EFFECT OF DAILY SELF-WEIGHING ON WEIGHT LOSS IN ADULTS

Dori M. Steinberg

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Nutrition, Gillings School of Global Public Health.

Chapel Hill
2012

Approved by:

Deborah F. Tate, Ph.D.

Dianne S. Ward, Ed.D.

Carmen Samuel-Hodge, R.D., Ph.D.

Susan Ennett, Ph.D.

Gary G. Bennett, Ph.D.

ABSTRACT

DORI STEINBERG: Effect of Daily Self-weighing on Weight Loss in Adults
(Under the direction of Deborah F. Tate)

Limited experimental evidence has examined the impact of daily self-weighing on weight loss and psychological outcomes. The purpose of this dissertation was to assess the effect of daily self-weighing on weight loss, behavioral, and psychological outcomes among overweight and obese adults using an experimental design and robust analytic methods. This dissertation followed three aims. Aim 1 consisted of a secondary data analysis among participants enrolled in a 12-month Internet-based weight loss intervention to examine the association between daily weighing and weight loss and explore whether diet and physical activity behaviors explain that relationship. Those who reported daily weighing had greater percent weight loss compared to those who reported less frequent weighing at 6 months [(8.27% (5.40) vs. 5.51% (5.41); p=.003] and 12 months [8.09% (7.81) vs. 4.60% (6.35); p=.004]. At 6 months, multiple mediation analysis showed that eating and exercise behaviors acted as mediators between daily self-weighing and weight loss. At 12 months, only eating behaviors explained the relationship. Aim 2 included a randomized controlled trial (n=91) comparing a 6-month low-intensity, daily self-weighing intervention to a delayed intervention control group that included an objective measure of self-weighing. On average, the intervention group self-weighed more days per week (6.1±1.1 vs. 1.1±1.5; p<.0001) and lost significantly more weight compared to the control group [Mean (95%CI); 3 months: -4.41%(-5.5, -3.3)

vs. -0.37%(-1.5, .76); 6 months: -6.55%(-7.7, -5.4) vs. -0.35%(-1.5, .79); group x time interaction: p<.001]. At 6 months, a greater percentage of the intervention group achieved 5% (42.6% vs. 6.8%; p<.0001) and 10% weight loss (27.7% vs. 0%; p<.0001). Aim 3 examined the psychological effects of the daily self-weighing intervention compared to controls. There were no significant differences between groups in depressive symptoms, anorectic cognitions, disinhibition, susceptibility to hunger, and binge eating. At 6 months, there was a significant group by time interaction for both body dissatisfaction (p=.007) and dietary restraint (p<.001) with the intervention group reporting improved outcomes on these constructs. The results of this dissertation indicate that daily self-weighing is a feasible and effective behavior for weight loss among overweight and obese adults that does not lead to adverse psychological outcomes.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support and guidance I have received from my dissertation committee: Deborah F. Tate (chair), Gary G. Bennett, Susan T. Ennett, Carmen Samuel-Hodge, and Dianne S. Ward. Dr. Tate has taught me a tremendous amount about intervention research and encouraged me to undertake a project of this magnitude. The support I received to help fund this dissertation from both the Lineberger Comprehensive Cancer Center, Cancer Control Education Program (#R25 CA057726), as well as the UNC Gillings School of Global Public Health Dissertation Award was invaluable. Without this funding, I would not have been able to include an objective measure of self-weighing frequency, which greatly improved the quality of this research.

I would also like to acknowledge the support I received for my second year of doctoral training from the NIH NRSA Predoctoral Traineeship for the Department of Nutrition (T32-DK07686-17), as well as NIH Grant R01-DK60058 provided to Dr. Tate for the HealtheLife Study. I am grateful for the supportive and helpful staff at the UNC Weight Research Program (Molly Diamond, Karen Erickson, Kristen Polzien, Keneisha Quick, and Megan McMullin), all the wonderful doctoral students and postdocs in the Tate Lab (Melissa Crane, Noel Kulik, Liz Lyons, Brie Turner-McGrivey), as well as Hannah Willmott for providing research assistance.

