Relative importance of calorie intake needed to gain weight and level of physical activity in anorexia nervosa[1-3]

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ABSTRACT We assessed whether level of physical activity of anorexia nervosa patients could influence caloric consumption needed to gain weight during hospitalization. Seventy-three percent of patients with anorexia nervosa had higher levels of motor activity than did healthy female volunteers. Anorectics required 8301 ± 2272 kcal (mean ± SD) to gain 1 kg body wt. Activity levels and caloric consumption needed to gain 1 kg were significantly correlated; the most active patients needed to consume more calories to gain weight. A median split of anorectic patients by level of activity showed that the group with lower activity levels gained 1 kg every 5.1 ± 1.2 d, whereas the group with higher activity levels gained 1 kg every 7.2 ± 1.9 d. These data suggest that the rate of weight gain can be accelerated, and the cost of hospitalization decreased, by restricting exercise in anorectics during refeeding. *Am J Clin Nutr* 1988;47:987–94.

KEY WORDS Anorexia nervosa, motor activity, caloric utilization, weight gain

Introduction

Underweight anorectics often require inpatient hospitalization for refeeding to restore body weight. Anorectics are psychologically resistant to weight restoration; they are afraid of becoming fat and they pursue thinness. Thus, weight restoration in anorexia nervosa often entails a long and costly hospitalization and a difficult psychological struggle.

Caloric requirements necessary for patients with anorexia nervosa to gain weight were investigated (1–4). Most of these studies found within broad limits similar ranges of caloric intake necessary for weight gain. However, there tends to be a large variation within each study and it is not clear why the variance is so great.

Level of physical activity might contribute to the cost of weight gain in anorexia nervosa. Many anorectics exercise vigorously (5–7). Typical exercise patterns include continuously standing or being in motion and spending a considerable portion of the day pacing, jogging, or doing calisthenics. To our knowledge no study has investigated the relationship between physical activity and caloric consumption necessary to gain weight in anorexia nervosa patients.

Methods

Subjects

All subjects were hospitalized in clinical research units of the National Institute of Mental Health Clinical Center, National Institute of Mental Health. Subjects gave informed consent for the study and they met DSM III criteria for anorexia nervosa (8). Eleven underweight anorectics (aged 25 ± 3 y) were admitted after being continuously underweight for ≥ 6 mo at < 75% of average body weight (underweight anorexia nervosa). Onset of anorexia nervosa occurred 87 ± 37 mo before admission.

Weight-restoration program

Subjects were restricted to a locked ward for control of environmental temperature, motor activity, and food intake. After admission underweight anorectics were nutritionally stabilized at a stable low weight that varied ≤ 1.0 kg for 4–6 wk until they began the weight-gaining phase of this program. Refeeding and weight gain were accomplished by a modified behavior-modification program; no medication was used. The target weight was defined as the weight at which women with secondary amenorrhea might be expected to menstruate (9, 10). After

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weight restoration anorectics were again asked to maintain a stable body weight (±1.0 kg) for 4–6 wk. We previously reported the caloric consumption necessary to maintain weight in the underweight, or low-weight, state and after short-term weight restoration in these 11 patients (11).

Subjects were weighed daily by the nursing staff at 0630 after subjects had voided. Subjects were dressed only in underpants and a standard hospital gown. The scale used was a Scale-Tronix (model #5005, White Plains, NY).

During hospitalization subjects were provided three 45-min periods per meal per day and three 15-min snack periods. No patients on the ward were allowed to have food in their rooms. All subjects were observed 24 h/d on the ward, including meal times and bathroom visits, to prevent surreptitious binging, vomiting, or hiding of food. Food in the centralized kitchen was prepared from standardized recipes. Standardized serving utensils were used to portion food not already proportioned. Meat was the only food item weighed. The tray was checked for accuracy at the end of the serving line by a dietetic assistant. After the subjects ate, the remaining portions of food were sent back on the tray to the main kitchen. A dietetic assistant recorded the amount and kind of food left on the tray. Registered dietitians then determined the amount of food removed from the tray by subtracting the food left on the tray from the food sent to the patient. Caloric intake was calculated from food exchange lists and food composition tables (12) and from Atwater's nutrient conversion factors (13) of 4, 9, and 4 kcal/g for carbohydrate, fat, and protein, respectively. The accuracy of our method of caloric estimation was checked in an independent study (12). Clinical caloric estimates were 102.4 ± 2.2% of the values found by chemical laboratory calorimetry, which was a nonsignificant difference.

