Irregular Patterns in the Daily Weight Chart at Night Predict Body Weight Regain

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This study examined whether charting daily weight patterns can predict weight regain in obese patients. The subjects were 98 moderately obese Japanese women aged 23 to 66 years who were obliged to precisely record their daily weights during the initial 4-month education period, but not thereafter. The patients were followed up at 8, 12, and 16 months. Abdominal fat areas and blood samples were assessed in the outpatient clinic at 0, 4, and 16 months. The standard deviations (SDs) of the differences in body weight between "after waking up" and "after breakfast" (SDa), "after dinner" (SDb), and "before going to bed" (SDc) were calculated, which were parameters reflecting the fluctuations in the daily weight patterns during the first 4 months. SDc, but not SDa or SDb, was correlated positively with weight regain at 8, 12, and 16 months (P = 0.049, P = 0.002, and P = 0.001, respectively). There were significant differences in temporal change in body weight and abdominal visceral fat between the small SDc group (SDc ≤25th percentile) and the large SDc group (SDc >75th percentile), but not for subcutaneous abdominal fat or the serum concentrations of glucose, insulin, or lipids. The results indicate that fluctuation of body weight immediately before going to bed is useful for predicting the rebound in body weight. Exp Biol Med 229:940–945, 2004

Key words: moderately obese Japanese women; rebound in body weight; charting daily weight pattern; fluctuation of body weight immediately before going to bed

The greatest difficulty in treating obesity is dealing with repeated bouts of weight loss and regain. American women who have achieved large weight losses tend to regain their weight (1). Obese patients with histories of weight cycling are reported to regain large amounts of weight after weight loss (2–4). Weight cycling increases blood pressure and serum lipids (5); therefore, it is crucial that the obese avoid weight cycling. Charting daily weight patterns offers an efficient aid for weight reduction and long-term weight maintenance because charting these patterns four times daily allows obese patients to continuously monitor their daily changes in body weight, which makes them aware of their distorted daily lifestyles and, in particular, their unusual eating habits (6, 7). One method plots body weight on a chart four times daily (6). It is well known that irregular lifestyles that include irregular eating styles such as frequent snacking and night-eating syndrome constitute one of the main pathological backgrounds for obese patients. Obese patients who easily regain lost weight do not pay attention to episodes that cause weight gain (7). However, few effective methods of preventing weight rebound have been developed. Given this context, and in order to properly understand body weight regulation, obese patients need to recognize, in advance, the precipitating factors that lead to weight rebound. The data from the daily charts prompted us to assume that predictive factors preventing the obese from regaining weight might appear through and in the activity of charting their daily weight patterns. The aim of this study, then, was to search for efficient predictors of weight cycling.

Materials and Methods

General Procedures. Obese subjects were recruited for admission to our weight-reduction program at the Nakamura-Gakuen University Health Promotion Center by means of public advertisements. The subjects were taught to record their weights each day and were given instructions on nutrition during the first 4 months of the weight-reduction program (the education period). Body weight, as a

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parameter for evaluating weight regain, was assessed at 0 (immediately before the education period), 4 (immediately after the education period), 8, 12, and 16 months after starting the weight-reduction program. Height was measured at 0 months and blood was sampled and fat distribution assessed by magnetic resonance imaging (MRI) at 0, 4, and 16 months.

Subjects. We enrolled 262 subjects in the weight-loss program. Nineteen subjects were excluded from the study (9 females suffering from type 2 diabetes, liver disease, or cancer and all 10 males). The final number of subjects was 243 and, of these, 162 charted their weights four times daily for more than 1 month during the education period (charting group), while 81 of the subjects did not (noncharting group). The 16-month weight-reduction program was completed by 98 women in the charting group and 17 women in the noncharting group. Consequently, we assessed 98 obese women who ranged in age from 23 to 66 years and who had no history of major diseases or medications known to influence the parameters examined in this study.

Type 2 diabetes mellitus was diagnosed using the criteria issued by the Japan Diabetes Society (8). Simple obesity was defined as a body mass index $\geq$25 kg/m^2, using the criteria of the Japan Society for the Study of Obesity (9). (The present study was approved by the ethics committee of Nakamura-Gakuen University). In accordance with the second Helsinki Declaration, all of the enrolled subjects gave written informed consent for their participation in the study.