I would also like to thank my friends who have made my doctoral training more complete (Dave Cavallo, Heather Paich, Carmina Valle, Heather Wasser) and my parents

for always supporting my educational endeavors. Finally, I would never have been able to pursue a doctoral degree and achieve my goals without the endless love, support, and patience I received from my husband, Dave, to whom I am forever grateful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BMI – Body Mass Index (kg/m^2)

EBI – Eating Behavior Inventory

PA – Physical Activity

SCT – Social Cognitive Theory

CHAPTER I

INTRODUCTION

I.A. Overview

Obesity continues to be a challenging public health problem.[1] Despite producing large reductions in weight, standard behavioral weight loss interventions require a significant amount of effort, as one of the main components is detailed self-monitoring of dietary intake and exercise habits. This behavior, although effective, is difficult to sustain and may contribute to weight regain post treatment.[2] Furthermore, because of the frequent face-to-face contact and detailed self-monitoring, these interventions have limited potential for dissemination. Interventions focused on enhancing simple strategies for self-monitoring may be just as effective and provide more lasting effects.

One of the simplest forms of self-monitoring is self-weighing. Self-weighing is an important tool for self-regulation of body weight as it provides feedback on how eating and exercise behaviors are impacting weight, and allows individuals to make adjustments to these behaviors to affect energy balance.[3] Observational research indicates that daily self-weighing is associated with greater weight loss as compared to less frequent self-weighing.[4] However, there is limited experimental evidence testing this association.[5,6] Furthermore, previous assessments of self-weighing were measured via self-report, which may introduce measurement error.[7] Despite evidence indicating that more frequent self-weighing has no

adverse psychological effects in adults participating in weight control interventions, there remains concern as to potential negative consequences as a result of daily weighing.[8]

The results of this dissertation provided experimental evidence tested under low-intensity conditions regarding the efficacy of daily self-weighing for weight loss. An objective measure of self-weighing frequency was collected via a scale that transmitted weight data. Given that self-weighing does not impact weight loss directly but rather via changes in diet and physical activity behaviors, a full understanding of the mechanisms explaining this relationship was conducted. Furthermore, this research examined psychological outcomes as a result of daily self-weighing to further add to the evidence surrounding the debate. The specific aims outlining the goals of the dissertation are listed below.

I.B. Specific Aims

AIM 1: Determine the association between daily self-weighing and weight loss via secondary data analyses with individuals enrolled in a 12-month Internet behavioral weight loss program.

1a. Examine the association between self-reported daily self-weighing and percent weight loss at 6 and 12 months.

1b. Examine the mechanisms linking daily self-weighing and weight loss via mediation analyses assessing diet and physical activity behaviors as potential mediators.

<u>Hypothesis 1a</u>*: Individuals who reported more frequent self-weighing will have greater weight loss after 6 and 12 months compared to individuals who reported less frequent self-weighing.*

Hypothesis 1b: Individuals who reported more frequent self-weighing will report greater engagement in diet and physical activity behaviors associated with weight loss, which will in turn lead to greater weight loss at 6 and 12 months compared to those who reported less frequent self-weighing.

AIM 2: Compare the efficacy of a daily self-weighing intervention against a delayed-intervention control group on weight loss and changes in diet and physical activity behaviors at 6 months.

Hypothesis: Participants in the group randomized to receive the daily self-weighing intervention will have greater percent weight loss at 6 months compared to those in the delayed control group. Participants in the intervention group will also report lower caloric intake and greater caloric expenditure compared to the control group at 6 months.

AIM 3: Examine the impact of treatment group on changes in psychological measures, including depressive symptoms, anorectic cognitions, body dissatisfaction, binge eating, dietary restraint, disinhibition, and susceptibility to hunger.

Hypothesis: Participants in the group receiving the daily self-weighing intervention will report no differences in psychological outcomes compared to those in the control group, and any improvements among the intervention group would be related to better weight losses.

CHAPTER II

THEORETICAL FRAMEWORKS

II.A. Introduction

Theoretical frameworks are helpful to guide intervention design and evaluation because they provide an understanding of the determinants and processes of health behavior change.[9] Social Cognitive Theory[10] and Kanfer's Model of Self-regulation[11,12] were utilized to understand and guide the research conducted in this dissertation. These theories were chosen because of their collective emphasis on self-regulation, a construct that is necessary for weight control. Theoretical and empirical support relevant to this research is outlined below.

II.B. Social Cognitive Theory

Social cognitive theory (SCT) focuses on the dynamic interplay between the person, the behavior, and the environment; a concept that is necessary for self-regulation of body weight.[13,14] Figure 1 depicts the reciprocal nature of these factors. Constructs within SCT that are relevant for the self-regulatory behavior changes necessary for weight loss include *self-efficacy, reinforcement, self-control, and behavioral capability*.

