Electrical muscle stimulation can be used to elicit cardiovascular exercise response at training intensities in obese adults.

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Abstract

This study was carried out to establish the energy cost of a pattern of rhythmical lower extremity muscle contractions induced by low frequency electrical muscle stimulation in obese subjects. 9 obese adult subjects underwent VO2max testing using a cycle protocol to establish their maximal aerobic capacity. They then completed a 1-hour session in which their quadriceps and hamstring muscle groups were rhythmically stimulated whilst their oxygen consumption was measured using open circuit spirometry. Obese subjects’ average oxygen consumption during EMS was equivalent to 4.0±0.8 METS or 47.3±4.7% of their maximal aerobic capacity (mean±sd). These results suggest that rhythmical EMS induced leg muscle contractions can be used to elicit a cardiovascular exercise response at therapeutic intensities in obese adults.

1 Introduction

The World Health Organization (WHO) estimates that globally more than 1 billion adults are overweight or obese, with increasing obesity rates projected over the next 20 years (1). The associated increased risk for a variety of chronic diseases means that obesity presents a major problem for public health.

Increasing physical activity by ~100 kcal per day can help to prevent gradual weight gain (2). The American College of Sports Medicine has recommended that adults who wish to lose weight should engage in moderate intensity physical activity on at least 3 separate days for a cumulative duration of 5 hours per week (3). However, participating in this quantity of exercise can often prove very difficult for obese adults (4) leading to problems with exercise compliance. There is clearly, therefore, a need to investigate novel intervention strategies to help to promote increased physical activity and caloric expenditure in obese adults.

One therapeutic modality that has received a lot of attention in this area in recent years is electrical muscle stimulation (EMS). The clinical use of EMS in provision of pain relief and promotion of muscle strengthening is long established. However, more recently, researchers have demonstrated that EMS training programmes are safe and can have a beneficial health effect in patients with COPD and heart failure by means of increasing capacity for exercise activity (5,6). In previous studies, we have demonstrated that low frequency EMS can be used to elicit a repeatable physiological response that is consistent with cardiovascular exercise with no adverse effects. Furthermore, when repeatedly subjected to this stimulation over a 6 week period, sedentary adults demonstrated clinically significant increases in aerobic fitness (VO2max), muscle strength and capacity for voluntary exercise (7).

This form of low frequency stimulation may also be very well suited to obese adults as it could offer them a safe and controllable means of engaging in cardiovascular exercise without having to subject themselves to potentially damaging repeated joint loading. Repeated exposure to this form of EMS should result in an increased capacity to engage in voluntary exercise and increased physical activity levels with resultant increases in caloric expenditure and weight loss.

Despite the potential physiological benefits of this form of low frequency EMS, its use in the obese population has not been reported up to now. This may be a reflection of a widely held view that large amounts of subcutaneous fatty tissue would result in excessive resistance to current flow to target neural tissue in obese subjects.

Thus, in the present study, we sought to apply low frequency EMS to a group of obese adults in order to assess the feasibility of using it as a therapeutic modality in this population.

2 Methods

2.1 Subjects

9 obese adults who were attending an outpatient weight management clinic volunteered to participate in this study. The institutional Ethics Committee ap-
proved the study and written informed consent was obtained in all cases. The 9 subjects included 3 males and 6 females with a mean age of 43.8 ± 3.0 years and an average mass and body mass index (BMI) of 116.8±8.3 kg and 41.5± 1.8 Kg/m² respectively. Prior to participation in the study, each subject underwent a complete physical examination (including a stress ECG) to ensure that they were fit to undertake physical activity.

2.2 Measurements

The measurements reported here were taken as part of a larger, ongoing prospective study in which obese adults are undergoing EMS exercise training (EMS-EX) for a period of 6 months to assess its long term effects on exercise capacity and body composition. Maximal aerobic capacity measurements were taken at the beginning of this study and the energy cost measurements during EMS-EX were taken following the first 4 weeks of EMS-EX training, when subjects had an opportunity to become accustomed to the stimulation.

