 ± 2.0	12.4 ± 1.8	0.938	0.079	0.297
Glucose (mmol/L)	5.20 ± 0.41	4.99 ± 0.34	5.04 ± 0.50	4.95 ± 0.29	5.16 ± 0.79	5.15 ± 0.53	0.124	0.396	0.795
Insulin (mIU/L)	25.01 ± 3.50	16.69 ± 3.20*	24.18 ± 3.34	21.81 ± 4.02*	24.64 ± 2.49	22.87 ± 4.24	0.084	0.000	0.000
HOMA-IR	5.76 ± 0.78	3.71 ± 0.85*	5.39 ± 0.76	4.82 ± 1.06*	5.63 ± 0.93	5.28 ± 1.34	0.126	0.000	0.004
IL-6 (pg/ml)	32.49 ± 5.24	24.50 ± 2.57*	34.36 ± 4.43	26.13 ± 3.65*	30.64 ± 4.21	29.14 ± 6.50	0.485	0.000	0.025
TNF-α (pg/ml)	68.21 ± 7.90	40.99 ± 8.72*	66.86 ± 10.13	51.36 ± 9.45*	63.10 ± 13.17	60.06 ± 12.07	0.185	0.000	0.000

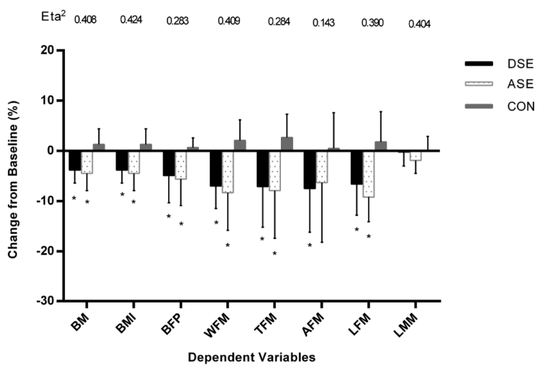

Figure 3. Changes (mean ± SD) in Body mass (BM) Body mass index (BMI), Body fat percentage (BFP), Whole-body fat mass (WFM), Trunk fat mass (TFM), Abdominal fat mass (AFM), Lower limb fat mass (LFM), and Lower limb muscle mass (LMM) from baseline (0%) to posttraining measures among DSE, ASE, and CON. *Significantly (*P* < 0.05) different from CON. Effect size (Eta^2) for the difference among the three groups is shown on the top of the graph.

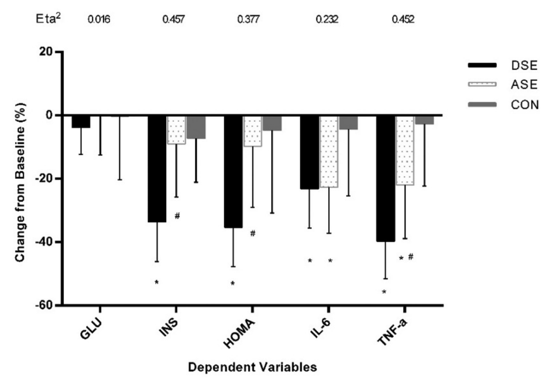

Figure 4. Changes (mean ± SD) in Glucose (GLU), Insulin (INS), HOMA-IR (HOMA), Interleukin-6 (IL-6), and Tumour necrosis factor-α (TNF-α) from baseline (0%) to posttraining measures among DSE, ASE, and CON. *Significantly (*P* < 0.05) different from CON. #significant (*P* < 0.05) different from DSE. Effect size (Eta^2) for the difference among the three groups is shown on the top of the graph.

value (*P* < 0.05), but there were no significant differences observed in the other groups.

Following the 12-week intervention, insulin and HOMA-IR in the DSE group reduced significantly (**Figure 4**) (*P* < 0.05), but there were no changes in the ASE or the CON groups (*P* > 0.05). TNF-α and IL-6 reduced significantly after the intervention in both exercise groups. The reduction in IL-6 between the two intervention groups was not significantly different (*P* > 0.05). However, the reduction in TNF-α concentrations in the DSE group was significantly lower compared to the concentrations observed in the ASE and CON groups (*P* < 0.05).

