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Physical activity and post-treatment weight trajectory in anorexia nervosa

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Abstract

Objective—This study compared an objective measurement of physical activity (PA) in individuals with anorexia nervosa (AN) at low-weight, weight-restored, and post-treatment time points, and also compared PA in AN with that of healthy controls (HC).

Method—Sixty-one female inpatients with AN wore a novel accelerometer (the IDEEA) which measured PA at three time points: a) low-weight, b) weight-restored, and c) one month post-hospital discharge. Twenty-four HCs wore the IDEEA at one time point.

Results—Inpatients with AN became more physically active than they were at low-weight at weight restoration and following treatment discharge. Post-treatment patients with AN were more physically active than HCs during the day and less active at night, which was primarily accounted for by amount of time spent on feet, including standing and walking. Greater time spent on feet during the weight-restoration time point of inpatient treatment was associated with more rapid decrease in BMI over the 12 months following treatment discharge. Fidgeting did not differ between patients and controls, did not change with weight restoration, and did not predict post-treatment weight change.

Discussion—Use of a novel accelerometer demonstrated greater PA in AN than in healthy controls. PA following weight restoration in AN, particularly time spent in standing postures, may contribute to weight loss in the year following hospitalization.

Keywords

anorexia nervosa; exercise; physical activity; treatment outcome; eating disorders

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Conflict of interest: None

Anorexia Nervosa (AN) is a serious psychiatric illness marked by self-starvation and overvaluation of shape and weight. There has been a longstanding interest in the role of physical activity (PA) in the etiology, maintenance, and prognosis of AN. A range of methods has been used to assess PA in AN, from subjective patient report of exercise frequency and drive to exercise, to objective devices such as accelerometers, which can quantify the frequency and duration of PA.

Despite low weight, a significant subset of individuals with AN report that they engage in “excessive” or “compulsive” exercise (1), with one of the earliest clinical observations of a patient with AN by Dr. William Gull from 1868 noting that despite extremely low weight, the patient was “restless and active...it seemed hardly possible that a body so wasted could undergo the exercise which seemed agreeable”(2). This elevated level of exercise is associated with heightened psychopathology, such as depression, anxiety, and eating disorder symptomatology (3-6). Compulsive exercise during treatment is also negatively associated with improvements in eating disorder pathology by treatment discharge (3) and subjective report of compulsive exercise is associated with long-term lack of recovery from AN (7).

Notwithstanding the longstanding clinical observation of heightened PA in AN, investigation of objective activity levels in patients with AN has yielded mixed results. While some studies have found that patients with AN are more active than healthy controls (8), others have found no significant difference in overall activity (9-12). Some investigators have found increases in PA with weight gain during inpatient treatment (13), while others have found a trend towards a decrease in PA during treatment (8). A study examining the relationships between objective measures of PA, self-report of PA, and eating disorder pathology in AN, anxious individuals, and healthy controls found no differences between groups in measured levels of PA, but noted that patients with AN *reported* higher levels of physical activity than controls, and also reported elevated drive to exercise (11). A possible reason for discrepancies among these studies is the varying methods of PA measurement (e.g., actometer, activity chamber, accelerometer) and the lack of distinction among different types of PA.

In addition to deliberate exercise, it has long been noted that patients with AN appear to engage in high levels of non-exercise physical activity, such as walking, standing, fidgeting, and general restlessness (14), although these behaviors remain difficult to measure (15). Non-exercise activity is of growing interest in the study of weight regulation in overweight individuals (16, 17), but surprisingly little is known about its role in AN. To date, no study to our knowledge has employed an objective monitor of physical activity type and postural allocation in the investigation of PA in AN, and no study has sought to determine whether these measures differ between AN patients and healthy controls.

