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Increased physical activity was associated with less weight regain six years after "The Biggest Loser" competition

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Abstract

Objective—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, six weeks, 30 weeks, and six years after the competition we measured body composition via dual energy X-ray absorptiometry, resting energy expenditure using indirect calorimetry, and EI and PA using doubly labeled water.

Results—Six years after the competition, median weight loss in 14 Biggest Loser participants was 13%, with those maintaining greater weight loss (mean ± SE) of 24.9 ± 3.8% having increased PA by 160 ± 23% compared to a PA increase of 34 ± 25 % (p = 0.0033) in the weight regainers who were 1.1 ± 4.0% heavier than the pre-competition 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 six years.

Conclusions—Consistent with previous reports, large persistent increases in physical activity may be required for long-term maintenance of lost weight.

Introduction

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, 2, 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" televised weight loss competition (4, 5, 6). After losing about 60 kg on

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average during an intensive 30 week diet and exercise intervention (5), participants experienced substantial average weight regain over the subsequent six years (4). However, there was a wide degree of individual variability, with one subject losing more weight after six years while five other subjects regained weight to within 1% or greater than their starting weight.

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, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17). However, self-reported PA may be quantitatively unreliable as it typically exceeds PA determined by objective measurements (18, 19, 20, 21, 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 to weight regainers after several years (24, 25). One study used a proprietary multi-sensor 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 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 (DXA) in the overnight fasted state. Body fat-free mass (FFM) and fat mass (FM) were calculated from weight and whole-body percent fat using the thick scan mode. All participants' whose supine body width exceeded the dimensions of the scan window and were analyzed using the iDXA MirrorImage™ application (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 (VO_2) and carbon dioxide production (VCO_2) for 20 minutes with the last 15 minutes used to determine REE according to:

$$\mathrm{REE(kcal)} = 3.85 \times \mathrm{VO_2(L)} + 1.07 \times \mathrm{VCO_2(L)}$$

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 pre-competition baseline, 10 participants at six weeks, 16 participants at 30 weeks, and 14 participants six years after the end of the competition.

The doubly labeled water (DLW) method was used to calculate the average carbon dioxide production rate (rCO_2) at baseline, week six, week 30, and six years after the end of the competition as estimated from the rate constants describing the exponential disappearance of

the labeled ^{18}O and D water isotopes (k_O and k_D) in repeated spot urine samples collected for 7 days during the competition and for 14 days at the six-year follow-up. We used the parameters of Racette et al. (29) with the poolsize, *N*, was estimated to be 73% of the FFM as determined by DXA measurements that were performed within the same week as DLW dosing:

$$\mathrm{rCO_2}=(N/2.078)(1.007k_o - 1.007R_{\mathrm{dil}}k_D) - 0.0246r_{\mathrm{GF}}$$

$$r_{\mathrm{GF}}=1.05(1.007k_o - 1.007R_{\mathrm{dil}}k_D)$$

$$R_{\mathrm{dil}}=1.034$$

The average total energy expenditure (TEE) from rCO_2 was calculated as:

$$\mathrm{TEE(kcal)}=\left[\frac{3.85}{\mathrm{RQ}}+1.07\right]\times \mathrm{rCO_2(L)}$$

where the daily respiratory quotient (RQ) was assumed to be 0.86 representative of the food quotient of a typical diet at baseline and six years. At weeks six 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 using mathematical model simulations (30). TEE data were available for all 16 subjects at the pre-competition baseline, 11 subjects at week six, 14 subjects at week 30, and 14 subjects after six years.

Since body weight was stable at baseline and six 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 using the intake balance method (31):

$$\mathrm{EI}=\mathrm{TEE}+\frac{\mathrm{dES}}{\mathrm{dt}}$$

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

$$\frac{\mathrm{dES}}{\mathrm{dt}}\approx 9300\,\mathrm{kcal/kg}\times\frac{\Delta\mathrm{FM(kg)}}{\Delta t}+1100\,\mathrm{kcal/kg}\times\frac{\Delta\mathrm{FFM(kg)}}{\Delta t}$$

The average TEE for the 30 week period was estimated as the mean of the week six and week 30 TEE measurements. The average TEE for the six-week period was estimated by the TEE measurement at six weeks. To the extent the TEE measurements occurring over week-long periods at weeks six and 30 may not necessarily represent the true mean TEE over the

entire six and 30 week durations, the intake balance method provides EI estimates that are somewhat uncertain (31).