Maximal aerobic exercise capacity was evaluated using an incremental cycle ergometer test protocol with simultaneous cardiopulmonary gas exchange analysis. Subjects wore a facemask and a gas analysis system calibrated against gases of known concentrations according to manufacturer’s guidelines (Quark B2, Italy) was used to measure the expired oxygen and carbon dioxide concentration and volume. VO2 was calculated from these measurements. Subjects were required to pedal at incremental workloads until any of the following endpoints were reached; a levelling of VO2 response despite increasing exercise intensity, abnormal cardiovascular signs, or fatigue. In all cases in this investigation the reason for terminating the treadmill test was subject fatigue. Peak VO2 was calculated from the average VO2 measurement during the last 30 seconds of the cycle test at each test session. HR was also recorded throughout the test.

Energy cost due to stimulation was measured over the course of a 1-hour EMS-EX session carried out following a 4 week period of habituation. Subjects performed their EMS-EX session in sitting or standing according to personal preference and were instructed to turn the stimulation intensity to a comfortable tolerable level. Physiological measurements, including VO2 and HR were recorded at rest and throughout the hour long session using open circuit spirometry as described above. The average VO2 and HR for the 1 hour session was calculated and taken as a representation of the energy cost due to EMS-EX.

2.3 Stimulation

A specially designed hand held muscle stimulator (NT2010, BioMedical Research Ltd, Galway, Ireland) was used to produce rhythymical contractions in the lower extremity muscle groups in this investigation. The stimulator current waveform was designed to produce rhythymical contractions in the lower extremity muscle groups occurring at a frequency of 5Hz. The maximum peak output pulse current used in the present study was 200mA. Impulses were delivered through 4 adhesive electrodes on each leg (area per leg = 800cm²). These were applied to the body via a neoprene ‘wrap’ garment that was secured to the thigh with Velcro straps. This array of electrodes produced contractions in the quadriceps, hamstrings, and calf muscles.

Study volunteers were instructed to use the stimulator at their maximal tolerable comfortable level, with the proviso that their HR response during stimulation could not go above a predetermined limit (85% of their max HR during their incremental exercise test).

Figure 1. Location of Stimulating Electrodes

2.4 Data Analysis

All subjects’ results for VO2 and HR at rest, during EMS-EX and at maximal capacity were averaged separately for male and female subjects prior to calculation of overall group mean results. Energy cost during EMS-EX was calculated in 2 ways; by expressing average VO2 during the 1-hour EMS-EX session as a percentage of VO2max measured during the incremental cycle test (%max) and as a percentage of resting VO2 levels (METS). Relationships between the measured variables during each condition were calculated using descriptive statistics.

3 Results

All tests were completed by subjects without any difficulty. Group mean VO2max during the cycle test was 18.5±1.3ml/min/kg whereas average VO2 over the course of the 1-hour EMS-EX session was 9.0±1.3ml/min/kg, equivalent to 4.0±0.8METS. Subjects’ average maximal HR during the cycle test was 161.2±3.3BPM compared to an average HR during EMS-EX of 114.8±7.5BPM. Male subjects exhibited higher relative energy cost levels than female subjects, represented by VO2 and MET levels during
Table 1. VO2 & HR at rest, during 1-hour EMS-EX and at maximal capacity during incremental exercise test.