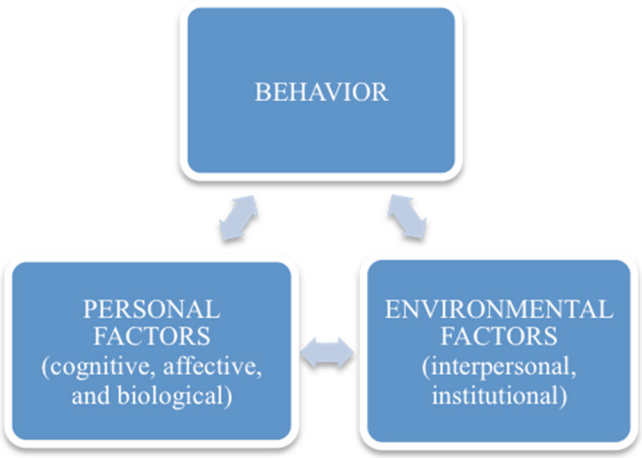


Figure 1: Social Cognitive Theory

Self-efficacy

Self-efficacy is defined as confidence in one's ability to perform a behavior across various situations, and has been shown to be predictive of behavior change, specifically with regard to weight management.[15] One of the central ways to increase self-efficacy is via focus on small goals or small behaviors.[14] This is because mastery, a key predictor of self-efficacy, is more easily achieved if the goal or behavior does not require large amounts of effort or cognitive load.[16] Furthermore, it has been shown that individuals who utilize a greater number of self-regulation strategies (e.g., self-monitoring, goal setting) have greater self-efficacy in the face of challenging situations, which can lead to better weight control.[17] Daily self-monitoring, specifically, is a predictor of self-efficacy because it provides daily accountability of a goal-oriented behavior.

Linde and colleagues found that eating and exercise self-efficacy predicted certain monitoring behaviors (e.g., days counting calories and days following eating plan) and other behaviors associated with weight control (e.g., fruit and vegetable intake, walking). Additionally, they found that a significant correlation was present when looking at cross-sectional data between both eating and exercise self-efficacy with monitoring behaviors (e.g.,

days following eating or exercise plans), including a strong correlation with days of self-weighing.[18]

Reinforcement and Self-control/Self-regulation

Reinforcement refers to responses to a person's behavior that increase or decrease the likelihood of reoccurrence. Using tools to promote self-initiated positive reinforcement of particular behaviors could increase the likelihood of action.[13,16] Mahoney found that adding a self-initiated award as a form of reinforcement enhanced weight loss.[19,20] For example, a body scale can act as a tool to reinforce particular diet and physical activity behaviors that may enhance weight loss. Self-control refers to personal regulation of goal-directed behavior or performance. Self-control is often used interchangeably with self-regulation and can be enhanced via opportunities for self-monitoring, goal setting, and problem solving.[13,16] Although an extreme example, Rosen found that individuals who observed themselves eating via a handheld mirror, a form of "active self-confrontation" that enhances self-control, were less likely to deviate from a prescribed eating plan for weight loss and more likely to report greater satisfaction and control with regard to their goals.[21] Similarly, weighing oneself everyday could act as a form of active confrontation, which could potentially enhance self-regulation allowing for greater engagement in diet and physical activity behaviors that could produce a caloric deficit. In general, self-directed approaches that focus on self-regulation may enhance self-control. Self-management and self-reliance can enhance empowerment, which in turn may increase self-efficacy, potentially leading to better weight loss outcomes.[22,23]

Behavioral Capability

Behavioral capability refers to the idea that "if a person is to perform a particular

behavior, he or she must know what the behavior is (knowledge of the behavior) and how to perform it (skill)."[13] The interplay between SCT constructs posits that self-efficacy for behavior change can be enhanced via behavioral skills training, further indicating it as an important construct to intervene upon.[24] Including a skills-based component in a weight loss intervention is important for providing individuals with the knowledge and skills necessary to make behavioral changes. This includes knowledge about nutrition and weight control topics, such as label reading or portion control, but also the behavioral skills training necessary to respond to a variety of circumstances with topics such as problem solving and relapse prevention.[25]

II.C. Kanfer's Model of Self-regulation

This model is relevant for self-monitoring behaviors and weight control, as it describes the three stages of self-monitoring, self-evaluation, and self-reinforcement as the process necessary for self-regulation.

