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Pattern of Daily Steps is Associated with Weight Loss: Secondary Analysis from the Step-Up Randomized Trial

Seth A. Creasy¹, Wei Lang², Deborah F. Tate³, Kelliann K. Davis⁴, and John M. Jakicic⁴

¹University of Colorado Denver, Anschutz Medical Campus, Denver, Colorado USA

²Wake Forest University School of Medicine, Winston-Salem, NC

³University of North Carolina at Chapel Hill, Chapel Hill, NC

⁴University of Pittsburgh, Pittsburgh, PA

Abstract

Objective—To examine the association between the amount, intensity, and pattern of steps·day⁻¹ with weight loss.

Methods—Participants (N=260, age=42.8±8.9, BMI=32.8±3.5 kg/m²) completed an 18-month weight loss intervention that included a calorie-restricted diet and prescribed physical activity. Participants were categorized by 18-month weight loss as weight gain (GAIN), weight loss of 0 to <5% (WL<5%), 5 to <10% (WL<10%), 10% (WL 10%). Steps·day⁻¹ were measured at 0, 6, 12 and 18 months and defined as total steps·day⁻¹, total steps·day⁻¹ of moderate-to-vigorous physical activity (MVPA; 3 metabolic equivalents) in bouts of 10 minutes (BOUT-MVPA), MVPA in bouts of <10 minutes (NON-BOUT-MVPA), or non-MVPA steps·day⁻¹ (NON-MVPA).

Results—There was a Weight Loss Category by Time interaction (p<0.0001) for total and BOUT-MVPA steps·day⁻¹. Total steps·day⁻¹ at 18 months was WL 10%=9822 (95% CI: 9073, 10571), WL<10%=8612 (7613, 9610), WL<5%=7802 (6782, 8822), GAIN=7801 (6549, 9053). BOUT-MVPA steps·day⁻¹ at 18 months was WL 10%=3482 (2982, 3981), WL<10%=1949 (1269, 2629), WL<5%=1735 (1045, 2426), GAIN=1075 (210, 1941). Participant were also categorized based on achieving 10% weight loss at either 6 or 18 months and a similar pattern was observed.

Conclusions—10,000 steps·day⁻¹, with approximately 3,500 steps·day⁻¹ performed as BOUT-MVPA, is associated with enhanced weight loss in a behavioral intervention.

Corresponding Author: John M. Jakicic, PhD, University of Pittsburgh, Department of Health and Physical Activity, Physical Activity and Weight Management Research Center, 32 Oak Hill Court, Pittsburgh, PA 15261, Telephone: 412-383-4001, FAX: 412-383-4045, jjakicic@pitt.edu.

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Keywords

physical activity; exercise; obesity

INTRODUCTION

Physical activity is an important component of weight management interventions.(1, 2, 3, 4, 5) Engagement in 200–300 minutes per week of moderate-to-vigorous physical activity (MVPA) is also predictive of improved longer-term weight loss.(6, 7, 8, 9, 10, 11, 12) Thus, promoting engagement in this level of MVPA may have public health implications for the effective treatment of overweight and obesity.

While current recommendations for physical activity for weight control are typically expressed in units of minutes per week, an alternative metric for physical activity is to prescribe a threshold of steps per day (steps·day⁻¹). Tudor-Locke et al. reported that adults achieving the 30 minutes of daily MVPA accumulate about 8,000 steps·day⁻¹, with 7,000 steps·day⁻¹ every day of the week being the parallel to 150 minutes of weekly MVPA.(13) However, whether the number of steps, the intensity of these steps, or the pattern for how these steps are accumulate is associated with improved long-term weight loss within the context of a behavioral weight loss program has not been reported. Given the current widespread availability of consumer-based activity monitors that provide feedback on physical activity in units of steps·day⁻¹,(14) clarifying the quantity of steps·day⁻¹ that is associated with improved weight loss may have important clinical and public health implications.

Therefore, the purpose was to conduct a secondary data analysis from a clinical trial to examine whether the amount of steps, intensity of steps, or patterns of steps is associated with weight loss within the context of an 18-month behavioral weight loss intervention.

