Associations between change in sedentary behavior and outcome in standard behavioral weight loss treatment

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Abstract

Sedentary behavior, particularly in prolonged periods, is an important determinant of health. Little research exploring changes in sedentary behavior during behavioral weight loss programs exists. This study evaluated the magnitude of changes in total and prolonged sedentary behavior and how these changes related to changes in weight and cardiovascular outcomes during a behavioral weight loss program. Participants ($n = 450$) in two lifestyle modification programs underwent assessments of sedentary behavior (by accelerometry), weight, waist circumference, blood pressure, and resting heart rate at baseline and after 6 months of treatment. Sedentary behavior was defined as both total and prolonged (≥ 30 continuous minutes) sedentary minutes/day. Reductions in total and prolonged sedentary time were significant and were accounted for by increases in moderate-to-vigorous physical activity (MVPA). Only changes in MVPA significantly predicted change in weight when entered into a model simultaneously with changes in sedentary behavior. Changes in total and prolonged sedentary time were not associated with changes in waist circumference, heart rate, or blood pressure. Change in sedentary time was not independently associated with change in health outcomes during a behavioral weight loss treatment. High variability in changes in sedentary time indicate that individual differences may be important to examine. Reducing sedentary time may not be powerful enough to impact these health outcomes above the effects of other changes made during these programs; alternatively, it may be that increasing focus in treatment on reducing sedentary time may engender greater decreases in sedentariness, which could lead to better health outcomes.

Keywords

Sedentary behavior, Obesity, Behavioral weight loss, Activity, Accelerometer

INTRODUCTION

Sedentary behavior has been identified as an important predictor of health outcomes. Recent research has observed positive associations between levels of sedentary time and risk of medical consequences, including diabetes, cardiovascular disease, and all-cause mortality [1, 2], and these relationships persist when controlling for moderate-to-vigorous physical activity (MVPA; [3–5]) and body mass index (BMI; [6]). Sedentary behavior may be particularly problematic when it occurs in prolonged periods. Independent of total sedentary time, evidence indicates that having fewer or shorter periods of sedentary behavior is associated with lower BMI

Implications

Practice: Standard behavioral weight loss treatments with prescriptions to increase moderate-to-vigorous physical activity (MVPA) reduce sedentary behavior, but this reduction does not independently relate to weight and health outcomes.

Policy: There is no indication that the addition of guidelines on sedentary behavior to recommendations targeting MVPA will improve health.

Research: Future research should be aimed at developing clinically meaningful guidelines regarding sedentary behavior and understanding the role of reductions in sedentary behavior on health in the context of other behavioral changes (e.g., weight loss, increasing MVPA), with particular focus on individual differences in response to activity recommendations.

and decreased cardiometabolic risk factors [3, 4, 7]. Additionally, experimental studies consistently find acute reductions in glucose and insulin when sedentary behavior is interrupted by any type of activity (e.g., standing; [8]).

The relationship between sedentary behavior and health outcomes may be of particular importance for individuals who are obese or overweight, as excess body weight is a risk factor for many of the same negative health outcomes as sedentariness [9]. Obese individuals engage in approximately two more hours per day of sedentary behavior compared to lean individuals [10] and sedentary behavior occurs in longer bouts [11]. Sedentary time is positively associated with waist circumference [3, 4, 7] and weight gain from childhood to adulthood [1]. In one study, overweight and obese adults had significant reductions in postprandial glucose and insulin when sedentary behavior was interrupted by 2 min of light or moderate activity every 20 min [12]. A better understanding of the relationship between total and prolonged sedentary behavior and weight control may improve health outcomes for overweight and obese individuals.