Given that PA is frequently commented on but poorly documented in AN, we sought to objectively measure PA in AN. The purpose of the current study was to use a novel accelerometer capable of distinguishing types of PA to compare PA of patients with AN at three time points: 1) shortly after admission to an inpatient unit (Time 1), 2) on the inpatient

unit after gaining to 90% of ideal body weight (Time 2), and 3) one month following discharge from the inpatient unit (Time 3). Additionally, this study sought to compare PA between healthy controls and patients with AN at one month following inpatient treatment (Time 3). A secondary aim was to explore which types of PA may contribute to total activity level in the overall sample and in patients with AN. Finally, this study sought to examine the associations between objectively measured PA with follow-up BMI, measured over the course of 12 months after inpatient treatment discharge. We hypothesized the following: 1) in AN, PA would decrease from time points 1 to 2 as patients gained weight during inpatient treatment, in line with the notion that elevated PA characterizes a more severely ill state; 2) Heightened PA at time point 2 would predict a more precipitous rate of change in BMI following discharge from inpatient treatment; and 3) Individuals with AN at time 3 would, on average, be more active than controls.

METHOD

Participants

Patients with anorexia nervosa—Participants were women between the ages of 15 and 40 years who met DSM-5 criteria for AN at the time of hospital admission (18). Participants with AN were receiving inpatient treatment for AN at the New York State Psychiatric Institute (NYSPI; (19)). Patients with AN were excluded from the study if they had a significant medical illness, psychosis, recent substance abuse, or acute suicidality.

Healthy Controls—Twenty-four age-matched, normal weight female healthy controls (HC) were recruited via advertisement to participate. Controls were included if they had no current or past psychiatric illness, including any history of an eating disorder, and had a BMI in the normal range (18–25 kg/m²).

Additionally, both groups were free of medications known to affect PA (e.g., neuroleptics, stimulants) for at least 2 weeks prior to monitoring. All participants provided written informed consent before participation in this study, and all study procedures were approved by the NYSPI Institutional Review Board.

Physical Activity Measures

The Intelligent Device for Energy Expenditure and Activity (IDEEA; MiniSun, Fresno, CA) is a novel microcomputer-based portable PA measurement device designed to capture body position and acceleration. The device consists of 5 small sensors that are attached to the chest, thighs, and feet with tape and transmit PA data to a small microcomputer on a waistband or belt. After sensors are secured on the body, the monitor is calibrated to ensure proper placement. The IDEEA provides information regarding the specific type and duration of daily activities and provides measurement of PA 32 times per second.

The IDEEA has been found to correctly identify at least 32 different types of PA at a rate of 98.7% and to correctly determine duration and intensity of walking or running (20). Strong correlations have also been reported between the IDEEA and manual step counts measured by investigators with handheld step-counters (21) and with PA assessed through an armband

accelerometer (22). The IDEEA has excellent reliability in assessing activity counts over a fixed distance across multiple days, and strong concurrent validity for gait assessment (23).

This study examined total activity, “fidgeting,” and time on feet as measured by the IDEEA. Total activity was defined as total “counts” per minute (with a higher number of counts indicating greater activity). Fidgeting was operationalized as “change counts” (changes in body position) while seated, a definition used in a previous study validating the IDEEA to measure fidgeting in healthy women (24). Time on feet was defined as the sum of minutes spent on all activities that occurred in the standing position, specifically, minutes spent standing, stepping up and down stairs, walking, running, and jumping.

Instruments

Patients (at Time 1 and Time 2) and HCs completed self-report measures of mood, anxiety, and eating disturbance. Mood was measured with the Beck Depression Inventory (BDI; (25)); anxiety with the Beck Anxiety Inventory (BAI; (26)); and eating disturbance with the Eating Disorder Examination-Questionnaire (EDE-Q; (27)).

Study Procedures

Patients wore the IDEEA at up to three time points: inpatient low-weight (Time 1), inpatient weight-restored (Time 2), and outpatient follow-up (Time 3). Low-weight (Time 1) monitoring occurred within two weeks of hospital admission, weight-restored (Time 2) monitoring within two weeks of achieving weight restoration on the inpatient unit (approximately 90% ideal body weight, and follow-up (Time 3) monitoring 4-6 weeks after hospital discharge in the patient's free-living environment. Controls wore the IDEEA at one time point. At each time point, participants were asked to wear the IDEEA for 72 continuous hours (while awake and asleep), except when showering, bathing, or swimming. Research staff placed and calibrated the sensors initially and instructed participants regarding proper removal and replacement.

