

Caloric Consumption and Activity Levels After Weight Recovery in Anorexia Nervosa: A Prolonged Delay in Normalization

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In the 2 to 6 weeks after completion of refeeding and termination of a weight restoration program, patients with anorexia nervosa required greater than normal caloric intake to maintain a stable weight and had elevated levels of activity. By contrast, such patients studied 6 months or longer after weight recovery had normal caloric intake and activity levels. The prolonged delay in normalization of caloric intake and activity is mirrored by the slow resolution to normal of the neuroendocrine dysregulation that characterizes this disorder. This suggests that treatment for weight maintenance in anorexia nervosa should be extended aggressively for months after the return of a healthy weight so as to restore normal neuroendocrine function and thereby enhance the likelihood of permanent recovery.

Anorexia nervosa is a disorder with a significant rate of morbidity and mortality. After weight restoration, about 50% of patients with an-

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orexia nervosa are not able to maintain their weight (Hsu, Crisp, & Harding, 1979; Schwartz & Thompson, 1981). The reasons for the recurrent weight loss are unknown, but have been thought to be a consequence of psychological factors. We present data in this report which suggests that physiologic disturbances may also contribute to the failure to maintain weight.

Research assessing caloric intake in anorexia nervosa was conducted in order to study the process of weight recovery. It was observed that in the weeks after weight recovery anorectics needed to consume larger than normal quantities of food to maintain their weight (Kaye, Ebert, Raleigh, & Lake, 1984). If this large caloric intake was not maintained, anorectics lost weight rapidly.

While data pertaining to caloric intake have been reported during in-hospital refeeding of underweight anorectics (Walker, Roberts, Halmi, & Goldberg, 1979; Russell & Mezey, 1962; Stordy, Kalucy, & Crisp, 1977; Dempsey, Crosby, Pertschuk, Feurer, Buzby, & Mullen, 1984), the amount of calories necessary for anorectics to maintain weight after weight recovery has not, to our knowledge, been investigated. The question arose as to whether anorectics would continue to need more calories to maintain weight for the rest of their lives. This question could have been answered by longitudinal follow-up of patients who maintained their weight. However, we anticipated that the probability of many patients having good outcomes was small because the NIMH is a tertiary referral center that tends to admit patients with chronic disease, prior treatment failures, and with a poor prognosis. To increase the number of patients studied, we combined our weight-recovered patients with a separate group of women, treated by other programs, who were once underweight with anorexia nervosa. At the time of our study these women had been at a stable weight for at least 6 months.

Anorectics have been observed to have increased motor activity (Kron, Katz, & Horzynski, 1978). We hypothesized that this increase in motor activity might be responsible for the enhanced caloric requirements after weight recovery. As a basis for comparison caloric intake and levels of motor activity appear to positively correlate in normal persons (Benedict, Miles, Roth, & Smith, 1984; Keys, Brozek, Herschel, Michelson, & Taylor, 1950; Edmundson 1977; Gorsky & Calloway, 1983; Epstein, Wing, & Thompson, 1978).

To record and measure motor activity we employed a device developed at the NIH by Colburn and colleagues (1976). This device is capable of recording continuous motor movement and has been used in studies of motor activity in other neuropsychiatric populations (Porriño, Rapoport, Behar, Sceery, Ismond, & Bunney, 1983; Wehr & Goodwin, 1981). To our knowledge there have been no naturalistic studies of motor activity in anorexia nervosa.

METHODS

Subjects

All patients were hospitalized on a clinical research unit of the National Institute of Mental Health at the Clinical Center, National Institutes of Health. All subjects gave informed consent for the study and each had fulfilled DSM II criteria for anorexia nervosa when they had been underweight. Patients were studied at two stages: (1) 13 anorectics were studied in consecutive order two to four weeks after the completion of a refeeding program to restore weight loss (recently weight recovered); and (2) 9 different women were studied who had been underweight with anorexia nervosa in the past and had been, at the time of the present study, weight recovered for greater than six months (long-term weight recovered).