Little research has evaluated how sedentary behavior changes in standard behavioral weight loss treatments (BWL). Activity recommendations in the context of BWL typically focus on increasing MVPA [13–15]. Given that waking time is divided among several activity levels (sedentary, light, moderate, and vigorous), increases in MVPA must be accounted for by decreases in other levels of activity. However, only a small number of studies have explored changes in sedentary behavior and associations between those changes and changes in MVPA during BWL. Preliminary studies suggest that individuals may experience modest, statistically significant decreases in sedentary behavior over the course of treatment [16]. In one study, a greater decline in self-reported TV viewing (a proxy for sedentary time) was observed in individuals receiving BWL than in individuals receiving metformin or a placebo control, though no recommendations regarding sedentary behavior were made. This decrease was associated with an increase in self-reported MVPA [17]. Another study using objective measurement of activity, which typically yields higher rates of sedentary time than self-report and is likely a better estimate of activity [18], found that a BWL program for overweight or obese adults (ages 18–35 years) produced small but significant decreases (12 min/day) in sedentary time [19].

An even smaller number of studies has evaluated whether changes in sedentary behavior relate to changes in weight in the context of BWL, yielding mixed results. One study showed no relationship between changes in total sedentary time and changes in weight in the context of BWL [19]. Another study of obese older adults found that modifying typical BWL by focusing considerable attention on increasing light-intensity activity by interrupting sedentary time improved weight outcomes compared to BWL alone [20].

No prior studies have explored changes in prolonged sedentary behavior or how changes in sedentary behavior relate to changes in cardiovascular outcomes in BWL. The current study sought to evaluate several hypotheses related to sedentary behavior in the context of BWL. We hypothesized that: (i) sedentary behavior (both total and prolonged) would decrease during a traditional BWL program, and (ii) changes in both total and prolonged sedentary time would be associated with changes in weight, waist circumference, resting heart rate, and blood pressure.

METHODS

Participants

The current study was a secondary analysis utilizing data from 603 overweight/obese adults enrolling in one of two randomized controlled trials of BWL. Participants were recruited through radio

advertisements, flyers, and referrals from health care providers. Eligible participants had a BMI of 27–45 kg/m² (Study 1) or of 27–50 kg/m² (Study 2). All other inclusion and exclusion criteria were identical between studies (i.e., must be between the ages of 18 and 70 years, able to walk at least two blocks without stopping for rest, not pregnant or planning to become pregnant during the study timeframe, had not recently begun a course of or changed the dosage of medication that may cause significant change in weight, and had not lost more than 5% of their weight within the past 6 months). In Study 1, 1,448 individuals were screened for participation, yielding 283 randomized participants [21]; in Study 2, 1,456 individuals were screened for participation, yielding 320 randomized participants.

Procedures

Participants attended assessments at baseline and 6 months into treatment. All study conditions included an active weight management treatment; treatments were based on standard BWL protocols adapted from the Diabetes Prevention Program and Look AHEAD [15, 22]. Each condition was given similar behavioral goals, such as daily self-monitoring of intake and activity, calorie goals based on the standard balanced deficit diet guidelines, and exercise prescription increasing gradually to 250 min/week of MVPA in bouts of at least 10 min [23, 24]. Participants met in groups of 10–15 for 75-min sessions that occurred weekly and biweekly during Months 1–6. This phase of the program was designed to induce a 10% weight loss. Sedentary behavior was not an explicit treatment target.

Measures

Height (at baseline) and weight (at each assessment) were measured with a digital Seca (Chino, CA) scale in the clinic while participants wore light street clothes. Waist circumference was measured to the nearest 0.1 cm at the minimum circumference between the iliac crest and the rib cage. In Study 2 only ($n = 313$), resting heart rate and blood pressure were measured with an automated Omron (Kyoto, Japan) blood pressure cuff after 2 min of resting silently in a seated position. The average of two measurements was obtained at each assessment.

Waist-worn Actigraph (Pensacola, FL) GT3X+ accelerometers were given to participants to wear during waking hours for 1 week at each assessment point. Outcome variables included total sedentary (<100 counts/min) time/day and prolonged sedentary time/day (defined as ≥ 30 continuous minutes [7, 25]). Light activity (100–2,019 counts/min) and MVPA (>2,019 counts/min) also were measured. Cut points defined by Troiano et al. [26] were used as these have previously been used to define activity level across weight statuses [27].