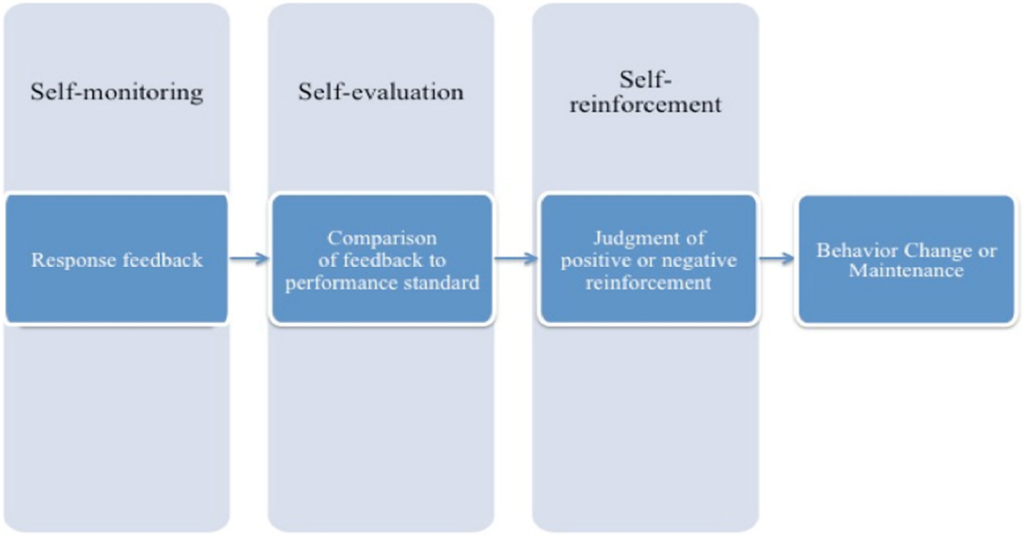


Figure 2: Kanfer's Model of Self-regulation

As is depicted in Figure 2, Kanfer posits that individuals self-monitor when behavior change is present or necessary in response to some feedback. Using feedback from environmental and personal cues, individuals then self-evaluate by comparing the feedback to the performance criterion that was set. From here, individuals assess whether their performance is above, below, or at the given standard. This allows for a judgment that either results in positive reinforcement or punishment regarding the behaviors, leading to either continued behavior change, maintenance or termination.[11,12]

II.D. Theoretical basis for self-monitoring

Evidence indicates that self-monitoring is one of the key behaviors associated with weight loss success.[26] Self-monitoring provides personal accountability and allows for greater awareness of how behaviors are impacting weight outcomes.[27] This is informed by SCT and Kanfer's model of self-regulation as self-monitoring allows for self-regulation via greater awareness, which can lead to greater self-efficacy, self-control, and self-initiated reinforcement.[28] Individuals are able to observe what they are eating, what activities/behaviors they are performing, and how these choices are impacting their weight.

II.E. Self-weighing as a self-monitoring strategy for weight control

Self-weighing has been shown to be a self-monitoring strategy that is associated with greater regulation of body weight.[7] Applying the theoretical frameworks to self-weighing helps understand this positive association. Individuals self-weigh and receive feedback regarding their weight and how their eating and activity behaviors are impacting their weight. They then are able to evaluate whether these behaviors were adequate to create the caloric deficit that is required for weight loss or whether a calorie imbalance occurred. From here, they receive positive reinforcement for continuing the behaviors that produce the deficit or a

lack of reinforcement for the behaviors that resulted in weight gain. This then leads to behavior change or maintenance of current strategies.

Based on these frameworks, more frequent weighing should lead to greater self-regulation as even small changes in body weight could be identified and resolved.[3] Weighing more frequently will allow for small day-to-day changes to be made to regulate body weight. These small changes are optimal over larger changes, as they are easier to achieve and sustain, leading to greater self-efficacy and empowerment over one's ability to regulate their body weight.[3] Compared to more intensive strategies typically included in lifestyle modification programs for weight loss, small, measureable goals that do not require drastic modifications to a person's lifestyle may be a better strategy for self-regulation as they have greater potential for longer lasting effects. The focus on self-weighing as a small, more achievable self-monitoring behavior may help enhance self-regulation, and possibly allow for greater sustainability of weight loss outcomes.