All anorectics studied during recent weight recovery were followed up 6 months after discharge. Three anorectics had been able to maintain weight within 5 kg of discharge weight. The others had lost more than 5 kg. Two of the three anorectics who were able to maintain weight after discharge agreed to be studied longitudinally during long-term weight maintenance. The weight loss experienced by both of these subjects in the months after discharge was relatively minor compared to their low weight when emaciated with anorexia nervosa. The first patient "A" had fallen to a low weight of 28 kg during the 48 months she had been underweight with anorexia nervosa in the past. A did not have return of menstruation at follow-up but B resumed menstruation 15 months postdischarge.

Nine additional anorectics were only studied after long-term weight recovery had occurred. Two had been previously hospitalized in the NIMH eating disorder program before this study had begun. Two subjects had been referred by colleagues who knew of our interest in this patient population. Three subjects contacted our program requesting employment and two subjects were found through local advertisement. All long-term weight-recovered subjects had some degree of continuing anorectic symptoms including distorted body image, peculiar eating habits, and obsessions concerning dietary intake of food.

Long-term weight-recovered anorectics had been able to maintain a relatively stable weight for a minimum of 6 months prior to study. Given the infrequency of anorexia nervosa, and the even greater difficulty of finding weight-recovered anorectics willing to volunteer for study we accepted subjects with weight fluctuations in the previous six months but who had, overall, managed to maintain their weight in the normal range.

Control subjects consisted of 11 healthy women who were found to

be free of medical and neurologic conditions. Controls were determined to be free of mental disorders on the basis of a structured psychiatric interview by an experienced psychiatrist.

Procedure

Caloric intake and activity measurements were quantitated in the hospital during a three- to five-day period of stable weight (± 0.5 kg). Subjects were weighed daily in a hospital gown on the same metabolic scale. Anorexics studied during recent weight recovery remained as inpatients while long-term weight-recovered subjects and controls were admitted to the hospital for these measurements.

During the time of these measurements all subjects remained restricted to a locked ward to control for environmental temperature and consistent range of movement. All food was ordered from the hospital kitchen and caloric content documented before being given to the patients. The uneaten food was returned to the kitchen and reweighed and an estimate of daily caloric intake was made. Subjects were only allowed to eat three 45 minute meals per day and three 15 minute snacks. No patients on the ward were allowed to have food in their rooms. All subjects were observed 24 hours per day on the ward including mealtime and bathroom visits so they could not secretly binge or vomit.

Recent weight-recovered subjects were instructed to maintain a stable target body weight (± 0.5 kg) after the termination of refeeding and the weight gaining portion of their hospitalization. This weight-stable phase of hospitalization lasted from 2 to 6 weeks while studies were performed. Target weight was defined as the weight where 10% of women with secondary amenorrhea would be expected to menstruate (Frish, 1977; Falk & Halmi, 1982). We observed that recent weight-recovered anorexics required elevated caloric intakes to maintain their weight. If these elevated levels of caloric intake were not reached, weight was lost quickly. Long-term weight-recovered anorexics and normal controls were also instructed to maintain a stable body weight (± 0.5 kg) during the 3 to 5 days they were studied.

In an independent study we calibrated the accuracy of the method of caloric estimation used in this report. Daily meals for a hypothetical patient were prepared under blind conditions by the kitchen and sent to the ward. Portions of the meals typical of what a patient might eat were saved and frozen by the ward staff. The difference between the remaining food and the food saved by the ward staff was estimated for caloric content. The portion of the meal retained by the staff was analyzed by bomb calorimetry. (Complete proximate analysis, Hazelton Labs, Madison, Wisconsin) 15 days of total caloric consumption ranging from 500 to 4500 kcalories per day were tested. Clinical caloric estimates were $102.2 \pm 2.2\%$ of the values found by calorimetry.

Motor activity was automatically and continuously recorded for 24 hours per day for 3 to 5 days by methods previously reported (Wehr & Goodwin, 1981; Porrino et al., 1983). Motor activity was measured by an acceleration-sensitive device with a solid-state memory that stores data on the number of movements per unit time over a 64 hour period (Colburn et al., 1976). Motor activity counts for consecutive 15-minute periods were recorded. The measurement of movement by the monitor is nonlinear, in that the presence of any acceleration above a certain threshold is recorded. Maximum sampling occurs at the rate of 1.14 movements per second. Because of limited memory capacity, each activity count represents the cumulation of 16 movements stored in the accumulator. Thus, for example, ten activity counts in an hour actually represent 160 movements. The accumulator accepts a maximum of 255 activity counts per time period. The total number of counts per hour was printed out daily by use of a computer. The monitors were worn continuously, attached to a belt around the waist of the subjects. Two monitors were used throughout the study. These monitors were initially calibrated to be equal to each other and throughout the study maintained a variance of less than 7%.