Follow-Up Assessments—Patients with AN were asked to provide weight measurements at 1, 2, 4, 8, and 12 months following hospital discharge. At each time point, patients who were able to return to the clinic were weighed by research staff. Those who were unable to attend an in-person visit provided a self-reported weight, which was verified by an outside clinician (e.g., primary care physician, therapist) when possible.

Data Analysis

Physical activity measures were aggregated in four-hour intervals to produce 6 measurements for each day and each subject (i.e., activity counts from 6am-10am, 10am-2pm and so on). Linear mixed effects models controlling for demographic variables (age and race) and baseline clinical variables (admission BMI, AN subtype, duration of illness, previous number of eating disorder hospitalizations, psychotropic medications on admission, leave against medical advice) were used to compare PA in patients with AN across the three time points (Time 1, Time 2, and Time 3) in a test of hypothesis one and to compare PA in patients with AN at one-month follow-up (Time 3) with PA in HCs in a test of hypothesis three. We modeled the periodic effect in PA measures by trigonometric series

(sine and cosine functions of time in a day) with random subject-specific intercepts and slopes. These analyses were done for the following PA variables: Total Activity, Time on Feet, and Fidgeting. Linear regression was used to explore which types of PA may contribute to total activity at all time points in the overall sample and in AN patients specifically. To examine whether BDI should be considered as a covariate in further analyses, correlations between BDI and PA were also calculated. Lastly, to test hypothesis two, linear mixed effects models with random intercepts and random slopes were constructed to examine the associations between standardized PA measures (e.g., PA measures for each subject divided by the standard deviation of the same subject) at Time 1, Time 2, or Time 3 and rates of change of patients' follow-up BMI. The relationship between PA at Time 2 and follow-up BMI was analyzed as per our a priori hypothesis. Relationships between PA at Times 1 and 3 and follow-up BMI were examined in an exploratory manner. Specifically, we fitted separate models using follow-up BMI as the outcome and each standardized PA measure (Total Activity, Time on Feet, or Fidgeting) at a session (Time 1, Time 2, or Time 3) as well as its interaction with follow up time as covariates. We adjusted for demographic variables and baseline clinical variables. The significance level was set at $p=0.05$ and all tests were two-tailed. All the analyses were done using SAS 9.4.

RESULTS

Participant Characteristics

Sixty-one patients with AN participated in this study. Patients with AN wore the IDEEA for three consecutive days at low-weight ($n=45$), at weight restoration ($n=35$), and at one month following inpatient discharge ($n=19$). Twelve participants wore the IDEEA at all three time points. Twenty-four healthy controls wore the IDEEA over three days. Follow-up weights were available for 52 participants with AN at month one following discharge, $n=54$ at month two, $n=45$ at month four, $n=54$ at month eight, and $n=49$ at month twelve. At the low-weight time point, 5 participants with AN were taking psychotropic medication, including 3 individuals taking antidepressants (SSRIs and SNRIs: i.e., fluoxetine and duloxetine), one individual taking an antidepressant and anticonvulsant (i.e., fluoxetine and levetiracetam), and one individual taking a sedative (i.e., zolpidem). At the weight restoration time point, 6 participants with AN were taking psychotropic medication, including 4 individuals taking antidepressants (SSRIs and SNRIs: i.e., escitalopram, fluoxetine, desvenlafaxine, and duloxetine), one individual taking an antidepressant and anticonvulsant (i.e., fluoxetine and levetiracetam), and one individual taking an anxiolytic (i.e., lorazepam). At the one month post-discharge time point, 7 participants with AN were taking psychotropic medication, including 6 individuals taking antidepressants (SSRIs and SNRIs: i.e., fluoxetine, sertraline, desvenlafaxine, and venlafaxine) and one individual taking an anxiolytic (i.e., alprazolam).

Psychopathology at Low Weight and Weight Restoration

Demographic variables are presented in Table 1. There were statistically significant improvements in measures of depression ($df=24$, $t=4.36$, $p<.001$) and eating disturbance ($df=23$, $t=5.95$, $p<.001$) from the low-weight time point to weight restoration, but not in a measure of anxiety ($df=24$, $t=1.09$, $p=.287$).

