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Effect of continuous exercise augmented by interval exercise on metabolic syndrome components: the first 16-week applied on-elliptical-trainer randomized-controlled trial

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Abstract

Introduction: To the best of searched limited knowledge, using an elliptical trainer (ET), no clinical randomized-controlled trial searched the effect of the combined form of exercise, moderate-intensity continuous training (MI-CAT) augmented by high-intensity-interval training (HI-IT) on metabolic syndrome (MS) components. This work aimed to study the response of MS parameters (MSP) to applied-on-ET 16-week combined exercise (MI-CAT augmented by HI-IT).

Material and methods: Forty MS patients –with ages ranging from 35-63 years old – were randomly assigned to the control group (CG) (one female + 19 males) and MI-CAT+HI-IT group (one female + 19 males). The CG patients were requested to maintain their normal physical activities. The exercise session of the other group was started with a 5-min warm-up, then 26-min MI-CAT, then HI-IT (four repetitions of a 3-minute interval with in-between-interval 180-second active-recovery workout, the 5-min cooling-up), and the session was introduced to every MS patient of this group 3 times weekly. Body mass index (BMI) and MSP: (high-density lipoprotein (HDL), blood systole and diastole, abdominal circumference, and triglyceride) were checked before and after the trial.

Results: After the trial, excluding HDL, BMI, and other MSP showed significant improvement within the MI-CAT+HI-IT group. All tested within-CG measures showed non-significant mentioned shifts.

Conclusions: Conducted combined training (16-week MI-CAT augmented by HI-IT) on ET can slow the deteriorated MSP.

Keywords: Exercise, Metabolic syndrome, Elliptical trainer, Continuous, Interval

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Introduction

The higher metabolic syndrome (MS) prevalence in adults (about 20 to 25% of the world population) adds a 3–time greater risk for cardiovascular diseases comorbidities involving insulin resistance and/or type 2 diabetes (T2D) and attacks related to the heart which may in sometimes leads to mortality. Many causes play a vital role in the development of MS: genetic causes, lifestyle causes (sedentary and unhealthy diet lifestyle), urbanization and modernization represent environmental/social causes and the final main physiological causes that include T2D and obesity in addition to raised levels of high-density lipoprotein (HDL), blood pressure (BP), and triglycerides (TG). One of the main recommended non-pharmacological lifestyle interventions for MS is increasing the levels of physical activity [1].

Exercise can be conducted at home, physical therapy centers, gyms, and hospitals on the most popular walking machine, the treadmill [2]. A relatively allowing-pedaling like-gait elliptical trainer (ET) device is another used popular rehabilitation device in cardiorespiratory fitness programs. When it is compared to a treadmill, ET carries more rehabilitation properties that allow patients with obesity, muscular/articular complaints particularly in lower limbs (LL), and risk of fall to exercise easily. Lower fallen stress on LL joints, lower chance to fall, simultaneous multi-integration of LL and upper limb (UL) muscles, a higher sense of balance derived from fixed bilateral feet contact, and higher energy expenditure derived from the concurrent continuous contraction of LL and UL muscles and alternative stepped movement pattern of UL and LL are great advantages promotes ET devices to be similar or relatively superior to a treadmill in the field of rehabilitation [3] or to get more attention from exercise therapists to study the physiological response of body/body metabolism to elliptical training.

The positive impact of commonly-used combined training, aerobic training (AT) plus resisted training, on MS has been searched redundantly [4,5]. Also, the other two common patterns of AT, moderate-intensity continuous AT (MI-CAT) and High-intensity interval training (HI-IT) - with the superiority to HI-IT – are documented to promote MS parameters: HDL, systolic and diastolic blood pressures (SBP, DBP), abdominal circumference (AC), fasting blood glycemia (FBG), and TG [6,7]. To the best of my limited knowledge, using ET, no clinical randomized-controlled trial searched the effect of the combined form of training (MI-CAT augmented by HI-IT) on MS components so this work aimed to study this aim.

Materials and methods

Design/clinical trial settings
Cairo University Hospitals (outpatient clinic for internal diseases) and a private physiotherapy center (in Cairo) were the based clinical settings for random selection of MS patients and exercise intervention, respectively. The time of conducting this randomized controlled for was between September (2020) to June (2021).