II.F. Conceptual Model

Using the relevant constructs from SCT and Kanfer's model of self-regulation, Figure 3 illustrates the conceptual model outlining the process through which daily self-weighing will impact weight loss within this intervention. Self-weighing, as a key self-monitoring behavior, along with skills training will enhance behavioral capability and self-regulation/self-control via positive reinforcement for behaviors and continued daily weighing, which will, in turn, increase self-efficacy across various circumstances. This will then increase the likelihood of engagement in diet and physical activity behaviors associated with produce a caloric deficit. These determinants will then increase the likelihood of action with regards to diet and physical activity behaviors associated with weight loss.

Figure 3: Conceptual Model of the Intervention

CHAPTER III

LITERATURE REVIEW

III.A. Obesity as a public health problem

Obesity continues to be one of the most important public health problems in the U.S given that 69% of adults are overweight or obese, 36% are obese and 15% are morbidly obese.[1] Chronic diseases affected by obesity such as cardiovascular disease, diabetes, and some cancers are of great concern.[29] Specifically, evidence indicates a positive association between obesity and hypertension, hyperlipidemia[30] and glucose intolerance,[31] and a recent review estimates that 20% of all cancer cases are caused by overweight and obesity.[32] Approximately 300,000 deaths are attributed to obesity each year,[33] and the yearly cost of obesity has been estimated to account for 9% of medical expenses, or approximately 75 billion dollars.[34] Fortunately, risk for most of these health outcomes is greatly reduced with achievement of a healthy body weight.[35]

III.B. Evidence of health benefits from weight loss

Most standard behavioral weight loss interventions produce impressive results in 6-12 months via changes in diet and physical activity behaviors that result in caloric deficits. These interventions include intensive 60-90 minute weekly or bi-weekly sessions for 16-26 weeks, facilitated by highly trained health professionals (e.g., registered dietitians, exercise physiologists, behaviorists).[2,36] Weight losses of 7-10% of initial body weight are seen after

6-12 months.[37,38] Weight loss of at least 5% is associated with clinically meaningful changes in biomarkers associated with chronic disease (i.e., blood pressure, glycemic control, blood lipid levels).[39-41]

Specifically, the Diabetes Prevention Program (DPP) was one of the pivotal weight loss trials examining the effect of weight loss on incidence of chronic disease. This trial was a multicenter study examining the effect of a 6-month lifestyle modification weight loss intervention on the incidence of Type-2 Diabetes after three years compared to a group that received standard lifestyle recommendations for weight loss plus the use of the Diabetes medication Metformin or a group that received standard lifestyle recommendations for weight loss plus a placebo twice daily. The lifestyle intervention group received a 16-lesson curriculum over 24 weeks that focused on promoting a low-fat diet, 150 minutes of brisk walking for exercise each week, and behavior modification strategies with the goal of achieving a 7% weight loss by the end of the study.[42] Results indicated that the lifestyle intervention group lost on average ~7% after 6 months and the incidence of Type-2 Diabetes was significantly lower among those in the lifestyle intervention group compared to the other groups with an incidence reduction of 58% in those receiving the lifestyle intervention and 17% in those receiving the Metformin compared to the placebo group.[43] These results were vital to our understanding about the efficacy of a lifestyle modification weight loss intervention and its impact on clinically meaningful health benefits.

Similarly, results from the Look AHEAD Study, a multisite, 11.5-year trial testing at the efficacy of a lifestyle weight loss intervention on cardiovascular outcomes in individuals with Type-2 Diabetes, indicated that participants assigned to the intervention group lost significantly more weight after 1 year (8.6%) compared to a control group (0.7%) that

received usual care. The intervention was similar to the DPP with regard to dosage, as it included weekly contact for the first 6 months and bi-weekly contact for the second 6 months with trained weight loss counselors either in the form of group or individual contact.[36] In addition to better weight loss outcomes, the intervention group experienced significant improvements compared to the control group in fitness levels, blood pressure, lipid levels, and markers of kidney function, as well as a decrease in the use of medications for hypertension, diabetes, and lipid reduction.[38] This study further indicates the benefit that weight loss can have on reducing the burden from chronic disease.

III.C. Challenges of current weight reduction strategies

Long-term sustainability of weight loss outcomes remains a concern. About 30-35% of participants in weight control trials return to their baseline weight within the 1st year following treatment and about 50% of participants by 5-years post treatment.[44] Although some weight loss was maintained, lifestyle intervention participants within the Diabetes Prevention Program and Look AHEAD Study saw weight regain 10 and 4 years post treatment, respectively.[45,46] Weight regain is likely attributed to difficulty maintaining newly adopted eating and exercise behaviors and consequently, individuals return to old behaviors. Examining approaches to help individuals maintain these behaviors is critical.

