Reduction of sleeping metabolic rate after vertical banded gastroplasty.

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Reduction of sleeping metabolic rate after vertical banded gastroplasty

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OBJECTIVE: To investigate whether long-term weight loss after vertical banded gastroplasty (VBG) results in a sustained reduction of sleeping metabolic rate (SMR) as a persistent risk factor for weight regain.
DESIGN: Longitudinal clinical intervention study of morbidly obese patients undergoing VBG.
PATIENTS: Group I: Six patients in which body composition and SMR were measured before and at 3, 6 and 12 months after VBG. Group II (long-term effect): nine patients in which body mass (BM) was measured before VBG, and body composition and SMR were measured 98 ± 30 months after VBG.
MEASUREMENTS: Body composition was assessed by deuterium dilution and hydrostatic weighing. SMR was measured (SMRm) in a respiration chamber and predicted (SMRp) based on body composition.
RESULTS: In group I, fat mass and fat free mass decreased significantly after VBG ($P < 0.05$). SMRm decreased from 11.1 ± 1.8 (s.d.) MJ/d before VBG to 8.1 ± 0.9 MJ/d ($P < 0.05$) at 12 months after VBG. In group II at a mean of 98 months after VBG, the SMRm (6.9 ± 0.7 MJ/d) was lower than the preoperative value of group I ($P < 0.05$). SMRm was lower than SMRp at all intervals after VBG ($P < 0.05$). The ratio measured *vs* predicted SMR was in group I: 1.02 ± 0.05 before VBG, 0.91 ± 0.08 at 12 months after VBG ($P < 0.05$), and in group II: 0.94 ± 0.08 at a mean of 98 months after VBG ($P < 0.05$).
CONCLUSION: The reduction of SMR adjusted for body composition after VBG is sustained as long as weight loss is maintained. The sustained and disproportional reduction of SMR may reflect the persistent susceptibility of the postobese to weight regain.

Keywords: morbid obesity; vertical banded gastroplasty; energy expenditure; sleeping metabolic rate; body composition

Introduction

There is accumulating evidence for a low habitual energy expenditure as a risk factor for obesity.[1] The most important determinant of total energy expenditure is resting energy expenditure, which is mainly determined by body size and composition. There remains considerable interindividual variation in resting metabolic rate (RMR), even when controlled for body size and composition, which is in part genetically determined.[2] Keesey[3] hypothesized that morbidly obese subjects strive to maintain a predetermined body weight and that weight loss is counteracted by a disproportional reduction of energy expenditure. This would explain the persistent propensity to overweight and weight regain after weight loss. This hypothesis is supported by the clinical observation that morbidly obese patients who reach and maintain ideal body weight for several years following surgical treatment return rapidly to their morbidly obese status when unlimited eating capacity is regained as a result of a technical failure.

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Kleiber[4] demonstrated a logarithmic relationship between body weight and resting metabolic rate for many different animal species. By means of this relationship the RMR can be predicted. However, this relationship holds only when the subject is at its normally maintained physiological body weight. After weight loss, the measured energy expenditure will be lower than the predicted energy expenditure because the weight loss is counteracted by a disproportional decrease in energy expenditure. The normally maintained and defended physiological body weight of morbidly obese persons may be preset at a higher level. It would explain why conservative treatment does not achieve long-term weight loss and is associated with high initial failure rates or recidivism.[5] Garrow[6] demonstrated that the decrease in metabolic rate is more than could be accounted for by the loss of lean tissue mass, and furthermore, that the energy equivalent of the body weight lost is affected by the rate of weight loss. At high rates of weight loss, the body weight lost is composed of a mixture of adipose tissue and lean tissue, while at low rates of weight loss, the body weight lost consists almost completely of adipose tissue.[6]

The results of studies regarding the role of energy expenditure in the pathogenesis of obesity are conflicting.[7] The majority of these studies did include morbidly obese subjects and investigated energy

expenditure over a short time after moderate dietary-induced weight loss. In the present study, a surgical study model was preferred in which morbidly obese patients undergo surgical treatment. Surgical treatment generally results in a substantial and long-lasting weight loss[8] and, consequently, larger changes in resting energy expenditure are expected and long term effects can be studied. To study the effect of weight loss on energy expenditure in a surgical study model, it is important to perform a restrictive surgical procedure, such as a vertical banded gastroplasty (VBG), where weight loss is purely the result of a restricted intake.