**Ethical instructions**

Before enrolling the 1st MS patient and conducting the intervention, this trial was recorded on clinicaltrials.gov website (NCT04635202 was the trial number on the website) after the given approval from the local ethical committee of scientific research (P.T.REC/012/002896 was the approval number from Physiotherapy Faculty – Cairo University). All recommendations of scientific research regarding patient consenting, Helsinki declaration, detailed trial explanation to patients, and rights to withdraw were applied.

**Inclusion criteria**

With 35-63 years (MS is common in middle-aged and older population) [1], the random recruitment of forty males and females who had MS was based on the presence of ≥ 3 parameters of the following: ≥ 110 FBG (expressed as mg/dl), TG ≥ 150 (mg/dl), AC ≥ 88 (cm) or ≥ 102 (cm) for women and men respectively, HDL < 50 (mg/dl), and drug administration for hypertension otherwise SBP and/or DBP above 130, 85 (mmHg) respectively [8].

**Exclusion criteria**

Patients with cancer, articular/muscular complaints of LL, cardiovascular and respiratory illness, hepatic or renal malady, neurological defect, pregnancy/lactation status, addiction on alcohols or illegal drugs, participation history in cardiorespiratory fitness or diet program (within last 24 weeks), and smoking custom were disallowed to participate in the trial.

**Randomization**

Randomly distributed through a computer block list, MS patients were equally assigned to either group 1 (one woman and 19 men) or group 2 (served as control patients, one woman and 19 men). While patients of group 2 were instructed to fix their daily physical activities without any changes for 16 weeks, group 1 received a 16-week training program on the Chinese Rocket ET model 3 times weekly (the detailed session stages are explained in Fig. 1). During exercise heart rate (HR) was monitored using placed in-wrist ID116-Plus Bracelet HR-Tracker.
Fig. 1. The stages of the applied training per session.

Assessments

Every MS patient in group 1 was tested with on-ergometer-cycle cardiopulmonary exercise testing before conducting the first MI-CAT augmented-by HI-IT session on Fracais ergoselect
(made in France). The following loads were distributed during the five cycling stages of the test: zero watt (3 min for fitting), 40 watts (3 min for warming-up), 20-watt (increased every 1 min until accomplishing 90% from maximal HR or feeling exhausted), 40 watts (3 min for cooling down), ended by zero watt (3 min relaxed cycling) [9].

Aside from body mass index (BMI), parameters of MS: SBP, DBP (examined via manual sphygmomanometer), lipids (HDL and TG examined via Synchron Blood Analyzer), AC (examined via non-stretchable tape at umbilicus level), and FBG (examined with a glucose meter, On Call Plus) were tested before and after the trial.

Sample size

The effect size, 1.1, of blood glucose (main outcome) was gained from conducting a sample size test (using G-power analysis program) on 10 MS patients (as a pilot study) with power 1-β error equal to 90%. To complete this elliptical training trial, thirty-six MS patients were needed.

Statistical analysis

Shapiro test approved the normality of all data so, before the intervention, the difference between groups regarding age was tested by unpaired test. Regarding BMI/parameters of MS, within and between groups were checked by paired and unpaired tests respectively. At P-value < 0.05, the significance of all applied tests - using SPSS 18 program – was examined.

Results

Figure 2 demonstrates the chart flow of this elliptical training trial. No approved significant before-interventional difference between groups regarding basic data (Tab. 1) or MS parameters (Tab. 2).
Fig. 2. The flow chart of the study.

Tab. 1. Based anthropometric and clinical data of groups.