Charting the Daily Weight Pattern. Each of the subjects was obliged to record her weight on a chart 4 times daily during the initial 4-month educational period; after this period, each subject could decide whether to continue to chart her weight. The subjects had to weigh themselves immediately after waking up, immediately after breakfast, immediately after dinner, and immediately before going to bed. These four times were critical for clearly charting the daily lives of the participants, especially with respect to the eating style of workers who were not shift workers (6, 7). The procedure used has been described in detail elsewhere (6). Briefly, the subjects were instructed to focus on the following instructions each time they weighed themselves:

To ensure the comparability of the charts between days, adherence to the exact times for weighing was critical (7). We emphasized the importance of recording weight "immediately" after waking up, after meals, and before going to bed, and strongly advised the subjects to strictly adhere to this instruction.

The scale had to be placed on a hard, flat floor and set to zero before each use.

The body weight was to be measured with clothing. The weight of the clothing was subtracted from the total weight whenever the weight was charted. The clothing was weighed after measuring body weight after waking up in the morning; this method of weighing the clothing has been found to help obese subjects weigh themselves over the long term (7).

We recommended that each subject make concise notes, describing the main cause of weight fluctuation in her chart whenever a daily fluctuation was observed so that the events would be recorded as they were fresh in her mind.

As shown in Figure 1, the following parameters of the daily fluctuations in body weight during the first 4 months were evaluated: the standard deviations (SDs) of the differences in body weight between "after waking up" and "after breakfast" (SDa), "after dinner" (SDb), and "before going to bed" (SDc). Based on the 25th and 75th percentiles of the SDc (10), the subjects were divided into the small (SDc $\leq$25th percentile) and large (SDc $>$75th percentile) SDc groups.

In parallel with the charting education program, all subjects completed a nutrition education program conducted by well-trained dietitians during the initial 4-month period. In brief, they were instructed to follow a diet consisting of 1400 kcal daily given as protein at a rate of 1.5 g/kg body weight, 30 g fat, and 20 g dietary fiber.

Blood Sampling. All subjects fasted overnight and rested for at least 10 min before blood sampling. Blood samples were taken at 0900 hrs. The fasting serum concentrations of total cholesterol, triglycerides, HDL-cholesterol, glucose, and insulin were measured at SRL Inc. (Tokyo, Japan). Total cholesterol, triglycerides, HDL-cholesterol, and glucose were measured using an automated analyzer model (Hitachi Co. Ltd., Tokyo, Japan). Total cholesterol (11), triglycerides (12), and glucose (13) were assayed enzymatically and HDL-cholesterol was assessed using the direct method (14). Serum insulin was determined using a commercially available enzyme immunoassay (15) and LDL-cholesterol was calculated using Friedwald's formula (16). Homeostasis model assessment (HOMA-R) was applied as an index of insulin resistance (17).

MRI. The cross-sectional areas of visceral and subcutaneous adipose tissue at the umbilical level were measured by MRI (using a method described elsewhere) (18).

Statistical Analysis. We compared the rate of attrition between the charting and noncharting groups using the Kaplan-Meier survival analysis with the log-rank test. One-way analysis of variance with repeated measurements (RM-ANOVA) was used to compare the parameters at 0, 4, 8, 12, and 16 months. The correlations between weight regain and SDa, SDb, or SDc were investigated using Pearson's correlation coefficient or the partial correlation coefficient. Temporal differences in body weight, fat distribution, serum blood glucose, insulin, lipids, and HOMA-R were compared between the small and large SDc groups using two-way RM-ANOVA (two-way RM-ANOVA consists of a grouping factor indicating the small or large SDc group and a within-subject factor reflecting the repeated parameters evaluated at 0, 4, 8, 12, and 16 months). The statistical significance of the time course differences was based on the interaction effect between the grouping and within-subject factors.