Discussion

In this study, the exercise mean values recorded for HR and RPE in the DSE group were significantly lower than those recorded for the ASE group. This indicates that the DSE group was working at a lower heart rate intensity than the ASE group. This also indicates that both exercise intervention protocols were of low or moderate intensity (about 54–73%HR$_{max}$) and were suitable for unfit subjects with obesity. These findings also confirm that the work to rest ratios used in this study provided adequate recovery enabling the subjects to maintain moderate or low intensity exercise heart rate values while exercising. Participants in each group completed all the training sessions, and there were no adverse events reported during the exercise intervention. Follow-up interviews were conducted following exercise intervention completion. All participants reported no delayed onset of muscle soreness (DOMS) for either protocol. These results were consistent with previous studies that used a visual analogue scale and plasma CK level relationships to determine muscle soreness or muscle damage respectively following gradual eccentric exercise (Chen et al., 2017; TCC Chen et al., 2017). This finding may be attributed to some extent to the "repeated bout effect", that exercise training promotes adaptability 2–14 days after the first eccentric training session (Chen et al., 2019). In addition, the slower pace of the steps used in this study compared to previous studies and lower intensities of exercise may have also contributed to the lack of muscle soreness observed (Paschalis et al., 2013). Therefore, compared to other forms of eccentric and concentric exercise, a DSE or ASE intervention has the advantage of being easy to administer and depending on the intensity of exercise used, does not result in muscle damage or DOMS. In addition, the protocols used were manageable for unfit individuals, did not require sophisticated equipment and were acceptable and compliant in female subjects with obesity (Julian et al., 2018).

By keeping the pre-intervention and intervention period energy consumption in relation to diet constant, this study was able to evaluate the effects of increasing energy expenditure using DSE and ASE on body composition parameters. DEXA measurements revealed that both the DSE and ASE protocols had a significant effect on reducing whole-body fat and regional fat mass when compared to controls, and changes in most body composition variables between the two exercise groups were not significantly different (**Figure 3**). However, abdominal fat was significantly decreased in the DSE group compared with the ASE and control groups following the exercise intervention. This finding may be explained by the fact that the DSE protocol, based on eccentric exercise, is more effective than the ASE for increasing fat oxidation. Studies have shown that eccentric exercise can increase post-exercise energy expenditure levels by 12% (Paschalis et al., 2011). Findings have also revealed that eccentric contractions can prolong elevated resting levels of post-exercise energy expenditure for up to 48 h, or even 72 h (Hackney et al., 2008). Higher values have been recorded for eccentric contractions compared to post-exercise concentric energy expenditure values using the same power outputs (Hackney et al., 2008; Paschalis et al., 2011). In addition, the results also showed a significant increase of 13% in post-exercise fat oxidation after an acute eccentric, but not following concentric exercise (Paschalis et al., 2011). Previous studies have determined the influence of a 16-week or 12-week eccentric training period on body fat measures (Marcus et al., 2008; Mueller et al., 2009). The results of these two studies have shown that eccentric training can reduce total fat and segmental body fat. In older participants, a 12-week DSE or ASE matched for relative volume showed a similar reduction in body fat percentage (Chen et al., 2017). However, in previous studies (Bassett et al., 1997; Chavanelle et al., 2014), DSE was performed at a lower metabolic and cardiorespiratory rate, and the energy expenditure of the descending stair exercise was about 50% lower than that of ASE. This indicates that the DSE may be an economical alternative for improving body fat profiles when compared to ASE. The reasons are likely related to the ability of eccentric training to mobilize more type IIb muscle fibres and promote the development of muscle protein turnover, resulting in more post-exercise energy expenditure than concentric training (Julian et al., 2018). However, more research is needed to explore further the physiological and biochemical mechanisms involved.

