Home-based aerobic interval training combined with resistance training improved daytime dysfunction in adults with obesity and sleep-disordered breathing

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ABSTRACT

Introduction: There are many barriers to perform the exercise at center-based due to the pandemic of COVID-19 worldwide. Home-based aerobic interval training (AIT) combined resistance training (RT) may be helpful for obese adults with sleep-disordered breathing (SDB) to overcome those barriers and improve their subjective sleep disorders. Thus, this study aimed to examine the effects of home-based AIT combined with RT on subjective sleep disorders in obese adults with SDB. Material and Methods: This study was a one-group pretest-posttest design. Twenty-one adults with obesity and SDB were assigned to perform eight weeks of AIT combined with RT. Subjective sleep disorder variables including the Pittsburgh Sleep Quality Index (PSQI), Berlin Questionnaire, and Epworth Sleepiness Scale were defined as primary outcomes. Anthropometric variables, physical fitness components, and blood biomarkers were assigned as secondary outcome. All outcome measurements were examined at baseline and post-8 weeks of training. Results: Daytime dysfunction of PSQI was significantly improved after 8 weeks of the exercise program (p < 0.05). Upper and lower chest expansion and estimated maximum oxygen consumption were significantly increased after 8 weeks of the exercise program (all p < 0.05). None of the blood biomarkers changed after 8 weeks of training. Conclusion: This study suggests that home-based AIT combined with RT effectively alleviates daytime dysfunction and seems to be more helpful in improving of global PSQI in adults with obesity. Future study with a larger sample size under a controlled trial is recommended to prove the benefits of the exercise program.


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Clinical Trials? TCTR20201113003

Ethics committee number: WUEC-20-005-01
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ABSTRACT

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Keywords: Physical Fitness; Exercise; Sleep Quality; Resistance training
INTRODUCTION

Sleep-disordered breathing (SDB) is a sleep disorder which is commonly found in adults with obesity. The SDB continuum comprises of primary snoring, partial airway collapse, upper airway resistance syndrome, and obstructive sleep apnea (OSA). OSA is the most severe form of SDB, with a prevalence of 3.7% to 97.3% in Asian adults. A common coexisting pathway between obesity and SDB is the inflammatory pathway. Numerous studies have found that some of the inflammatory markers and metabolic markers, such as C-reactive protein (CRP), and glycated hemoglobin (HbA1c) are associated with SDB. A linkage between SDB and obesity can also be activated of oxidative stress, and endothelial dysfunction, which persuade atherosclerosis and cardiovascular diseases. Therefore, early diagnosis and treatment of SDB are needed to inhibit the adverse consequences of cardiovascular diseases.

Weight management program is suggested as the preliminary treatment for SDB. A recent meta-analysis found that physical exercise improves subjective sleep parameters such as daytime sleepiness, increases quality of life, and reduces OSA severity. Most physical exercise studies have an emphasis on individual aerobic exercise or combined with a diet program. Aerobic interval training (AIT) or high intensity interval training (HIIT) is an intermittent aerobic training at high intensity alternated with lower intensity. It has been widely used in a wide range of populations, for example, obese adults, and other vulnerable subjects. There is evidence support that AIT or HIIT is safe, time-efficient, and superior than traditional aerobic training for improving aerobic capacity, vascular function, and blood biomarkers. Supervised training at centers is commonly used to examine the effects of AIT or HIIT programs in SDB patients found to improve sleep indices and subjective sleep disorders. However, there are many restrictions in performing such a center-based training program with individual supervision due to the COVID-19 pandemic. Therefore, home-based AIT combined with resistance training (RT) was chosen in this study to gain the maximum effect in adults with obesity and SDB.