The hypothesis tested in this study, was that long-term weight loss after VBG results in a sustained and disproportionate reduction of sleeping metabolic rate (SMR) as a persistent risk factor for weight regain.

Patients and methods

Patients

Two series of patients were included in the analysis. Group I consisted of six patients measured before VBG and 3, 6 and 12 months after VBG in a prospective manner. A second group of patients several years after VBG was studied to investigate whether the results of the first study could be confirmed after sustained (long-term) weight reduction. Initially, group II consisted of 10 patients measured once, more than 36 months after VBG and with $>40\%$ excess weight loss. Preoperatively, only the body mass (BM) was measured in the latter group. One patient from group II was excluded from the study, because this patient developed a septic episode during the study period, as a result of an enterocutaneous fistula after correction of an incisional hernia.

The study protocol and the equipment used were identical for both groups. All patients gave their written informed consent before participation in the study.

Body composition measurements

Body composition was assessed by deuterium oxide dilution and hydrostatic weighing. The patients drank the deuterium oxide solution at 23.00 h after collection of a baseline urine sample. The deuterium oxide dilution was measured in the urine sample of the second voiding in the morning, resulting in an equilibration time of 9–10 h. The dose of deuterium oxide solution (99.8% ^2H_2O) was approximately 0.1 g ^2H_2O/kg body water resulting in an excess enrichment of 100 ppm. Total body water before administration was estimated from age- and gender-specific formulae.[9] Isotope abundance in the urine samples was measured with an isotope ratio mass spectrometer (VG Isogas, Aqua Sira, Cheshire, UK). Total body water was calculated as the deuterium dilution space divided by 1.04 for correction of a 4% over-estimation of the dilution space.[10]

Whole body density was determined by hydrostatic weighing. Total BM and underwater weight were measured to the nearest 0.05 kg on a digital scale (Mettler, 240C, Greifensee, Switzerland). Simultaneously, residual lung volume was measured by the Helium dilution tech-nique (Mijnhardt Volugraph, Breda, The Netherlands).

A three body-compartment model was used to calculate fat mass (FM) and fat free mass (FFM) from BM, water mass and body volume.[11]

Energy expenditure measurement

SMR was measured in a respiration chamber. The patients were instructed to maintain their normal diet for at least 3 days prior to the experiment. SMR was measured during an overnight stay (20.00–07.30 h) in a respiration chamber. The subjects were not allowed to eat in the chamber and coffee or tea were allowed until 22.00 h. SMR was measured over a period of three consecutive hours during minimal activity level as judged from Doppler radar observation. In the respiration chamber, the oxygen and carbon dioxide concentrations of the ingoing and outgoing air were measured with a paramagnetic analyser (Magnos 6G, Hartman & Braun, Frankfurt, Germany) and an infrared analyser (URAS 3G, Hartman & Braun, Frankfurt, Germany), respectively.[12] Energy expenditure was calculated using Weir's formula.[13]

SMR, as measured in the respiration chamber (SMRm), was compared with a predicted value (SMRp) based on FFM and FM using a regression formula: $\mathrm{SMRp} = 0.85 + 0.102\mathrm{FFM} + 0.024\mathrm{FM}$.[14] Westerterp *et al*[14] combined the data of 11 studies containing a total of 290 healthy subjects with a wide range of body weights (38–215 kg) in a multiple regression analysis to predict basal metabolic rate (BMR).[14] BMR was calculated from FFM and FM. In the present study, the regression formula developed to predict BMR turned out to predict SMR very well. A regression formula to predict SMR based on the preoperative data of group I is practically the same as the regression formula developed by Westerterp *et al.*[14] The latter regression formula was chosen for the present study since it is better validated.

