Predictors of Long-term Weight Maintenance

Neeltje Vogels, Kristel Diepvens, and Margriet S. Westerterp-Plantenga

Abstract

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Objective: The purpose of this study was to evaluate available variables of a long-term weight maintenance study to investigate possible factors predisposing to weight regain after a period of weight loss.

Research Methods and Procedures: The Maastricht Weight Maintenance Study is an ongoing longitudinal study of healthy men and women (29 men and 62 women; 18 to 65 years of age; BMI = 30.2 ± 3.1 kg/m^2). A variety of parameters were measured before and after a very-low-energy diet and after a follow-up of at least 2 years.

Results: Mean weight loss was 7.9 ± 3.6 kg, and percent weight regain was 113.8 ± 98.1%. Percent BMI regain was negatively associated with an increase in dietary restraint ($r = -0.47$, $p < 0.05$). Percent weight regain was negatively correlated with baseline resting metabolic rate ($r = -0.38$, $p = 0.01$) and baseline fat mass ($r = -0.24$, $p = 0.05$) and positively correlated with the magnitude of change in body weight (BW) expressed as maximum amplitude of BW ($r = 0.21$, $p < 0.05$). In addition, amplitude of BW was positively correlated with the frequency of dieting ($r = 0.57$, $p < 0.01$).

Discussion: The best predictors for weight maintenance after weight loss were an increase in dietary restraint during weight loss, a high baseline resting metabolic rate, a relatively high baseline fat mass favoring a fat-free mass–sparing effect during weight loss, a rather stable BW, and a low frequency of dieting. Therefore, BW maintenance after BW loss seems to be a multifactorial issue, including mechanisms that regulate an individuals' energy expenditure, body composition, and eating behavior in such a way that energy homeostasis is maintained.

Key words: weight loss, resting metabolic rate, dietary restraint, body composition, dieting

Introduction

Obesity results from a chronic imbalance between energy intake and expenditure. It increases the risk of numerous conditions including type 2 diabetes, hypertension, and coronary heart disease, which themselves are associated with increased morbidity and mortality (1,2). Modest weight loss reduces the risks associated with obesity-related disorders and diseases (3,4). Although typically prescribed weight loss strategies produce short-term success, sustained weight maintenance is rarely achieved (5–7). Determining and understanding the possible parameters that predispose individuals to body weight (BW)[1] regain after a period of weight reduction is, therefore, necessary to improve current weight maintenance strategies.

A large number of studies have previously addressed this issue. Weight (re)gain has been associated with a low resting metabolic rate (RMR) (8–12), a high respiratory quotient (RQ) (13–17), and higher scores on cognitive dietary restraint measured with the Three-Factor Eating Questionnaire (TFEQ) (6,18–21). RMR is the component of energy expenditure that explains the largest proportion of an individual's total daily energy expenditure. A low RMR may, therefore, explain why some individuals regain weight more easily than others. An elevated postabsorptive RQ after discontinuation of a low-energy diet shows that the endogenous fat oxidation is reduced (13). Therefore, a high fasting RQ should be considered predictive of BW regain (14). The TFEQ is a self-report measure of eating behaviors that are believed to be particularly relevant to the development and maintenance of obesity. The TFEQ has been widely used in obesity treatment and includes three subscales: cognitive dietary restraint (Factor 1), disinhibition of dietary restraint and emotional eating (Factor 2), and hunger (Factor

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[1] Nonstandard abbreviations: BW, body weight; RMR, resting metabolic rate; RQ, respiratory quotient; TFEQ, Three-Factor Eating Questionnaire; VLCD, very-low-calorie diet; TBW, total body water; FFM, fat-free mass; FM, fat mass; EE, energy expenditure; EI, energy intake.

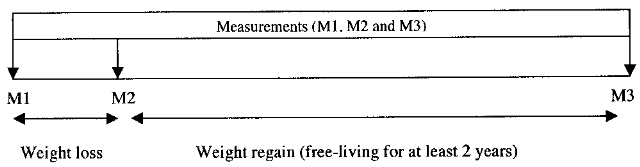

Figure 1: Study design. Measurements, including BW, BMI, body composition, attitude toward eating, BW amplitude, RMR, and RQ, were taken three times over at least 2 years.