METHODS

Participants

Participants were recruited to participate in a behavioral weight loss intervention between May 2008 and February 2010. This study utilized two clinical sites (Pittsburgh, PA and Chapel Hill, NC), thus, study procedures were approved by the Institutional Review Boards at both institutions. Data collection was completed by September 2011. The primary outcomes of this study have been published previously.(15)

Participants were recruited through various types of advertisements and media outlets including television commercials, newspaper advertisements, and others. Prior to entry into the study, participants completed a telephone screening to determine initial eligibility. Once determined to be initially eligible, participants attended an orientation session where all study procedures were outlined and explained. After the orientation session and prior to entry into the study, interested participants provided written informed consent. Participants provided physician's clearance, medical history, and completed a physical activity readiness questionnaire (PAR-Q) prior to engagement in baseline assessments and subsequent

engagement into the weight loss intervention. Eligibility criteria included age 18 to 55 years old, BMI of 25.0 to <40.0 kg/m², and other criteria that have been previously reported.(15)

There were 363 individuals randomized in this study. Justification of sample size, randomization procedures, and the CONSORT diagram for the primary analysis have been published previously(15) along with the CONSORT diagram based on the categories of weight change patterns.(8) Thus, for the secondary data analyses that were conducted and presented in this reported, only those participants with weight data available at both 0 and 18 months (N=260) or 0, 6, and 18 months (N=258) were included (Figure 1). Participant demographic information is provided in Table 1, and is similar to what has previously been reported.(8)

Behavioral Weight Loss Intervention

Participants were randomized to either a standard behavioral weight loss intervention (SBWL) or a stepped-care weight loss intervention (STEP). Both interventions were 18-months long and included group meetings and phone call contacts. Both interventions received the same dietary recommendations and physical activity prescription. The details of each intervention and the main study outcomes have been reported previously, however, a brief description is provided below.(15)

Dietary Recommendations

SBWL and STEP were prescribed the same calorie-restricted diet consisting of 1,200–1,800 kcal/day based on initial body weight. In addition, both intervention groups were recommended to reduce fat intake to 20–30% of total energy intake. Participants were instructed to self-monitor dietary intake throughout the study using a weekly food diary; however, this self-monitoring was used as a weight loss strategy and these data were not intended to be used to quantify dietary intake for the purpose of data analysis.

Physical Activity

SBWL and STEP were prescribed identical physical activity programs. The physical activity prescription started at 100 min/week of moderate-to-vigorous intensity physical activity (MVPA) and increased by 50 minutes every 4 weeks until a prescription of 300 min/week was reached. Participants were encouraged to be physically active in bouts that were >10 min in duration and at a moderate-to-vigorous intensity. Physical activity was mainly prescribed in the form of a brisk walking program, however, other forms of aerobic physical activity (e.g., bicycling, swimming, running, etc.) were considered accepted alternatives to walking.

SBWL Intervention

SBWL was offered group-based intervention sessions regularly throughout the 18-month intervention. Group-based intervention sessions were conducted weekly during months 1–6, every other week during months 7–12, and monthly during months 13–18. Lessons focused on topics surrounding weight loss including dietary recommendations, physical activity, or behavioral strategies that would promote adherence to recommendations and ultimately success in the program. Participants were advised to attend all of the group sessions,

however, participants who were unable to attend a group session were offered an individual make-up session. If an individual make-up session was not possible an attempt was made to conduct a brief session by telephone.

STEP Intervention

STEP was offered one group-based intervention session per month throughout the 18-month intervention. Investigators set a priori weight loss goals of 5% at 3 months, 7% at 6 months, and 10% at months 9, 12, and 15. If a participants did not achieve the pre-determined weight loss goal and any of the time points, additional intervention contact or other strategies were added in an attempt to improve weight loss as previously described.(15) Group-based intervention sessions had similar lessons to SBWL. Also, participants who were unable to attend a scheduled in-person intervention session were offered a make-up sessions similar to the process used for SBWL.

Assessment of Outcomes

Height, Weight, and BMI—Body weight was assessed at 0, 6, 12, and 18 months. Weight was assessed on a digital scale to the nearest 0.1 kg with the participant clothed in a hospital gown or light-weight clothing. Height was only measured at baseline to the nearest 0.1 cm using a wall-mounted stadiometer. BMI was computed as kilograms of body weight divided by height in meters squared (kg/m^2).