This study aimed to investigate the effects of AIT combined with RT on subjective sleep disorders, physical fitness components, anthropometric variables, and blood biomarkers in adults with obesity. We hypothesized that obese adults with SDB would have greater improvement in subjective sleep disorders, anthropometric variables, physical fitness components, and blood biomarkers than prior to receiving exercise intervention.
MATERIAL AND METHODS

Study population

This study was conducted at the Snoring Clinic at Maharaj Nakhon Si Thammarat Hospital, and from XXX University between September - December of 2020. A total of 21 obese adults in the age range of 18-65 years old were recruited and asked to complete three subjective sleep questionnaires (QN) including the Pittsburgh Sleep Quality Index (PSQI) (total PSQI score > 5), Berlin Questionnaire (score for Category 1 or 2 ≥ 2), and Epworth Sleepiness Scale (total score ≥ 10). The participants who had positive responses to one of these three QN were enrolled in the study. All participants were classified as obese based on their body mass index (BMI) using the International Obesity Task Force (IOTF) criteria. Participants who had other treatments were excluded from the study including continuous positive airway pressure therapy, oral appliance and/or other treatment option, medicine that would affect the study results, behavior modification program (e.g. an exercise or diet program), and had any medical conditions that limited exercise ability (e.g. symptomatic cardiac disease or neurological deficits). This study was approved by the Human Research Ethics Committee of XXX University (#WUEC-20-005-01). Written informed consent was mandatory to be included in the study. (Thai Clinical Trials Registry: TCTR20201113003).

Study design

A one-group pretest–posttest design was conducted. Participants were assigned to perform 8 weeks of AIT combined with RT as the intervention group (n=21). Primary outcomes included the Pittsburgh Sleep Quality Index (PSQI), Berlin Questionnaire, and Epworth Sleepiness Scale. Secondary outcomes included anthropometric variables (i.e. body weight (BW), body mass index (BMI), percent of body fat (%BF), physical fitness components (respiratory muscle strength, chest muscle strength, estimated maximum oxygen consumption, chest expansion), and blood biomarkers. All of the outcome measurements were examined at baseline and post-8 weeks of the exercise program. Importantly, the intra-rater reliability of the anthropometric variables, and physical fitness components were evaluated prior to the start of the study. All measurements found an acceptable intraclass correlation coefficient (ICC >0.9, all p<0.001).

Intervention (home-based exercise program)

The exercise program was designed as a home-based training program including a combination of 20-24 minutes of aerobic interval training (AIT) plus 20 minutes resistance training (RT). All participants were encouraged to perform these exercises three days per week for eight weeks. The AIT and RT program was modified according to previous studies. The AIT program composed of four 3-min bouts with an intensity...
higher than 75% maximum heart rate (MHR) (rating perceived of exertion (RPE) (modified Borg’s scale) > 4 of 10, or talk test = not able to speak comfortably), interspersed with 3 minutes of recovery period with an intensity lower than 75% MHR. The AIT exercise types included brisk walking/ jogging/ running on a treadmill or outdoors, and leg ergometer cycling or outdoor cycling. The target heart rate (THR) was calculated for each participant prior to the start of the first exercise session which was instructed by a physiotherapist. During the AIT session, the THR was monitored using a Polar H10. If the THR reached 75% MHR, the participants were asked to rate a dyspnea scale using a modified Borg’s scale. The participants must be memorized their dyspnea RPE score if the THR reached at 75% MHR. The modified Borg scale was used for monitoring the exercise intensity of the participants if they did not have a running watch. An exercise training room was also provided for participants who were not able to exercise at home according to the restriction on exercise tools. Heart rate monitoring tools were offered to participants if they preferred to utilize our training room. However, the participants needed to exercise and monitor their heart rate by themselves. After the AIT, the 20-minute RT program was conducted using a dumbbell, and body weight (BW). The RT comprised of a minimum of 50% of 1-repetitive maximum (RM), 10-15 repetitions for 2-3 sets with a 1-minute rest interval. Exercise poses included bicep curls, tricep extensions, curl-ups, back extensions, push-ups, bodyweight squats (with or without additional weight), and dumbbell chest press. The participants were taught to apply different sizes of water bottles that contain water or sand instead of using dumbbells for exercise at home. A 5-minute stretching exercise was conducted as a warm-up and cool-down period before and after the training sessions. A logbook was given to the participants for recording their exercise sessions at home. In addition, the procedures to perform the exercise intervention, HR monitoring during exercise, and the RT poses were also provided in the logbook. All participants were asked to return the logbook to confirm that they followed our exercise prescriptions. We also created a private group via online application to monitor their exercise and interchange knowledge during participation in the study.