Statistics

BM, FFM and FM (kg) and SMR (MJ/d) are expressed as the mean value $\pm$ s.d. Data were analyzed using the Statistical Package for Social Science (SPSS release 6.0, SPSS Inc, Chicago).[15] Differences within the group were tested with the Wilcoxon Signed Ranks test and differences between groups with the Mann-Whitney U test. Statistical significance was considered present at $P < 0.05$.

Table 1 Preoperative characteristics of group I and II (mean ± s.d.).

	Group I	*Group II*
n	6	9
Age	28 ± 7	32 ± 5
Male:female	5:1	3:7
BM (kg)	155.5 ± 31.1	131.1 ± 17.0
BMI (kg/m^2)	48.1 ± 7.0	45.7 ± 5.7

Group I consists of six patients measured in a prospective manner after vertical banded gastroplasty (VBG). Group II (long-term effect) consists of nine patients measured once, 98 ± 30 months after VBG and with 57 ± 13% excess weight loss. The only significant difference between groups is the male : female ratio ($P < 0.05$). BM = body mass, BMI = body mass index.

Results

Patients

The preoperative characteristics of group I and II were comparable, except for the male : female ratio (Table 1). The mean period after surgical treatment was 98 ± 30 months (40–150 months) for the patients of group II and the mean percentage excess weight loss was 57 ± 13%. The body weight curve after VBG of both groups shows a rapid weight loss in the first 6 months and a slow weight loss from 6–12 months. At 12 months after VBG, stable body weight was achieved in both groups (Figure 1).

Body composition

The mean BM, FFM and FM of group I were significantly reduced after VBG ($P < 0.05$) (Table 2). The mean body weight lost at one year after VBG was 53.2 ± 16.0 kg and consisted of 83 ± 41% FM and 17 ± 15% FFM. During rapid weight loss in the first six months after VBG, the mean body weight lost was 48 ± 11 kg and consisted of 78 ± 27% FM and 22 ± 14% FFM. From 6–12 months after VBG, the body weight lost was only 5 ± 12 kg and was entirely composed of FM. In the latter period, the FFM showed a slight recovery.

The mean BM of group II was also significantly reduced after VBG (131 ± 17 *vs* 93 ± 11; $P < 0.01$).

Energy expenditure

The mean SMRm of group I was significantly reduced at all intervals after VBG compared to the preoperative value ($P < 0.05$) (Table 3). Before VBG the mean SMRm of group I was not different from the mean SMRp resulting in a SMRm/p ratio of 1.02 ± 0.05. At three and six months after VBG, during rapid weight loss, the mean SMRm of group I was significantly reduced compared to the mean SMRp ($P < 0.05$) and remained so in the weight-stable post-obese situation at 12 months after VBG ($P < 0.05$) (Figure 2). Consequently, the SMRm/p ratio dropped below 1.0 at three and six months after VBG, during rapid weight loss, and remained lower than 1.0 in the weight-stable post-obese situation at 12 months after VBG in group I ($P < 0.05$) (Figure 3).

The results of the prospective measurements of group I could be confirmed in group II, in which the long-term effects of sustained weight loss on SMR were studied. In group II the mean SMRm was lower than the mean SMRp ($P < 0.05$), and also lower than the preoperative mean SMRm of group I ($P < 0.01$). The SMRm/p ratio of group II was significantly lower than the preoperative SMRm/p ratio of group I ($P < 0.05$).