Physical Activity Across Time points in AN

Many HCs and patients with AN removed the IDEEA device after two days, resulting in a large amount of missing data for the third day of PA monitoring at each time point. Therefore, only data from the first two days of PA monitoring at each time point were used in further analyses. To examine the potential impact of mood on PA, we computed the Pearson's correlations between BDI and total activity at Time 1 ($R=-0.032$, $p=0.88$), and at Time 2 ($R=0.43$, $p=0.09$). Additionally, we computed the correlation between change in activity levels between Time 1 and Time 2 with the change in BDI during this period ($R=-0.15$, $p=0.61$). In all cases, correlations were not statistically significant, and therefore were not included as covariates in further analyses.

Total Physical Activity Across Time Points—Contrary to our first hypothesis, patients were significantly more active at weight restoration than at low-weight (Time 2 vs. Time 1: $df=(1, 830)$, $F=4.50$, $p=.034$) as measured by Total Activity Count. Patients with AN were also significantly more active at one month following discharge compared to low-weight (Time 3 vs. Time 1: $df=(1, 830)$, $F=21.88$, $p<.001$) and weight-restored time points (Time 3 vs. Time 2: $df=(1, 830)$, $F=7.94$, $p=.005$) (See Figure 1).

Time on Feet Across Time Points—There was a trend for patients' time on their feet at weight restoration to be greater than at low-weight (Time 2 vs. Time 1: $df=(1, 830)$, $F=3.53$, $p=.061$). Patients with AN spent significantly more time on their feet at one month following discharge compared to low-weight time points (Time 3 vs. Time 1: $df=(1, 830)$, $F=8.84$, $p=.003$). Time on feet accounted for 49% of the variability of the Total Activity Count in the overall sample and 51% in patients with AN across all three time points. Time on feet was comprised primarily of time spent standing (78%), followed by walking (21%), stepping (0.7%), running (0.1%), and (0.06%) jumping.

Fidgeting Across Time Points—Fidgeting among patients with AN did not differ significantly from low-weight to weight restoration to one month following treatment discharge (Time 2 vs. Time 1: $df=(1, 830)$, $F=0.41$, $p=.522$, Time 3 vs. Time 2: $df=(1, 830)$, $F=0.44$, $p=.510$, Time 3 vs. Time 1: $df=(1, 830)$, $F=0.02$, $p=.881$). Fidgeting accounted for 15% of the variability of the Total Activity Count in the overall sample and 14% in patients with AN across all three time points.

Physical Activity in Patients with AN versus Healthy Controls

The PA of patients following discharge (Time 3) was compared to that of HCs in a test of our third hypothesis. The Total Activity Count of HCs differed significantly from that of patients with AN at one month following discharge ($df=(3, 310)$, $F=2.73$, $p=.044$) (see Figure 2). To determine if this difference was accounted for by specific periods of time, mean activity count was then examined in consecutive four hour blocks spanning from 10:00 am- 2:00 pm on Day 1 through 2:00 am- 6:00 am on Day 2. Results of these analyses revealed that patients with AN were significantly more active than HCs from 10:00 am to 2:00 pm on Day 2 ($df=309$, $t=2.05$, $p=.042$), and significantly less active than HCs from 10:00 pm to 2:00 am ($df=309$, $t=-2.18$, $p=.030$). There was also a trend for patients with AN to be more active than HCs from 6:00 am to 10:00 am on Day 2 ($df=309$, $t=1.80$, $p=.$

072) and less active than HCs from 6:00 pm to 10:00 pm on Day 1 ($df=309$, $t = -1.72$, $p = .086$).