Outcome measurements

Subjective sleep disorders

Subjective sleep disorders were measured through the Pittsburgh Sleep Quality Index (PSQI), Berlin Questionnaire, and Epworth Sleepiness Scale (ESS). These are all self-administered questionnaires. The PSQI is used to examine the sleep quality for the last month, which was translated in Thai by Sitasuwan et al. It contains 19 self-rated questions, and takes 10 minutes to complete. It is divided into seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The score of all seven components ranges from 0-21, with total score higher than 5 indicating
poor sleep quality. The ESS is used to examine excessive daytime sleepiness (EDS). It was translated into Thai version by Banhiran et al.\textsuperscript{24}. It composes of eight situations for the potential of dozing off or falling asleep with a rating scale of 0-3. A score > 10 of the ESS is classified as a person with EDS and at risk of SDB. The Berlin Questionnaire is used to identify the risk of a person who may have OSA. It is categorized into three subgroups including snoring, daytime sleepiness, and risk for obesity and hypertension. It was translated into Thai by Suksakorn et al.\textsuperscript{25}. It has good validity and reliability for assessing a person with OSA or SDB. It composes of 10 question items and takes 5 minutes to administer. A total score ≥ 2 for each category displays a positive risk for having OSA or SDB. Interestingly, these sleep questionnaires are valid, reliable, and commonly used in various SDB dimensions\textsuperscript{26}.

**Anthropometric variables**

BW, BMI, %BF, and visceral fat were measured using a bioelectrical impedance analyzer (Tanita BC-418, Tokyo, Japan). Participants were requested to stand on the scale with barefoot, and both hands hold the machine’s handheld for 10 seconds.

**Physical fitness components**

**Chest expansion**

Three levels of chest expansion including the upper (2\textsuperscript{nd} intercostal space), middle (4\textsuperscript{th} intercostal space), and lower chest (5\textsuperscript{th} intercostal space) were determined using tape measurement. Participants were asked to take a deep breath in and out while the tape measure was placed on their chest wall. The chest expansion score is the chest expansion after full inspiration minus the chest expansion after full expiration. The average of two times of chest expansion measurements was recorded.

**Muscle strength**

Participants were asked to stretch their chest muscle and extremities muscles before examining muscle strength. A seated chest press machine was used to determine the pectoralis muscle strength. Meanwhile, the other poses included bicep curls, tricep extensions, curl-ups, back extensions, push-ups, and squats using body weight and dumbbell to determine muscle strength. One-repetition maximum (1RM) was used to calculate muscle strength. The formula for estimating 1-RM (kg) is as follows: \(1\text{-RM (kg)} = \text{lifting weight (kg)} / (1 - 0.02 \times \text{repetitions})\\textsuperscript{27}. All muscle strengths were determined one time (at baseline) except for chest muscle strength examined at baseline and post 8 weeks of training.
**Respiratory muscle strength**

Respiratory muscle strength including maximum inspiratory pressure (MIP), and maximum expiratory pressure (MEP) were examined using MicroRPM respiratory muscle testing (Germany). The maximum value obtained from at least three trials which met the ATS criteria was chosen for analysis.

**Estimated maximum oxygen consumption (VO$_{2\text{max}}$)**

The Åstrand–Ryhming cycle ergometer test was used to determine an estimated VO$_{2\text{max}}$. Participants were asked to perform cycling for 6 minutes by following the guidelines. The average heart rate of the last 2 minutes was used to determine an estimated VO$_{2\text{max}}$ using a nomogram. The absolute estimated VO$_{2\text{max}}$ (l/min) and relative estimated VO$_{2\text{max}}$ (ml/kg/min) were used for analysis.