Discussion

In the present study, the measured SMR was equal to the predicted SMR in the weight-stable obese situation, in which the patients were apparently at their

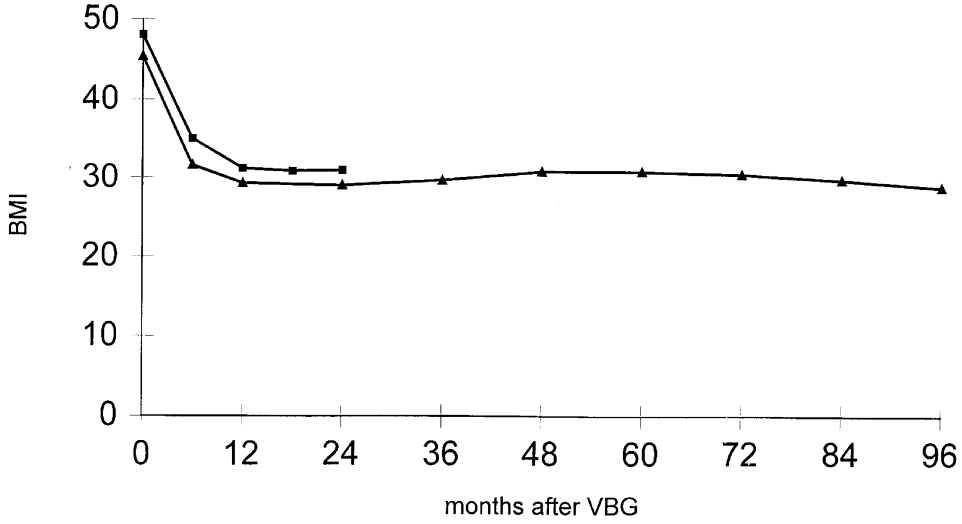

Figure 1 Body weight curve after vertical banded gastroplasty (VBG). The body weight curve expressed as body mass index (BMI (kg/m^2)) exhibits a rapid weight loss in the first six months after VBG. From 6–12 months after VBG, little body weight is lost and stable body weight is achieved at 12 months after VBG. The squares represent group I and the triangles represent group II.

Table 2 Body composition at different intervals after vertical banded gastroplasty (VBG) (mean ± s.d.).

	Group I				*Group II*
	0 months	*3 months*	*6 months*	*12 months*	*> 36 months*
BM (kg)	155.5 ± 31.1	123.2 ± 28.2*	107.4 ± 25.9*	102.3 ± 24.1*	93.2 ± 10.5**
FM (kg)	74.0 ± 28.6	49.2 ± 22.3*	36.6 ± 17.0*	30.0 ± 11.4*	39.0 ± 8.2**
FFM (kg)	81.5 ± 13.6	73.9 ± 13.7*	70.8 ± 13.6*	72.3 ± 13.0*	54.2 ± 7.2**

Group I consists of six patients measured in a prospective manner after VBG. Group II (long-term effect) consists of nine patients measured once, 98 ± 30 months after VBG and with 57 ± 13% excess weight loss. BM = body mass, FM = fat mass, FFM = fat free mass. $^{*}P < 0.05$, $^{**}P < 0.01$ for differences with the preoperative values of group I (differences within group I are tested with the Wilcoxon Signed Ranks test and between group I and II with the Mann-Withney U Test).

Table 3 Measured (SMRm) and predicted sleeping metabolic rate (SMRp) at different intervals after vertical banded gastroplasty (VBG) (mean ± SD)

	Group I				*Group II*
	0 months	*3 months*	*6 months*	*12 months*	*> 36 months*
SMRm	11.1 ± 1.8	8.4 ± 1.6*	7.9 ± 1.6*	8.1 ± 0.9*	6.9 ± 0.7**
SMRp	10.9 ± 1.5	9.6 ± 1.6*	9.0 ± 1.6*		9.0 ± 1.6*
	7.3 ± 0.8**		1.02 ± 0.05	0.88 ± 0.06*	0.88 ± 0.04*
		SMRm/p			
	0.91 ± 0.08*	0.94 ± 0.08*			

Group I consists of six patients measured in a prospective manner after VBG. Group II (long-term effect) consists of nine patients measured once, 98 ± 30 months after VBG and with 57 ± 13% excess weight loss. SMRm/p = ratio measured *vs* predicted energy expenditure. $^{*}P < 0.05$, $^{**}P < 0.01$ for differences with the preoperative values of group I (differences within group I are tested with the Wilcoxon Signed Ranks test and between group I and II with the Mann-Withney U Test).