3) (22). Restrained eating has been studied extensively. In general, lower overall intake of food energy, especially fat and carbohydrate intake, has been associated with higher cognitive restraint scores, especially in the obese (23–26). Weight cycling has also been put forward as an important predictor of weight gain. Different studies have shown that repeated weight losses and regains do not improve the success of future weight loss attempts (27–29); they may even be related to net weight gain (7,18,30–32) and may, therefore, have truly negative health consequences (27,29). Weight cycling may induce an unfavorable change in body composition, elevated blood pressure, and decreased resting energy expenditure (29). Moreover, weight regain is associated with life stress, negative coping style, and use of eating to cope with negative emotions (33).

The purpose of this study was to evaluate relevant variables of different long-term weight maintenance studies to determine possible factors predisposing to weight regain after a period of weight loss. In addition to taking the frequency of dieting into account, the magnitude of dieting will be addressed.

Research Methods and Procedures

Subjects

The Maastricht Weight Maintenance Study is an ongoing longitudinal study of healthy men and women (age, 18 to 65 years; BMI > 25 kg/m^2) living in the south of The Netherlands. They were recruited by advertisement in local newspapers. All subjects evaluated in this study ($n = 91$; 29 men and 62 women) participated in a very-low-calorie diet (VLCD) to lose weight. After a follow-up of at least 2 years, all subjects were re-measured; most had regained weight. The follow-up period varied from 2 to 8 years among the different weight loss studies that made up the Maastricht Weight Maintenance Study. There was, however, no effect of the duration of follow-up period on percentage of BW regain.

Study Design

The experimental design (Figure 1) shows that BW, BMI, body composition, attitude toward eating, RMR, and RQ were measured before (M1) and after (M2) a VLCD. The diet was followed by a period where the subjects followed a free-living eating pattern for 2 years or more. Measurements were repeated once after 2 years or more had elapsed since the end of the VLCD (M3). The protocol was approved by the Ethics Committee of Maastricht University.

Measurements

Anthropometry. Height was measured using a wall-mounted stadiometer (model 220; Seca, Hamburg, Germany), and BW was measured to the nearest 0.1 kg using a digital balance (Seca, model 707; Seca, Hamburg, Germany). Measurements were made with the subjects in underwear, after an overnight fast, and after voiding the bladder. BMI was calculated by BW divided by height squared (kilograms per meter squared). Waist circumference was measured at the site of the smallest circumference between the rib cage and the ileac crest with the subjects in standing position.

Body Composition. Body composition was measured using the deuterium dilution technique (34). ^2H_2O dilution was used to measure total body water (TBW). Subjects were asked to collect a urine sample in the evening just before drinking the deuterium-enriched water solution. After ingestion of this solution, no further fluid or food consumption was allowed. Ten hours after drinking the water solution, another urine sample was collected. The dilution of the deuterium isotope is a measure of the TBW of the subject. Deuterium was measured in the urine samples with an isotope ratio mass spectrometer (VG-Isogas Aqua Sira; VG Isogas, Middlewich, Cheshire, United Kingdom). TBW was obtained by dividing the measured deuterium dilution space by 1.04 (34). Fat-free mass (FFM) was calculated by dividing TBW by the hydration factor of 0.73. By subtracting FFM from BW, fat mass (FM) was obtained. FM expressed as a percentage of BW revealed body fat percentage.

Attitude toward Eating, Frequency of Dieting, and BW Amplitude

Eating behavior was assessed before and after losing weight and at the last measurement session using a validated Dutch translation of the TFEQ (22,35). Cognitive restrained and unrestrained eating behavior (Factor 1), emotional eating and disinhibition (Factor 2), and the subjective feeling of hunger (Factor 3) were scored. BW concern and chronic dieting behavior were studied once, using the Herman-Polivy questionnaire, which addresses weight consciousness (36).

BW amplitude is the sum of a person's maximum weight loss (over a period of 1 month) and a person's maximum lifetime weight gain in kilograms of BW above desired BW (measured by two questions of the Herman-Polivy questionnaire).