Individuals with obesity usually have eating or medical disorders that can lead to increases in blood glucose, which subsequently result in the secretion of insulin leading to a decrease in insulin sensitivity over time (Dandona et al., 2004; Mathur & Pedersen, 2008). The results of this study suggest that the effects of DSE on insulin sensitivity in young women with obesity were more prominent than that of ASE (**Figure 4**). In a previous study, it was observed that insulin sensitivity was significantly improved following participation in an eccentric exercise regime for 8 weeks (Paschalis et al., 2011). Additional studies have also investigated improvements in insulin sensitivity, and the results obtained indicated that insulin sensitivity improved after eccentric training (TCC Chen et al., 2017). These findings are consistent with the results of this study. In previous studies, a hiking downwards exercise protocol seemed to be more effective for improving insulin resistance compared to hiking upwards exercise in healthy middle-aged populations (Drexel et al., 2008; Zeppetzauer et al., 2013). During DSE, the eccentric contractions used were similar to those used in the descending hiking exercise, and both were more effective in improving insulin resistance than that of concentric activity. In support of this, a previous study examining the effects of stair walking using DSE or ASE for elderly populations with obesity, also concluded that the DSE was superior to ASE in reducing insulin resistance (Chen et al., 2017). Overall, the eccentric contractions used during DSE are characterized by a low internal load (less energy consumption) and better insulin sensitivity than ASE. Our findings indicate that DSE is an effective method in enhancing insulin sensitivity for female adults with obesity, especially for those who have difficulties in participating in higher intensity, and more demanding exercise protocols.

In addition to previous studies, we explored potential biochemical mechanisms involved in DSE and why this method of exercise improved insulin sensitivity. An important consideration related to insulin resistance is the increase in inflammation levels in the body during exercise, which are more common in populations with obesity (Mathur & Pedersen, 2008). The inflammatory factors, TNF-α and IL-6, inhibit the activities of the glucose transporter (GLUT)-4 and phosphoinositide 3-kinase (PI-3 K), thus inhibiting insulin signal transduction and leading to insulin resistance (Gupta et al., 2005; Rotter et al., 2003). Our study showed that 12-weeks of DSE and ASE reduced the levels of IL-6 and TNF-α in young women with obesity and that DSE improved the levels of TNF-α to a greater extent than ASE (**Figure 4**). It is possible the greater decrease in TNF-α following DSE could partly relieve the inhibitions of GLUT-4 and PI-3 K activities, leading to the improvement in insulin sensitivity. Some researchers (Rattray et al., 2014) have reported similar findings to the results in this study using an exercise intervention of 2 weeks duration using eccentric and concentric exercise in type 2 diabetic patients. The eccentric training group showed a decrease in the level of TNF-α, but the concentric group showed no change. Usually, for untrained individuals, the first eccentric exercise training event will lead to an increase in the inflammatory state which may be due to the excessive muscular stimulation caused by eccentric exercise. This may result in increased muscle damage, and increases in the secretion of inflammatory factors (Philippe et al., 2016). However, following the second exercise period, inflammation profiles gradually improve. Any inflammatory state induced by exercise in this study may have been due to lack of activity and not the intensity of exercise. Indeed, as reported earlier, the intensity of exercise as measured by heart rate was low to moderate in this study. Overall, it appears from the findings of this study that DSE can improve insulin sensitivity more favourably than ASE, and the changes observed may be related to the alleviation of chronic inflammation. The low exercise intensities used may have benefited the inflammation profiles recorded, and provided beneficial effects on the markers of insulin sensitivity.

In the current study, while measures for RPE and HR were recorded, the energy expenditure during actual stair climbing was not calculated and should be considered in future research. Despite any minor limitations, this study attempted to investigate eccentric and concentric muscular contractions and relationships with body composition and selected biochemistry. We focused on possible improvements in body composition and insulin sensitivity using two different types of training intervention. Few studies have tried to apply the methodologies used here for exercise prescription in populations with obesity. This study verifies the favourable intervention effects in young female populations with obesity. The findings indicate that using stair walking exercise as a training mode instead of elevators in our daily lives can reduce body fat and improve insulin sensitivity, especially when using descending stair exercise.