**Blood biomarkers**

Approximately, 9 mL of venous blood samples were drawn from each participant at the antecubital area after 12 h restraint of food and beverage. Total cholesterol (TC), triglyceride, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), glycosylated hemoglobin (HbA1c), and C-reactive protein (CRP) were analyzed by the standard laboratory method. All tests were performed using an Auto Analyser A15 (BioSystems S.A, Barcelona, Spain). Low-density lipoprotein cholesterol (LDL-C) was measured by the Freidewald equation. HbA1c was measured using high performance liquid chromatography (HPLC). CRP was examined by immunoturbidimetric assay.

**Sample size calculation**

The sample size was calculated based on a previous study using G-Power software (Version 3.1). Sleep variables including EDS and the Berlin Questionnaire (category 2) were used to calculate the sample size. The effect size ranged from 0.85 to 1.10 with a power of 0.95. In addition, twenty percent of participants were added for the elimination of dropout. Thus, the maximum number of 21 participants was derived from the calculation and enrolled in the study.

**Statistical analysis**

All data were recorded, entered and analyzed using the Statistical Package for the Social Sciences (SPSS) Version 22.0 (SPSS Co., Ltd. Bangkok, Thailand). Data distribution was examined using the Shapiro-Wilk test. The Paired Sample t-test and Wilcoxon-Signed Rank-test were used to compare baseline and post 8-weeks of the training program for normal distribution, and non-normal distribution data, respectively. Descriptive data was expressed as mean ± SD for continuous normal data distribution, median [Interquartile Range (IQR)] for
continuous skewed data, and counts (percentages) if indicating categorical data. The significance level was set at $p < 0.05$.

RESULTS

Participant characteristics

There were 28 participants were initially enrolled in the study, however, 7 of them were excluded because they were unavailable (lack of time), received other treatments, and had a history of asthma as shown in Figure 1. Later, another 4 participants were identified as dropout samples because they lacked the time to perform the exercise programs or had traveling obstacles. Nineteen, seventeen, and twenty participants were positive on the PSQI, ESS, and Berlin Questionnaire (Category 1) at baseline, respectively. Eleven participants (52%) were positive for all three questionnaires at the first screening. The average AIT session and RT session for all participants were 15 times (62.5%) and 12 times (50%), respectively. The types of exercise in all the AIT included walking/running on treadmill (53%), walking/running outside (27%), and cycling (20%). The reason for the participants who did not complete the exercise program (24 times) is explained in Figure 1. The other baseline characteristics of the participants are shown in Table 1.

Primary and secondary outcomes measurements

Component 7 of the PSQI (daytime dysfunction) improved after 8 weeks of training ($p = 0.017$). Meanwhile, the other subjective sleep disorder tended to improve at the end of training (Figure 2). In addition, there were significant increases in upper and lower chest expansion, the absolute and relative estimated VO$_2$ after 8 weeks of training (all $p < 0.05$). However, all of the blood biomarkers found no changes after 8 weeks of intervention (all $p > 0.05$) (Table 2).

DISCUSSION

The main findings of this study was the improvement of daytime dysfunction of the PSQI after 8 weeks of AIT combined with RT. In addition, the other sleep subjective disorders tended to improve in all questionnaire forms, especially the global PSQI. Among all of the physical fitness components found an increment of the estimated VO$_2$max and chest expansion at upper and lower part of thoracic wall after 8 weeks of AIT and RT but none of the anthropometric variables and blood biomarkers changed after 8 weeks of training.

