Increased Physical Activity Associated with Less Weight Regain Six Years After “The Biggest Loser” Competition

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Objective: The aim of this study was to explore how physical activity (PA) and energy intake (EI) changes were related to weight loss and regain following “The Biggest Loser” competition.

Methods: At baseline, week 6 and week 30 of the competition, and 6 years after the competition, body composition was measured via dual-energy x-ray absorptiometry, resting energy expenditure was measured by using indirect calorimetry, and EI and PA were measured by using doubly labeled water.

Results: Six years after the competition, median weight loss in 14 of “The Biggest Loser” participants was 13%, with those maintaining a greater weight loss (mean ± SE) of 24.9% ± 3.8% having increased PA by 160% ± 23%, compared with a PA increase of 34% ± 25% (P = 0.0033) in the weight regainers who were 1.1% ± 4.0% heavier than the precompetition baseline. EI changes were similar between weight loss maintainers and regainers (−8.7% ± 5.6% vs. −7.4% ± 2.7%, respectively; P = 0.83). Weight regain was inversely associated with absolute changes in PA (r = −0.82; P = 0.0003) but not with changes in EI (r = −0.15; P = 0.61). EI and PA changes explained 93% of the individual weight loss variability at 6 years.

Conclusions: Consistent with previous reports, large and persistent increases in PA may be required for long-term maintenance of lost weight.

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Introduction

The maintenance of lost weight is an elusive yet important goal of patients with overweight and obesity, as partial or complete weight regain remains the most common long-term outcome of lifestyle interventions (1-3). A very public example was recently provided by our investigation of subjects with class III obesity who participated in a single season of “The Biggest Loser,” a televised weight loss competition (4-6). After losing about 60 kg on average during an intensive 30-week diet and exercise intervention (5), participants experienced substantial weight regain over the subsequent 6 years (4). However, there was a wide degree of individual variability, with one subject losing more weight after 6 years, while five other subjects regained weight to within 1% of their starting weight or more.

What determines successful weight loss maintenance? Previous studies using self-reported measures have suggested that high levels of physical activity (PA) decrease the risk of short- and long-term weight regain after weight loss (7-17). However, self-reported PA may be quantitatively unreliable, as it typically exceeds PA determined by objective measurements (18-22) and is poorly correlated with actual PA (20,21,23). Two studies using accelerometry found that weight loss maintainers engaged in significantly more PA as well as more time in higher-intensity activities compared with weight regainers after several years (24,25). One study used a proprietary multisensor device to show that PA was increased in subjects with greater percent weight losses over 18 months of a behavioral weight loss intervention (26).

Here, we report an exploratory analysis of “The Biggest Loser” participants (4,5) to investigate the correlates of long-term weight regain.

Methods

The detailed methods for this study were previously described (4,5). Briefly, the study protocol was approved by the Institutional Review Board.
Board of the National Institute of Diabetes and Digestive and Kidney Diseases (ClinicalTrials.gov identifier NCT02544009), and all subjects provided informed consent. Body composition was determined by dual-energy x-ray absorptiometry in the overnight fasted state. Body fat-free mass (FFM) and fat mass (FM) were calculated from weight and whole-body percent fat by using the thick scan mode. All participants whose supine body width exceeded the dimensions of the scan window were analyzed by using the iDXA MirrorImage application (GE Healthcare, Chicago, Illinois) (27).

Resting energy expenditure (REE) measurements were performed following a 12-hour overnight fast. Participants rested supine in a quiet, darkened room for 30 minutes before making measurements of oxygen consumption (VO₂) and carbon dioxide production (VCO₂) for 20 minutes, with the last 15 minutes used to determine REE according to

\[
REE = 3.85 \times VO_2(L) + 1.07 \times VCO_2(L)
\]

assuming that protein oxidation contributed 15% to REE (28). REE measurements were available for all 16 participants in a single season of “The Biggest Loser” at the precompetition baseline, 10 participants at week 6 of the competition, 16 participants at week 30 of the competition, and 14 participants 6 years after the end of the competition.