After the period of underweight stabilization, patients began the weight-gaining program. In the underweight period patients ate ~20–30 kcal·kg^{-1}·d^{-1} to maintain their weight. The weight-gain program involved a gradual increase in calories per day. This was done for both psychological (resistance to eating increased amounts of food) and physiological (concerns with gastrointestinal distention) reasons. Thus, we began the weight-restoration part of the program by giving the patients 40 kcal·kg^{-1}·d^{-1} and gradually increasing this amount of food. The behavior-modification program requires a weight gain of 1.0–1.5 kg/wk. As a general rule many patients needed to have their caloric intake increased at intervals to maintain this rate of weight gain. Patients gained 13.5 ± 3.2 kg (mean ± SD) in 79 ± 14 d (**Table 1**). The weight-restoration portion of the program was terminated when patients achieved target weight.

For the most part solid food was consumed; only rarely were patients given liquid feedings. Patients required tube feeding even less often. The compliance of our patients was probably due to their being an older, more chronically ill group. In fact, only two patients (#5 and #11) had not been previously hospitalized for weight gain. Thus, the majority of the patients had experienced inpatient treatment.

The procedures followed in this study were in accord with the ethical standards of the NIMH Institute Clinical Research Subpanel.

Method for calculating calories to gain weight

We previously reported (11) caloric consumption necessary to maintain weight in the underweight state and after short-term weight restoration for these patients (Table 1). Because of the lengthy duration of these weight-stable periods, these values were presumably a good approximation of caloric requirements for weight maintenance. We calculated maintenance caloric requirements (Table 1, G) during weight gain by extrapolating a line between the underweight state and short-term weight restoration and calculating the area under that line. We assumed that the amount of maintenance caloric requirement gradually increased as weight was gained. Caloric consumption was measured daily during weight restoration. The total caloric consumption over the period of weight gain was summed (F) and from this value we subtracted the calculated maintenance caloric requirement during weight gain. The excess caloric intake (H), which was the difference between actual caloric intake and estimated caloric requirements, was assumed to be the calories needed for weight gain. We divided this excess caloric consumption by the number of kilocalories gained during weight restoration to obtain an estimate of calories required to gain 1 kg body wt (I).

Motor activity

Motor activity was automatically recorded during four or five separate phases (**Table 2**). In each phase continuous recordings were made of activity for 3–5 d (24 h/d) by methods reported previously (14–16). Thus, subjects had their motor activity recorded in the underweight state on two or three occasions during weight gain (approximately after each gain of 10% body wt), and after weight restoration.

Motor activity was measured by an acceleration-sensitive device with a solid-state memory that stores data on the number of motor movements (16). The monitors were attached to belts around the waists of the subjects and thus reflected trunk and leg movement. Two monitors were used on each subject throughout the study. These monitors were individually calibrated to be equal to each other and they maintained a variance of < 7% throughout the study. We calculated mean daily activity levels during hospitalization and used these data as an index of overall activity during hospitalization.

We intended this study to be a naturalistic study of caloric requirements and associated factors during weight restoration. Thus, we allowed anorectics to exercise ad lib during their hospitalization as long as they stayed on the locked ward. Anorectics were permitted to exercise in their rooms, in the lounge, or in the halls. They most commonly exercised by walking up and down the hallway along the length of the unit.

Statistical analyses

Statistical tests included coefficient of variance and linear correlation analysis (17), a covariance analysis (18), and partial correlation coefficient and two-tailed group *t* test (19).

Results

We found that the mean ± SD caloric intake necessary to gain 1 kg body wt was 8301 ± 2272 kcal (Table 1). Individual values, however, revealed almost a threefold range of calories required to gain 1 kg (4561–12 723 kcal) with a CV of 27%.