<table>
<thead>
<tr>
<th></th>
<th>Male Subjects (n=3)</th>
<th>Female Subjects (n=6)</th>
<th>Population Results (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resting VO2 (ml/min/kg)</strong></td>
<td>2.8±0.5</td>
<td>2.2±0.3</td>
<td>2.4±0.3</td>
</tr>
<tr>
<td><strong>EMS-EX VO2 (ml/min/kg)</strong></td>
<td>13.0±2.1</td>
<td>7.0±0.9</td>
<td>9.0±1.3</td>
</tr>
<tr>
<td><strong>VO2max (ml/min/kg)</strong></td>
<td>21.7±2.1</td>
<td>16.8±1.2</td>
<td>18.5±1.3</td>
</tr>
<tr>
<td><strong>Energy Cost during EMS-EX (%max)</strong></td>
<td>59.8±4.3</td>
<td>41.1±4.9</td>
<td>47.3±4.7</td>
</tr>
<tr>
<td><strong>Energy Cost during EMS-EX (METS)</strong></td>
<td>5.4±2.1</td>
<td>3.3±0.5</td>
<td>4.0±0.8</td>
</tr>
<tr>
<td><strong>Resting HR (BPM)</strong></td>
<td>70.3±4.1</td>
<td>66.3±1.6</td>
<td>67.7±1.7</td>
</tr>
<tr>
<td><strong>EMS-EX HR (BPM)</strong></td>
<td>139.3±11.0</td>
<td>102.5±4.7</td>
<td>114.8±7.5</td>
</tr>
<tr>
<td><strong>Max HR (BPM)</strong></td>
<td>158.7±5.4</td>
<td>162.5±4.4</td>
<td>161.2±3.3</td>
</tr>
</tbody>
</table>

Values are mean±SD

EMS-EX (59.8±4.3% Vs 41.1±4.9% VO2max). A breakdown of male and female’s results at rest, during 1-hour EMS-EX, and at maximal capacity is detailed in Table 1.

4 Discussion

The principal finding from this investigation is that adult obese subjects can use EMS-EX to elicit cardiovascular exercise responses at intensities that were equivalent to 45-50% of their VO2max. This intensity of exercise is consistent with the American College of Sports Medicine’s recommendations on the training stimulus required for increasing maximal aerobic capacity and promoting weight loss in adult subjects (3). The subjects were able to achieve this training intensity without any great difficulty or adverse physiological response, indicating that this form of EMS may have significant potential as an alternative exercise modality in the management of obesity. Though the training intensities involved were at the lower end of the scale, they are very reasonable and safe exercise intensities to implement in an obese population who have very low baseline levels of fitness and often find participation in voluntary exercise very difficult (4).

The stimulation parameters employed in this investigation produced a pattern of rapid, rhythmical, deep muscle contractions in the large lower extremity muscle groups of our subjects. Electrodes were only placed over the quadriceps and hamstrings but manual palpation revealed that the calf muscles were also stimulated to contract during EMS-EX. This large scale rhythmical contraction of muscle mass resulted in a large energy demand in the muscles, resulting in increased supply and consumption of Oxygen. The results obtained from male subjects were significantly higher than those obtained from females. Men, on average, achieved more than 2METS more than women during EMS-EX. The male subjects also reported increased comfort levels at equivalent stimulation intensities compared to females. We hypothesise that the reason for this was the relative regional adipose tissue deposition differences that are commonly seen in men and women. Men tend to have increased abdominal fat whereas women have a tendency towards deposition of fat on the buttocks and thighs. This increased deposition of fat under the stimulation area in the women is likely to result in increased resistance to current flow.

This form of EMS-EX is not likely to be a realistic proposition as an alternative to voluntary exercise in all scenarios. However, we believe that it may provide a real opportunity for obese subjects to begin to engage with aerobic exercise in a safe and controlled manner and may form a ‘bridge’ to participation in other forms of exercise. EMS-EX may also have significant potential in other populations who, like those with obesity, have barriers to participation in voluntary exercise. For example, patients with degenerative joint disease may benefit from it as it can offer an opportunity to participate in unloaded aerobic exercise. It may also have potential as an exercise modality in patients with spinal cord injury. However, the lack of muscle bulk would need to be addressed in this population prior to being able to use EMS-EX to induce a therapeutic aerobic exercise response.

5 Conclusion

This investigation represents a significant advance in the clinical use of EMS. Adult obese subjects can use EMS-EX at intensities that are high enough to induce a training response. Therefore EMS has potential as an exercise modality in the management of obesity

6 Literature

3. ACSM. 2001. New position stand on losing weight & keeping it off