RMR and RQ

RMR and RQ were measured after an overnight fast. O_2 consumption and CO_2 production were determined using a computerized, open-circuit, ventilated hood system. Gas analyses were performed using a paramagnetic O_2 analyzer (type 500A; Servomex, Crowborough Sussex, United Kingdom) and an infrared CO_2 analyzer (type 12-X1; Servomex), similar to the analysis system described by Schoffelen et al. (37). Calculation of RMR was based on Weir's formula (38). RQ was calculated as CO_2 produced divided by O_2 consumed.

Statistical Analysis

Data are presented as mean ± SD. Statistical analyses were performed with Statview SE Graphics for Macintosh. Pearson correlation coefficients, r, were calculated to determine the relationship between selected variables. Subsequently, multiple regression analyses were performed to obtain the combined independent predictors of weight regain. Differences were considered significant at $p < 0.05$.

Results

Total BW loss was 7.9 ± 3.6 kg (2.3 ± 1.3 kg/m^2). Mean BMI regain was 2.6 ± 2.5 kg/m^2; i.e., percent BMI regain was 114%. Percent weight regain was 113.8 ± 98.1%.

Percent BMI regain was negatively associated with the increase in dietary restraint during weight loss ($r = -0.47$, $p < 0.05$), which means that an early increase in dietary restraint was associated with less regain.

Baseline characteristics of the subjects, as well as the characteristics after weight loss and after follow-up, are shown in Table 1. Weight maintenance was expressed as percent weight regained from the weight lost. With respect to this flexibility, multiple regression analysis showed that baseline RMR seemed to be the explanatory variable for percent weight regain ($r = -0.38$, $p = 0.01$; Figure 2), without FFM adding to the explained variation (Table 2). Furthermore, simple regression analyses showed that percent weight regain was positively correlated with the magnitude of change in BW (maximum amplitude of BW; $r = 0.21$, $p < 0.05$; Figure 3) and negatively correlated with baseline FM ($r = -0.24$, $p = 0.05$) and baseline fat percentage ($r = -0.25$, $p < 0.05$).

Moreover, amplitude of BW was positively correlated with the frequency of dieting ($r = 0.57$, $p < 0.01$).

The other variables at baseline (age, waist circumference, and RQ) did not contribute to the variation in percent BMI or weight regain.

Table 1. Subject characteristics at baseline (M1), after weight loss (M2), and after follow-up (M3)

	M1	M2	M3
Age (years)	44.6 ± 9.6	44.8 ± 9.6	48.8 ± 9.6
Height (m)	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1
Body weight (kg)	87.3 ± 12.3	79.4 ± 12.3	88.0 ± 14.3
BMI (kg/m^2)	30.2 ± 3.1	27.9 ± 3.3	30.6 ± 3.9
FM (kg)	31.3 ± 7.2	25.3 ± 8.8	30.6 ± 9.2
FFM (kg)	66.5 ± 9.9	65.3 ± 10.0	71.0 ± 8.5
Body fat (%)	31.9 ± 5.8	27.9 ± 8.0	29.7 ± 5.9
RMR (MJ/d)*	6.7 ± 1.1	6.1 ± 1.1	
RQ*	0.84 ± 0.05	0.80 ± 0.05	
F1 (of the TFEQ)	7.4 ± 4.2	12.6 ± 4.6	9.2 ± 4.6
F2 (of the TFEQ)	6.9 ± 2.6	5.2 ± 3.2	5.5 ± 3.0
F3 (of the TFEQ)	5.9 ± 2.7	3.5 ± 3.0	6.8 ± 4.6
Herman Polivy questionnaire†			17.9 ± 3.4
Body weight amplitude†			17.5 ± 6.5

Values are means ± SD. FM, fat mass; FFM, fat free mass; RMR, resting metabolic rate; RQ, respiratory quotient; F1, factor 1; F2, factor 2; F3, factor 3; TFEQ, Three Factor Eating Questionnaire.
* Measured twice: before and after weight loss.
† Measured only once: after follow-up.

Discussion

We evaluated data collected during the Maastricht Weight Maintenance Study, which itself was a compilation of long-term weight maintenance studies that included a variety of measurements made 2 to 8 years after initial weight loss.

An inverse relationship between an increase in dietary restraint during energy restriction and subsequent percent BMI regain (corrected for height) was found; the explained variance was 22%. This is in line with many previous observations that have been made over the short and long term (6,19,21,39,40). Because of an improved successful restrained eating behavior, energy intake is decreased, which will result in less weight regain. We speculate that in the present affluent society, with its abundant choice of food and decreased energy expenditure level, successful dietary restraint is necessary to prevent subsequent weight gain.