The doubly labeled water (DLW) method was used to calculate the average carbon dioxide production rate (rCO₂) at baseline, week 6, week 30, and 6 years after the end of the competition, as estimated from the rate constants describing the exponential disappearance of the labeled 18O and D water isotopes (k₀ and kₐ) in repeated spot urine samples collected for 7 days during the competition and for 14 days at the 6-year follow-up. We used the parameters of Racette et al. (29) with the pool size, N, estimated to be 73% of the FFM as determined by dual-energy x-ray absorptiometry measurements that were performed within the same week as DLW dosing:

\[
\begin{align*}
rCO₂ &= (N/2.078)(1.007k₀ - 1.007R_dil/kD) \times 0.0246rGF \\
rGF &= 1.05(1.007k₀ - 1.007R_dil/kD) \\
R_dil &= 1.034
\end{align*}
\]

The average total energy expenditure (TEE) from rCO₂ was calculated as

\[
TEE = \frac{3.85}{RQ} + 1.07 \times rCO₂(L)
\]

where the daily respiratory quotient (RQ) was assumed to be 0.86, representative of the food quotient of a typical diet at baseline and 6 years. At weeks 6 and 30, daily RQ was assumed to be 0.76 and 0.8, respectively, to account for the contribution from body fat oxidation to fuel usage, as estimated by using mathematical model simulations (30). TEE data were available for all 16 subjects at the precompetition baseline, 11 subjects at week 6, 14 subjects at week 30, and 14 subjects after 6 years.

Because body weight was stable at baseline and 6 years after the end of “The Biggest Loser” competition, energy intake (EI) was assumed to be equal to TEE. During the weight loss competition, average EI was estimated by using the intake balance method (31):

\[
EI = TEE + \frac{dES}{dt}
\]

The average rate of change of body energy stores, dES/dt, was calculated by using the FM and FFM changes from baseline at weeks 6 and 30 as follows:

\[
\frac{dES}{dt} \approx 9300 \text{ kcal/kg} \times \frac{\Delta FFM(kg)}{\Delta t} + 1100 \text{ kcal/kg} \times \frac{\Delta FMM(kg)}{\Delta t}
\]

The average TEE for the 30-week period was estimated as the mean of the week 6 and week 30 TEE measurements. The average TEE for the 6-week period was estimated by the TEE measurement at 6 weeks. Because the TEE measurements occurring over week-long periods at weeks 6 and 30 may not necessarily represent the true mean TEE over the entire 6- and 30-week durations, the EI estimates calculated by the intake balance method are somewhat uncertain (31).

PA energy expenditure was calculated as the nonresting energy expenditure (TEE – REE) minus the estimated thermic effect of food, which was assumed to be 10% of EI and was calculated as 0.1 x TEE at baseline and 6 years. As previously described (4), we assumed the thermic effect of food was 0.1 x TEEbaseline – 240 kcal/d and 0.1 x TEEbaseline – 180 kcal/d because EI was estimated to have decreased by ~2,400 kcal/d and ~1,800 kcal/d compared to baseline at weeks 6 and 30, respectively (30). Because most PA involves locomotion, and therefore has an energy cost that is proportional to body weight for a given intensity and duration (32), we normalized the PA energy expenditure by dividing by body weight.

Statistical analyses were performed by using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina). Data are expressed as mean ± SE and were analyzed by analysis of variance (PROC GLM, SAS) with each subject as a fixed block effect. Associations were examined by using Pearson correlation (PROC CORR, SAS). Significance was declared at P < 0.05.

**Results**

Table 1 presents the mean body composition and energy expenditure data for “The Biggest Loser” participants at the precompetition baseline, at weeks 6 and 30 of the intervention, and 6 years later. The median weight loss after 6 years was 13%, with the seven subjects above the median (the maintainers) weighing (mean ± SE) 24.9% ± 3.8% less than baseline, while the seven subjects below the median (the regainers) were 1.1% ± 4.0% above their baseline body weight (P = 0.0005). The increase in PA from baseline was significantly higher in the weight loss maintainers (160% ± 23%) compared with the weight regainers (34% ± 25%; P = 0.0033; Figure 1). Weight loss maintainers had a mean PA of 12.2 ± 1.3 kcal/kg/d at 6 years, which was significantly greater than the PA of 8.0 ± 1.4 kcal/kg/d in the weight regainers (P = 0.04). The percent change in EI from baseline was similar between weight loss maintainers and regainers (−8.7% ± 5.6% vs. −7.4% ± 2.7%, respectively; P = 0.83).

Across the entire cohort, there was no significant correlation between absolute weight loss (r = 0.32; P = 0.27) or percent weight loss (r = −0.004; P = 0.99) at the end of the competition with the
Six years after “The Biggest Loser” competition, the median percent weight loss compared to the precompetition baseline was 13%. The increase in physical activity from baseline to 6 years was significantly higher in the seven weight loss maintainers (160% ± 23%) compared with the seven weight regainers (34% ± 25%; P = 0.0033), while the percent change in energy intake did not significantly differ between weight loss maintainers and regainers (−8.7% ± 5.6% vs. −7.4% ± 2.7%, respectively; P = 0.83).