The parameters body weight *per se*, triglycerides, glucose, insulin, HOMA-R, and visceral and subcutaneous

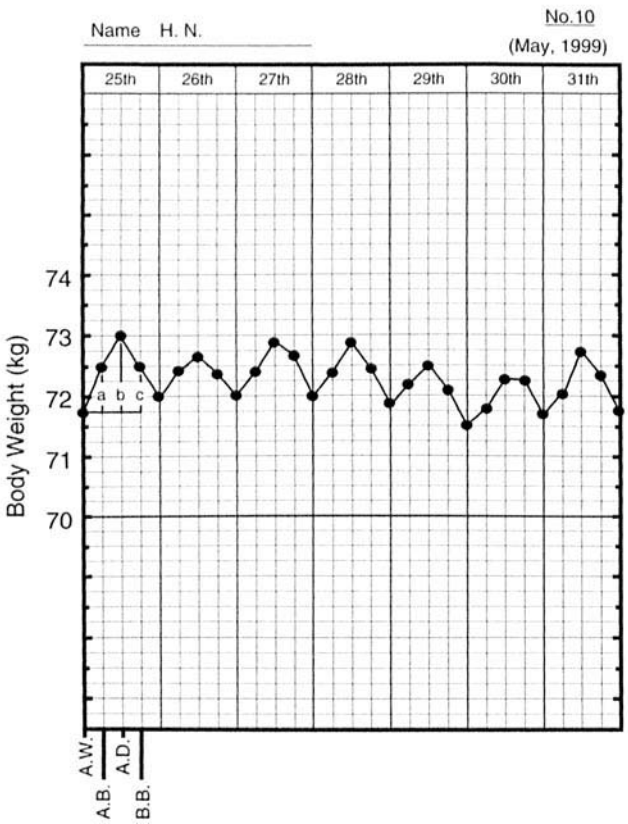

Figure 1. A typical chart showing the daily weight pattern. Differences in body weight between "after waking up" and (a) "after breakfast," (b) "after dinner," and (c) "before going to bed." AW, immediately after waking up; AB, immediately after breakfast; AD, immediately after dinner; BB, immediately before going to bed.

fat masses were transformed logarithmically, as these data did not fit normal distributions. The results were considered statistically significant at the two-tailed $\alpha < 0.05$. All data were analyzed using the SPSS 11.0 software package (SPSS Inc., Chicago, IL).

Results

Comparison of the Rate of Attrition in the Charting and Noncharting Groups. The rate of attrition at 4, 8, 12, and 16 months in the charting and noncharting groups was 2.5 versus 18.5%, 14.8 versus 46.9%, 28.4 versus 64.2%, and 39.5 versus 79.9%, respectively. The rate of attrition in the charting group was lower than that in the noncharting group ($P < 0.0001$). Nearly 80% of the subjects in the noncharting group dropped out of the study by the final stage.

Effectiveness of the Weight-Reduction Program Considering Body Weight, Body Mass Index (BMI), Blood Glucose, Insulin, HOMA-R, and Serum Lipids. The mean age, height, and BMI of the 98 subjects enrolled were 49.3 ± 7.8 years (mean ± SD), 154.9 ± 4.2 cm, and 29.0 ± 2.3 kg/m^2, respectively. As shown in Figure 2, body weight at 4 months (65.7 ± 5.7 kg) was lower than that at 0 months (69.6 ± 6.0 kg) ($P < 0.001$). Body weight at 8 and 12 months remained lower than that at 0 months ($P < 0.001$) and 4 months ($P < 0.01$). Body weight at 16 months remained lower than that at 0 months ($P < 0.001$), but not at 4 months. The temporal changes in the statistical difference of BMI were the same as those for the body weight (data not shown).

Visceral and subcutaneous fat, glucose, insulin, HOMA-R, and triglycerides at 4 and 16 months remained lower than at 0 months ($P < 0.001$), as with the temporal changes in body weight (Fig. 2). Total and LDL-cholesterol (LDL data not shown) at 4 months were lower than at 0 months ($P < 0.001$), but were higher at 16 months than at 4 months ($P < 0.05$; Fig. 2). HDL-cholesterol increased over time, and the value at 16 months was higher than that at 0 months ($P < 0.05$; Fig. 2).