Weight maintenance was indicated by percent weight regained from the weight lost. For weight maintenance, being in energy balance is crucial. Here we approached energy balance by measuring RMR [the largest part of energy expenditure (EE)] and dietary restraint [the degree to which subjects restrain their energy intake (EI)], because we were not able to measure total EE (because the doubly labeled water method was too expensive) or total EI [because of the frequent problem of under-reporting of food intake (41,42)]. We found that the best predictor for weight

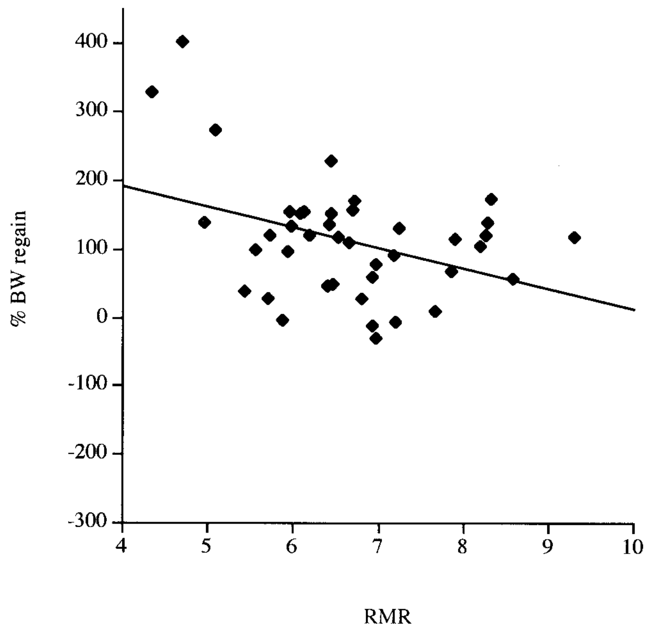

Figure 2: Percent BW regain as a function of RMR in a subset of 41 subjects ($r = -0.38$, $p = 0.01$).

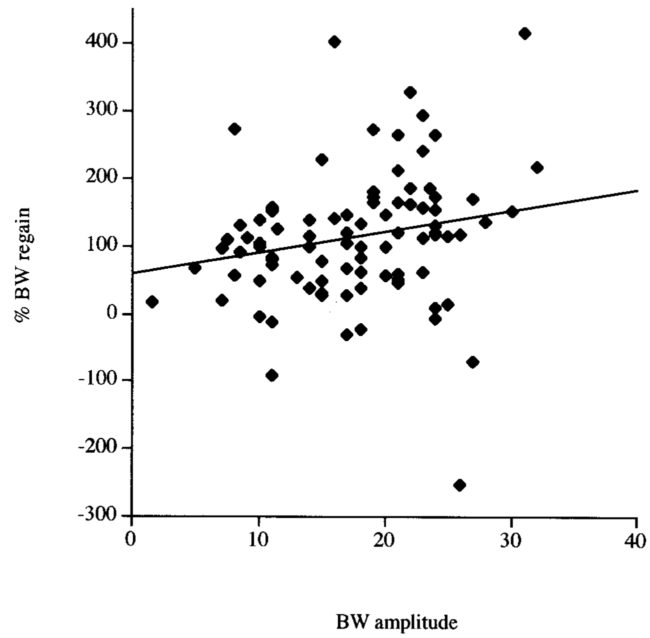

Figure 3: Percent BW regain as a function of BW amplitude (the sum of person's maximum weight loss over a period of 1 month and maximum weight gain in kilograms of BW above desired BW; $r = 0.21$, $p < 0.05$).

maintenance over a follow-up period of at least 2 years was RMR at baseline, which predicted 14% of the variability in the ability to maintain weight. Baseline RMR was found to be inversely related to percent weight regain, and the correlation did not disappear when RMR was expressed as a function of FFM. This is in agreement with the results from Astrup et al. (8), who previously concluded that a low RMR may contribute to weight regain in some formerly obese subjects, and with the results from Ravussin and colleagues (10–12), who showed that, in Pima Indians, the RMR for a given body composition was a predictor of subsequent weight gain. Recently, Buscemi et al. (9) concluded that, in adult whites, a low relative RMR at baseline was associated with body weight gain in the long run. In contrast, other studies have reported no association between RMR and weight gain (14,15,43–46). They mainly concluded that RMR values returned to baseline values when obese individuals regained their lost weight (44), even within 10 days of energy balance, which was reflected by a return to the euthyroid state (43). Thus, similar to previous studies, we conclude that, in this study, a low RMR explained why some individuals regained weight more easily than others. Whether a low RMR is acquired or genetic (47,48) is still unclear.