Figure 1

| Table 1 Anthropometric and energy expenditure variables (mean ± SE) in participants of “The Biggest Loser” weight loss competition |
|---------------------------------------------------------------|
| **Precompetition baseline** | **Week 6 of the competition** | **Week 30 of the competition** | **6 years after the competition** |
| n (F/M) | 16 (9/7) | 11 (7/4) | 16 (9/7) | 14 (8/6) |
| Age (y) | 33.2 ± 2.7 | 36.0 ± 3.2 | 33.8 ± 2.7 | 41.3 ± 2.8 |
| Weight (kg) | 149.2 ± 9.5 | 129.9 ± 10.6 | 91.6 ± 5.7 | 131.6 ± 12.1 |
| BMI (kg/m²) | 49.4 ± 2.4 | 43.6 ± 2.7 | 30.4 ± 1.6 | 43.8 ± 3.6 |
| FM (kg) | 73.5 ± 5.3 | 59.1 ± 5.8 | 26.4 ± 3.5 | 61.4 ± 8.0 |
| REE (kcal/d) | 2,595 ± 151 | 2,209 ± 145 | 2,001 ± 83 | 1,903 ± 125 |
| TEE (kcal/d) | 3,827 ± 220 | 4,417 ± 294 | 3,066 ± 150 | 3,429 ± 155 |
| PA (kcal/kg/d) | 5.8 ± 0.5 | 16.8 ± 1.8 | 10.3 ± 1.2 | 10.1 ± 1.1 |

FM, fat mass; PA, physical activity; REE, resting energy expenditure; TEE, total energy expenditure.
the weight gain was body fat (4), FM gain at 6 years was also strongly correlated with changes in PA ($r = -0.82; P = 0.0003$).

During “The Biggest Loser” competition, the weight lost at neither 6 weeks ($r = 0.53; P = 0.12$; Figure 4A) nor 30 weeks ($r = 0.16; P = 0.58$; Figure 4B) was significantly associated with PA changes. Conversely, changes in EI were significantly associated with weight loss at both 6 weeks ($r = 0.87; P = 0.0005$; Figure 4C) and 30 weeks ($r = 0.91; P < 0.0001$; Figure 4D). EI change at 30 weeks was significantly correlated with EI change at 6 years ($r = 0.69; P = 0.006$), but PA changes were not correlated between these time points ($r = 0.31; P = 0.33$). Finally, concurrent EI and PA changes were not significantly correlated with each other at either 30 weeks ($r = 0.20; P = 0.49$) or 6 years ($r = 0.34; P = 0.23$).

Discussion

Ours is the first study to use the gold-standard DLW method to measure both EI and PA in weight-reduced individuals with obesity beyond the first year of weight loss. We found that both the weight lost at 6 years as well as the weight regained since the end of “The Biggest Loser” competition were strongly inversely correlated with changes in PA. These correlations persisted regardless of whether PA and weight changes were expressed in absolute terms or as percentages. In contrast, percent change in EI from baseline was not significantly correlated with percent weight loss or weight regained 6 years after the competition. However, absolute changes in EI and PA from baseline both significantly correlated with absolute weight loss after 6 years and together explained ~93% of the individual weight loss variability.

Only two previous reports have used the DLW method to relate PA with the future maintenance of lost weight (33,34). Schoeller et al. showed that higher PA at the end of the weight loss phase was associated with less weight regain 1 year later in women who previously had obesity, but neither PA nor EI was reported at the 1-year time point (34). Schoeller et al. suggested that a PA threshold of 11 kcal/kg/d was required to maintain weight loss (34), a value midway between the observed mean PA of 12.2 ± 1.3 kcal/kg/d in weight loss maintainers and 8.0 ± 1.4 kcal/kg/d in the weight regainers who participated in “The Biggest Loser” competition. The 11 kcal/kg/d PA threshold for maintenance of lost weight corresponds to approximately 80 min/d of moderate PA or 35 min/d of vigorous activity (34). Therefore, a relatively high degree of PA may be required for the long-term maintenance of lost weight.

The DLW study by Del Corral et al. is more difficult to interpret because the investigators first split their sample into tertiles of women according to adherence to a very-low-calorie diet during a weight loss intervention (33). Highly adherent women had lower EI 1 year after the intervention, and they also maintained greater weight loss after 2 years compared with women in the lowest adherence tertile. Interestingly, the women with greater dietary adherence also had lower PA expenditure during the weight loss intervention, but, subsequently, PA increased in the highly adherent women such that there was no difference between the groups at 1 year. No data on PA or EI were presented after the first year. Therefore, in contrast to “The Biggest Loser” participants, the highly adherent women studied by Del Coral et al. (33) maintained greater weight loss after 1 year by reducing EI rather than by increasing PA.