Physical activity energy expenditure was calculated as the non-resting 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×TEE at baseline and six years. As previously described (4), we assumed the thermic effect of food was $0.1\times TEE_{baseline}$ - 240 kcal/d and $0.1\times TEE_{baseline}$ - 180 kcal/d since energy intake was estimated to have decreased by ~2400 kcal/d and ~1800 kcal/d compared to baseline at weeks six and 30, respectively (30). Because most physical activities involve locomotion and therefore have an energy cost that is proportional to body weight for a given intensity and duration (32), we normalized the physical activity energy expenditure by dividing by body weight.

Statistical Analysis

Statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC). 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 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 pre-competition baseline, after six weeks and 30 weeks of the intervention, and six years later. The median weight loss after six 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 to 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 six 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) nor percent weight loss (r=−0.004, p=0.99) at the end of the competition with the respective values six years later. The percent weight change after six years was not significantly correlated with percent change in EI from baseline (r=0.27, p=0.36), but was significantly correlated with percent change in PA from baseline (r=−0.63, p=0.017). The absolute weight change from baseline was not significantly correlated with percent change in EI at six years (r=0.46, p=0.10) but was significantly correlated with changes in absolute EI (r=0.54, p=0.046) (Figure 2A) and PA (r=−0.57, p=0.035) (Figure 2B). The linear combination of the absolute changes in EI and PA explained ~93% of the individual weight loss variability at six years.

Figure 3A shows that EI changes from baseline were not significantly correlated with weight regained in the six years after the competition (r = −0.15, p=0.61). In contrast, Figure 3B illustrates a significant inverse relationship between PA changes from baseline with six-year weight gain (r= −0.82, p=0.0003). Since most of the weight gain was body fat (4), FM gain at six years was also strongly correlated with changes in PA (r=−0.82, p=0.0003).

During the Biggest Loser competition, neither the weight lost at six 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 correlated with weight loss at both six 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 six 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 six 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 six 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 nor weight regained six years after the competition. However, absolute changes in EI and PA from baseline both significantly correlated with absolute weight loss after six years and together explained ~93% of the individual weight loss variability.

Only two previous reports have used the DLW method to relate PA with 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 one 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 physical activity threshold for maintenance of lost weight corresponds to approximately 80 min/d of moderate physical activity or 35 min/d of vigorous activity (34). Therefore, a relatively high degree of physical activity may be required for 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 one year after the intervention and they also maintained greater weight loss after two years compared to 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 one year. No data on PA or EI was 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 one year by reducing EI rather than by increasing PA.

Several previous studies have reported associations between increased PA and long-term maintenance of weight loss, but most have used self-reported measures of activity (7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17). For example, over 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 one year, reported expending an average estimated 2,621 ± 2,252 kcal/week 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 one maintained at least 10% weight loss after eight 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 eight 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 (≥ five year) 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, 25, 26). Phelan et al. used accelerometry to compare a group of previously overweight or obese women who had lost and maintained at least 10% of their maximum body weight for at least 5 years to a control group of never-overweight women 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 two years (mean 14.2 years) with a group of matched never-obese subjects as well as an overweight control group (24). Weight-loss maintainers spent significantly more time per day than overweight controls in bouts of moderate-vigorous PA, but no significant differences were found in other PA measures. Furthermore, weight-loss-maintainers did not significantly differ from never-obese controls in total PA time, intensity, or number of PA bouts. Jakicic et al. used a proprietary multi-sensor device to measure PA during an 18 month behavioral weight loss intervention and found that increased moderate-vigorous PA as well as light PA were associated with improved percent weight loss at 18 months (26).

We found that PA changes were unrelated to weight losses at weeks six 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 Biggest Loser competition and there is a relatively large degree of imprecision for individual subject energy expenditure measurements using the doubly labeled water method during caloric restriction (35). Furthermore, body fat and fat-free mass changes were used in the calculation of EI at weeks six and 30 and these body composition variables are themselves strongly related to weight loss. Thus, changes in EI and body weight were not independent variables during the active weight loss phase of the Biggest Loser and the likelihood of obtaining spurious correlations is quite high.