SDc as a Predictor of the Hazard of Weight Regain. Table 1 shows the correlation coefficients between the SD parameters in the daily fluctuations in body weight during the 4-month education period and subsequent body weight regained. SDa and SDb were not correlated with weight regain after the education period. By contrast, SDc was correlated with the difference in body weight between 4 and 8 ($P = 0.049$), 12 ($P = 0.002$), and 16 ($P = 0.001$) months. The correlations at these three times remained significant, even after adjusting for baseline BMI. The partial correlation coefficients for those periods were r = 0.202 ($P = 0.047$), r = 0.304 ($P = 0.002$), and r = 0.340 ($P = 0.001$), respectively. Therefore, an increase in the SD of the weight difference between "after waking up" and "before going to bed" represented an increased likelihood of a rebound increase in body weight.

Difference in Weight Regain and Visceral Fat Accumulation Between the Small and Large SDc Groups. Figure 3 compares the temporal change in body weight and visceral fat accumulation in the small and large SDc groups. Two-way RM-ANOVA revealed significant interaction effects between the grouping factor and the within-subject factor for both body weight ($P < 0.001$) and abdominal visceral fat accumulation ($P = 0.048$). There were significant differences in the temporal change in body weight and abdominal visceral fat between the small and large SDc groups, but not for abdominal subcutaneous fat area or humoral parameters.

The differences in body weight between 4 and 8 months in the small and large SDc groups did not differ, although there was a difference between 4 and 12 months ($P < 0.05$), which became more marked between 4 and 16 months ($P < 0.01$). The difference in visceral fat between 4 and 16 months did not differ significantly in the small and large SDc groups, although there were significant interaction effects, as previously mentioned.

Discussion

Plotting the daily body weight measured daily at four critical times is effective in weight reduction, maintaining