Comparison of Time on Feet Between AN and HC—Time on Feet of HCs differed significantly from that of patients with AN at one month following discharge (Time 3) ($df=(3, 310)$, $F=4.22$, $p=0.006$). Mean Time on Feet count was then examined in consecutive four hour blocks spanning from 10:00 am- 2:00 pm on Day 1 through 2:00 am- 6:00 am on Day 2. Results of these analyses revealed that patients with AN spent significantly more time on their feet than HC from 2:00 pm to 6:00 pm on Day 2 ($df=309$, $t = 2.30$, $p = .022$), and significantly less time on their feet than HC from 10:00 pm to 2:00 am ($df=309$, $t = -2.27$, $p = .024$), 2:00 am to 6 am ($df=309$, $t = -3.65$, $p < .001$) and 6:00 am to 10:00 am ($df=309$, $t = -2.28$, $p = .023$) on Day 1.

Comparison of Fidgeting between AN and HC—Fidgeting did not differ significantly between patients with AN at one month following discharge (Time 3) and HCs ($df=(3, 310)$, $F=1.72$, $p = .163$).

Association Between Activity and Follow-Up BMI in AN

The overall average rate of decline in BMI was 0.0036 BMI units per day. Total Activity Count at low-weight (Time 1, $df=63$, $t = 0.67$, $p = .508$), weight restoration (Time 2, $df=40$, $t = 0.37$, $p = .711$), and one month following discharge (Time 3, $df=34$, $t = -1.57$, $p = .126$) did not predict rate of change in BMI in the 12 months following discharge from inpatient treatment. Time on Feet at the weight restoration time point (Time 2, $df=40$, $t = -2.03$, $p = .05$) but not the low-weight (Time 1, $df=63$, $t = -0.90$, $p = .372$) or one month following discharge time points (Time 3, $df=34$, $t = -0.53$, $p = .600$) predicted rate of change in BMI during the twelve month follow-up period, such that more time on feet at weight restoration was associated with accelerated rate of change in BMI, in support of our second hypothesis. Time on Feet at Time 2 accounted for 7.7% of the variance in the rate of decline of BMI during the follow-up period. Specifically, on average subjects who spent 1 unit greater adjusted time on feet has a faster rate of decline in BMI by 0.00081 BMI units per day. Fidgeting at low-weight (Time 1, $df=58$, $t = 0.32$, $p = .749$), weight restoration (Time 2, $df=37$, $t = 1.22$, $p = .229$), and one month following discharge (Time 3, $df=34$, $t = 0.08$, $p = .938$) were not predictive of rate of change in BMI during the follow-up period.

DISCUSSION

Objective assessment of PA in AN using a novel activity monitor revealed that contrary to our hypothesis, patients became significantly more active from low-weight to weight-restoration. Patients were also significantly more active at one month post-treatment discharge compared to low-weight and weight-restored time points. This increase in PA was primarily driven by an increase in the amount of time patients spent on their feet, which in turn was primarily comprised of time spent standing. Given that measures of depression and eating disturbance showed significant improvements during the time in which participants became more physically active, these results provide evidence that elevated PA in AN is not directly related to the severity of eating pathology or general pathology. These results are

consistent with other studies finding a lack of association between objectively measured PA, eating pathology, or general pathology (12, 13, 28). At the same time, it is likely that environmental factors contributed to increases in PA from low weight to weight restoration, namely fewer restrictions placed on patients' mobility with weight restoration (e.g., patients were allowed to leave the inpatient unit for passes). Furthermore, a return to a self-determined level of PA after treatment discharge limits conclusions that can be drawn from differences between post-treatment discharge PA and PA while on the inpatient unit. Of note, while overall PA and time spent on feet increased over time, time spent fidgeting did not change for participants with AN from low-weight to weight restoration to post-treatment discharge.

Activity levels of HCs were significantly different from those of participants with AN at one month following treatment discharge. When examining how PA levels varied over the course of the day in these two groups, patients were more active than controls during daytime hours but less active at night, and this was again driven by differences in amount of time spent on feet, while fidgeting did not differ between the two groups. There are several possible explanations for this pattern. It may have been that due to being more active during the day, patients with AN were fatigued in the evening hours, resulting in less activity. Social functioning is also impaired in individuals with AN (29, 30), and it is therefore possible that patients with AN were less active than HCs in the evening because they had fewer social engagements to attend. Past research comparing PA in AN and HCs has been mixed, with some studies showing greater activity in AN (8), while others finding no difference (9-12). The IDEEA accelerometer is able to provide more detailed, nuanced data regarding the type and frequency of PA and it is possible that it was able to detect differences that more crude accelerometers may fail to capture.