Physical Activity—Physical activity was objectively measured SenseWear Pro Armband (BodyMedia, Inc.), which has been shown to provide a valid measure of energy expenditure. (16, 17) Participants were provided the device to wear for a period of one week at 0, 6, 12 and 18 months. Data were considered valid for each assessment period and used for analyses if the device was worn for 10 hours per day for 4 days, which is similar to other trials that have previously evaluated objectively measured physical activity patterns.(8, 18, 19, 20, 21)

The device provided steps data for each minute. Thus, data were available for total steps-day⁻¹. Moreover, because energy expenditure at each minute was available from the device, steps across each minute were able to be categorized as meeting the criteria for moderate-to-vigorous physical activity (MVPA; 3METs) or not meeting this criteria (NON-MVPA; <3 METs). Moreover, steps meeting the criteria for MVPA were grouped as being performed in bouts of at least 10 consecutive minutes (BOUT-MVPA) or not meeting the criteria of at least 10 consecutive minutes (NON-BOUT-MVPA). These categories of steps-day⁻¹ (total, NON-MVPA, NON-BOUT-MVPA, BOUT-MVPA) were used for data analysis.

Energy Intake—Energy intake, expressed as kilocalories per day, was assessed using a food frequency questionnaire that participants were asked to complete at 0, 6, 12, and 18 months.(22, 23) This questionnaire requires the participant to report the frequency and amount of consumption of common food items, and this information is used to estimate energy intake.

Statistical Analyses

Statistical analyses were performed using SAS (version 9.4). The type I error rate was fixed at 0.05 (two-tailed). Furthermore, we used the Bonferroni adjustment to account for multiple comparisons.

Two grouping variables were created: one based on weight change from 0 to 18-months and the other based on weight change patterns from 0 to both 6- and 18-months. For change in weight from baseline to 18 months, participants were categorized as gaining weight (GAIN), achieving weight loss of <5% (WL<5%), achieving weight loss of 5 to <10% (WL<10%), or achieving weight loss of ≥10% (WL ≥10%). These categories were selected based upon previous literature which suggests that health benefits can be observed with at least 5% weight loss(4) and the general acceptance of 10% weight loss being an important clinical target that has also been shown to be associated with reduced cardiovascular disease in the Look AHEAD trial.(24) Participants were also grouped based on whether they lost ≥10% of their baseline weight at 6 and 18 months. Thus, participants were categorized as NON-LOSS (weight loss <10% at both 6 and 18 months), LATE-LOSS (weight loss <10% at 6 months and ≥10% at 18 months), NON-MAINTAIN (weight loss ≥10% at 6 months and <10% at 18 months), or MAINTAIN (weight loss ≥10% at both 6 and 18 months).

Only participants with objective physical activity measured for at least one time point (0, 6, 12, or 18 months) were included in the analysis. At each time point, participants were considered to provide valid data if they met the following criteria: minimum of 4 full days with ≥10 hours wear time per day. Separate mixed effects models with 4 time points were fitted to the steps-day⁻¹ for each of the following activity bouts: total, NON-MVPA, NON-BOUT-MVPA, BOUT-MVPA. Pairwise comparisons were performed at a significance level that was adjusted using the Bonferroni method, resulting in a type I error rate of 0.008 for each of the 6 pairwise comparisons among the 4 groups. The models included covariate adjustment for clinic, gender, and race (white: yes/no), with inference focusing on the grouping variable, time, and their interaction. The main effect for randomization group assignment was also examined in these models.

Separate mixed effects models with weight change as outcome were also fitted. Change in steps-day⁻¹ were included for each of the following activity bouts: total, NON-MVPA, NON-BOUT-MVPA, BOUT-MVPA, as time-varying covariate in these models. Other covariates included clinic, gender, race (white: yes/no), and baseline measure of the steps-day⁻¹ variable for each activity bouts.

RESULTS

Comparison Based on Categories of Weight Change at 18 Months

Only participants who provided measured weight at both 0 and 18 months were categorized, which resulted in 260 individuals included in this analysis. Baseline characteristics of this sample (n=260) are shown in Table 1, which is similar to the characteristics of this sample that have been previously reported.(8) Percent weight change at 18 months and its standard error was consistent with the weight loss categories (3.1±0.7% in GAIN, -3.2 ± 0.6% in WL<5%, -7.8±0.6% in WL<10%, and -17.0±0.5% in WL ≥10%).

Steps data, expressed as steps-day⁻¹, are presented as LS Means (95% confidence interval) and are shown in Table 2. When the main effect of randomization group assignment (STEP vs. SBWL) was added to these models examining the pattern of change in steps-day⁻¹ (total steps-day⁻¹, BOUT-MVPA steps-day⁻¹, NON-BOUT-MVPA steps-day⁻¹, or NON-MVPA steps-day⁻¹) and whether there was a significant difference among weight loss category, the main effect of randomization group assignment was not significant in all models (all p's >0.05).