Table 2. Multiple regression analysis of predictors for weight regain

	ß-coefficient	SE	*p*	Partial *F*
Intercept	327.04			
Baseline FFM	0.73	1.26	0.57	0.33
Baseline RMR	−38.59	13.74	0.01	7.89

SE, standard error; FFM, fat free mass; RMR, resting metabolic rate.

With respect to EE, data about the subject's physical activity level would also be valuable. Physical activity level had been measured before and after previous weight loss and after 3 months of weight maintenance in ~50% of the subjects in this study. The level was 1.6 ± 0.15 at every time it was measured (49). Therefore, the changes in total EE were dependent mainly on the changes in RMR.

To a minor extent, the new concept, amplitude of BW, which explained 5% of the variance in weight regain, was correlated positively with percent weight regain. BW amplitude is measured as the sum of an individual's maximum weight loss (over a period of 1 month) and their maximum lifetime weight gain (in kilograms of BW above desired BW). Thus, it describes the magnitude of change in BW over an individual's lifetime. It seems that people who have previously experienced large weight losses, followed by large weight regains, are at a higher risk to regain weight after a period of energy restriction.

Frequency of dieting was correlated positively with the amplitude of BW. This suggests that individuals who frequently follow diets have a greater predisposition to regain a large amount of weight. In the past, this phenomenon has been described as weight cycling, or the yo-yo effect, and has been put forward as an important predictor of weight regain (7,18,27–32). In addition to the yo-yo frequency, the yo-yo amplitude also seems to be of importance. Kajioka et al. (29) concluded that weight cycling induced a decrease in resting EE, which can be one possible explanation for this phenomenon. Lejeune et al. (21) suggested an additional mechanism for weight cycling, namely a limit in the ability to increase cognitive restrained eating behavior. When the restraint score approaches the limit (an F1 score of 21), the success of subsequent dieting will decrease.

In this study, we found that (absolute and relative) FM were an unexpected predictor of weight regain, explaining 5% of the variance in weight regain. Subjects with a high FM regained less weight. The explanation for this phenomenon is speculative. Obese people have a lot of body fat, which results in a body composition that is out of proportion (50). In this study, the highest FM was 42%. It is easier for obese people to lose a lot of weight in a small period of time than it is for non-obese or very lean people (21,51–55). After losing weight, which is mostly fat (56), subsequent FM and FFM are going toward a more "common" ratio (~33% FM and ~67% FFM) of body composition. This new, more favorable body composition may explain why less weight regain is followed. The initial high FM, which changes by weight loss, and the regain in a relatively lower FM may be the result of an FFM-sparing effect. Previously Dulloo et al. (56) described this sparing effect in which the body composition of a given individual changes continuously toward a leaner composition during the course of starvation. In our study, we found this sparing effect in the weight loss phase as well as in the weight maintenance phase.

In summary, we found that the maintenance of BMI was predicted by an increase in cognitive dietary restraint during weight loss. The best predictors of weight maintenance after weight loss were a high baseline RMR, a rather stable body weight (referring to a low BW amplitude), a low frequency of dieting, and a relatively high baseline FM that favored a FFM-sparing effect during weight loss. The explained variance is 5% to 22%; i.e., dietary restraint or limiting food intake, physiological variables such as body composition and RMR, and previous dieting periods contribute to a small proportion of the explanation of BMI or weight regain. Therefore, other factors such as social support of the environment (57,58) and habitual physical activity (30,57,59,60) still are of importance.

To conclude, preventing weight gain is obviously the best way of curbing the obesity epidemic. However, for individuals who are already overweight, weight loss, but more importantly, the maintenance of this weight loss, is vital for optimal health. Ingredients that increase RMR (e.g., green tea) (61) may be helpful in maintaining the newly reduced body weight.