Follow-Up BMI

The more time patients with AN spent on their feet at the weight-restored time point, the more quickly they lost weight during the 12 months following treatment discharge. Time on feet was comprised primarily by time spent standing, followed by time spent walking. The weight-restoration time point occurred while patients were still residing on an inpatient unit where physical activity was restricted; however, they could begin to take unaccompanied passes off of the unit which afforded patients greater opportunity to spend time on their feet. These results are notable, as they are the first to identify a relationship between a particular type of objectively-measured PA and post-treatment weight trajectory in patients with AN. These results suggest it may be fruitful for inpatient units to develop interventions to specifically curtail standing and walking or to help patients engage in these behaviors in a manner that does not lead to weight loss. These results also echo and extend findings that increased time spent in the standing position can facilitate weight loss in overweight individuals as well (17).

There was no significant relationship between time spent on feet at low-weight or one-month post-treatment discharge time points and 12-month BMI trajectory. While it is unclear what may have led to this lack of relationship, the sample size at one month post treatment was smaller (n=19) relative to the low-weight and weight-restoration time points (n= 45, n=35,

respectively), which may have limited our ability to detect an effect. Furthermore, it is possible that individuals who were doing more poorly after treatment discharge were less likely to return for the one-month post treatment study time point.

Limitations

While the IDEEA is able to distinguish and measure many different types of PA, the device has several leads and wires, making it somewhat unwieldy. Data collected from the third day at each time point were unreliable and unusable. It is possible that participants were not able to re-affix the device in a reliable way. Furthermore, given the unwieldy nature of the IDEEA, participants were well-aware of the device, increasing the likelihood that they may have changed their behavior due to the observer effect and demand characteristics. Future studies would benefit from the use of highly accurate, but less obtrusive PA monitoring in order to increase the likelihood that participants would act more naturally while wearing the device. As described above, the first two PA assessments for the sample with AN took place while participants resided on an inpatient unit and the third PA assessment took place after patients had been discharged. Thus, changes in patients living arrangements and access to the outdoors limit the ability to draw conclusions regarding differences in activity levels across time points. As noted earlier, there was attrition across the three study time points. Many participants with AN did not live locally and therefore were unable to return to complete the third PA assessment at one-month post treatment discharge, thereby limiting the amount of data at that time point. Additionally, mood measures, such as the BDI and BAI, were collected at the low weight and weight restoration time points, but not the post-discharge time point, limiting the ability to compare depression and anxiety of HCs and patients with AN at that time point, and to examine the relationship between mood, anxiety, and PA. Finally, data from HCs were collected at a single time point for three consecutive days, whereas data were collected from ANs on three occasions. Future studies might include several assessment points for both HCs and patients.

CONCLUSIONS

Objective assessment of PA using an activity monitor demonstrated that inpatients with AN became more physically active after weight restoration and following treatment discharge. One month following hospital discharge patients with AN were more physically active than HCs during the day and less active at night, which was primarily accounted for by amount of time spent on feet, including standing and walking. Greater time spent on feet at the weight-restored time point of inpatient treatment was associated with more rapid decrease in BMI over the 12 months following treatment discharge. Fidgeting did not differ between patients and controls, did not change with weight restoration, and did not predict post-treatment weight change. The current results document that PA in AN, assessed objectively, differs significantly from that of controls and likely contributes to weight loss after acute treatment. Further research is warranted into the biological and psychological underpinnings of this behavior, potential treatment interventions, and the possibility that propensity toward higher-level PA and standing postures itself represents a risk factor for the development of AN.