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of MS patients (years)</td>
<td>51.35(8.20)</td>
<td>51.75±8.42</td>
<td>0.879*</td>
</tr>
<tr>
<td>MS♀/MS♂</td>
<td>1/19</td>
<td>1/19</td>
<td></td>
</tr>
<tr>
<td>Glibenclamide agent</td>
<td>3 MS patients</td>
<td>3 MS patients</td>
<td></td>
</tr>
</tbody>
</table>
Pharmacotherapeutic agents (n) administered by diabetic MS Subjects

<table>
<thead>
<tr>
<th>Pharmacist agents</th>
<th>Metformin agent</th>
<th>3 MS patients</th>
<th>3 MS patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statins agent</td>
<td>2 MS patients</td>
<td>2 MS patients</td>
<td></td>
</tr>
<tr>
<td>Angiotensin-II blockers agents</td>
<td>2 MS patients</td>
<td>2 MS patients</td>
<td></td>
</tr>
<tr>
<td>βeta-blockers agents</td>
<td>3 MS patients</td>
<td>2 MS patients</td>
<td></td>
</tr>
</tbody>
</table>

♀, Women; ♂, Man; Data are expressed in table 1 as mean± standard deviation or n (number); MS, Metabolic syndrome; Group 1, Elliptical exercise group; Group 2, Non-exercised (control) group; BMI, Body mass index; * , non-significant P-value ( > 0.05).

The comparison managed by the statistician between the pre and post values of all assessed outcomes (except HDL) showed a significant difference within group 1 but when the statistician held the same comparison for group 2, he reported a non-significant difference for all measured outcomes (Tab. 2). Excluding HDL, the post-built between-group comparison disclosed a significantly improved outcome measures toward trained group 1 (Tab. 2).

Tab. 2. Group-1 and group-2 pre/post-measures

<table>
<thead>
<tr>
<th>Evaluated measures</th>
<th>Group 1</th>
<th>Group 2</th>
<th>P value (among group 1 &amp; 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Index of body mass expressed as Kg/m²</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>33.21(1.96)</td>
<td>33.31(2.13)</td>
<td>0.878(NS)</td>
</tr>
<tr>
<td>The value after treatment</td>
<td>32.15(1.78)</td>
<td>33.44(2.13)</td>
<td>0.044(S)</td>
</tr>
<tr>
<td>Significance of p value within groups</td>
<td>0.003(S)</td>
<td>0.096(NS)</td>
<td></td>
</tr>
<tr>
<td><strong>Abdominal circumference expressed as cm</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>112.95(5.89)</td>
<td>113.15(5.64)</td>
<td>0.913(NS)</td>
</tr>
<tr>
<td>The value after treatment</td>
<td>109.60(5.70)</td>
<td>113.30(5.74)</td>
<td>0.047(S)</td>
</tr>
<tr>
<td>Significance of p value within groups</td>
<td>0.001(S)</td>
<td>0.083(NS)</td>
<td></td>
</tr>
<tr>
<td><strong>Systolic pressure expressed as mmHg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>139.45(8.19)</td>
<td>139.55(8.19)</td>
<td>0.969(NS)</td>
</tr>
<tr>
<td>The value after treatment</td>
<td>127.85(5.50)</td>
<td>140.20(7.89)</td>
<td>0.0001(S)</td>
</tr>
<tr>
<td>Significance of p value within groups</td>
<td>&lt; 0.001(S)</td>
<td>0.097(NS)</td>
<td></td>
</tr>
<tr>
<td><strong>Diastolic pressure expressed as mmHg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>91.95(3.88)</td>
<td>91.60(4.39)</td>
<td>0.790(NS)</td>
</tr>
<tr>
<td>The value after treatment</td>
<td>80.95(2.30)</td>
<td>91.80(4.31)</td>
<td>0.0001(S)</td>
</tr>
<tr>
<td>Significance of p value within groups</td>
<td>&lt; 0.001(S)</td>
<td>0.163(NS)</td>
<td></td>
</tr>
<tr>
<td><strong>Blood-glucose (fasting-status) expressed as mg/dL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>119.75(10.52)</td>
<td>119.90(10.24)</td>
<td>0.963(NS)</td>
</tr>
<tr>
<td>The value after treatment</td>
<td>108.30(7.86)</td>
<td>119.75(9.98)</td>
<td>0.0003(S)</td>
</tr>
<tr>
<td>Significance of p value within groups</td>
<td>&lt; 0.001(S)</td>
<td>0.330(NS)</td>
<td></td>
</tr>
<tr>
<td><strong>plasma HDL expressed as mg/dL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The value before treatment</td>
<td>34.25(4.08)</td>
<td>34.05(3.83)</td>
<td>0.873(NS)</td>
</tr>
</tbody>
</table>
The value after treatment | 35.35(5.16) | 34.06(3.85) | 0.375(NS)  
Significance of p value within groups | 0.112(NS) | 0.330(NS) 
plasma TG expressed as mg/dL |  
The value before treatment | 190.00(8.64) | 193.70(8.26) | 0.174(NS)  
The value after treatment | 162.70(7.62) | 193.95(8.26) | 0.0001(S)  
Significance of p value within groups | < 0.001(S) | 0.330(NS) 