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References

1. **Burton BT, Foster WR.** Health implications of obesity: an NIH Consensus Development Conference. *J Am Diet Assoc*. 1985;85:1117–21.
2. **Pi-Sunyer FX, Becker DM, Bouchard C, et al.** NHLBI obesity education initiative expert panel on the identification, evaluation, and treatment of overweight and obesity in adults. *Obes Res.* 1998;6:51S–209S.
3. **Lean ME, Powrie JK, Anderson AS, Garthwaite PH.** Obesity, weight loss and prognosis in type 2 diabetes. *Diabet Med*. 1990;7:228–33.
4. **Goldstein DJ.** Beneficial health effects of modest weight loss. *Int J Obes Relat Metab Disord*. 1992;16:397–415.
5. **Pasman WJ, Rossner S, Westerterp-Plantenga MS, Saris WH.** Body weight changes after treatment of obesity or pregnancy. In: Westerterp-Plantenga MS, Steffens A, Tremblay A, eds. *Regulation of Food Intake and Energy Expenditure.* Milan, Italy: Edra; 1999, pp. 269–284.
6. **Westerterp-Plantenga MS, Kempen KP, Saris WH.** Determinants of weight maintenance in women after diet-induced weight reduction. *Int J Obes Relat Metab Disord*. 1998;22: 1–6.
7. **Pasman WJ, Saris WH, Westerterp-Plantenga MS.** Predictors of weight maintenance. *Obes Res*. 1999;7:43–50.
8. **Astrup A, Gotzsche PC, van de Werken K, et al.** Meta-analysis of resting metabolic rate in formerly obese subjects. *Am J Clin Nutr*. 1999;69:1117–22.
9. **Buscemi S, Verga S, Caimi G, Cerasola G.** Low relative resting metabolic rate and body weight gain in adult Caucasian Italians. *Int J Obes Relat Metab Disord*. 2005;29:287–91.
10. **Ravussin E, Lillioja S, Knowler WC, et al.** Reduced rate of energy expenditure as a risk factor for body-weight gain. *N Engl J Med*. 1988;318:467–72.
11. **Ravussin E.** Low resting metabolic rate as a risk factor for weight gain: role of the sympathetic nervous system. *Int J Obes Relat Metab Disord.* 1995;19(Suppl 7):S8–9.
12. **Tataranni PA, Harper IT, Snitker S, et al.** Body weight gain in free-living Pima Indians: effect of energy intake vs expenditure. *Int J Obes Relat Metab Disord*. 2003;27:1578–83.
13. **Froidevaux F, Schutz Y, Christin L, Jequier E.** Energy expenditure in obese women before and during weight loss, after refeeding, and in the weight-relapse period. *Am J Clin Nutr*. 1993;57:35–42.
14. **Hainer V, Kunesova M, Parizkova J, et al.** Respiratory quotient in obesity: its association with an ability to retain weight loss and with parental obesity. *Sb Lek*. 2000;101:99–104.