There was a significant Weight Loss Category by Time interaction (p<0.0001) for total steps-day⁻¹. Post hoc analysis with Bonferroni's adjustment for multiple comparisons indicated that WL 10% had significantly more total steps-day⁻¹ [9822 (9151, 10531)] compared to GAIN [7801 (6549, 9053)] and WL<5% [7802(6782, 8822)] (p<0.008). Total steps-day⁻¹ for WL 10% and WL<10% [8612(7613, 9610)] were not significantly different at 18 months, and GAIN, WL<5%, and WL<10% did not differ at 18 months.

There was a significant Weight Loss Category by Time interaction (p<0.0001) for BOUT-MVPA steps-day⁻¹ across the 18 months. Post-hoc analysis showed that WL 10% had more BOUT-MVPA steps-day⁻¹ [3482(2982, 3981)] compared to GAIN [1075(210, 1941)], WL<5% [1735(1045, 2426)], and WL<10% [1949(1269, 2629)] (p 0.008). GAIN, WL<5%, and WL<10% did not differ significantly from each other in BOUT-MVPA steps-day⁻¹ at 18 months.

There was a significant Time effect (p=0.0002) for NON-BOUT-MVPA steps-day⁻¹; however, there were no differences between weight loss categories. NON-MVPA steps-day⁻¹ did not change across the 18 months, and there were no differences between the weight loss categories.

Data for energy intake was compared between the weight loss categories (Table 2). There was no significant difference in total energy intake (kcal-day⁻¹) between these weight loss categories.

Comparison Based on Categories of Weight Change at 6 and 18 Months

Only participants who provided measured weight at 0, 6, and 18 months were categorized, which resulted in 258 individuals included in this analysis. Baseline characteristics of this sample (n=258) are shown in Table 1, and reflect the characteristics as previously reported. (8) Percent weight change and its standard error at 18 months was consistent with the weight loss categories (-1.8±0.5% in NON-LOSS, -13.5±1.2% in LATE-LOSS, -6.8±0.8% in NON-MAINTAIN, and -17.9±0.6% in MAINTAIN).

Steps data, expressed as steps-day⁻¹, are presented as LS Means (95% confidence interval) and are shown in Table 3. When the main effect of randomization group assignment (STEP vs. SBWL) was added to these models examining the pattern of change in steps-day⁻¹ (total steps-day⁻¹, BOUT-MVPA steps-day⁻¹, NON-BOUT-MVPA steps-day⁻¹, or NON-MVPA steps-day⁻¹) and whether there was a significant difference among weight loss category, the main effect of randomization group assignment was not significant in all models (all p's >0.05).

There was a significant Weight Loss Category by Time interaction ($p < 0.0001$) for total steps·day⁻¹. Post hoc analysis with Bonferroni's adjustment for multiple comparisons indicated that at 18 months MAINTAIN had significantly higher total steps·day⁻¹ [9850 (9032, 10668)] than NON-LOSS [7981 (7192, 8771)], with neither LATE-LOSS [9776 (8056, 11495)] nor NON-MAINTAIN [8520 (7421, 9618)] differing from the other categories.

There was a significant Weight Loss Category by Time interaction ($p < 0.0001$) for BOUT-MVPA steps·day⁻¹ across the 18 months. Post-hoc analysis showed that at 18 months MAINTAIN had more BOUT_MVPA steps·day⁻¹ [3645 (3098, 4192)] compared to the NON-LOSS [1543 (1012, 2073)] and NON-MAINTAIN [1869 (1120, 2617)], but not LATE-LOSS [2701 (1508, 3894)] ($p = 0.008$). No other weight loss category comparisons were significantly different from each other in BOUT-MVPA steps·day⁻¹ at 18 months.

There was a significant Time effect ($p = 0.0017$) for NON-BOUTMVPA steps·day⁻¹; however, there were no differences between weight loss categories. NON-MVPA steps·day⁻¹ did not change across the 18 months, and there were no differences between the weight loss categories.

Data for energy intake was compared between the weight loss categories (Table 3). There was no significant difference in total energy intake (kcal·day⁻¹) between these weight loss categories.