(NS), non-significance of P value (> 0.05); Data are expressed in table 2 as mean± standard deviation; Group 1, Elliptical exercise group; HDL, High density lipoprotein; Group 2, Non-exercised (control) group; TG, Triglycerides; (S), significant P value (< 0.05).

Discussion

Besides increased vasodilating substances (as nitric oxide), arterial elasticity, macro/microcirculation, and endothelial functioning, the improved BP –as one of MS components - after AT may be related to reduced plasma vasoconstrictors, sympathetic stimulation to within-muscle vessels, and insulin resistance [10]. Due to its abundance of oxidation-related proteins (GLUT4, hexokinase II, and electron transport chain complex-II), stimulating oxidative proteins of oxidative muscle fibers - via incorporating lower limb muscles (especially large ones) in fast walking - can lower blood glucose by increasing glycemic transference, phosphorylation, and oxidation levels [11].

Due to the increased activity of lipolytic enzymes (lipoprotein A and LPL), sympathetic nervous system, and growth hormone, AT reduces bloodstream TG. Destructed TG is used as a fuel for muscle contraction [12]. Non-significant AT-induced HDL increase of this trial is supported by Casella-Filho et al. [13] who stated that exercise-induced paraoxonase-1 binding to HDL surface can cause earlier significant increased functional subcomponents of HDL (FS-HDL) which does not have to be followed by a significant serum-HDL increase so it is important to evaluate serum FS-HDL not serum total-HDL after non-pharmacological interventions of MS.

The 2018-systematic review by Lemes et al. [14] related the average decrease of metabolic risk factors (two centimeters for AC, 5 mmHg for SBP, and 3 mmHg for DBP) to the regular commitment to performing AT. Except for reached-to-significance HDL (opposite to the trial HDL outcome), the response of other MS components followed the trial results after the moderate-intensity applied AT for MS patients by Kang et al. [15]. Swift et al. [16] positively supported HDL finding of this trial but in overweight/obese persons. Also, the same comment in MS university students was found by Morales-palomo et al. [17] who found that the conduction of sixteen-week AT (applied in 3 forms: moderate-intensity continuous, high-intensity continuous, and high-intensity interval) built non-significantly HDL increase.
Again, HI-IT in MS elderly [18] or moderate-intensity continuous applied AT in obese men [19] and girls [20] built the aspired significant TG. The results for MS components in males with risk factors for metabolic disease [21] or in post-menopausal women with obesity [22] were similar to ours. The use of ET in exercise protocols can significantly improve MS indices [23] or risk factors for metabolic diseases as blood glucose [24-26], AC [25, 27], blood pressure [25].

Opposing presented MS outcomes, 12-week training by Wang et al. [28] built a significant HDL increase within-MS exercised women in addition to the post-non-significant changed TG, blood pressure, and blood glucose between MS-exercised and MS-non-exercised women and MS non-exercised postmenopausal women. Again, besides the opposed significant HDL increase to our results [29, 30], the introduced 3-month HI-IT for women with metabolic risk factors did not promote the improved AC, blood pressure, blood glucose [18, 29], TG, and BMI [29] to significance.

Limitations

Many limitations of this trial should be treated in MS future studies as investigating the response of the functional subfraction components of HDL, treadmill vs ET effect on MS components, the additional effect of restricted diet, and follow up.

Conclusion

Combined elliptical training (MI-CAT augmented by HI-IT) can slow the deteriorated MS parameters when performed for 16 weeks.

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No

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Conflict of interest

The author declares no conflict of interest

References