15. **Larson DE, Ferraro RT, Robertson DS, Ravussin E.** Energy metabolism in weight-stable post-obese individuals. *Am J Clin Nutr*. 1995;62:735–9.
16. **Valtuena S, Salas-Salvado J, Lorda PG.** The respiratory quotient as a prognostic factor in weight-loss rebound. *Int J Obes Relat Metab Disord*. 1997;21:811–7.
17. **Zurlo F, Lillioja S, Esposito-Del Puente A, et al.** Low ratio of fat to carbohydrate oxidation as predictor of weight gain: study of 24-h RQ. *Am J Physiol*. 1990;259:E650–7.
18. **McGuire MT, Wing RR, Klem ML, Lang W, Hill JO.** What predicts weight regain in a group of successful weight losers? *J Consult Clin Psychol*. 1999;67:177–85.
19. **Pekkarinen T, Takala I, Mustajoki P.** Two year maintenance of weight loss after a VLCD and behavioural therapy for obesity: correlation to the scores of questionnaires measuring eating behaviour. *Int J Obes Relat Metab Disord*. 1996;20:332–7.
20. **Hays NP, Bathalon GP, McCrory MA, et al.** Eating behavior correlates of adult weight gain and obesity in healthy women aged 55–65 y. *Am J Clin Nutr.* 2002;75:476–83.
21. **Lejeune MP, Van Aggel-Leijssen DP, Van Baak MA, Westerterp-Plantenga MS.** Effects of dietary restraint vs exercise during weight maintenance in obese men. *Eur J Clin Nutr*. 2003;57:1338–44.
22. **Stunkard AJ, Messick S.** The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res*. 1985;29:71–83.
23. **Laessle RG, Tuschl RJ, Kotthaus BC, Pirke KM.** Behavioral and biological correlates of dietary restraint in normal life. *Appetite*. 1989;12:83–94.
24. **Tuschl RJ, Platte P, Laessle RG, Stichler W, Pirke KM.** Energy expenditure and everyday eating behavior in healthy young women. *Am J Clin Nutr*. 1990;52:81–6.
25. **Wardle J, Beales S.** Restraint and food intake: an experimental study of eating patterns in the laboratory and in normal life. *Behav Res Ther*. 1987;25:179–85.
26. **Lindroos AK, Lissner L, Mathiassen ME, et al.** Dietary intake in relation to restrained eating, disinhibition, and hunger in obese and non-obese Swedish women. *Obes Res*. 1997;5:175–82.
27. **National Task Force on the Prevention and Treatment of Obesity** Weight cycling. *JAMA*. 1994;272:1196–202.
28. **Korkeila M, Rissanen A, Kaprio J, Sorensen TI, Koskenvuo M.** Weight-loss attempts and risk of major weight gain: a prospective study in Finnish adults. *Am J Clin Nutr*. 1999;70:965–75.
29. **Kajioka T, Tsuzuku S, Shimokata H, Sato Y.** Effects of intentional weight cycling on non-obese young women. *Metabolism*. 2002;51:149–54.
30. **Bild DE, Sholinsky P, Smith DE, et al.** Correlates and predictors of weight loss in young adults: the CARDIA study. *Int J Obes Relat Metab Disord*. 1996;20:47–55.
31. **Field AE, Austin SB, Taylor CB, et al.** Relation between dieting and weight change among preadolescents and adolescents. *Pediatrics*. 2003;112:900–6.
32. **Haus G, Hoerr SL, Mavis B, Robison J.** Key modifiable factors in weight maintenance: fat intake, exercise, and weight cycling. *J Am Diet Assoc*. 1994;94:409–13.
33. **Foreyt JP, Brunner RL, Goodrick GK, et al.** Psychological correlates of weight fluctuation. *Int J Eat Disord*. 1995;17:263–75.
34. **Schoeller DA, van Santen E, Peterson DW, et al.** Total body water measurement in humans with 18O and 2H labeled water. *Am J Clin Nutr*. 1980;33:2686–93.
35. **Westerterp-Plantenga MS, Rolland V, Wilson SA, Westerterp KR.** Satiety related to 24 h diet-induced thermogenesis during high protein/carbohydrate vs high fat diets measured in a respiration chamber. *Eur J Clin Nutr*. 1999;53:495–502.
36. **Herman CP, Polivy J.** Restrained eating. In: Stunkard AJ, ed. *Obesity.* Philadelphia, PA: Saunders; 1980, pp. 208–24.
37. **Schoffelen PF, Westerterp KR, Saris WH, Ten Hoor F.** A dual-respiration chamber system with automated calibration. *J Appl Physiol*. 1997;83:2064–72.
38. **Weir JB.** New methods for calculating metabolic rate with special reference to protein metabolism. *Nutrition*. 1990;6:213–21.
39. **Provencher V, Drapeau V, Tremblay A, Despres JP, Lemieux S.** Eating behaviors and indexes of body composition in men and women from the Quebec family study. *Obes Res*. 2003;11:783–92.
40. **Bjorvell H, Aly A, Langius A, Nordstrom G.** Indicators of changes in weight and eating behaviour in severely obese patients treated in a nursing behavioural program. *Int J Obes Relat Metab Disord*. 1994;18:521–5.
41. **Goris AH, Westerterp-Plantenga MS, Westerterp KR.** Undereating and under-recording of habitual food intake in obese men: selective under-reporting of fat intake. *Am J Clin Nutr*. 2000;71:130–4.
42. **Goris AH, Meijer EP, Westerterp KR.** Repeated measurement of habitual food intake increases under-reporting and induces selective under-reporting. *Br J Nutr*. 2001;85:629–34.
43. **Weinsier RL, Nagy TR, Hunter GR, et al.** Do adaptive changes in metabolic rate favor weight regain in weight-reduced individuals? An examination of the set-point theory. *Am J Clin Nutr*. 2000;72:1088–94.
44. **Wadden TA, Foster GD, Stunkard AJ, Conill AM.** Effects of weight cycling on the resting energy expenditure and body composition of obese women. *Int J Eat Disord*. 1996;19:5–12.
45. **Wadden TA, Bartlett S, Letizia KA, et al.** Relationship of dieting history to resting metabolic rate, body composition, eating behavior, and subsequent weight loss. *Am J Clin Nutr*. 1992;56:203S–8S.
46. **Jebb SA, Goldberg GR, Coward WA, Murgatroyd PR, Prentice AM.** Effects of weight cycling caused by intermittent dieting on metabolic rate and body composition in obese women. *Int J Obes Relat Metab Disord*. 1991;15:367–74.
47. **Bouchard C, Tremblay A, Nadeau A, et al.** Genetic effect in resting and exercise metabolic rates. *Metabolism*. 1989;38:364–70.
48. **Bogardus C, Lillioja S, Ravussin E, et al.** Familial dependence of the resting metabolic rate. *N Engl J Med*. 1986;315:96–100.
49. **Westerterp-Plantenga MS, Lejeune MP, Nijs I, van Ooijen M, Kovacs EM.** High protein intake sustains weight maintenance after body weight loss in humans. *Int J Obes Relat Metab Disord*. 2004;28:57–64.