Association Between Steps per Day and Weight Loss

Data were also analyzed to examine the association between steps·day⁻¹ and weight loss, with separate analysis performed for total steps·day⁻¹, BOUT-MVPA steps·day⁻¹, NON-BOUT-MVPA steps·day⁻¹, or NON-MVPA steps·day⁻¹. Within these analyses steps·day⁻¹ was considered a time varying covariate. After controlling for randomization group X time interaction, clinic (Pittsburgh vs. North Carolina), sex, ethnicity, and baseline steps·day⁻¹ the analysis of total steps·day⁻¹ showed a significant association with weight change (kg) across the 18-month intervention period ($\beta = -0.00021$, $p = 0.0003$), suggesting that there was an additional 0.21 kg of weight loss with each additional 1,000 total steps·day⁻¹. The analysis was repeated for BOUT-MVPA steps·day⁻¹ and showed a significant association with weight change (kg) across the 18-month intervention period ($\beta = -0.00033$, $p < 0.0001$), suggesting that there was an additional 0.33 kg of weight loss with each additional 1,000 BOUT-MVPA steps·day⁻¹. Neither NON-BOUT-MVPA steps·day⁻¹ ($\beta = -0.00019$, $p = 0.2153$) or NON-MVPA steps·day⁻¹ ($\beta = 0.00013$, $p = 0.3009$) were significantly associated with absolute weight change (kg) across the 18-month intervention period. These analyses were repeated replacing absolute weight change (kg) with percent weight change, and similar findings were observed (data not shown).

CONCLUSIONS

Physical activity has previously been shown to be associated with improved weight loss in comprehensive behavioral weight loss interventions, with the volume of physical activity typically expressed as time or energy expenditure.(1) This current report expands the

scientific literature in this area and provides data on physical activity, expressed as steps, and their association with weight change across an 18-month behavioral weight loss intervention. The results show that those individuals achieving 10% weight loss at 18 months were engaging in approximately 10,000 total steps-day⁻¹, which is consistent with a common public health recommendation for physical activity.

The results of this study are important because they provide additional insight into physical activity recommendations that may be important to facilitate weight loss success. Others have reported the association between physical activity expressed as energy expenditure from doubly-labeled water(25) and self-report.(6, 7, 10, 11, 12) Minutes of MVPA have also been shown to be associated with enhanced weight loss within a behavioral weight loss intervention.(6, 7, 9) Jakicic et al.(8) have reported that the pattern of minutes of MVPA may be important when determining the association with weight loss within a behavioral weight loss intervention. Thus, this study further contributes to this body of literature and suggests that the pattern of physical activity expressed as steps-day⁻¹ is associated with enhanced weight loss within a behavioral weight loss intervention. These results suggest that the target physical activity expressed as steps-day⁻¹ is approximately 10,000 with approximately 3,500 of these steps achieved at an intensity consistent with MVPA and in bouts of at least 10 minutes in duration. Assuming that 1 mile of walking is equivalent to 2,000 steps, and assuming a walking pace of 20 minutes per mile (3 miles per hour pace), this would suggest the need for approximately 35 minutes per day of MVPA performed in bouts of at least 10 minutes plus an additional 6,500 steps-day⁻¹ of non-structured forms of physical activity. These data may have important public health implications when encouraging adults to engage in physical activity that is monitored as steps-day⁻¹, and also implies the importance of intensity and duration when recommending the accumulation of steps of physical activity to impact body weight. These findings also have important translational implications for research, clinical and public health sectors which may further inform physical activity recommendations for long-term weight loss and weight management.

The public health recommendation for physical activity is to engage in at least 150 minutes per week of MVPA. Tudor-Locke et al. reported that individuals who attained 150 minutes per week of physical activity were taking an average of 7,000 steps-day⁻¹.(13) The data from this study suggest that this amount of physical activity may not be sufficient to enhance long-term weight loss within the context of a behavioral weight loss intervention. In the current study, adults who successfully lost at least 10% of their baseline body weight by 18 months were engaging on average approximately 10,000 steps-day⁻¹ at 6, 12, and 18 months (see Table 2). Moreover, adults who successfully lost at least 10% of their baseline weight at 6 months and were able to maintain at least this magnitude of weight loss at 18 months were also engaging in approximately 10,000 at 6, 12, and 18 months (see Table 3).

The finding of this study should be considered within the potential limitations. This is a secondary analysis of data from a randomized clinical trial that was not designed to empirically examine the magnitude, intensity, and duration of bouts of steps of physical activity that were associated with weight loss within the context of a behavioral weight loss intervention. Thus, we are unable to completely isolate the pattern of steps of physical activity from total physical activity or from the contribution of diet on weight loss. Thus,

these results need confirmation in a properly designed and statistically powered randomized study. Moreover, while physical activity, including steps, was assessed objectively with a device shown to provide a valid measure of physical activity, it is possible that the data collected during one week periods at 0, 6, 12, and 18 months was not representative of all physical activity across the entire 18-month intervention. It is also possible that not all forms of physical activity were accurately measured with the device used in this study, resulting in the estimates of steps to be under- or over-estimated.