Daily self-monitoring of food intake and exercise is the central tenet of most weight loss interventions, typically requiring detailed monitoring of calories and fat content of all foods and beverages consumed, daily physical activity, and weekly monitoring of weight.[2] However, after completion of the program and cessation of frequent accountability, these monitoring behaviors are difficult to sustain.[27,37] This leads to a decrease in actual performance of diet and physical activity behaviors associated with weight loss, and weight

regain occurs.[2]

Results from the National Weight Control Registry (NWCR), a cohort study following approximately 5000 individuals who have lost at least 30 lbs. and maintained that loss for at least 1 year, indicate that individuals who are successful at weight loss maintenance continue to perform the behavioral strategies included in weight loss programs,[47] further confirming the effectiveness of these strategies. After completion of a weight loss intervention, the lack of continued contact may make it difficult to continue compliance with self-monitoring and other weight control behaviors, suggesting that motivation to sustain these behaviors relies on some type of external accountability.[2,37] Interventions focusing on strategies for self-management and self-regulation may help decrease this reliance and lead to greater sustainability of self-monitoring and performance of behaviors associated with weight loss.

III.D. Self-directed, low-intensity approaches for weight control

To help address the recidivism of weight that often occurs post treatment, a self-directed or low-intensity approach to weight loss has been considered a viable alternative to standard behavioral weight loss programs.[48] This lower intensity approach may decrease the reliance on external accountability that so often occurs during standard behavioral weight loss interventions. Self-directed approaches include self-administered manuals, written or email correspondence, computer assisted courses or information, or use of commercial self-guided programs.[49] The addition of minimal contact with a trained therapist may help enhance the effectiveness of this type of approach.[50]

A study from the NWCR found that approximately 30% of individuals who have successfully maintained their weight loss lost the weight on their own, without the assistance of a formal weight loss program.[51] The strategies they utilized are consistent with those

included in formal programs, including weekly self-monitoring of weight, daily self-monitoring of intake, consistent physical activity, and a reduction in caloric intake via use of portion control, decreases in fat intake, and a reduction in certain types or classes of foods (e.g., dessert, sugars). It is important to note, however, that individuals who utilized self-directed approaches to achieve their weight loss tended to be less overweight prior to losing the weight, report less weight cycling, and report less disinhibition for eating behaviors.[51] This suggests individuals seeking a self-directed approach may have fewer barriers to achieving weight control, making this approach more effective, and for others, an intensive program may be more beneficial.

Interventions to test self-directed, lower-intensity approaches for weight control have shown promise. Miller and colleagues tested this type of approach (n=35) against a wait list control group (n=9) among individuals who were previously unsuccessful with self-administered weight loss programs. The 6-month intervention consisted of an initial face-to-face contact followed by a self-guided workbook that included worksheets for self-monitoring of dietary intake and exercise behaviors that focused more on changes in dietary and exercise patterns, and not on severe restrictions in caloric intake. The only additional contacts consisted of the interactions with the staff at the 3 and 6-month assessment visits and monthly mailing of the worksheets to the clinic. Although they experienced 34% attrition, after 6 months the intervention group lost on average 8.1kg ± 0.09kg. This was significantly greater than the control group, which did not show a measureable change in body weight.[52]

Cameron et al. conducted a study to test the effects of a correspondence-based program against a delayed control group that consisted of evaluating the various possible

combinations of 4 components (weekly lessons, weekly homework, interim weigh-ins, and monetary deposits by participants). There were 8 groups total and after 15 weeks, they found a significantly greater weight loss in all the possible groups, except the group receiving lessons only, compared to the delayed control group. What is interesting from these results is that the group receiving lessons plus interim weigh-ins had a significantly greater reduction in BMI compared to the delayed control group.[53] Similarly, Lally and colleagues conducted a brief self-directed weight loss intervention that consisted of similar weigh-ins and a leaflet with recommendations for eating and activity behaviors promoting weight loss, and a self-monitoring checklist. They tested the effect of this approach using a 3-group design, assessing the leaflet with monthly weighing or with weekly weighing in clinic against a delayed control group. Both intervention groups lost significantly more weight after 8 weeks compared to the control group, however, there were no differences between intervention groups.[54] These results suggest that a low-intensity approach that includes weigh-ins and lessons can produce enough of a caloric deficit to result in weight loss.