50. **Webster JD, Hesp R, Garrow JS.** The composition of excess weight in obese women estimated by body density, total body water and total body potassium. *Hum Nutr Clin Nutr*. 1984; 38:299–306.
51. **Wadden TA, Foster GD, Wang J, et al.** Clinical correlates of short- and long-term weight loss. *Am J Clin Nutr.* 1992;56: 271S–4S.
52. **Womble LG, Williamson DA, Greenway FL, Redmann SM.** Psychological and behavioral predictors of weight loss during drug treatment for obesity. *Int J Obes Relat Metab Disord*. 2001;25:340–5.
53. **Stein PM, Hassanein RS, Lukert BP.** Predicting weight loss success among obese clients in a hospital nutrition clinic. *Am J Clin Nutr*. 1981;34:2039–44.
54. **Krotkiewski M, Sjöström L, Björntorp P, et al.** Adipose tissue cellularity in relation to prognosis for weight reduction. *Int J Obes Relat Metab Disord*. 1977;1:395–416.
55. **Hansen D, Astrup A, Toubro S, et al.** Predictors of weight loss and maintenance during 2 years of treatment by sibutramine in obesity. Results from the European multi-centre STORM trial. Sibutramine Trial of Obesity Reduction and Maintenance. *Int J Obes Relat Metab Disord*. 2001;25:496–501.
56. **Dulloo AG, Jacquet J.** The control of partitioning between protein and fat during human starvation: its internal determinants and biological significance. *Br J Nutr*. 1999;82:339–56.
57. **Williamson DA, Stewart TM.** Behavior and lifestyle: approaches to treatment of obesity. *J LA State Med Soc.* 2005; 157(Suppl 1):S50–5.
58. **Elfhag K, Rossner S.** Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. *Obes Rev*. 2005;6:67–85.
59. **van Baak MA, van Mil E, Astrup AV, et al.** Leisure-time activity is an important determinant of long-term weight maintenance after weight loss in the Sibutramine Trial on Obesity Reduction and Maintenance (STORM trial). *Am J Clin Nutr*. 2003;78:209–14.
60. **Klem ML, Wing RR, McGuire MT, Seagle HM, Hill JO.** A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *Am J Clin Nutr*. 1997;66: 239–46.
61. **Dulloo AG, Duret C, Rohrer D, et al.** Efficacy of a green tea extract rich in catechin polyphenols and caffeine in increasing 24-h energy expenditure and fat oxidation in humans. *Am J Clin Nutr*. 1999;70:1040–5.