Several previous studies have reported associations between increased PA and the long-term maintenance of weight loss, but most have used self-reported measures of activity (7-17). For example, more than 3,600 participants in the National Weight Control Registry (NWCR), a large observational cohort of self-reported successful weight losers who have maintained at least a 13.6 kg weight loss for at least 1 year, reported expending an average estimated 2.621 ± 2.252 kcal/wk in PA to maintain their weight loss (8). A similar observational study looking at 2,886 NWCR subjects who completed at least 10 years of follow-up determined that 86.6% of participants were estimated to be maintaining at least a 10% weight loss from their maximum weight at 10 years, and that those participants who reported large decreases in PA were more likely to regain lost weight (17).

The Look AHEAD Study, the largest and longest prospective randomized controlled trial of an intensive lifestyle intervention for weight loss undertaken to date, reported that 39.3% of 825 subjects in the intensive lifestyle intervention who had lost >10% of their baseline weight at year 1 maintained at least a 10% weight loss after 8 years, while 14.2% of these initially successful subjects regained...
weight above their baseline (15). The subjects who successfully maintained at least a 10% weight loss at 8 years reported significantly more PA energy expenditure than did the regainers.

While the NWCR and the Look AHEAD study have large cohorts of subjects who have lost weight and had long-term (≥5 years) follow-up, the use of self-reported PA is a significant limitation. Three studies have objectively examined PA in long-term weight-reduced subjects with obesity (24-26). Phelan et al. used accelerometry to compare a group of women who previously had overweight or obesity, and who had lost and maintained at least 10% of their maximum body weight for at least 5 years, to a control group of women who never had overweight and found that the weight loss maintainers spent significantly more time engaged in PA as well as more time in higher-intensity activities (25). Catenacci et al. used accelerometry to compare subjects who had maintained at least a 13.6-kg weight loss (mean 24.7 kg) for at least 2 years (mean 14.2 years) with a group of matched subjects who never had obesity as well as a control group with overweight (24). Weight loss maintainers spent significantly more time per day than controls with overweight in bouts of moderate to vigorous PA, but no significant differences were found in other PA measures. Furthermore, weight loss maintainers did not significantly differ from controls who never had obesity in total PA time, intensity, or number of PA bouts.

Jakicic et al. used a proprietary multisensor device to measure PA during an 18-month behavioral weight loss intervention and found that increased moderate to vigorous PA as well as light PA was associated with improved percent weight loss at 18 months (26). We found that PA changes were unrelated to weight losses at weeks 6 and 30 during the intensive diet and exercise intervention. While increased PA likely contributed to short-term weight loss in the group as a whole (30), the individual weight loss differences could not be attributed to differences in PA. In contrast, short-term weight losses were strongly correlated with changes in EI, suggesting that weight loss differences were likely attributable to different degrees of EI reduction. However, it is important to note that the intake balance method has not been validated under periods of rapid weight loss that were observed during the 30-week “The Biggest Loser” competition, and there is a relatively large degree of imprecision for individual subject energy expenditure measurements using the DLW method during caloric restriction (35). Furthermore, FM and FFM changes were used in the calculation of EI at weeks 6 and 30, and these body composition variables are themselves strongly related to weight loss. Thus, the calculated changes in EI were not independent of the measured body weights during the active weight loss phase of “The Biggest Loser”, and the likelihood of obtaining spurious correlations between changes in EI and body weight is quite high.

Figure 4 The weight lost at neither (A) 6 weeks nor (B) 30 weeks was significantly associated with physical activity changes from the precompetition baseline. Changes in energy intake were significantly correlated with weight loss after both (C) 6 weeks and (D) 30 weeks.
Other limitations of our study include its relatively small sample size because of investigating only the participants of a single season of “The Biggest Loser” competition. We also lack data between the end of the competition and the 6-year follow up, so the detailed time courses of weight and energy balance dynamics are unknown. Despite the extreme nature of “The Biggest Loser” intervention, our results concord with previous estimates of the overall PA requirement for the long-term maintenance of lost weight, and they correspond to increases of about 80 minutes of daily moderate activity or 35 minutes of daily vigorous activity compared to baseline (34). While these estimates provided by the DLW method provide an accurate and objective measure of overall PA expenditure, they do not specify the PA patterns, intensities, or durations that can be obtained with other methods such as accelerometry.

In conclusion, “The Biggest Loser” participants who were the most successful in maintaining lost weight had the greatest increase in PA after 6 years. Our results support previous recommendations that large and persistent increases in PA may be required for the long-term maintenance of lost weight.

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