Anorectics had more than a twofold range of mean activity counts (1524–3457 counts/24 h) during the course of weight restoration. As can be seen in Table 2, most anorectic subjects tended to show relatively consistent activity levels throughout hospitalization. In fact,

TABLE 1
Results of the weight-restoration program*

Patient no	Height	Maintenance mean daily caloric intake at low weight (A)†	Mean weight at low weight (B)†	Maintenance mean daily caloric intake after weight restoration (C)†	Mean weight after weight restoration (D)†	Days of feeding necessary for weight gain (E)	Total caloric intake during weight gain (F)	Calculated maintenance caloric requirements during weight gain (G)	Calculated excess caloric intake during weight gain (H)	Calculated calories to gain 1 kg (I)
	cm	*kcal*	*kg*	*kcal*	*kg*		*kcal*	*kcal*	*kcal*	*kcal*
1	172	925	39.9	2130	49.5	77	239766	117617	122148	12723
2	168	1168	36.6	2001	49.5	51	165738	81268	84469	6548
3	160	713	32.6	2068	47.4	71	166236	98725	67510	4561
4	159	963	30.8	1451	44.1	95	242350	114665	127685	9600
5	170	601	32.5	1807	47.6	111	296830	133644	163186	10807
6	169	1150	31.7	2399	46.1	74	212870	131313	81557	5663
7	159	1163	25.5	2645	43.5	81	272097	154224	117873	6548
8	157	939	33.4	2197	40.6	73	182765	114464	68301	9486
9	154	927	29.9	2592	41.6	82	250430	144279	106051	9072
10	155	1029	28.6	2203	41.7	76	233057	122816	110241	8415
11	159	1015	27.9	2214	46.5	81	277596	130774	146821	7983
Mean	162	963	31.8	2155	45.3	79	230885	122163	108722	8301
SD	6	171	3.8	323	3.0	14	42523	19459	29709	2272

* $G = (A \times E) + (C - A) \times E/2)$, $H = F - G$, $I = H/(D - B)$.
† These data come from an earlier study (11).

the CVs of activity counts during hospitalization were between 5 and 25% in 10 of the subjects. One patient (patient 6) had a CV of 50% because of very high activity counts (mean of 6292) during the underweight state which decreased during weight restoration. By way of comparison, healthy control women studied under similar conditions (11) had activity levels of 1400 ± 423 counts/d (range 824–2183 counts/d). Only 3 of the 11 anorectics in this study had mean activity counts that were within the range of healthy control women.

When activity counts were correlated with calories necessary to gain 1 kg body wt (**Fig 1**) we found a significant positive relationship ($r = 0.73$, $p < 0.02$). This suggests that the anorectics with the most activity required the greatest amount of caloric intake to gain 1 kg.

Because the effect of activity is included in our estimate of caloric cost of weight maintenance, it was important to examine activity levels in greater detail. We wanted to discern whether activity levels were also an important determinant of energy requirements for

TABLE 2
Activity levels (counts/d) at five phases of treatment*

Patient no	Phase 1 at low weight	Phase 2 at 35.1 kg	Phase 3 at 38.9 kg	Phase 4 at 42.9 kg	Phase 5 after weight restoration (at 45.3 kg)	Mean during hospitalization	CV during hospitalization
							%
1	2550	3363	4195	3500	3252	3372	16
2	3249	2957	2582	2369	2311	2693	13
3	1209	1220	—	1416	1048	1224	11
4	3870	3174	2370	2540	1847	2760	25
5	6292	—	3154	2723	1662	3457	50
6	2099	—	1532	1323	2477	1857	26
7	2833	3183	3155	3302	2963	3087	5
8	2330	2882	3504	3124	3066	2981	13
9	1655	2414	2901	32165	3378	2721	23
10	3103	—	2808	3034	2662	2901	6
11	1200	1211	1694	1730	1786	1524	17
Mean	2533	2267	2536	2356	2204	2597	19
SD	1375	814	759	738	712	704	12

* Mean weight for each phase of treatment is shown.