Other limitations of our study include its relatively small sample size due to 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 six-year follow up, so the detailed time course of weight and energy balance dynamics is unknown. Despite the extreme nature of the Biggest Loser intervention, our results concord with previous estimates of the overall PA requirement for long-term maintenance of lost weight and correspond to increases of about 80 min of daily moderate activity or 35 min of daily vigorous activity compared to baseline (34). While these estimates provided by the doubly labeled water 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 most successful maintaining lost weight had the greatest increase in physical activity after six years. Our results support previous recommendations that large persistent increases in physical activity may be required for long-term maintenance of lost weight.

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JCK was previously a contestant on another season of The Biggest Loser as well as a medical consultant.

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What is already known about this subject

- Lifestyle interventions to treat obesity often result in short-term weight loss, but long-term maintenance of lost weight is rare
- High levels of physical activity have been associated with improved long-term weight loss maintenance

What this study adds

- The doubly labeled method was used to objectively measure energy intake and physical activity beyond the first year of weight loss
- Long-term weight regain in Biggest Loser participants was significantly inversely correlated with changes in physical activity from baseline
- Percent changes in energy intake were not significantly related to weight loss or regain six years after the competition.

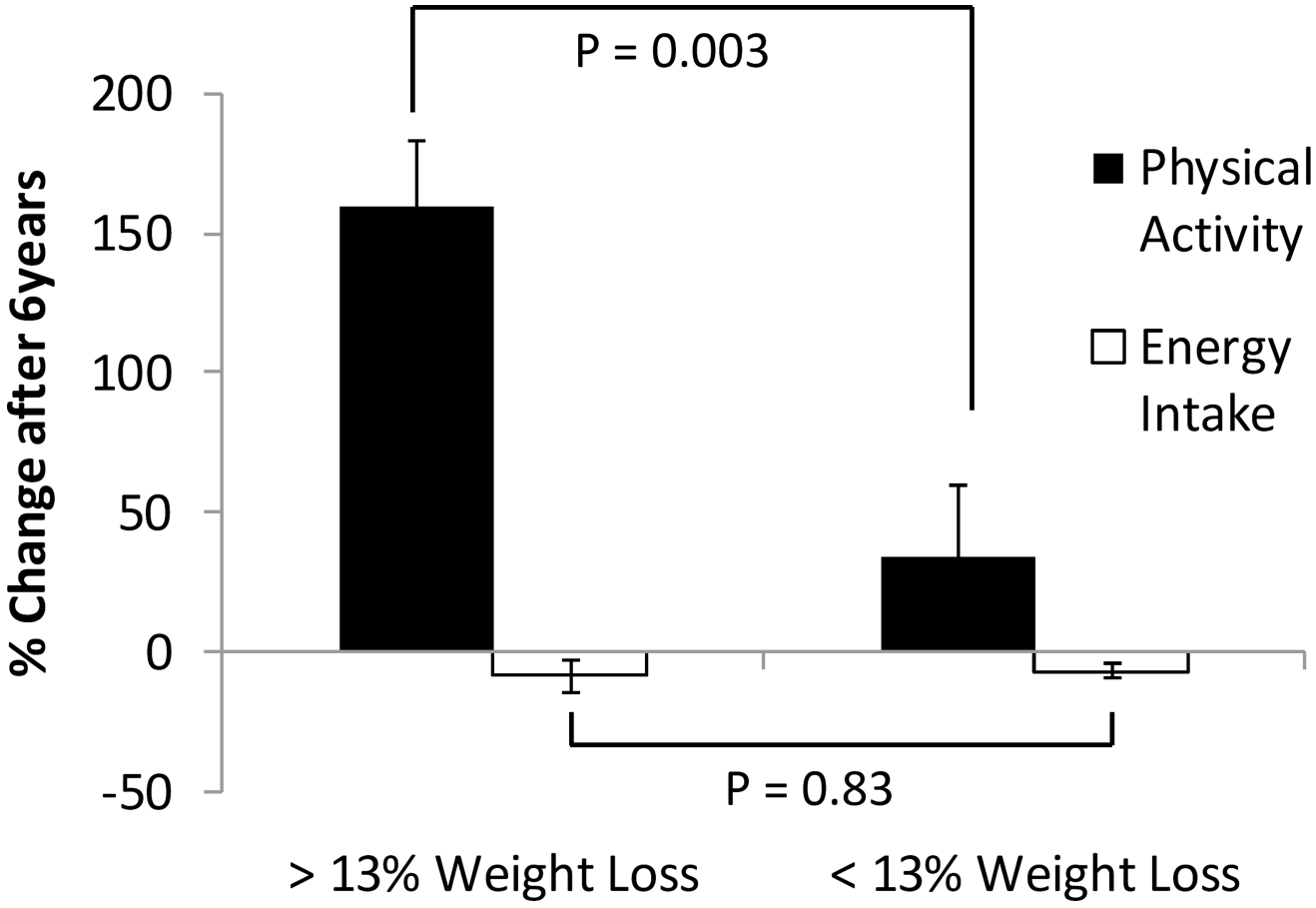

Figure 1.