Conclusion

Our results demonstrate that 12-weeks induced stair walking impacted favourably on body composition parameters and that a DSE protocol was superior in improving insulin sensitivity. This finding might be related to decreases in inflammatory markers (TNF- α). Due to the effects on insulin sensitivity, the DSE which mainly utilizes eccentric contractions may be recommended as an alternative exercise prescription in populations with obesity. We suggest that a combination of DSE and ASE utilizing different intensities of exercise and recovery periods may provide the most beneficial results for Chinese females with obesity. However, further research is required to confirm this suggestion.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Natural Science Foundation of China [31771319].

ORCID

Bik Chu Chow http://orcid.org/0000-0002-0282-3743
Xiangui Zhu http://orcid.org/0000-0002-4483-4862
Haifeng Zhang http://orcid.org/0000-0002-9930-9993

References

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett, D. R., Tudor-Locke, C., Greer, J. L., Vezina, J., Whitt-Glover, M. C., & Leon, A. S. (2011). Compendium of physical activities: A second update of codes and MET values. *Medicine and Science in Sports and Exercise*, *43*(8), 1575–1581. https://doi.org/10.1249/MSS.0b013e31821ece12

Bassett, D. R., Vachon, J. A., Kirkland, A. O., Howley, E. T., Duncan, G. E., & Johnson, K. R. (1997). Energy cost of stair climbing and descending on the college alumnus questionnaire. *Medicine and Science in Sports and Exercise*, *29*(9), 1250–1254. https://doi.org/10.1097/00005768-199709000-00019

Chavanelle, V., Sirvent, P., Ennequin, G., Caillaud, K., Montaurier, C., Morio, B., Boisseau, N., & Richard, R. (2014). Comparison of oxygen consumption in rats during uphill (concentric) and downhill (eccentric) treadmill exercise tests. *Journal of Sports Science and Medicine*, *13*(3), 689–694. https://pubmed.ncbi.nlm.nih.gov/25177200/

Chen, T. C., Hsieh, C. C., Tseng, K. W., Ho, C. C., & Nosaka, K. (2017). Effects of descending stair walking on health and fitness of elderly obese women. *Medicine and Science in Sports and Exercise*, *49*(8), 1614–1622. https://doi.org/10.1249/MSS.0000000000001267

Chen, T. C., Yang, T. J., Huang, M. J., Wang, H. S., Tseng, K. W., Chen, H. L., & Nosaka, K. (2019). Damage and the repeated bout effect of arm, leg, and trunk muscles induced by eccentric resistance exercises. *Scandinavian Journal of Medicine & Science in Sports*, *29*(5), 725–735. https://doi.org/10.1111/sms.13388

Chen, T. C. C., Tseng, W. C., Huang, G. L., Chen, H. L., Tseng, K. W., & Nosaka, K. (2017). Superior effects of eccentric to concentric knee extensor resistance training on physical fitness, insulin sensitivity and lipid profiles of elderly men. *Frontiers in Physiology*, *8*, 209. https://doi.org/10.3389/fphys.2017.00209

Dandona, P., Aljada, A., & Bandyopadhyay, A. (2004). Inflammation: The link between insulin resistance, obesity and diabetes. *Trends in Immunology*, *25*(1), 4–7. https://doi.org/10.1016/j.it.2003.10.013

Debnath, M., Agrawal, S., Agrawal, A., & Dubey, G. P. (2016). Metaflammatory responses during obesity: Pathomechanism and treatment. *Obesity Research & Clinical Practice*, *10*(2), 103–113. https://doi.org/10.1016/j.orcp.2015.10.012