Data analysis

Data were pooled between the two studies. Measured sedentary time is highly correlated with accelerometer wear time [17] and activity tends to vary predictably based on time of day [27]. Thus, to capture unbiased estimates of sedentary time, data for all wear days were used from 8 am to 10 pm (which constitute the hours during which the majority of data were non-missing, and represent times that can be reasonably expected to represent “waking hours”). Prior work has established that data missing from part of a day of accelerometer wear can be effectively imputed using non-missing data [28]. Individuals with at least 4 days of partial wear were included in the present analyses (i.e., whole days of missing data and whole assessments of missing data were excluded from analyses). This plan for accelerometer data was designed to reduce bias introduced by variable wear time and to reduce bias in imputations due to insufficient wear time. Of the 603 individuals enrolled in the parent studies, 450 had adequate data available at both baseline and 6 months and were included in the current analyses. Missing weight [28–30] and accelerometer data were handled with multiple imputation with five iterations. Results presented are based on pooling the results across the five data sets. Change scores were calculated for total and prolonged sedentary time, light activity, and MVPA. Percent weight loss and change in waist circumference were calculated for all participants. For participants in Study 2, change was also calculated for resting heart rate and systolic and diastolic blood pressure. Change over time in activity levels per day was evaluated using repeated-measures ANOVAs. Pearson correlations explored the relationship between changes in sedentary behavior and changes in weight and cardiovascular measures. Multiple regression analyses evaluated the hypothesis that changes in sedentary time and changes in MVPA would independently predict weight loss.

RESULTS

The sample was predominantly White (69.1%; 26.7% Black/African-American, 2.7% more than one race, and 1.5% American Indian/Alaskan Native, Asian, or Native American), female (78.9%), and had obtained a graduate or professional degree (44.5%; 33.9% had a bachelor’s degree). The modal household income level was \$75,000–\$100,000 per year. At baseline, average age was 53.6 years ($SD = 9.6$) and average BMI was 35.1 kg/m^2 ($SD = 4.8$).

On average, from baseline to 6 months participants significantly reduced daily prolonged time spent sedentary by 12.3 min/day. Total time spent sedentary decreased significantly by 9.6 min/day. Small (0.7 min/day), nonsignificant reductions in light activity were observed. MVPA significantly increased by 10.6 min/day. Thus, reductions in

Table 1 | Changes in Activity Levels and Pearson Correlations Between Changes in Activity Level and Change in Weight and Cardiovascular Outcomes

	Baseline [95% CI]	Mid-treatment [95% CI]	F-value	Correlation with weight loss	Correlation with Δ in waist circumference	Correlation with Δ in systolic BP	Correlation with Δ in diastolic BP	Correlation with Δ in resting heart rate
Δ in prolonged sedentary time	298.0 [289.1, 306.9]	285.7 [277.1, 294.2]	9.89**	.10*	.06	-.05	-.06	.02
Δ in total sedentary time	633.6 [629.2, 637.9]	624.0 [619.8, 628.2]	21.36**	.10*	.03	-.01	-.06	.00
Δ in light activity	177.4 [173.5, 181.3]	176.7 [172.9, 180.4]	0.12	-.01	.04	.06	.11	.05
Δ in MVPA	38.9 [37.4, 40.4]	49.5 [47.7, 51.2]	125.1**	-.15*	-.07	-.06	-.08	-.06

Δ change; BP blood pressure; MVPA moderate-to-vigorous physical activity.

* $p < .05$, ** $p < .01$.