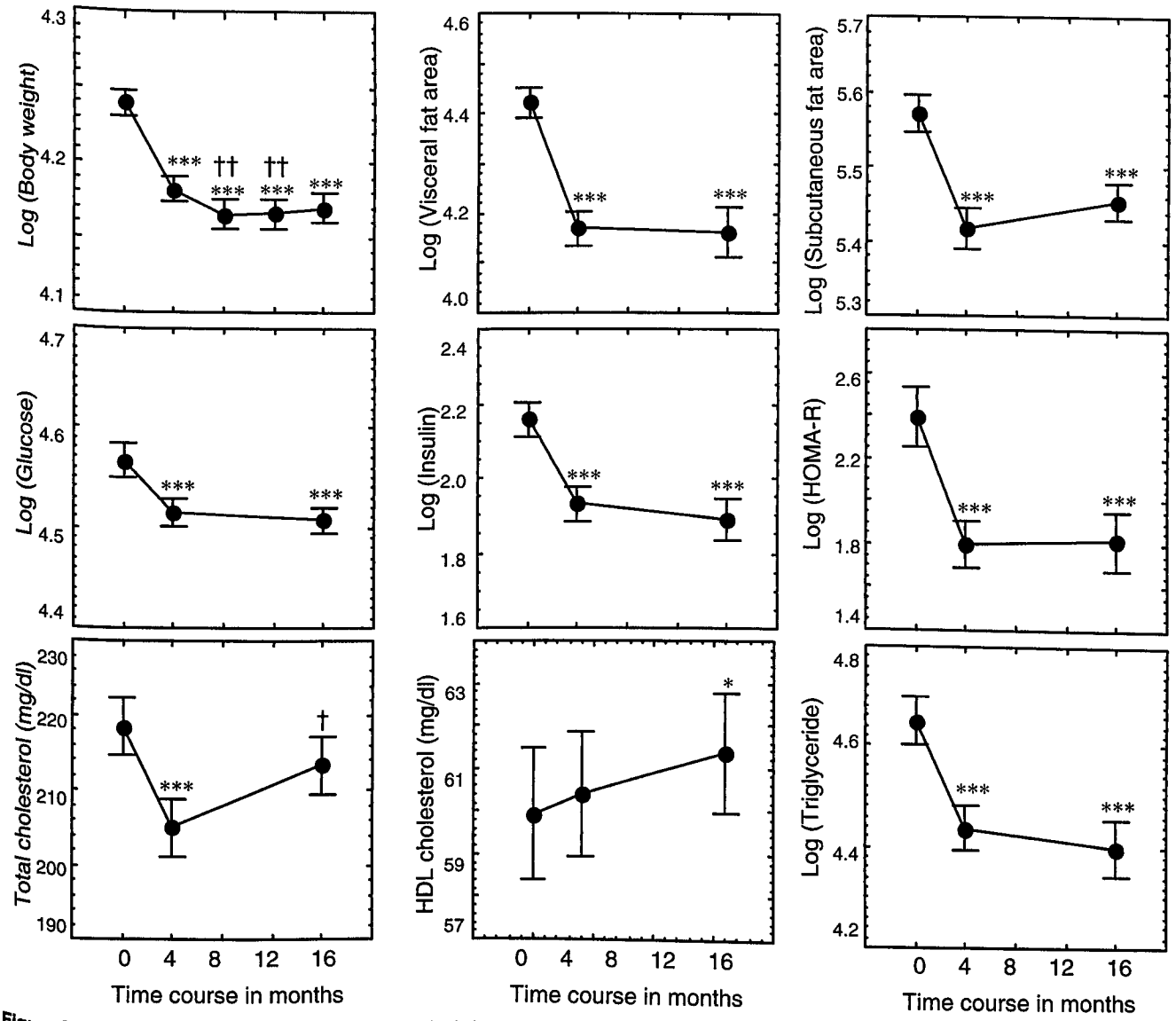

Figure 2. Temporal changes in body weight, abdominal visceral fat, abdominal subcutaneous fat, lipids, glucose, insulin, and HOMA-R in all the subjects (analysis of variance with repeated measurements was used). HOMA-R, homeostasis model assessment. $^{*}P < 0.05$ versus 0 months. $^{***}P < 0.001$ versus 0 months. $\dagger P < 0.05$ versus 4 months. $\dagger\dagger P < 0.01$ versus 4 months.

weight loss, and preventing subjects from dropping out of a weight-loss program (6, 7). Based on the rate of attrition, the performance of the subjects in the charting group was clearly superior to that in the noncharting group, which confirms our previous finding (6).

Charting daily weight patterns helps the obese become aware of harmful food and fluid intake habits and is an effective weight-loss tool (6, 7). Irregular food and fluid intake, which reflects fluctuating lifestyles, results in a "messy" pattern in the body weight charts of obese patients. In other words, the persistence of this "messy" pattern on the charts constitutes a typical characteristic of obese

Table 1. Correlation Coefficients Between the Standard Deviations (SDs) of the Daily Weight Fluctuations During the 4-Month Education Period and Subsequent Weight Gain[a]

	SDa		SDb		SDc	
Difference in body weight	*r*	*P* value	*r*	*P* value	*r*	*P* value
Between 4 and 8 months	0.024	0.812	0.118	0.248	0.199	0.049
Between 4 and 12 months	0.024	0.814	0.123	0.226	0.306	0.002
Between 4 and 16 months	0.054	0.595	0.165	0.105	0.345	0.001

[a] SDa, SDb, SDc, standard deviation of the difference in body weight between the periods "after waking up" and "after breakfast," "after dinner," and "before going to bed," respectively (see the text for details); *r* value, Pearson's correlation coefficient.

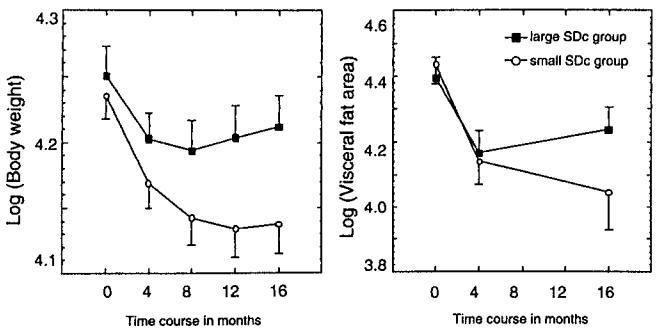

Figure 3. Temporal change in the difference in body weight and visceral fat accumulation in the small and large SDc groups. The small and large SDc groups were defined as SDc ≤25th percentile and SDc >75th percentile (see the text for details). SDc, standard deviation of the difference in body weight between the periods "after waking up" and "before going to bed"; ○—○, small SDc group; ■—■, large SDc group.

patients. In this study, obese patients with sustained "messy" patterns on their charts during the education period quickly regained their lost weight by the end of the study.