Six years after the Biggest Loser competition, the median percent weight loss compared to the pre-competition baseline was 13%. The increase in physical activity from baseline to six years was significantly higher in the seven weight loss maintainers (160 ± 23%) compared to 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).

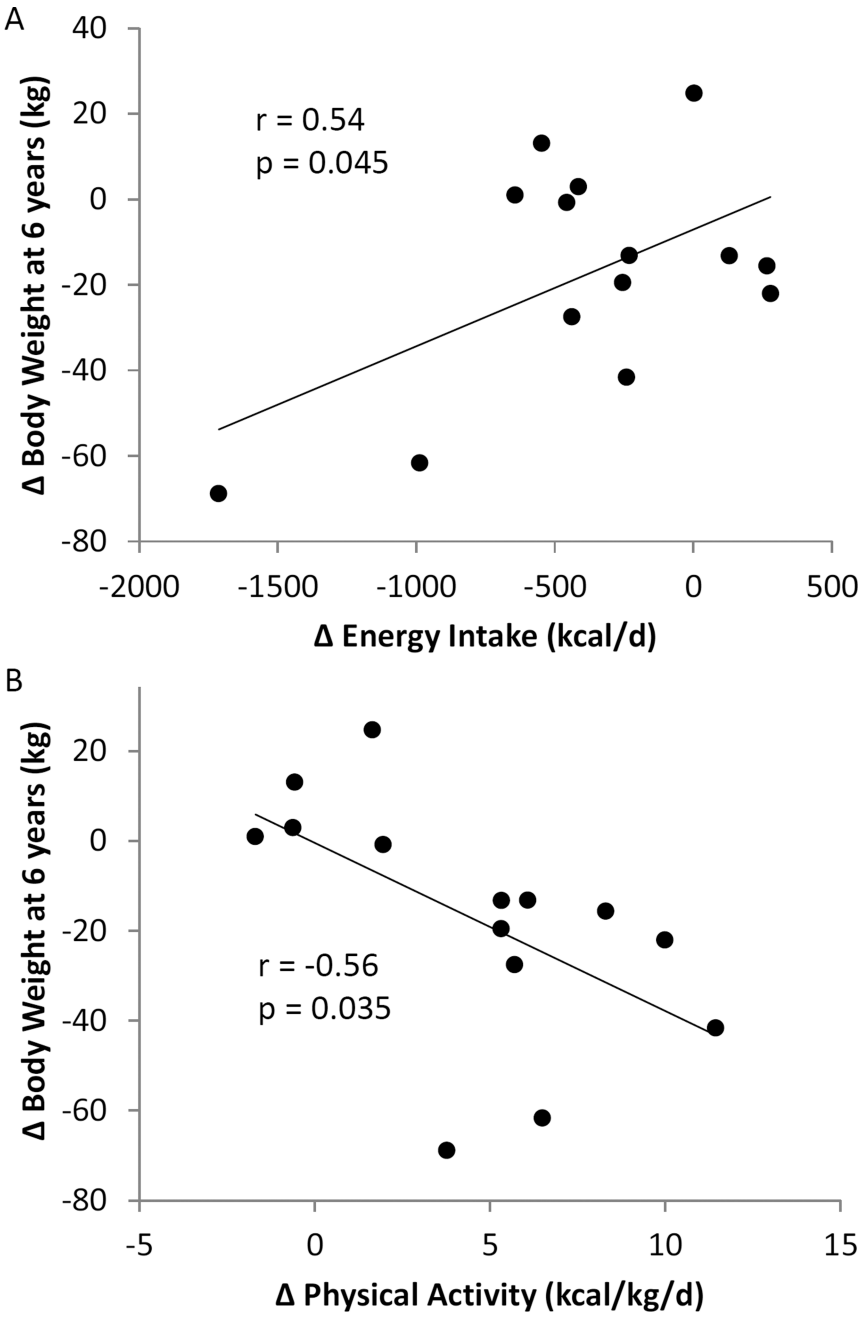

Figure 2.