Drexel, H., Saely, C. H., Langer, P., Loruenser, G., Marte, T., Risch, L., Hoefle, G., & Aczel, S. (2008). Metabolic and anti-inflammatory benefits of eccentric endurance exercise – A pilot study. *European Journal of Clinical Investigation*, *38*(4), 218–226. https://doi.org/10.1111/j.1365-2362.2008.01937.x

Gupta, A., Ten, S., & Anhalt, H. (2005). Serum levels of soluble tumor necrosis factor-alpha receptor 2 are linked to insulin resistance and glucose intolerance in children. *Journal of Pediatric Endocrinology and Metabolism*, *18*(1), 75–82. https://doi.org/10.1515/JPEM.2005.18.1.75

Hackney, K. J., Engels, H. J., & Gretebeck, R. J. (2008). Resting energy expenditure and delayed-onset muscle soreness after full-body resistance training with an eccentric concentration. *Journal of Strength and Conditioning Research*, *22*(5), 1602–1609. https://doi.org/10.1519/JSC.0b013e31818222c5

Jacobs, J. L., Marcus, R. L., Morrell, G., & LaStayo, P. (2014). Resistance exercise with older fallers: its impact on intermuscular adipose tissue. *Biomed Research International*, *2014*, 398960, 1–7. https://doi.org/10.1155/2014/398960

Johnstone, A. M., Faber, P., Gibney, E. R., Lobley, G. E., Stubbs, R. J., & Siervo, M. (2014). Measurement of body composition changes during weight loss in obese men using multi-frequency bioelectrical impedance analysis and multi-compartment models. *Obesity Research & Clinical Practice*, *8*(1), E46–E54. https://doi.org/10.1016/j.orcp.2012.07.006

Julian, V., Thivel, D., Costes, F., Touron, J., Boirie, Y., Pereira, B., Perrault, H., Duclos, M., & Richard, R. (2018). Eccentric training improves body composition by inducing mechanical and metabolic adaptations: A promising approach for overweight and obese individuals. *Frontiers in Physiology*, *9*, 1013. https://doi.org/10.3389/fphys.2018.01013

Kim, J., & Hartzema, A. G. (2020). Metabolic syndrome and metabolically healthy status in adults with overweight or obesity, expressing no desire to lose weight. *Obesity Research & Clinical Practice*, *14*(1), 47–53. https://doi.org/10.1016/j.orcp.2019.11.007

Lemos, T., & Gallagher, D. (2017). Current body composition measurement techniques. *Current Opinion in Endocrinology Diabetes and Obesity*, *24*(5), 310–314. https://doi.org/10.1097/MED.0000000000000360

Marcus, R. L., LaStayo, P. C., Dibble, L. E., Hill, L., & McClain, D. A. (2009). Increased strength and physical performance with eccentric training in women with impaired glucose tolerance: A pilot study. *Journal of Womens Health*, *18*(2), 253–260. https://doi.org/10.1089/jwh.2007.0669

Marcus, R. L., Smith, S., Morrell, G., Addison, O., Dibble, L. E., Wahoff-Stice, D., & LaStayo, P. C. (2008). Comparison of combined aerobic and high-force eccentric resistance exercise with aerobic exercise only for people with type 2 diabetes mellitus. *Physical Therapy*, *88*(11), 1345–1354. https://doi.org/10.2522/ptj.20080124

Mathur, N., & Pedersen, B. K. (2008). Exercise as a mean to control low-grade systemic inflammation. *Mediators of Inflammation*, *2008*, 109502, 1–6. https://doi.org/10.1155/2008/109502

Mueller, M., Breil, F. A., Vogt, M., Steiner, R., Lippuner, K., Popp, A., Klossner, S., Hoppeler, H., & Däpp, C. (2009). Different response to eccentric and concentric training in older men and women. *European Journal of Applied Physiology*, *107*(2), 145–153. https://doi.org/10.1007/s00421-009-1108-4