Since the subject groups differed in weight, some method of correction of caloric intake for differences in weight was necessary. Several methods of correction are available (Webster, 1981; Bastow, 1972; Keys, Fidanza, Karvonen, Kimura, & Taylor, 1972) and there is no clear agreement on the best method. We corrected total daily caloric intake for overall weight (kcal/kg/day), weight of nonfat body mass (kcal/lean body mass/day) or some combination of height and weight (kcal/body mass index/day, kcal/skin surface area/day). Lean body mass was measured by potassium 40 (Forbes & Hursh, 1963) on a subgroup of subjects.

The continuous variables were evaluated with a one-way analysis of variance (ANOVA) and Student's t-test (two-tailed). Differences found on the one-way ANOVA were evaluated by the Scheff test. Two subjects were studied both as recently recovered and as long-term weight-recovered anorectics. For ANOVA data analysis the two anorectics studied longitudinally as both recent and long-term weight-recovered conditions were excluded from the recent weight-recovered group and included in the long-term weight-recovered group. This arbitrary decision also made groups equal at eleven subjects each.

RESULTS

All groups of subjects had similar ages and heights. Recent and long-term weight-recovered anorectics weighed less than controls. Recent and long-term weight-recovered anorectics showed no statistically sig-

nificant differences between ages of onset or in duration of anorexia nervosa symptoms. Recent weight-recovered anorectics had been at significantly lower weight during their illness than the long-term weight-recovered group. The recently weight-recovered anorectics were studied 20.0 ± 2.1 days (range 14 to 40 days) after the completion of the refeeding portion of the program. The long-term weight-recovered anorectics were studied 37.4 ± 8.0 months (range 6 to 84 months) after attaining and maintaining a stable and normal weight.

Each group studied had a significantly different total daily caloric intake. The recently weight-recovered anorectics had the largest daily caloric intake and the long-term weight-recovered anorectics had the smallest. When total caloric intake was adjusted for weight, by any correction factor, the recently weight recovered anorectics had significantly greater caloric intake than the long-term weight-recovered anorectics and the normal controls. The long-term weight-recovered anorectics were similar to the normal controls.

The two anorectics studied longitudinally demonstrated a reduction in caloric intake during the interval of time after discharge from the hospital. Anorectic A had a significant reduction in kcal/kg per day necessary to maintain a stable weight (while in the hospital for study) during the 15-month interval since discharge. Anorectic B was studied at 6-month intervals after discharge and demonstrated a progressive reduction in kcal/kg per day necessary to maintain a stable weight while in the hospital for study. The reduction in kcal/kg per day intake was not significant at 6 months after discharge, but became significant 13 months after discharge.

Recently weight-recovered anorectics had significantly greater total daily activity counts than long-term weight-recovered anorectics or controls (Table 1). Anorectic B had a significant reduction in activity at the 6-month follow-up and continued to have a reduction in activity in the months after discharge (Table 3). Anorectic B did not have activity measured on follow-up during her long-term weight-recovered admission as she was studied during the initial phase of this investigation.

The relationship between mean daily caloric intake corrected for weight and activity levels of all subjects are presented in Figure 1. Only in the recent weight-recovered anorectics is there a significant positive relationship between total daily activity counts and total daily caloric intake ($r = .58, p < .05, n = 11$), activity and total caloric intake per day corrected for kg of body weight ($r = .64, p < .05, n = 11$), and activity and caloric intake corrected for surface area ($r = .60, p < .05, n = 11$). A trend was found for activity and kcal/day corrected for lean body mass ($r = .57, p = .08, n = 10$) but not for activity corrected for body mass index. No relationships were demonstrated for activity and caloric intake for the long-term weight-recovered subjects and normal controls.