Individual changes in absolute (A) energy intake, and (B) physical activity from pre-competition baseline to six years after the Biggest Loser competition were both significantly correlated with weight loss six years after the competition.

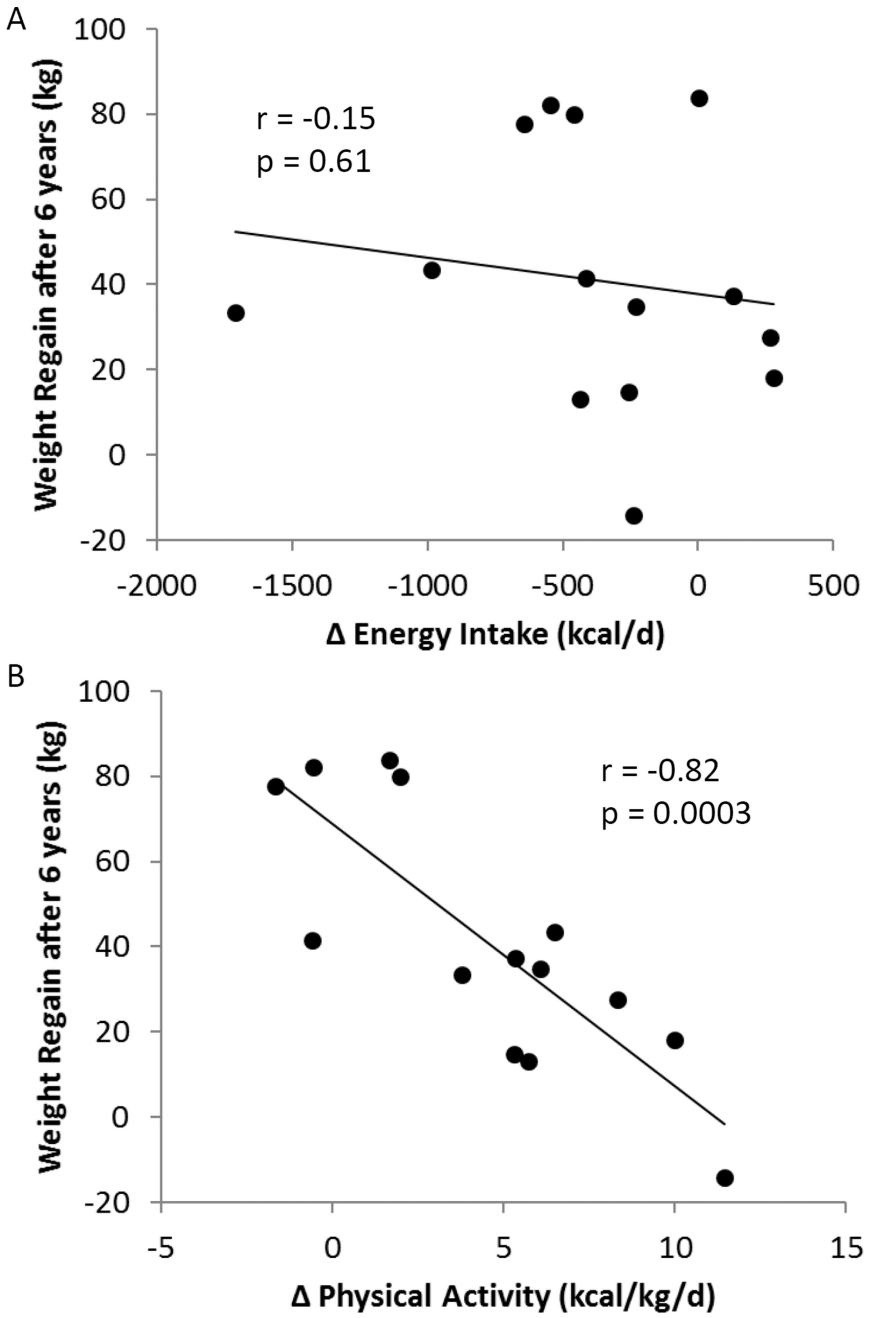

Figure 3.

(A) Energy intake changes were not significantly correlated with weight regained in the six years after the Biggest Loser competition. (B) Physical activity changes were significantly inversely related to weight regained.