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mull any, E. C., Biryukov, S., Abbafati, C., Abera, S. F., Abraham, J. P., Abu-Rmeileh, N. M. E., Achoki, T., AlBuhairan, F. S., Alemu, Z. A., Alfonso, R., Ali, M. K., Ali, R., Guzman, N. A., Ammar, W., & Gakidou, E. (2014). Global, regional, and natio nal prevalence of overweight and obesity in children and adults during 198 0-2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet*, *384*(9945), 766–781. https://doi.org/10.1016/S0140-6736(14)60460-8

Pasanen, T., Tolvanen, S., Heinonen, A., & Kujala, U. M. (2017). Exercise therapy for functional capacity in chronic diseases: An overview of meta-analyses of randomised controlled trials. *British Journal of Sports Medicine*, *51*(20), 1459. https://doi.org/10.1136/bjsports-2016-097132

Paschalis, V., Nikolaidis, M. G., Theodorou, A. A., Panayiotou, G., Fatouros, I. G., Koutedakis, Y., & Jamurtas, A. Z. (2011). A weekly bout of eccentric exercise is sufficient to induce health-promoting effects. *Medicine and Science in Sports and Exercise*, *43*(1), 64–73. https://doi.org/10.1249/MSS.0b013e3181e91d90

Paschalis, V., Theodorou, A. A., Panayiotou, G., Kyparos, A., Patikas, D., Grivas, G. V., Nikolaidis, M. G., & Vrabas, I. S. (2013). Stair descending exercise using a novel automatic escalator: Effects on muscle performance and health-related parameters. *Plos One*, *8*(2), e56218. https://doi.org/10.1371/journal.pone.0056218

Pedersen, B. K., & Saltin, B. (2015). Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scandinavian Journal of Medicine & Science in Sports*, *25*(s3), 1–72. https://doi.org/10.1111/sms.12581

Penailillo, L., Blazevich, A., & Nosaka, K. (2014). Energy expenditure and substrate oxidation during and after eccentric cycling. *European Journal of Applied Physiology*, *114*(4), 805–814. https://doi.org/10.1007/s00421-013-2816-3

Philippe, M., Junker, G., Gatterer, H., Melmer, A., & Burtscher, M. (2016). Acute effects of concentric and eccentric exercise matched for energy expenditure on glucose metabolism in healthy females: A randomized crossover trial. *Springerplus*, *5*(1), 1455. https://doi.org/10.1186/s40064-016-3062-z

Rattray, B., Steele, J., & Semple, S. (2014). Short-term eccentric exercise in newly diagnosed type II diabetics: An exploratory study. *Sport Sciences for Health*, 10, 199-204. https://doi.org/10.1007/s11332-014-0193-x

Rotter, V., Nagaev, I., & Smith, U. (2003). Interleukin-6 (IL-6) induces insulin resistance in 3T3-L1 adipocytes and is, like IL-8 and tumor necrosis factor-alpha, overexpressed in human fat cells from insulin-resistant subjects [J]. *Journal of Biological Chemistry*, *278*(46), 45777–45784. https://doi.org/10.1074/jbc.M301977200

Thompson, P. D., Arena, R., Riebe, D., & Pescatello, L. S. (2013). ACSM's new preparticipation health screening recommendations from ACSM's guidelines for exercise testing and prescription, ninth edition. *Current Sports Medicine Reports*, *12*(4), 215–217. https://doi.org/10.1249/JSR.0b013e31829a68cf

Zeppetzauer, M., Drexel, H., Vonbank, A., Rein, P., Aczel, S., & Saely, C. H. (2013). Eccentric endurance exercise economically improves metabolic and inflammatory risk factors. *European Journal of Preventive Cardiology*, *20*(4), 577–584. https://doi.org/10.1177/2047487312444236

Zhang, H. F., Tong, T. K., Qiu, W. F., Zhang, X., Zhou, S., Liu, Y., & He, Y. (2017). Comparable effects of high-intensity interval training and prolonged continuous exercise training on abdominal visceral fat reduction in obese young women. *Journal of Diabetes Research*, *2017*, 5071740, 1–9. https://doi.org/10.1155/2017/5071740