In this study, we used the SD calculated from the weight charts as parameters of the daily fluctuations in body weight (SD is commonly used as a measure of dispersion or variation) (19). The value measured immediately after waking was used as the baseline body weight for that day. The weight measured immediately after breakfast confirmed whether the subjects were eating meals regularly because obese patients habitually skip breakfast. The weights measured immediately after dinner and immediately before going to bed were critical in reflecting an increase in body weight (6, 7). In the process of calculating SD, the body weight after meals or before going to bed was subtracted from the weight after waking up each day. The subtraction procedure was useful for avoiding weight fluctuation caused by reproductive cycles, as all of our subjects were female. For these reasons we calculated SDa, SDb, and SDc because obese patients rarely maintain healthy lifestyles (7).

Our results revealed that SDc predicted the rebound increase in body weight. Why was SDc, but not SDa or SDb, a predictor of weight regain? Snacking after dinner facilitates lipogenesis and leads to more fat accumulation, as compared to snacking during the daytime. The predominance of sympathetic nerve activity is reduced at night in humans (20), and the lipolytic response in white adipose tissue is mediated by the sympathetic nervous system (21). These findings indicate that, in humans, lipolytic response, heart rate (22), and physical activity at night are lower than those in the daytime. Indeed, the energy expenditure during the night (2300–0800 hrs) is lower than that during the day (0800–2300 hrs) in humans (23). An irregular weight pattern seen immediately before going to bed may depend on patterns of transient exercise after dinner. An obese patient often has a history of decreasing body weight by unusually and strenuously exercising whenever weight is gained (24) and, subsequently, readily returns to a sedentary lifestyle. Alternatively, obese patients have the distinct characteristic of excessive snacking during the period before going to bed, which is called *night-eating syndrome* (25). Excessive energy intake during the night results in a rebound increase in fat accumulation. Looked at in combination, our charting results imply that an irregular weight pattern during the period before going to bed is a sign of excessive energy intake or expenditure during the night.

We did not precisely assess caloric intake or physical activity in the daily lives of the subjects. However, each subject was instructed to make concise notes in her chart whenever she behaved unusually during the day (this included unusual calorie intake or physical activity). However, we do not consider either calorie intake or physical exercise in detail here. The main purpose of this study was to detect efficient predictors of weight regain, and SDc represents the sum of the subjects' unusual behaviors related to energy intake and expenditure. Indeed, according to our preliminary data, the subjects who focused on the SDc avoided weight regain (7).

Using the fluctuation in body weight before going to bed, we divided our subjects into the small and large SDc groups so that we could evaluate whether the parameters measured depended on SDc. The temporal changes in body weight and visceral fat accumulation differed between the small and large SDc groups; however, the remaining parameters did not. The changes in body weight between 0 and 4 months did not differ between the two groups, although the weight changes between 4 and 12 months and later clearly did. Visceral fat better reflects restricted energy intake and physical exercise than subcutaneous fat (26). In this study, there was a 2.6-kg difference in body weight between the end of the education period and the end of the study for the small and large SDc groups. This small difference in body weight may have arisen because the other parameters were not affected by the size of SDc including subcutaneous fat, serum glucose, insulin, or lipids. In other words, when there is a slight difference in weight loss, the size of SDc is sufficiently sensitive such that it can predict weight regain and visceral fat accumulation. In view of the implications of the SDc findings, it would seem useful for the obese to focus on weight fluctuation immediately before going to bed. Indeed, our unpublished data reveal that obese patients who successfully focus on the implications of SDc avoid weight regain.

In conclusion, this study sought to determine a parameter from daily charts of body weight that could be used to predict weight regain, as the four body weights measured differed in how they reflected therapeutic efficacy. We found that SDc, the daily fluctuation in body weight

immediately before going to bed, was a predictor of weight regain and accompanying visceral fat accumulation.

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