Table 2 | Changes in Weight and Cardiovascular Outcomes by Quartile of Change in Total and Prolonged Sedentary Behavior

	Quartile 1 Mean	Quartile 2 Mean	Quartile 3 Mean	Quartile 4 Mean	F-value (p-value)
Total sedentary time	43.9	1.7	-21.8	-62.0	
Weight loss (%)	-9.3	-9.9	-10.4	-11.1	2.12 (.10)
Waist circumference (cm)	-8.1	-8.3	-9.1	-8.9	0.77 (.51)
Systolic blood pressure	-4.8	-5.6	-3.9	-5.7	0.20 (.99)
Diastolic blood pressure	-8.0	-7.0	-4.7	-6.4	0.36 (.78)
Resting heart rate	-4.3	-5.8	-4.5	-6.1	0.44 (.73)
Prolonged sedentary Time	88.8	14.0	-34.6	-117.5	
Weight loss (%)	-9.2	-10.3	-10.6	-10.7	1.28 (.30)
Waist circumference (cm)	-8.1	-8.4	-9.1	-8.7	0.50 (.68)
Systolic blood pressure	-5.8	-4.5	-6.2	-3.6	0.45 (.72)
Diastolic blood pressure	-6.5	-8.2	-7.1	-4.2	1.03 (.38)
Resting heart rate	-4.8	-3.8	-6.7	-5.2	0.80 (.50)

Quartile 1 indicates the greatest increase in sedentary behavior; Quartile 4 indicates the greatest decrease in sedentary behavior.

sedentary behavior were largely accounted for by increases in MVPA (see Table 1). There was great variation in changes in sedentary behavior. Changes in total sedentary behavior ranged from decreases of 276.8 min/day to increases of 267.1 min/day. Changes in prolonged sedentary time ranged from decreases of 169.1 min/day to increases of 167.8 min/day. Quartiles of change in total and prolonged sedentary behavior were computed; there were no significant differences between quartiles in weight or cardiovascular outcomes (see Table 2).

At 6 months, participants lost an average of 10.2% of their initial weight, reduced their waist circumference by 8.6 cm, resting heart rate by 5.2 beats/min, systolic blood pressure by 5.0 mm Hg, and diastolic blood pressure by 6.4 mm Hg. Changes in weight were significantly associated with changes in MVPA and total and prolonged sedentary time, but not light activity. Changes in cardiovascular outcomes were not associated with changes in activity level (see Table 1). When entered simultaneously into a model, MVPA ($b = -0.04$, $SEb = 0.02$; $t = -2.48$, $p = .01$) predicted weight loss while prolonged sedentary time ($b = 0.003$, $SEb = 0.003$; $t = 1.04$, $p = .30$) did not; in a second model, MVPA ($b = -0.04$, $SEb = 0.02$; $t = -2.28$, $p = .02$) predicted weight loss while prolonged sedentary time ($b = 0.001$, $SEb = 0.008$; $t = 0.18$, $p = .86$) did not. Assumptions of collinearity (Tolerance = 0.65, VIF = 1.55 and Tolerance = 0.85, VIF = 1.17, respectively) and visual inspection of residual plots indicated all assumptions of normality were met in each model.

DISCUSSION

Individuals in BWL made significant decreases on average in total and prolonged sedentary behavior between baseline and 6 months. However, great variation in the degree and direction of change in sedentary time was observed, indicating that changes in activity differ at an individual level. Decreases in total sedentary time appear to be accounted for by

increases in MVPA, and associations between sedentary behavior and weight were nonsignificant when accounting for changes in MVPA. Results indicate that standard BWL approaches may have small effects on sedentary behavior through increases in MVPA and that increases in MVPA, rather than decreases in sedentary time, predict change in weight.

Consistent with prior literature, average decreases in both total and prolonged sedentary time were observed [16, 19]. Average decreases in sedentary time (and increases in MVPA) amounted to over an hour per week, which is clinically meaningful given the increase in energy expenditure resulting from an hour per week of additional MVPA. Despite significant average reductions in sedentary behavior, a wide degree of variability was observed. This may indicate that there are important individual differences in how sedentary time changes during BWL. Some individuals may compensate for increased physical activity by also increasing sedentary time (i.e., decreasing light activity); other individuals may increase total activity (i.e., increasing light activity or MVPA), reducing the amount of sedentary time. Additionally, some individuals make small or no changes to their activity patterns. Understanding these individual differences will be important to further develop interventions designed to alter activity patterns.

