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Abstract

Background and Purpose: Sleeve gastrectomy is a major therapy for morbid obesity, but recent reports suggest that its effects on weight loss are improved when patients increase their muscular activity, while a weight regain may occur in more than 30% of patients after 40 months. Exercise is an effective mean of preventing weight regain. In a recent preliminary study, we reported that exercise training targeted at the level of maximal lipid oxidation (LIPOXmax) improved weight loss and weight stabilization at 30 months. This study extends this previous one and aims at describing the kinetics of weight loss on 60 months after sleeve in people performing or not a LIPOXmax training and to see whether this variety of training exerts a satiogenic effect in sleeve patients as has been evidenced in nonoperated obese subjects.

Methods: We present a longitudinal study of sleeve associated or not with regular exercise prescribed and followed over 60 months. Two groups of obese patients matched for baseline BMI and age were compared. The first group was treated by sleeve gastrectomy alone and patients did not increase their muscular activity. The second group practiced 3x45 min/week endurance exercise targeted at the level of maximal lipid oxidation (LIPOXmax) after sleeve gastrectomy.

Findings: In a series of 43 patients (split into two matched subgroups, 20 trained, and 23 untrained) we confirm that LIPOXmax training associated to sleeve induces a greater weight loss than sleeve alone (p=0.001). In a subset of 10 subjects (6 women and 4 men) we show that the first sessions of of training decrease all items related to hunger (p<0.05) and increase satiety (p<0.05). However, the intensity of these effects is lower than previously observed in nonoperated obese subjects.

Conclusion: Therefore, the long lasting, moderate, and slightly progressive weight-reducing action of LIPOXmax endurance training is observed after sleeve gastrectomy and synergistically adds its effect to that of surgery. This effect is associated with a decrease in orexigenic drive and an improvement of satiety.

Introduction

Sleeve gastrectomy (SG) is a major therapy for morbid dietary-resistant obesity [1,2]. This operation leads to considerable weight loss accompanied by important morphological and psychological changes [3], but on the long term there is a considerable number of patients who regain weight [4]. Reported rates of weight regain range from 5.7% at 2 years to 75.6% at 6 years. Proposed causes of this weight regain included initial sleeve size, sleeve dilation, increased ghrelin levels, inadequate follow-up support and maladaptive lifestyle behaviours [5]. Recent literature emphasizes the importance of regular physical exercise as a prevention for this weight gain [6-8]. We recently reported that low intensity training targeted at the maximal level of lipid oxidation, ie, a very easy to apply and well-tolerated exercise protocol [9,10], is a very efficient strategy for this purpose [11].

However, the reasons for the efficiency of such a soft exercise protocol after sleeve gastrectomy is not clear. According to the classical paradigm [12] exercise induces weight loss because it induces an energy deficit. Clearly, a volume of 3x45 min of LIPOXmax training results in very little energy deficit (less than 200 kcal per session), and this mechanism
Exercise calorimetry

Exercise Calorimetry was performed in all patients before targeting exercise on the zone where lipid oxidation is maximal [23]. All subjects were asked to come and perform test in the morning after an overnight fast (12 hours). The test consisted of five six minute steady–state workloads theoretically set at 20, 30, 40, 50, and 60% of Pmax. However these intensity levels can be modified during the test according to the evolution of the respiratory exchange ratio (RER=VCO2/VO2) in order to obtain values of RER below and above 0.9 which is the level of the Crossover Point (COP). The subjects performed the test on an electromagnetically braked cycle ergometer (Ergoline Bosch 500). Heart rate and electrocardiographic parameters were monitored continuously throughout the test by standard 12-lead procedures. Metabolic and ventilatory responses were assessed using a digital computer based breath to breath exercise analyzing system (COSMED Quark CPET). Thus, we could measure VO2, VCO2 (in ml/min) and calculate the non–protein RER. Lipid oxidation (Lipox) and carbohydrate utilization (Glucox) rates were calculated by indirect calorimetry from gas exchange measurements according to the non–protein respiratory quotient technique as previously reported [24]. This technique provided carbohydrate and lipid oxidation rates at different exercise intensities. Additionally, after smoothing the curves, we calculated the two parameters quantifying the balance between carbohydrates and lipids induced by increasing exercise intensity: the maximal lipid oxidation point (LIPOXmax) and the Crossover Point (COP). The LIPOXmax is the exercise intensity at which lipid oxidation reaches its maximal level before decreasing while carbohydrate utilization further increases. It is calculated as previously reported after smoothing of the curve plotting lipid oxidation as a function of power [24].

Coaching and follow-up of patients

Each subject included in the exercise group of the 1st study or in the 2nd study was enrolled in eight exercise sessions of 45 min at the LIPOXmax determined with the exercise test in order to include in his/her everyday life at least 3 similar bouts of low intensity endurance exercise per week. Subjects were then followed monthly in outpatient unit for the first year and then every 3 or 4 months [9].

Evaluation of training-induced changes in hunger and satiety

As usual in this kind of studies we used a French adaptation of Hill & Blundell’s scale [25–27]. The original version of this questionnaire contained six questions: 1) How hungry do you

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Table 1: Anthropometric characteristics of the subjects of study N°1. Values are given as mean±SEM. No significant difference among the two groups.