More recently, Carels and colleagues sought to examine a low-intensity approach via an 18-week stepped-care study where individuals were first provided with a self-directed program and then, if necessary, "stepped up" to a more intensive program with greater support and accountability by trained professionals. The self-directed approach consisted of a one-time session at baseline where individuals received the LEARN manual weight loss program[55] with instructions on how to self-monitor their dietary intake and physical activity and weekly chapters with information about how to produce caloric deficits necessary to lose 1-2 lbs. each week. They found that 41.4% of individuals were successful at meeting the study weight loss goal (2.5%) after 6 weeks and therefore, continued with the self-directed

approach in phase two. This group lost on average 4.5% ± 0.1% of their initial body weight during the first 6 weeks, while those who "stepped up" lost on average only 0.7% ± 0.1% of their initial body weight. During the second phase those who "stepped up" did not achieve any further weight loss, and similarly, the self-directed group maintained their weight losses from phase one without further weight loss.[56] Self-monitoring was the greatest predictor of success for those in the self-directed group, suggesting that including self-monitoring, as a component of a self-directed approach, is necessary to enhance weight loss outcomes.

III.E. Weight loss interventions delivered via the Internet

Delivering weight loss treatment via the Internet may increase sustainability and dissemination potential given no face-to-face contact. Gold and colleagues tested an intensive program delivered via the Internet compared to a commercial online weight loss program. The intervention was similar to the traditional treatments for obesity with the exception of face-to-face contact. The intervention consisted of hour-long weekly group chats with a trained weight loss counselor, weekly weighing, self-monitoring of diet and physical activity behaviors, and prescriptions to achieve diet and physical activity goals associated with achieving a weight loss of 1-2 lbs. per week. After 6 months, intervention participants achieved 7.3±7.8% weight loss on average, while the comparison group lost on average 3.6±6.1%.[57] These results are comparable with findings from standard face-to-face interventions, indicating that an intensive approach can be delivered via the Internet.

Similarly, Tate and colleagues compared an Internet education group to a group that received behavioral weight loss therapy via the Internet, which included weekly emails and behavioral weight control lessons, as well as weekly submission of food and exercise diaries. After 6 months, they found significantly greater weight loss among the group receiving the

Internet-based behavioral weight loss program (1.6 ± 3.3 kg vs. 4.0 ± 2.8 kg, respectively; $p = 0.005$).[58] This indicates that the Internet and email are a viable method to delivery weight loss therapy. Although barriers typical to face-to-face contacts were removed, concerns with regard to long-term sustainability of both of these interventions remain because of the strong reliance on external accountability and detailed self-monitoring that was involved.

Both of the interventions described above included individualized feedback via weekly emails or chats based on self-monitoring behaviors and weight loss progress. However, this type of individualized feedback may contribute to the high intensity nature of the program, which increases reliance of external accountability and may limit the potential for dissemination. The inclusion of tailored feedback may help address some of these concerns. Although this feedback remains individualized, it is less intensive as it relies on the results of particular goals (e.g., eating less fat) and does not require one-on-one email or group chat-based counseling. The effectiveness of this type of feedback was investigated in a study that examined the effect of a computer-automated program for weight loss that included tailored feedback regarding weight and other self-monitoring behaviors (e.g., diet and physical behaviors) compared to a group that received an interactive website but no weekly behavioral feedback. After 3 months, the tailored feedback group lost significantly more weight compared to the no-feedback group (−5.3 ± 4.2 kg vs. −2.8 ± 3.5 kg; p=.005).[59] Within the group receiving the computer-automated program, there was a significant positive relationship between submission of online food and exercise diaries and weight loss, indicating that those that self-monitored more often had better weight loss outcomes. These participants also received more tailored feedback as the tailored responses were based on submission of online diaries. These results suggest that tailored feedback based on self-

monitoring behaviors is an effective approach for weight loss delivered via the Internet.