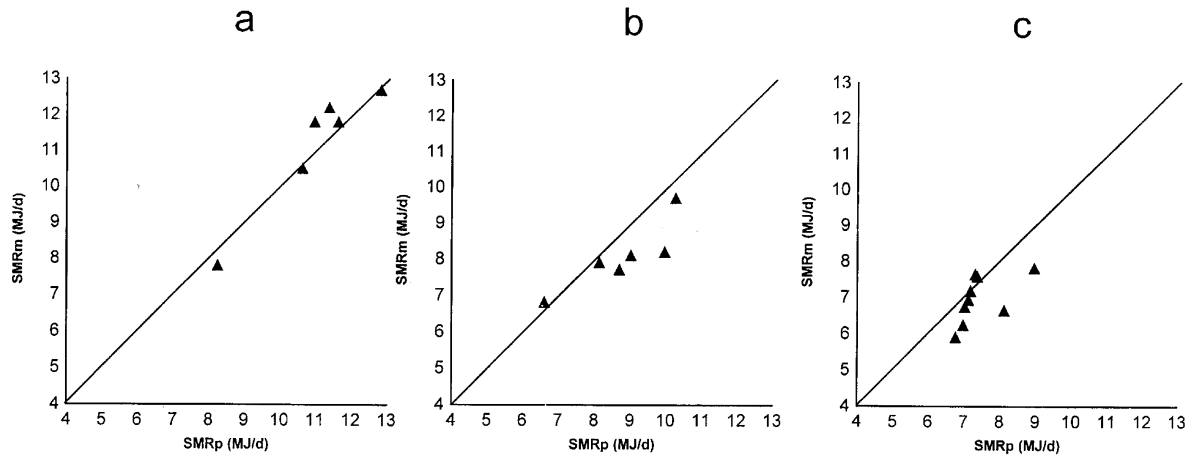

Figure 2 Measured (SMRm) and predicted (SMRp) sleeping metabolic rate in the weight-stable situations. These figures show the individual values of SMRm and SMRp in the weight-stable situations: group I before vertical banded gastroplasty (VBG) (a), group I at 12 months after VBG (b) and group II > 3 y after VBG (c). The individual values of group I before VBG are distributed around the reference line SMRm/p = 1, while 12 months after VBG in group I and in group II the individual values are distributed below the reference line.

predetermined physiological body weight. As soon as weight loss occurs, the measured SMR drops below the predicted SMR. At three and six months after VBG, the reduction of SMR is at least partially explained by a prevailing negative energy balance, since the patients were still losing weight. However, a long-term stable weight reduction after VBG, results in a measured SMR which is still significantly lower than the predicted SMR, implying that the disproportionate reduction of SMR is sustained as long as weight loss is maintained.

Reports in the literature are conflicting regarding the effect of weight loss on the disproportionate reduction in energy expenditure. Although many studies showed a reduced energy expenditure disproportional to weight loss[16–26], other studies could not confirm these results.[27–34] Most of the studies in which the subjects are used as their own controls, show a reduction of RMR larger than expected, based on body composition.[16,17,19,21–23] In contrast, the majority of studies comparing stable post-obese subjects with weight-matched controls, did not yield a