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References

1. Davis C. Eating disorders and hyperactivity: a psychobiological perspective. *Canadian Journal of Psychiatry*. 1997; 42(2):168–75. [PubMed: 9067066]
2. Gull WW. V.-Anorexia Nervosa (Apepsia Hysterica, Anorexia Hysterica). *Obesity research*. 1997; 5(5):498–502. [PubMed: 9385628]
3. Dalle Grave R, Calugi S, Marchesini G. Compulsive exercise to control shape or weight in eating disorders: prevalence, associated features, and treatment outcome. *Comprehensive Psychiatry*. 2008; 49(4):346–52. [PubMed: 18555054]
4. Bewell-Weiss CV, Carter JC. Predictors of excessive exercise in anorexia nervosa. *Comprehensive psychiatry*. 2010; 51(6):566–71. [PubMed: 20965301]
5. Sternheim L, Danner U, Adan R, Elburg A. Drive for activity in patients with anorexia nervosa. *International Journal of Eating Disorders*. 2015; 48(1):42–5. [PubMed: 24687461]
6. Shroff H, Reba L, Thornton LM, Tozzi F, Klump KL, Berrettini WH, et al. Features associated with excessive exercise in women with eating disorders. *International Journal of Eating Disorders*. 2006; 39(6):454–61. [PubMed: 16637047]
7. Rigaud D, Pennacchio H, Bizeul C, Reveillard V, Vergès B. Outcome in AN adult patients: A 13-year follow-up in 484 patients. *Diabetes & Metabolism*. 2011; 37(4):305–11. [PubMed: 21317006]
8. Bratland-Sanda S, Sundgot-Borgen J, Rø Ø, Rosenvinge JH, Hoffart A, Martinsen EW. “I’m not physically active - I only go for walks”: Physical activity in patients with longstanding eating disorders. *International Journal of Eating Disorders*. 2010; 43(1):88–92. [PubMed: 19728373]
9. Hechler T, Rieger E, Touyz S, Beumont P, Plasqui G, Westerterp K. Physical activity and body composition in outpatients recovering from anorexia nervosa and healthy controls. *Adapted Physical Activity Quarterly*. 2008; 25(2):159. [PubMed: 18493090]
10. Bouten CV, van Marken Lichtenbelt W, Westerterp KR. Body mass index and daily physical activity in anorexia nervosa. *Medicine and science in sports and exercise*. 1996; 28(8):967–73. [PubMed: 8871905]
11. Keyes A, Woerwag-Mehta S, Bartholdy S, Koskina A, Middleton B, Connan F, et al. Physical activity and the drive to exercise in anorexia nervosa. *International Journal of Eating Disorders*. 2015; 48(1):46–54. [PubMed: 25196139]
12. El Ghoch M, Calugi S, Pellegrini M, Milanese C, Busacchi M, Battistini NC, et al. Measured physical activity in anorexia nervosa: Features and treatment outcome. *International Journal of Eating Disorders*. 2013; 46(7):709–12. [PubMed: 23712420]
13. Falk JR, Halmi KA, Tryon WW. Activity measures in anorexia nervosa. *Archives of general psychiatry*. 1985; 42(8):811–4. [PubMed: 4015326]
14. Beumont PJ, Arthur B, Russell JD, Touyz SW. Excessive physical activity in dieting disorder patients: proposals for a supervised exercise program. *International Journal of Eating Disorders*. 1994; 15(1):21–36. [PubMed: 8124324]
15. Mazloum A, Johnston M, Lundrigan M, Birmingham C. The interrater reliability of rating non-exercise activity of inpatients with eating disorders using a visual analogue scale. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*. 2008; 13(4):e100–e2.
16. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. *Science (New York, NY)*. 1999; 283(5399):212–4.
17. Levine JA, Lanningham-Foster LM, McCrady SK, Krizan AC, Olson LR, Kane PH, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science (New York, NY)*. 2005; 307(5709):584–6.
18. American Psychiatric A. Diagnostic and statistical manual of mental disorders : DSM-5. 2013. Available from: <http://dsm.psychiatryonline.org/book.aspx?bookid=556>