Table 1. Recent weight-recovered anorectics, short-term weight-recovered anorectics, and normal controls compared by one-way ANOVA.

	Recent Weight-Recovered Anorectic	Long-Term Weight-Recovered Anorectic	Normal Control Women	df	F Value	P
Age (Years)	25.0 ± 1.1	24.9 ± 1.7	22.5 ± 1.0	2,30	1.16	NS
Height (cm)	161.0 ± 2.3	162.9 ± 2.1	165.3 ± 1.9	2,30	1.07	NS
Weight (kg)	44.7 ± 1.0 ^a	49.6 ± 2.1 ^a	57.5 ± 2.2	2,30	12.17	.0001
Weight (% of weight necessary to menstruate)	95.4 ± 1.1 ^a	104.1 ± 3.7 ^a	117.5 ± 3.4	2,30	14.36	.0001
Kcal/day	2057 ± 63 ^{a,b}	1349 ± 103 ^a	1702 ± 83	2,30	16.87	.0001
Kcal/kg/day	46.2 ± 1.8 ^{a,b}	27.1 ± 2.10	30.2 ± 1.8	2,30	30.06	.0001
Kcal/surface area/day	14.4 ± .5 ^{a,b}	8.9 ± .7	10.5 ± .5	2,30	24.05	.0001
Kcal/lean body mass/day	58.1 ± 2.8 ^{a,b}	35.7 ± 4.6	38.2 ± 1.9	2,21	19.11	.0001
Kcal/body mass index/day	119.6 ± 4.7 ^{a,b}	72.4 ± 5.2	81.8 ± 5.0	2,30	25.76	.0001
Activity counts/day	2396 ± 228 ^{a,b}	1656 ± 184	1402 ± 142	2,28	7.50	.0025

Differences on the one-way ANOVA were evaluated by a Scheffé post-hoc test. ^a indicates a significant ($p < .05$) difference between the group of anorectics and controls and ^b indicates a significant difference between recent and short-term weight-recovered anorectics. Data is expressed as means and SEM. There were 11 subjects in each group.

Table 2. Group t-test comparisons between short- and long-term weight-recovered anorectics

	Recent Weight-Recovered Anorectics	Long-Term Weight-Recovered	T	P
Low weight (kg) when emaciated with anorexia nervosa	28.5 ± 1.1	32.9 ± 1.4	2.51	.0211
Low weight (%)	61.0 ± 2.1	66.2 ± 2.3	1.64	NS
Age of onset of anorexia nervosa (years)	17.6 ± 0.9	16.5 ± 1.4	.63	NS
Duration of anorexia nervosa (months)	84.1 ± 13.2	100.1 ± 14.7	.81	NS

DISCUSSION

Patients with anorexia nervosa, in the weeks after achieving target weight and terminating refeeding, have elevated levels of activity and caloric intake, compared to normal controls. In contrast, caloric intake and activity in anorectics who had maintained weight for months after weight recovery were similar to controls.

The objection might be raised that since the majority of the data of this study are cross-sectional the possibility cannot be excluded that there are two separate subgroups of anorectics: those with good and those with poor outcome. Increased activity and caloric intake found in the recently weight-recovered anorectics might contribute to poor outcome because these factors could combine to make the process of continued weight maintenance more difficult. In contrast, the long-term weight-recovered anorectics might have also had a normal range of activity and caloric intake at the time they were short-term weight recovered. Lower caloric requirements may have given them an advantage in the fight to maintain weight after returning to a healthy weight.

The limited longitudinal data, however, support the view that a reduction in caloric intake and activity occurs during the months of transition from short- to long-term recovery in anorexia nervosa. In addition, in the recent weight-recovered cohort, we compared the three with good outcome (maintenance of weight after discharge) against those who lost weight after discharge. There were no differences in caloric intake or activity levels in the recent weight-recovered stage between those that had good or poor outcome. Replication of this finding is necessary.