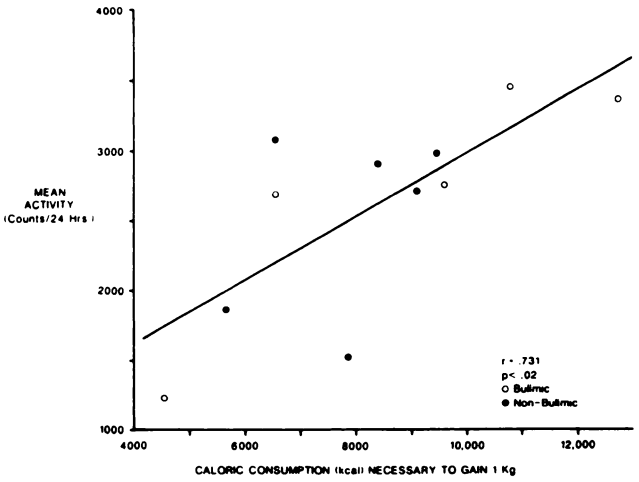

FIG 1. Correlation between mean activity and caloric consumption necessary for gain of 1 kg body wt (n = 11).

weight maintenance. No relationship between activity levels and caloric intake was found in the underweight state (r = 0.34) whereas there was a trend towards such a relationship (r = 0.59) after weight restoration.

Most importantly, however, it was necessary to determine whether activity levels varied differentially across the three periods of hospitalization: during low weight, during weight restoration, and after weight restoration. We found that there was a relatively small change in activity counts across periods for most patients. Thus, in most subjects activity did not greatly increase or decrease over time and therefore would not have biased our estimate of caloric cost of weight maintenance at the low-weight and weight-restored phases of hospitalization. Moreover, there was no significant difference in mean activity counts at each phase of treatment. To remove the influence of activity to obtain an estimate of the caloric cost of weight gain, we covaried maintenance caloric intake with activity levels to recalculate the excess amount of calories necessary to gain 1 kg body wt. This recalculation made no appreciable difference in the calories necessary to gain 1 kg (8301 vs 8022 kcal). After recalculation a significant relationship between mean activity levels during hospitalization and caloric cost of weight gain remained.

It was also possible that body size might be a confounding variable in assessing the caloric expenditure. Subjects with greater body mass might require more calories to gain weight because they might expend more calories for a given degree of physical activity. We found that the partial correlation coefficient between activity levels and calories needed to gain 1 kg of weight independent of body weight was similar (r = 0.74) to the unadjusted correlation reported above. We also found that the partial correlation coefficient between activity levels and caloric intake independent of body weight was similarly significant for underweight anorectics (r = −0.34) and for anorectics after weight recovery (r = 0.52).

Finally, we analyzed the data from a different perspective to determine whether the influence of activity was still a significant contributor to variability of weight gain. Instead of relating activity levels to the caloric cost of weight gain, which depends on the accuracy and validity of our estimate of calories required to maintain weight, we compared activity levels with the number of days it took to gain 1 kg. We did a median split between the five anorectics with the lowest levels of activity (mean 2002 ± 606 counts/d) and the six anorectics with the highest levels of activity (3093 ± 249 counts/d). These two groups consumed similar numbers of calories per day during weight gain (2990 ± 373 vs 2878 ± 319 kcal/d) and gained similar amounts of weight (14.5 ± 2.3 vs 12.7 ± 3.5 kg). However, the group with lower activity gained 1 kg every 5.1 ± 1.2 d whereas the group with higher activity gained 1 kg every 7.2 ± 1.9 d, a significant difference (t = 2.13, $p < 0.05$). In other words, despite having similar daily caloric intakes the group with lower activity gained 1 kg while the group with higher activity gained only 0.71 kg in the same 5-d period.

We found no difference between bulimic and nonbulimic anorectics in terms of calories needed to gain 1 kg or in activity counts during weight restoration.

Discussion

This study shows that amount of physical activity may be an important factor in caloric needs during weight restoration even when opportunity and scope of physical activity are limited to the boundaries of an inpatient hospital ward. Mean caloric intake (and CVs) in this and other studies that have examined the calorie requirements for weight gain in anorectics were similar (**Table 3**). In the four studies listed in Table 3, the mean number of calories required to gain 1 kg body wt ranged from a low of 5340 kcal (4) to a high of 9768 kcal (3). Except for the metabolic-balance study of Russell and Mezey (1) in which the CV of caloric requirements for weight gain was low (8%), previous studies (2–4) and the present one report a large degree of variability (25–43%).

One factor that may account for variation in caloric

TABLE 3
Chronic requirements for weight gain in anorexia nervosa: results from five studies*

References	Cost of weight gain	CV
	kcal/kg	%
Russell and Mezey, 1962 (1)	7525 ± 585	8
Walker et al, 1979 (2)	6401 ± 1627	25
Dempsey et al, 1984 (3)	9768 ± 4212	43
Forbes et al, 1984 (4)	5340 ± 1850	35
Present study	8301 ± 2272	27

* Mean ± SD.

cost of weight gain is possible differences in body composition. In two studies that measured body composition (1, 4), it was evident that the greater the proportion of fat gained, the greater the caloric cost of weight gain. Unfortunately it was not possible to measure the composition of weight gain in this study.