This study is the first of its kind to determine the effect of home-based AIT combined with RT in adults with obesity and SDB. Previously, there were studies on home-based traditional aerobic exercise programs in
patients with SDB\textsuperscript{30, 31}. Brandão et al.\textsuperscript{30} examined the effects of 12 weeks of a home-based exercise program including aerobic exercises, strengthening exercises, balance training, coordination, and flexibility in the elderly with poor sleep quality. This study showed an improvement in all seven PSQI components and ESS\textsuperscript{30}, whereas, the present study found an improvement of daytime dysfunction, and tended to alleviate in global PSQI. Meanwhile, the study by Servantes et al.\textsuperscript{31} found that 3 months of home-based aerobic exercise with/ without RT improved functional capacity, strength, endurance, and sleep indices in patients with chronic heart failure and sleep apnea\textsuperscript{31}. Interestingly, both studies\textsuperscript{30, 31} showed a high adherence rate (98-100\%) of the exercise programs compared to the present study (62.5\%). Meanwhile, those previous studies\textsuperscript{30, 31} were intensively monitor the exercise program using phone calls and visited the participants’ homes when compared to the present study. Consequently, our results showed less effective and improvement than previous studies\textsuperscript{30, 31}. In addition, the present study did not control the diet habits of the participants, therefore all of anthropometric variables found no changes. To our knowledge, obesity is the most common risk of SDB\textsuperscript{1}. Thus, the improvement on daytime dysfunction in our study may be irrelevant to obesity, which is similar to previous studies\textsuperscript{9, 10}. Meanwhile, the previous review studies also supported our finding that physical exercise can improve daytime sleepiness and sleep quality independently from body composition eg. BMI in sleep apnea patients\textsuperscript{32, 33}. However, there are many mechanisms behind the improvement of sleep parameter\textsuperscript{33}. One theory claims that the severity of sleep apnea is related to the exercise capacity\textsuperscript{34}, oxidative stress, endothelial dysfunction\textsuperscript{35} and nocturnal hypoxemia\textsuperscript{36}. Interestingly, many previous studies confirmed that AIT or HIIT improved in aerobic capacity and endothelial function\textsuperscript{37, 38}. Thus, an obviously increment in exercise capacity (estimated VO\textsubscript{2}max) in our study may consequently improve daytime dysfunction and even other subjective sleep parameters e.g. sleep quality. Furthermore, the improvement of ventilatory muscle and peripheral muscle play a crucial role in increasing oxygen capacity\textsuperscript{39}. Therefore, even though the effect of AIT combined RT in our study did not show significant improvement in MIP & MEP, however, the mean difference of data showed an increase in respiratory muscle strength. It has been known that the accumulation of fat on the chest wall or mediastinum causes a reduction of lung compliance, chest wall mobility, and functional residual capacity, which may induce more suffer on breathing during sleep\textsuperscript{40}. Interestingly, even though our study found no changes in body composition, the effect of the combination exercise intervention remained to persuade the increasing most part of chest expansion. The latter mechanism may finally reinforce an improvement of some sleep parameters in this study. However, all of the blood biomarkers were not altered after 8 weeks of training. Thus, these blood biomarkers may counterbalance the positive effects of the exercise program. It might be induced by an increase in inflammatory markers, oxidative
stress, impaired vascular endothelium, and induced by an intermittent hypoxia and sleep fragmentation in OSA or SDB\textsuperscript{41}. These mechanisms might be the hindering cornerstone that results most of the subjective sleep disorders have limited improvement of subjective sleep disorders.

Recently, the studies have investigated the effects of a HIIT program in obese adults with SDB\textsuperscript{19, 20}. These studies showed an improvement in sleep indices\textsuperscript{19} and subjective sleep disorders\textsuperscript{20}. However, these studies prescribed a center-based exercise program tailored by the researchers, which was different to the present study\textsuperscript{19, 20}. The center-based training may have fewer confounding factors and be easier for the participants to follow the study protocol. However, the home-based AIT combined with RT in our study was safe, practically use in general and especially feasible to prescribe in obese adults with SDB because none of the participants reported any serious events during exercise.