Results from the present study differed from one prior study that observed no relationship between changes in total sedentary time and change in weight [19]. However, sedentary time in the present analyses was derived from a standard 14-hr wear day; in Jakicic et al.'s [18] study, percentage of wear time in sedentary behavior was utilized, and wear time was not standardized across individuals. In the present study, individuals engaged in approximately 75% of that 14-hr wear day in sedentary behavior, as opposed to approximately 65% in Jakicic et al.'s [18] study. The present sample is additionally older and has a

higher BMI. Thus, differences in results across studies may reflect differences in statistical approaches or sample characteristics (e.g., age, weight) that could influence relationship between sedentary behavior and weight, or the amount of sedentary behavior individuals engage in.

Finally, changes in sedentary behavior and changes in cardiovascular outcomes (i.e., waist circumference, blood pressure, and heart rate) were not related. While associations with changes in other health risks not evaluated here are unknown, present data fail to support the idea that reductions in sedentary behavior during a standard BWL meaningfully contribute to improvements in markers of cardiovascular health. Notably, BWL involves several components that likely have large impacts on blood pressure, heart rate, and waist circumference, including increases in bouts of MVPA and reductions in weight. It may be that, given the intensity of these programs, associations between change in sedentary behavior and changes in cardiovascular outcomes are too small to observe. It is unknown whether larger changes in sedentary time, which could potentially be achieved through more focused intervention targeting of sedentary behavior or light activity, may impact weight or cardiovascular outcomes in BWL.

Several limitations to this study exist. Participants received an intervention that did not explicitly target sedentary behavior. Thus, it is unknown whether targeting reductions in sedentary behavior might improve outcomes. Additionally, no specific guidelines for sedentary behavior exist, which limits our ability to understand the clinical significance of changes in sedentary behavior. It will be important to establish guidelines for adults regarding total time spent sedentary, what a clinically meaningful cutoff of a sedentary bout is, and what behaviors may constitute a “break” (i.e., how long one needs to discontinue sedentary time to achieve health benefits [31]). Related to this, it is unclear what activities may have been associated with the interruption of a prolonged period of sedentary behavior. For example, non-exercise activity thermogenesis (NEAT) includes activities such as toe-tapping or standing [32]. Though greater engagement in these activities has been related to lower risk of metabolic syndrome and abdominal obesity [33], it is unclear whether these small movements may constitute interrupting a prolonged period. The use of a predetermined wear day afforded several advantages (e.g., reduced bias in sedentary time due to total wear), but also has limitations. Variation in activity outside of this time range is not captured. Additionally, if variations in sedentary time before 8 am or after 10 pm impact health outcomes, results will not reflect those relationships. Finally, participants in this study were more educated and had higher incomes than the general population, which may limit the generalizability of findings.

Despite its limitations, this study adds to a growing body of literature regarding sedentary behavior and health. Within a 14-hr wear day, reductions in total sedentary time were largely accounted for by increases in MVPA, while little change in light activity was observed. Relationships between changes in sedentary behavior and weight were accounted for by changes in MVPA. It remains uncertain whether the addition of content focused on reducing sedentary behavior may induce larger reductions in sedentary behavior and whether larger reductions in sedentary behavior may impact weight and health outcomes. As research continues to focus on understanding and targeting individual differences in treatment responses, a better understanding of how individuals alter activity patterns may inform treatment development. For example, genetic or phenotypic variables may be associated with the propensity toward active or sedentary behaviors, as well as to the physiological response to active and/or sedentary behavior. Thus, it is possible that individuals may differentially respond to treatments focused on increasing MVPA, increasing light, or decreasing sedentary time. Research on the association between sedentary behavior and weight change is in its infancy; additional research is needed to further understand this relationship and how it may impact treatment recommendations.

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Conflict of interest: No potential conflicts of interest exist.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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