<table>
<thead>
<tr>
<th></th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Height (m)</th>
<th>BMI (kg/m²)</th>
<th>BP max (mmHg)</th>
<th>BPmin (mmHg)</th>
<th>Waist circumference (cm)</th>
<th>Hip circumference (cm)</th>
<th>Fat free mass (kg)</th>
<th>% body fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trained subjects (n=20)</td>
<td>36.75±2.80</td>
<td>137.6±5.74</td>
<td>1.72±0.02</td>
<td>46.46±1.92</td>
<td>113.00±2.00</td>
<td>67.00±1.00</td>
<td>134.00±8.38</td>
<td>126.13±7.52</td>
<td>59.7±3.44</td>
<td></td>
</tr>
<tr>
<td>Untrained subjects (n=23)</td>
<td>44.09±3.43</td>
<td>126.44±5.97</td>
<td>1.67±0.02</td>
<td>44.22±1.82</td>
<td>125.33±3.18</td>
<td>79.00±5.86</td>
<td>122.88±5.37</td>
<td>126.13±7.52</td>
<td>60.21±3.22</td>
<td>47.57±1.78</td>
</tr>
</tbody>
</table>

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feel?’ (not at all hungry/as hungry as I’ve ever felt); ‘How full do you feel?’ (not at all full/as full as I have ever felt); ‘How strong is your desire to eat?’ (very weak/very strong); ‘How much do you think you could eat now?’ (nothing at all/a large amount); ‘Urge to eat’ (no urge to eat/strong, want to eat now, waiting is very uncomfortable); ‘Preoccupation with thoughts of food’ (no thoughts of food/very preoccupied difficult to concentrate on other things). All items were quoted on an analogic numeric scale.

Statistical analysis

Descriptive statistics were performed. A two-way analysis of variance (ANOVA) was used to determine whether there was an effect of training vs non training over time and whether it was different between the two groups (study one), and whether there was an acute effect of a LIPOXmax training session over Hill’s scale and whether this effect changed after a period of training (study two). ANOVA was performed with Sigmastat (Jandel Scientific). A p-value less than 0.05 was used to assess statistical significance.

Results

Figure 1 shows the average decrease in body weight over 5 years. There is a highly significant difference between sleeve only and sleeve+lipoxmax (p=3.1 x 10^{-34}). Curves become significantly different after 30 months (p=0.047). At 60 months the trained group has lost on the average 57.92±19.4 kg vs only 23.25±6.76 in the group of patients who did not benefit of training.

Figure 2 shows weight loss in the two groups expressed in percentage of initial weight. There is a highly significant difference between sleeve only and sleeve+lipoxmax (F=155.28 p=8.5 x 10^{-55}). Curves become significantly different after 30 months (p=0.047). At 60 months the trained group has lost on the average 57.92±19.4 kg vs only 23.25±6.76 in the group of patients who did not benefit of training.

Figure 3 and table 3 show the evolution of the ratings of eating behavior an Hill’s scale. This picture represents ‘induction of training’ in the hospital outpatient unit on cycloergometer before training was continued at home and regularly followed in consultations.

Efficacy of LIPOXmax training in patients undergoing sleeve gastrectomy. On the whole, trained patients have lost 35% more weight than untrained patients after 60 months. In addition, it shows that LIPOXmax training sessions in patients in whom a sleeve gastrectomy has been performed induce significant changes in satiety and orexigenic drive leading to a tendency to eat less and to be more rapidly satiated.

Therefore, this work confirms over a period of 5 years (60 months) that low intensity exercise training targeted at the LIPOXmax has an additional efficiency on weight loss in patients treated by sleeve gastrectomy. While patients treated by sleeve alone have lost on the average 31 kg and exhibit a...
Table 3: Two-way analysis of variance over sessions of training analyzing the effect of one session and the effect obtained after repeated sessions (Figure 3). Training decreases items related to hunger and the orexigenic drive while it increases the sensation of fullness after eating.

<table>
<thead>
<tr>
<th>Item</th>
<th>Effect of one session</th>
<th>Training effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>« How hungry do you feel? (not at all hungry/as hungry as I've ever felt) »</td>
<td>F=18 p=0.02</td>
<td>F=8.4 p=0.017</td>
<td>P=0.664</td>
</tr>
<tr>
<td>'How full do you feel? (not at all full/as full as I have ever felt):</td>
<td>F=4.25 p=0.062</td>
<td>F=6.87 p=0.027</td>
<td>P=0.28</td>
</tr>
<tr>
<td>How strong is your desire to eat? (very weak/very strong);</td>
<td>F=6.3 p=0.033</td>
<td>F=6.13 p=0.035</td>
<td>P=0.76</td>
</tr>
<tr>
<td>'How much do you think you could eat now?' (nothing at all/a large amount);</td>
<td>F=1.95 p=0.195</td>
<td>F=9.76 p=0.013</td>
<td>P=0.783</td>
</tr>
<tr>
<td>'Urge to eat' (no urge to eat/strong, want to eat now, waiting is very uncomfortable);</td>
<td>F=11.6 p=0.08</td>
<td>F=4.52 p=0.06</td>
<td>P=0.024</td>
</tr>
<tr>
<td>'Preoccupation with thoughts of food' (no thoughts of food/very preoccupied difficult to concentrate on other things).</td>
<td>F=22.18 p=0.001</td>
<td>F=13.16 p=0.005</td>
<td>P=0.82</td>
</tr>
</tbody>
</table>

Of three similar groups will be useful to do, but such a study will probably be extremely expensive and difficult to manage.

In conclusion, our study clearly demonstrates that regular exercise training targeted at the LIPOXmax, which is a simple and easily acceptable procedure in such patients, is a powerful complement to sleeve gastrectomy and improves its weight lowering effect over more than 60 months, preventing weight regain over this period. The mechanism of this fair effect of a very soft procedure in not clear and may involve epigenetic reprogramming of various metabolic functions, but we show here that this exercise training has favorable effects on eating behavior, similar to those previously observed in non-operated obese subjects.

References


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