However, we were able to monitor activity of the subjects. Varying amounts of physical activity could be a potent factor influencing caloric requirements. Ravussin et al (20) recently reported that *fidgetiness* (motor activity not connected with overt exercise or physical activity) is an important determinant of 24-h energy expenditure that can account for a significant portion of its variation. Because we found a significant positive correlation between activity and energy cost of weight gain, this study supports the idea that in addition to body composition, physical activity could be an important clinical factor underlying the variability in the energy requirements for weight gain. Physical activity could also be a factor underlying the degree of resistance to weight gain that has been commonly observed in anorectics.

Activity counts measured in this study are not necessarily linearly related to, nor are they a direct measure of, energy expenditure. Therefore, they cannot be used to estimate the portion of the 24-h energy requirements attributable to activity. Nevertheless, activity counts are a qualitative indicator of the amount of physical activity subjects engage in. Because the activity monitors were placed on the subjects' waists, the measurements reflect large muscle movements of the trunk and legs. Activity counts induced by large groups of muscles would therefore be indicative of higher caloric expenditures compared with expenditures when resting, standing, or sitting.

Because this study was not designed as a metabolic balance study, the results are not based on precise direct measurements of all components of energy balance. Nevertheless, they can be used to estimate energy requirements of weight gain indirectly. The accuracy of caloric intake was previously documented (12) and was shown to be 102% of actual values as measured by chemical determinations. Thus the error introduced from food-intake estimates is likely to be small. The estimate of caloric requirements necessary to maintain body weight is derived from caloric intake measurements corresponding to long periods of consecutive days, lasting 11 ± 5 d for underweight anorectics and 23 ± 11 d for short-term weight-recovered anorectics, during which a stable body weight was maintained (11). These measurements should therefore serve as a reasonably good estimate of caloric requirements for weight maintenance.

The excess calories consumed during weight gain were adjusted to reflect the increasing energy cost of weight maintenance that occurs with weight gain. This method of estimating maintenance caloric requirements from which excess calories consumed were calculated differs from other studies because the method is empirically determined. Except for the balance study of Russell and Mezey (1) in which 24-h energy expenditure was measured, previous studies estimated baseline energy requirements by adding an arbitrary figure of 10 or 50% to either measured resting metabolic rate or predicted resting metabolic rate derived from a nomogram. In this study, rather than relying on arbitrary assignment of energy costs of activity and food, we used documented weight-stable periods to estimate energy requirements for weight maintenance.

In a previous study (11) we reported that the same patients divided into bulimic and nonbulimic subgroups had differences in caloric consumption necessary to maintain both low weight and weight after refeeding. Activity levels of bulimic and nonbulimic subjects did not appear to be responsible for the differences in caloric consumption for weight maintenance. It is not known why bulimic and nonbulimic anorectics have differences in caloric intake necessary to maintain weight. In the present study, differences in maintenance caloric intake between bulimic and nonbulimic anorectics were factored out because maintenance caloric requirements (Table 1, G) were subtracted from total caloric intake (Table 1, F).

In summary, these data may be clinically important in terms of treatment of patients with anorexia nervosa because they suggest that the rate of weight gain may be significantly increased if physical exercise is limited. To our knowledge no previous study has quantitated the relationship between activity and the caloric requirements for gaining weight. Minimizing activity during weight gain may significantly decrease the number of days of hospitalization necessary for weight restoration in anorexia nervosa patients.

Restriction of physical activity, however, may have several effects on anorectics. Rigotti et al (21) found that a high level of physical activity may protect bone density in anorexia nervosa because anorectics with low levels of activity had more extensive osteoporosis. It remains to be determined whether restricted activity during several months of weight gain would contribute to significant change in bone density. It is also possible that restricting activity may increase the proportion of weight that is gained as fat mass instead of as fat-free mass. An increase in fat mass may be psychologically repugnant to anorectics although it may be physiologically beneficial given their severe fat-mass deficit.

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