There were some limitations found in this study. First, some of participants used the RPE scale or talk test to monitor their exercise intensity. Thus, error in measuring the THR might have occurred even though the RPE scale or talk test was used instead of the heart rate tracker watch. Second, the exercise adherence rate in our study was lower than previous studies\textsuperscript{30, 31}. To solve this problem, an online-based exercise program using various mobile applications might be appropriate for monitoring and incrementing the exercise adherence. In addition, phone calls and internet-based communications via mobile applications could be applied for increasing the exercise adherence rate. These implementations might result for better improvements in subjective sleep disorders than the present study. However, there were some strengths found in our study. First, three subjective sleep disorders questionnaires were used in our study to monitor a diversity of subjective sleep disorders including sleep quality, nighttime sleepiness, and daytime sleepiness. Therefore, the primary outcome measurement was comprehensively assessed by our teams. Second, this study was the first study to examine AIT using a home-based program, and none of the participants reported any serious adverse events during their exercise. Thus, AIT combined with RT with a home-based setting is suitable for the current situation with the pandemic of COVID-19 worldwide. It was effective for an improvement in daytime dysfunction and other subjective sleep disorders. Future study with a larger sample size under a controlled trial design is highly recommended to confirm the present findings.

ACKNOWLEDGEMENTS

The authors are deeply grateful to all participants who dedicated their time to participate in this study.
FUNDING STATEMENT

The authors are thankful to the Research Institute for Health Science of XXX University for partially granting the research fund (Research Grant WU-IRG-63-004).

CONFLICT OF INTEREST

Authors declare no conflict of interest relating to this work.

REFERENCES


Table 1. Baseline characteristics of the participants.

<table>
<thead>
<tr>
<th>Completed exercise program (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
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<tr>
<td>Gender, n (%)</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Subjective sleep disorders</strong></td>
</tr>
<tr>
<td>PSQI</td>
</tr>
<tr>
<td>Com1 (Subjective sleep quality)</td>
</tr>
<tr>
<td>Com2 (Sleep latency)</td>
</tr>
<tr>
<td>Com3 (Sleep duration)</td>
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<tr>
<td>Com4 (Habitual sleep efficiency)</td>
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<tr>
<td>Com5 (Sleep disturbances)</td>
</tr>
<tr>
<td>Com6 (Medication use)</td>
</tr>
<tr>
<td>Com7 (Daytime dysfunction)</td>
</tr>
<tr>
<td>Global PSQI</td>
</tr>
<tr>
<td><strong>Epworth Sleepiness Scale (0–24)</strong></td>
</tr>
<tr>
<td><strong>Berlin Questionnaire (Items 1–5)</strong></td>
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<tr>
<td><strong>Berlin Questionnaire (Items 6–8)</strong></td>
</tr>
<tr>
<td><strong>Comorbidities</strong></td>
</tr>
<tr>
<td>Hypertension, n(%)</td>
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<tr>
<td>Diabetes mellitus, n(%)</td>
</tr>
</tbody>
</table>