Increased activity is known to be associated with increased caloric

Table 3. Longitudinal data on two patients with anorexia

	Months Weight-Recovered at Study	Weight (kg)	Kcal/Day	Kcal/kg per Day	Activity Counts/Day
Patient A:					
Recent weight recovery	.47	46.5	1948 ± 78	41.9 ± 1.7	1371
Long-term weight recovery	15.0	42.0	1407 ± 120*	33.5 ± 2.8*	—
Patient B:					
Recent weight recovery	.87	46.7	2278 ± 56	48.8 ± 1.2	1786
Long-term weight recovery	6.0	43.8	1989 ± 14	45.4 ± .3	1075*
Long-term weight recovery	13.0	44.9	1665 ± 167	37.1 ± 3.7**	1370*
Long-term weight recovery	19.0	45.7	1595 ± 114	34.9 ± 2.5**	1243*

Subjects were studied initially as recent weight recovered anorectics. The first anorectic ("A") was restudied 15 months after discharge. The second anorectic was restudied at six month intervals after discharge.

Indicates a significant reduction ($p < .05$, ** $p < .01$) in caloric intake or activity in comparison to the recent weight-recovered state.

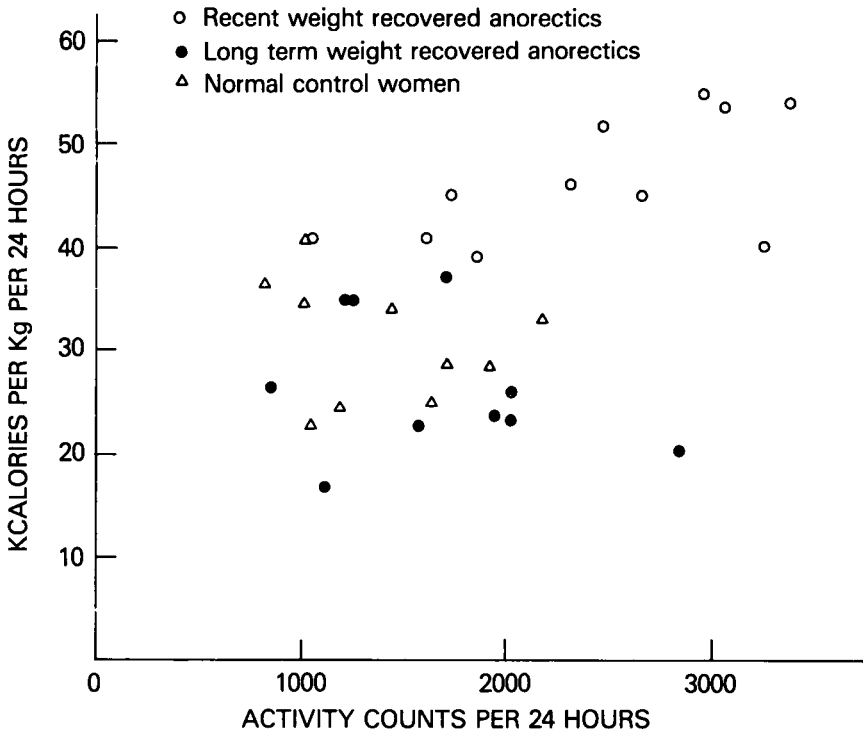


Figure 1. Activity counter per day and caloric intake per day (corrected for weight) for recent and long term weight recovered anorexics and normal controls

intake in the normal population (Benedict et al., 1919; Keys et al., 1950; Edmundson, 1977; Gorsky & Calloway, 1983; Epstein et al., 1978). Decrease in physical activity appears to be a plausible explanation for the reduction in caloric requirements found during the transition from recent to long-term recovery in anorexia, but this is not necessarily the only factor.

It is unlikely that malabsorption is responsible for increased caloric needs. Russell and Mezey (1962) have demonstrated that during refeeding with a liquid diet, when daily caloric intake was much greater, anorexics were able to absorb a normal proportion of ingested calories. Only one patient in this study had clinically observable refeeding edema. It is unlikely that excess caloric intake replaced significant accumulated fluid.

Could increased caloric intake in recently weight-recovered anorexics be a consequence of factors other than activity? It has been debated in recent years whether alterations can occur in the efficiency with which animals utilize the energy contained in food (Hervey & Tobin,

1983; Rothwell & Stock; 1983; Stordy et al., 1977) found that during refeeding, when activity was equalized by complete bed rest, subgroups of anorectics had differences in the efficiency with which caloric intake produced weight gain.