Within this study energy intake was assessed and no significant differences were observed between the weight loss categories (see Tables 2 and 3), despite these categories representing different magnitudes of weight loss. However, it is unlikely that the differences in steps-day⁻¹ accounted for all of the weight loss difference across these categories, with the results suggesting that an increase of 1,000 total or BOUT-MVPA steps-day⁻¹ accounted for an enhanced weight loss of 0.22 kg and 0.33 kg, respectively. Thus, there may have been limitations with the use of a food frequency questionnaire to assess energy intake, which may have result in self-reporting bias and an inaccurate quantification of energy intake. Thus, the lack of a difference in energy intake between the weight loss categories (Table 2 and 3) may be influenced by the limitations of using a food frequency questionnaire.

An additional limitation of this study is that there were participants who were initially randomized to this study who were not included within these secondary analyses (see Figure 1). These participants were excluded due to missing weight loss data that did not allow for them to be placed into one of the weight loss categories for analysis. It is unclear whether the results of this secondary analysis would have differed if these additional participants would have provided data and been able to be included in the analysis and results presented here.

Results support the recommendation of accumulating 10,000 steps-day⁻¹, with approximately 3,500 of these steps-day⁻¹ be performed at a moderate-to-vigorous intensity in bouts of at least 10 minutes, to enhance weight loss in response to a behavioral weight loss intervention. While these results have implications that inform public health recommendations for physical activity, confirmation of these findings is needed with properly designed clinical trials.

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What is already known about this subject

- Physical activity is a key contributor in weight loss interventions and contribute additional initial weight loss (within 6 months of treatment) and is associated with enhanced long-term weight loss maintenance and prevention of weight regain.
- The dose of moderate-to-vigorous physical activity associated with enhanced weight loss has typically been described in units of minutes or energy expenditure.

What this study adds

- Few studies have examined the number or pattern of physical activity steps that are associated with enhanced weight loss within the context of a behavioral intervention. This study shows that accumulating 10,000 steps per day, with approximately 3,500 of these steps performed at a moderate-to-vigorous intensity and in bouts of at least 10 continuous minutes, is associated with enhanced 18-month weight loss in response to a behavioral intervention in adults.

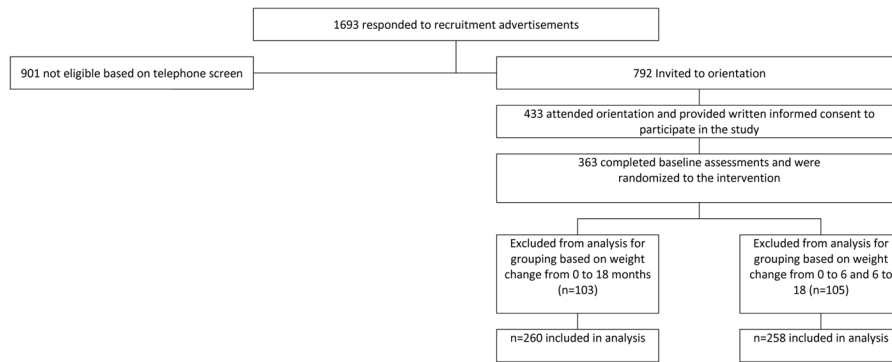


Figure 1.
Consort Diagram

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Table 1

Descriptive characteristics of participants [N (%) for categorical variables and mean±SD for continuous variables]

	Subjects Randomized	Subjects with both Baseline and 18 Month Weight Measured	Subjects with both Baseline, 6, and 18 Month Weight Measured
Number of Subjects [Number (% of total)]	363 (100%)	260 (100%)	258 (100%)
Gender(Females) [Number (% of total)]	300 (82.6%)	206 (79.2%)	206 (79.8%)
Age(years)	42.2±9.0	42.8±8.9	42.9±8.9
Body Mass Index(kg/m ²)	33.0±3.6	32.8±3.5	32.8±3.5
Ethnicity [Number (% of total)]			
Asian	N=2 (0.6%)	N=2 (0.8%)	N=2 (0.8%)
Black or African-American	N=103 (28.4%)	N=69 (26.5%)	N=68 (26.4%)
Hispanic, Latino, Portuguese, Cape Verdean	N=7 (1.9%)	N=5 (1.9%)	N=5 (1.9%)
White	N=243 (66.9%)	N=181 (69.6%)	N=180 (69.8%)
Other	N=8 (2.2%)	N=3 (1.2%)	N=3 (1.2%)

Table 2

Differences in steps per day of physical activity by weight change categories at 18 months [LS Means (95% confidence interval)].