19. Attia E, Walsh BT. Behavioral management for anorexia nervosa. *The New England journal of medicine*. 2009; 360(5):500–6. [PubMed: 19179317]
20. Zhang K, Werner P, Sun M, Pi-Sunyer FX, Boozer CN. Measurement of Human Daily Physical Activity. *Obesity Research*. 2003; 11(1):33–40. [PubMed: 12529483]
21. Marsh AP, Vance RM, Frederick TL, Hesselmann SA, Rejeski WJ. Objective assessment of activity in older adults at risk for mobility disability. *Medicine and Science in Sports and Exercise*. 2007; 39(6):1020–6. [PubMed: 17545894]
22. Klein, DA.; Gershkovich, M.; Bush, J.; Walsh, BT. Measurement of physical activity in anorexia nervosa. Eating Disorders Research Society; Brooklyn, NY: 2009.
23. Maffiuletti NA, Gorelick M, Kramers-de Quervain I, Bizzini M, Munzinger JP, Tomasetti S, et al. Concurrent validity and intrasession reliability of the IDEEA accelerometry system for the quantification of spatiotemporal gait parameters. *Gait & Posture*. 2008; 27(1):160–3. [PubMed: 17336070]
24. Klein, DA.; Levine, E.; Walsh, BT.; Sazonov, ES., editors. Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE. IEEE; 2014. Validation of two novel monitoring devices to measure physical activity in healthy women..
25. Beck AT, Steer RA, Carbin MG. Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. *Clinical psychology review*. 1988; 8(1):77–100.
26. Beck AT, Epstein N, Brown G, Steer RA. An inventory for measuring clinical anxiety: psychometric properties. *Journal of consulting and clinical psychology*. 1988; 56(6):893. [PubMed: 3204199]
27. Fairburn CG, Beglin SJ. Assessment of eating disorders: Interview or self-report questionnaire? *International Journal of Eating Disorders*. 1994; 16(4):363–70. [PubMed: 7866415]
28. Klein DA, Mayer LES, Schebendach JE, Walsh BT. Physical activity and cortisol in Anorexia Nervosa. *Psychoneuroendocrinology*. 2007; 32(5):539–47. [PubMed: 17462830]
29. Wentz E, Gillberg C, Gillberg IC, Råstam M. Ten-year Follow-up of Adolescent-onset Anorexia Nervosa: Psychiatric Disorders and Overall Functioning Scales. *Journal of Child Psychology and Psychiatry*. 2001; 42(5):613–22. [PubMed: 11464966]
30. Fairburn CG, Cooper Z, Doll HA, Welch SL. Risk factors for anorexia nervosa: three integrated case-control comparisons. *Archives of General Psychiatry*. 1999; 56(5):468–76. [PubMed: 10232302]

Figure 1.
Total Activity Counts of Healthy Controls Compared to Post-Treatment Discharge Patients with Anorexia Nervosa.

Figure 2.
 Total Activity Counts of Patients with Anorexia Nervosa at Low-Weight, Weight Restoration, and Post-Treatment Discharge.

Table 1

Means and standard deviations of demographic and psychological variables

	Patients with Anorexia Nervosa						Healthy Controls			
	Low Weight N=45	Weight Restoration N=35	Post-discharge N=19	Low Weight vs. Weight Restoration	N=24	Weight Restored AN vs. HC				
	Mean ± SD	Mean ± SD	Mean ± SD	t	p	df	t	df	t	p
Age	24.4±6.5	-	-	-	-	-	1.36	70	1.36	.179
BMI (kg/m ²)	16.1±1.0 ^a	20.2±0.7 ^b	19.5±2.0	18.32	<.001	57	0.68	37	0.68	.502
Duration of Illness (years)	8.3±6.6	-	-	-	-	-	-	-	-	-
BAI	24.9±10.6	22.5±13.4	-	1.09	.287	24	7.35	56	7.35	<.001
BDI	27.3±12.3	22.5±13.2	-	4.36	<.001	24	7.57	55	7.57	<.001
EDE-Q	4.3±1.5	2.9±1.3	-	5.95	<.001	23	9.78	51	9.78	<.001

Note. AN= anorexia nervosa; BAI= Beck Anxiety Inventory; BDI= Beck Depression Inventory, BMI= Body Mass Index; EDE-Q= Eating Disorder Examination-Questionnaire; HC= Healthy Control.

^a significant difference between low weight and post-discharge BMI, $t(22) = -6.90$, $p < .001$;

^b no significant difference between weight restored and post-discharge BMI, $t(20) = 1.46$, $p = .161$.