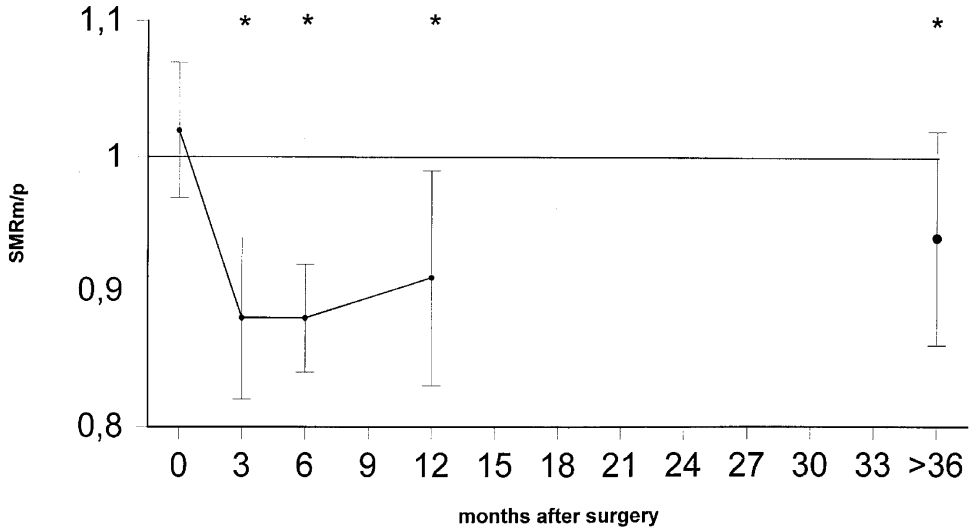

Figure 3 The ratio's measured *vs* predicted sleeping metabolic rate (SMRm/p) of group I and group II. The SMRm/p of group I before vertical banded gastroplasty (VBG) is approximately one. At 3, 6 and 12 months after VBG the SMRm/p ratio of group I drops below one (closed circles). The SMRm/p ratio of group II >3 y after VBG is also below one (open circle). The error bars represent the s.d. $^{*}P<0.05$ for differences with the preoperative value of group I (differences within group I are tested with the Wilcoxon Signed Ranks test and between group I and II with the Mann-Withney U Test).

disproportionate reduction in RMR.[27–30,32] The latter studies had in common that the study population was recruited by advertisement and some of these studies had a high drop out rate, which introduces a selection bias.

Furthermore, most of these studies have a small sample size which creates the risk that an actual difference may be overlooked. An overview of 11 studies comparing post-obese with matched controls, revealed a subnormal resting energy expenditure for a given body composition in all studies, however, the differences were significant in only three studies.[35] Because the difference in resting energy expenditure is only 4–5%, the sample sizes of these studies were not large enough to detect this difference consistently. A pooled analysis of these 11 studies by Astrup[35] provided a larger sample size, and the 4–5% difference in resting energy expenditure became significant.

In the present study, the SMR was adjusted for body composition by using the ratio of measured *vs* predicted SMR, in which the predicted SMR incorporates FFM as well as FM. The way in which RMR is expressed is important, since it can change the conclusions drawn. Heshka *et al*[17] measured RMR and FFM in 35 obese subjects enrolled in a conservative weight loss program. The RMR-FFM ratio did not change with weight loss. However, regression analysis showed that the RMR declined to a greater degree than the FFM alone. The additional decline correlated significantly with the loss of FM. Hoffmans *et al*[36] reported a significant contribution of FM to the explained variance in SMR or RMR in normal and moderately obese subjects. In most studies RMR is expressed per unit FFM, without correction for FM, resulting in an overestimation of measured RMR, since FM contributes significantly to RMR. This error becomes more significant with increasing degrees of obesity and thus, greater FM.

The disproportionate reduction in RMR in post-obese individuals may reflect the genetic component of obesity. Once a defect in energy metabolism is established, it is important to identify the underlying mechanisms. Different mechanisms leading to obesity seem to be involved and emphazise the heterogeneous nature of obesity, for example, an altered responsiveness of the sympathoadrenal system,[37] defects in substrate oxidation[38] and lower levels of thyroid hormones.[26] These mechanisms can cause a disproportionate reduction in RMR in post-obese individuals and, with that, a susceptibility to weight regain. Further research is necessary to investigate in depth the mechanisms responsible for the defects in energy metabolism.

Conclusion

The data of the present study demonstrate a normal SMR adjusted for body composition in the morbidly obese patients prior to VBG, while long-term weight loss after VBG results in a SMR which is significantly lower than expected, based on body composition. The sustained disproportionate reduction in SMR may explain the persistent susceptibility of the post-obese subjects to regain weight. As a consequence, the treatment of morbid obesity may only be successful when the therapeutic measures taken have a lifelong effect.

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