Physical Activity Variable	Weight Change Category Based On 18-Month Weight Loss	Assessment Periods (Steps per Day)				P-Values**		
		Baseline	6 Months	12 Months	18 Months	Time	Weight Change Category	Weight Change Category X Time
Total steps·day ⁻¹	GAIN (N=36)	8134(7212, 9056)	8603(7490, 9716) ^a	7965(6815, 9114)	7801(6549, 9053) ^a	<0.0001	0.0588	<0.0001
	WL<5% (N=55)	7233(6444, 8022)	9613(8681, 10545)	8187(7217, 9157)	7802(6782, 8822) ^b			
	WL<10% (N=57)	7869(7096, 8641)	9852(8933, 10771)	8602(7676, 9528)	8612(7613, 9610)			
	WL 10% (N=106)	7280(6680, 7880)	10576(9882, 11270) ^a	9456(8749, 10164)	9822(9073, 10571) ^{a,b}			
NON-MVPA steps·day ⁻¹	GAIN	4259(3805, 4713)	4415(3894, 4937)	4213(3661, 4765)	4242(3674, 4809)	0.9423	0.2032	0.9715
	WL<5%	3919(3532, 4306)	3952(3515, 4390)	3994(3528, 4460)	4018(3554, 4482)			
	WL<10%	4278(3898, 4657)	4126(3696, 4557)	4157(3712, 4602)	4153(3707, 4599)			
	WL 10%	3914(3620, 4208)	3802(3475, 4128)	3775(3435, 4115)	3831(3493, 4169)			
NON-BOUT-MVPA steps·day ⁻¹	GAIN	2491(2088, 2895)	2646(2222, 3071)	2576(2147, 3006)	2500(2046, 2954)	0.0002	0.6600	0.1839
	WL<5%	2228(1886, 2571)	2692(2338, 3046)	2264(1903, 2625)	2125(1754, 2496)			
	WL<10%	2539(2203, 2875)	2675(2327, 3022)	2421(2078, 2764)	2525(2163, 2887)			
	WL 10%	2230(1971, 2489)	2585(2320, 2850)	2377(2112, 2642)	2520(2245, 2795)			
BOUT-MVPA steps·day ⁻¹	GAIN	1404(918, 1890)	1496(671, 2322) ^{a,b,d}	1272(498, 2047) ^a	1075(210, 1941) ^a	<0.0001	<0.0001	<0.0001
	WL<5%	1097(684, 1511)	2990(2299, 3681) ^{a,c}	1941(1286, 2596) ^b	1735(1045, 2426) ^b			
	WL<10%	1058(653, 1463)	3059(2358, 3761) ^d	2040(1423, 2658) ^c	1949(1269, 2629) ^c			
	WL 10%	1131(816, 1447)	4145(3634, 4656) ^{b,c}	3301(2837, 3764) ^{a,b,c}	3482(2982, 3981) ^{a,b,c}			
Energy Intake kcal·day ⁻¹	GAIN	1981(1709, 2253)	1580(1374, 1786)	1570(1364, 1776)	1587(1367, 1806)	<0.0001	0.9773	0.2378
	WL<5%	1986(1756, 2217)	1531(1366, 1696)	1681(1510, 1853)	1589(1410, 1768)			
	WL<10%	2177(1954, 2400)	1567(1406, 1728)	1612(1448, 1776)	1561(1384, 1738)			
	WL 10%	2175(2006, 2343)	1546(1421, 1671)	1543(1417, 1669)	1546(1411, 1681)			

** indicates no significant difference between randomized groups (data not presented)

Note: Groups with the same superscript at the same assessment point are significantly different at $\alpha < 0.008$ (p-value of 0.05 adjusted using Bonferroni adjustment for 9 group comparisons at that time point.)