Note: PSQI = Pittsburgh Sleep Quality Index
Table 2. Comparison of anthropometric variables and physical fitness at baseline and post-8 weeks of training.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Post-8 weeks</th>
<th>Mean difference (95%CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anthropometric variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW (kg)</td>
<td>85.54 ± 13.28</td>
<td>85.09 ± 13.92</td>
<td>-0.44 (-1.74 to 0.85)</td>
<td>0.474</td>
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<tr>
<td>BMI (kg/m²)</td>
<td>29.92 ± 3.64</td>
<td>29.68 ± 3.41</td>
<td>-0.24 (-0.69 to 0.20)</td>
<td>0.265</td>
</tr>
<tr>
<td>%BF</td>
<td>32.86 ± 5.12</td>
<td>32.65 ± 4.73</td>
<td>-0.21 (-0.86 to 0.44)</td>
<td>0.500</td>
</tr>
<tr>
<td>Visceral fat</td>
<td>15.59 ± 5.59</td>
<td>15.35 ± 5.87</td>
<td>-0.24 (-1.02 to 0.55)</td>
<td>0.536</td>
</tr>
<tr>
<td><strong>Chest expansion</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Upper chest</td>
<td>3.05 ± 0.49</td>
<td>3.75 ± 0.99</td>
<td>0.70 (0.15 to 1.25)</td>
<td>0.016</td>
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<tr>
<td>Middle chest</td>
<td>3.30 ± 0.66</td>
<td>3.63 ± 1.19</td>
<td>0.33 (-0.28 to 0.93)</td>
<td>0.267</td>
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<tr>
<td>Lower chest</td>
<td>3.12 ± 0.56</td>
<td>3.82 ± 1.30</td>
<td>0.70 (0.03 to 1.36)</td>
<td>0.041</td>
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<tr>
<td><strong>Respiratory muscle strength</strong></td>
<td></td>
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<tr>
<td>MIP (cmH₂O)</td>
<td>105.88 ± 35.72</td>
<td>109.53 ± 28.35</td>
<td>3.65 (-4.74 to 12.03)</td>
<td>0.370</td>
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<tr>
<td>MEP (cmH₂O)</td>
<td>83.94 ± 30.46</td>
<td>88.59 ± 29.45</td>
<td>4.65 (-7.70 to 16.99)</td>
<td>0.437</td>
</tr>
<tr>
<td><strong>Estimated VO₂max</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Relative VO₂max (ml/kg/min)</td>
<td>29.89 ± 6.70</td>
<td>35.45 ± 6.62</td>
<td>5.56 (3.09 to 8.02)</td>
<td>0.000</td>
</tr>
<tr>
<td>Absolute VO₂max (L/min)</td>
<td>2.52 ± 0.55</td>
<td>2.95 ± 0.40</td>
<td>0.43 (0.22 to 0.64)</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Chest muscle strength (1-RM, kg)</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TC (mg/dL)</td>
<td>209.94 ± 40.86</td>
<td>207.94 ± 36.44</td>
<td>-2.00 (-13.05 to 9.05)</td>
<td>0.706</td>
</tr>
<tr>
<td>Triglyceride (mg/dL)</td>
<td>166.94 ± 41.12</td>
<td>172.35 ± 38.55</td>
<td>5.41 (-20.80 to 31.62)</td>
<td>0.667</td>
</tr>
<tr>
<td>LDL-C (mg/dL)</td>
<td>148.94 ± 42.74</td>
<td>150.88 ± 37.49</td>
<td>1.94 (-9.86 to 13.74)</td>
<td>0.732</td>
</tr>
<tr>
<td>HDL-C (mg/dL)</td>
<td>47.88 ± 11.57</td>
<td>49.88 ± 9.21</td>
<td>2.00 (-0.52 to 4.52)</td>
<td>0.112</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>6.08 ± 0.57</td>
<td>6.05 ± 0.51</td>
<td>-0.03 (-0.13 to 0.07)</td>
<td>0.532</td>
</tr>
<tr>
<td>CRP (mg/L)*</td>
<td>2.21 ± 1.47</td>
<td>2.78 ± 2.02</td>
<td>0.56 (-0.15 to 1.28)</td>
<td>0.114</td>
</tr>
</tbody>
</table>

Notes: BW = body weight; BMI = body mass index; %BF = percent of body fat; MIP = maximum inspiration pressure; MEP = maximum expiration pressure; VO$_{2}$max = maximum oxygen consumption; 1-RM = 1-repetition maximum; TC = total cholesterol; LDL-C = low density lipoprotein cholesterol; HDL-C = high density lipoprotein cholesterol; HbA1C = glycated haemoglobin type A1C; CRP = C-reactive protein
Subjective sleep disorders questionnaire

Figure 2: Comparison of subjective sleep disorders questionnaire between baseline and post-8 weeks of exercise (*=significant difference between baseline and post 8 weeks of training)

Flow diagram

Figure 1 Flow diagram for participants throughout this study.