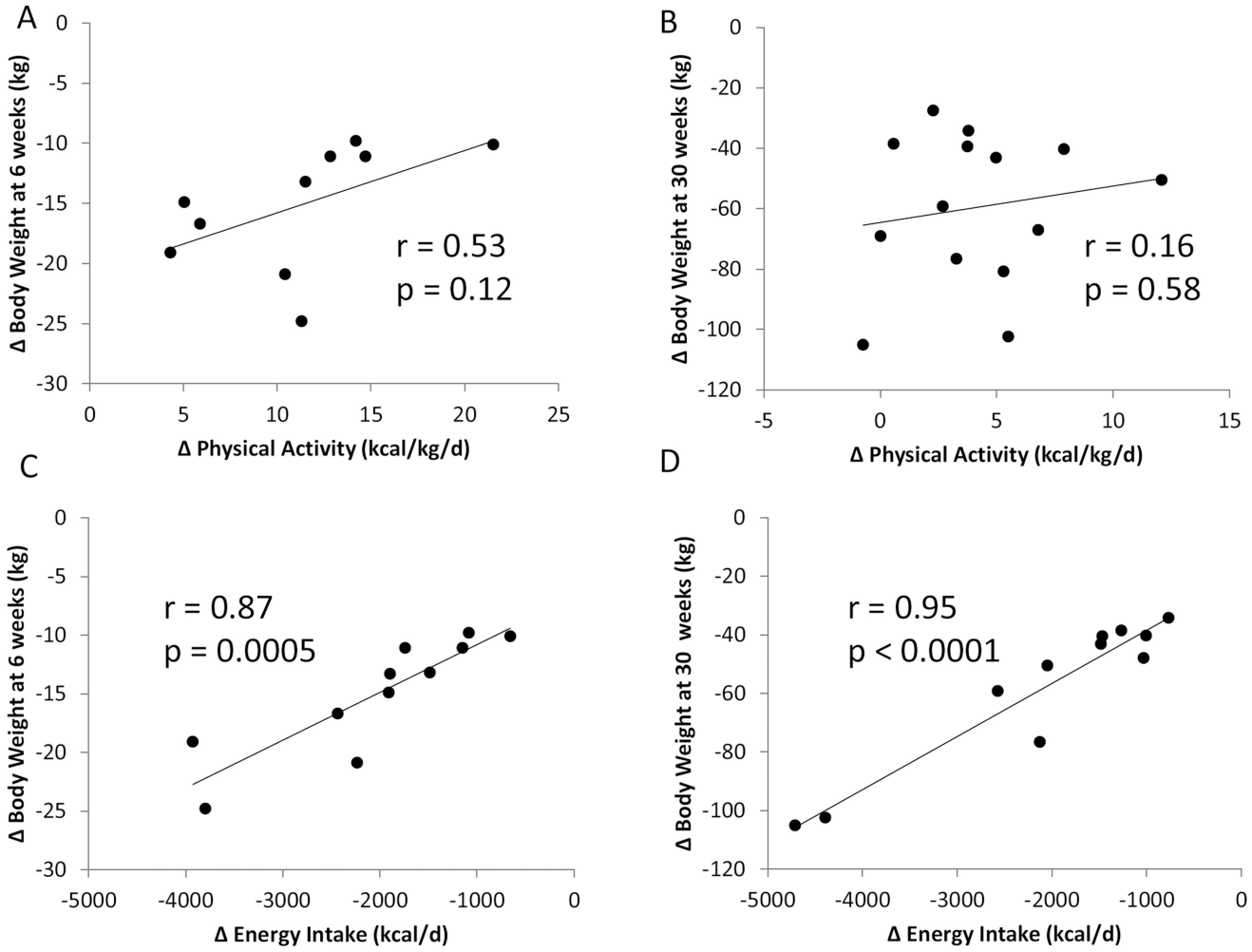

Figure 4.

Neither the weight lost at six weeks (A), nor 30 weeks (B) was significantly associated with physical activity changes from the pre-competition baseline. Changes in energy intake were significantly correlated with weight loss after both six weeks (C) and 30 weeks (D).

Table 1

Anthropometric and energy expenditure variables (mean ±SE) in participants of the Biggest Loser weight loss competition.

	Pre-competition Baseline	Week six of the competition	Week 30 of the competition	Six 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/m^2)	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)	2595±151	2209±145	2001±83	1903±125
TEE (kcal/d)	3827±220	4417±294	3066±150	3429±155
PA (kcal/kg/d)	5.8±0.5	16.8±1.8	10.3±1.2	10.1±1.1