Weight Change Category Based On 18-Month Weight Loss

GAIN: Weight gain 0% of baseline weight

WL<5%: weight loss <5% of baseline weight

WL<10%: weight loss of 5% to <10% of baseline weight

WL 10%: weight loss 10% of baseline weight

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Table 3

Differences in steps per day of physical activity by weight change categories at 6 and 18 months [LS Means (95% confidence interval)].

Physical Activity Variable	Weight Change Category Based On 6 and 18-Month Weight Loss*	Assessment Periods (Steps per Day)				P-Values**		
		Baseline	6 Months	12 Months	18 Months	Time	Weight Change Category	Weight Change Category X Time
Total steps·day ⁻¹	NON-LOSS (N=103)	7572(6954, 8190)	9074(8353, 9795) ^a	8205(7460, 8949)	7981(7192, 8771) ^a	<0.0001	0.0501	<0.0001
	LATE-LOSS (N= 19)	8241(6959, 9524)	10579(9060, 12099)	9327(7770, 10885)	9776(8056, 11495)			
	NON-MAINTAIN (N=44)	8092(7233, 8952)	10404(9400, 11407)	8659(7635, 9683)	8520(7421, 9618)			
	MAINTAIN (N= 86)	7094(6433, 7755)	10600(9839, 11360) ^a	9508(8730, 10287)	9850(9032, 10668) ^a			
NON-MVPA steps·day ⁻¹	NON-LOSS	4094(3792, 4397)	4109(3770, 4449)	4163(3806, 4520)	4173(3813, 4533)	0.6764	0.1010	0.8698
	LATE-LOSS	4367(3736, 4998)	4455(3742, 5167)	4279(3534, 5024)	4094(3324, 4864)			
	NON-MAINTAIN	4328(3905, 4750)	4251(3779, 4722)	4080(3591, 4569)	4132(3641, 4622)			
	MAINTAIN	3825(3501, 4149)	3668(3310, 4026)	3675(3302, 4048)	3776(3407, 4144)			
NON-BOUT-MVPA steps·day ⁻¹	NON-LOSS	2322(2057, 2587)	2576(2301, 2852)	2349(2069, 2629)	2307(2018, 2596)	0.0017	0.1850	0.5059
	LATE-LOSS	2550(1991, 3110)	2859(2288, 3431)	2626(2052, 3201)	3038(2420, 3655)			
	NON-MAINTAIN	2679(2305, 3052)	2925(2545, 3305)	2551(2173, 2930)	2539(2143, 2934)			
	MAINTAIN	2164(1879, 2448)	2528(2239, 2818)	2326(2035, 2617)	2421(2124, 2719)			
BOUT-MVPA steps·day ⁻¹	NON-LOSS	1180(853, 1508)	2368(1840, 2896) ^a	1726(1235, 2218) ^a	1543(1012, 2073) ^a	<0.0001	<0.0001	<0.0001
	LATE-LOSS	1343(665, 2020)	3277(2096, 4458)	2447(1405, 3490)	2701(1508, 3894)			
	NON-MAINTAIN	1092(637, 1546)	3225(2466, 3983)	2031(1353, 2710) ^b	1869(1120, 2617) ^b			
	MAINTAIN	1093(743, 1443)	4339(3774, 4904) ^a	3496(2986, 4006) ^{a,b}	3645(3098, 4192) ^{a,b}			
Energy Intake kcal·day ⁻¹	NON-LOSS	2064(1893, 2235)	1594(1466, 1722)	1651(1517, 1786)	1581(1442, 1720)	<0.0001	0.1613	0.0935
	LATE-LOSS	2322(1946, 2698)	1594(1466, 1722)	1734(1466, 2002)	1725(1428, 2023)			
	NON-MAINTAIN	2094(1843, 2344)	1484(1312, 1656)	1573(1396, 1750)	1570(1377, 1763)			
	MAINTAIN	2109(1924, 2293)	1433(1300, 1565)	1479(1342, 1616)	1481(1335, 1626)			

** indicates no significant difference between randomized groups (data not presented)

Note: Groups with the same superscript at the same assessment point are significantly different at $\alpha < 0.008$ (p-value of 0.05 adjusted using Bonferroni adjustment for 6 group comparisons at that time point.)

Weight Change Category Based On 6 and 18-Month Weight Loss

NON-LOSS: <10% weight loss at both 6 and 18 months

NON-MAINTAIN: 10% weight loss at 6 months and <10% weight loss at 18 months

LATE-LOSS: 6 month weight loss <10% & 18 month weight loss 10%

MAINTAIN: 10% weight loss at both 6 and 18 months

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