Investigators have suggested that the mechanism underlying regulation of energy efficiency may, in part, involve adrenergic and thyroid systems (Rothwell, Saville, Stock, 1982; Jung, Shetty, & James, 1980; Landsberg & Young, 1978). It is uncertain whether adrenergic metabolism normalized during short-term weight recovery (Halmi, Dekirmenjian, Davis, Casper, & Goldberg, 1978; Gross, Lake, Ebert, Ziegler, & Kopin, 1979; Abraham, Beumont, & Cobbin, 1981; Gerner & Gwirtsman, 1981; Biederman et al., 1984; Kaye et al., 1984) and may even continue to be abnormal in long-term weight-recovered anorectics (Kaye, Jimerson, Lake, & Ebert, 1985). Some disturbances of thyroid activity may be present after weight gain in anorexia nervosa (Moore & Mills, 1979; Leslie, Issacs, Gomez, Raggatt, & Bayliss, 1978; Casper & Frohman, 1982). The suggestion of endogenous differences in energy utilization as well as the suggestion of disturbances in adrenergic and thyroid regulation after recent weight recovery, and perhaps in the long-term recovered state, cautions against an oversimplified interpretation of these data.

If a slow normalization of caloric intake and activity takes months after weight recovery, then it would be similar in pattern to the long delay in normalization described in several neuroendocrine systems. This delay is most clearly seen in menstrual regulation (Sherman, Halmi, & Zamudis, 1975; Pirke, Fichter, Land, & Doerr, 1979) but has also been described in vasopressin (Gold, Kaye, Robertson, & Ebert 1983) modulation and perhaps cortisol (Doerr, Fichter, Pirke, & Lunde, 1980) regulation. The interrelationships among activity, energy metabolism, neurotransmitter, and hormonal systems are complex and not well understood. These interrelationships require further investigation in anorexia nervosa.

This study relies upon the accuracy of the caloric and activity data, both areas known to be difficult to quantify in clinical settings. Other investigators have confirmed that caloric intake can be measured accurately by similar methods (Patterson & McHenry, 1941; Marr, 1971; Pekkarinen, 1970; Whiting & Leverton, 1960). We also documented the accuracy of our methods by calorimetry. We used precautions to prevent food being binged and vomited, or hidden and thrown away by restricting subjects to a locked ward and by observing them at meals and in the bathrooms. While loss of food meant to be consumed occurred occasionally, it was rarely a significant problem.

The activity monitor records trunk movement but does not quantify energy utilization. Our rationale for location of the monitor on the waist was the observation that anorectics most often exercised by pac-

ing or calisthenics. The assumption that trunk movement was a valid indication of energy expended by subjects is in part substantiated by its significant relation with caloric intake in recent weight-recovered anorectics.

Another problem is choosing a method to adjust caloric consumption for differences in weight between subjects. Investigators have suggested a variety of methods (Webster, 1981; Bastow, 1972; Keys et al., 1972). We found that correction of total daily caloric intake for total weight, lean body mass, or some relationship of height and weight (skin surface area or body mass index) all yielded a similar relationship between groups of subjects.

High caloric intake in recently weight-recovered anorectics suggests aggressive treatment beyond immediate weight recovery might be clinically useful. These data led to changes in the treatment program at the NIMH. A pilot program of gradual transition from the hospital was developed that takes into account this need for increased caloric intake in the period after weight recovery. Patients and families were instructed to expect increased caloric requirements for months after discharge. It is difficult enough for anorectics to maintain a "normal" caloric intake, and quite overwhelming to have to ingest this enormous quantity of food. To insure that patients could succeed at this task a pilot program was instituted to give patients the experience of buying and preparing food themselves in a kitchen on the ward before discharge. We wanted to give anorectics the experience of being responsible for consuming sufficient calories to maintain weight before discharge.

Can these data explain why some anorectics return to health, while others waste away and die? Would all anorectics, if forced to maintain weight, gradually normalize caloric intake, activity, and neuroendocrine function? Or are some anorectics predetermined to have a poor prognosis? Our data raise a number of questions that may have heuristic value in stimulating new directions in treatment. It appears to be just as important to focus clinical resources on weight maintenance after weight recovery as it is to aggressively refeed underweight anorectics.

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