III.F. Self-weighing frequency and weight loss

The majority of self-weighing evidence indicates that more frequent self-weighing is associated with greater weight loss, however, there remains debate among researchers and practitioners regarding the most appropriate recommendation for self-weighing frequency, with specific focus on the merits of daily self-weighing versus less frequent weekly self-weighing.[7]

Most evidence comparing daily vs. less frequent self-weighing is derived from observational designs in the form of post hoc analyses. The seminal study by Linde and colleagues found, when assessing self-reported self-weighing within the "Weigh to Be" intervention at baseline, 12, and 24 months that a dose-response relationship was present with regards to self-weighing frequency and reduction in BMI. Specifically, individuals who reported daily self-weighing lost on average 1.3 and 2 BMI units at 12 months and 24 months, while those who reported weekly or never weighing lost 1 BMI unit or gained at both time points respectively ($p<.05$).[4] What is even more promising about these results is that they were derived from a community-based weight loss intervention, where weight losses were smaller given the inclusion of lower intensity intervention strategies. Another post hoc analysis looking at effects of self-weighing and weight loss within the "Drop It At Last" trial showed that individuals who reported daily self-weighing lost significantly more weight compared to those who reported weekly or less often self-weighing [-6.8kg (1.3) vs. -3.5kg (1.2) vs. -1.2 (2.0); $p=.04$].[60]

A limited number of interventions tested the impact of daily weighing for weight loss using an experimental design. VanWormer and colleagues evaluated the effect of a 6-month

daily self-weighing intervention on weight loss among participants enrolled in the Weigh by Day Trial with follow-up at 12 and 18 months. This study also used an objective scale that transmitted weight information via a phone line that was received by trained counselors for telephone-based counseling. They found the intervention to be effective compared to a delayed control group (-7.5±1.5 lbs., vs. 1.3±1.4; $p<.05$).[6] Furthermore, those who reported weighing at least weekly were 6 times more likely to have lost at least 5% of their body weight compared to those that weighed less than weekly, and a significant self-weighing by time interaction was found at 6 months ($p<.001$), but not at 12 or 18 months.[61] One concern is the poor adherence to daily weighing during the 6-month intervention period; participants weighed on average 50% of possible days. Furthermore, the amount of attrition seen in this study was concerning (30% at 12 months and 50% at 18 months). Given these attrition rates, the results may not accurately reflect the effect this behavior can have on weight loss.

Only one study manipulated self-weighing examining daily vs. less frequent self-weighing using a randomized controlled design. Gokee-LaRose and colleagues conducted a pilot study (n=40) to assess differences in weight loss after a 10-week intervention and 10-week follow-up period between those receiving a Behavioral Self-regulation program that included daily self-weighing at home, and a Standard Behavioral Treatment program that included weekly weighing in-clinic. There were no differences between groups after 10 weeks [-6.4 kg (4.0) vs. -6.2 kg (4.5)] or 20 weeks [-6.6 kg (5.5) vs. -5.8 kg (5.2)] ($p=0.84$ for time x group analyses).[5] However, the intervention was only 10 weeks, had a small sample size, and only the Behavioral Self-Regulation group was prescribed self-weighing, while intervention staff weighed the Standard Behavioral Treatment group in the study clinic.

Lastly, daily self-weighing was used as a tool to self-regulate body weight within the

STOP Regain trial. The goal of this study was to test the efficacy of delivering a self-regulation program for weight loss maintenance either via the Internet or face-to-face interactions compared to a control group receiving the standard of care. Using the scale, participants were instructed to weigh daily and respond to the number on the scale based on color zones, where green equated to <1.4kg regained, yellow was a regain of 1.4-2.2kg and red was a regain ≥2.3kg. They were told to use the scale in a way similar to using a home thermostat, making adjustments as needed to remain in energy balance. Specifically, they received guidance on how to make changes to their eating and exercise behaviors based on the different color zones. Daily self-weighing increased in both intervention groups and was associated with an 82% reduction in risk of regaining 2.3 kg or more as compared to the control group ($p<0.001$). These results indicate not only that daily self-weighing is associated with better weight loss maintenance, but also that self-weighing frequency can be enhanced within the context of a scale-based intervention. Furthermore, the study achieved 93% retention across all groups at 18 months, indicating that participants were willing to participate in a scale-based intervention that focused on daily self-weighing for self-regulation.[62]

These results indicate that daily weighing is effective for weight control, but that more experimental research for weight loss is needed examining either the additive benefit of daily weighing compared to less frequency weighing or daily weighing within a self-regulation program for weight loss.

III.G. Dietary and physical activity behaviors associated with self-weighing

Self-weighing does not impact weight loss directly, but rather likely via diet and physical activity behaviors that result in caloric deficits. Limited evidence specifically links

self-weighing frequency with diet and physical activity behaviors. Linde and colleagues examined differences in baseline characteristics of individuals who reported greater than or equal to weekly weighing compared to those who reported less than weekly weighing. The results indicated that those who reported at least weekly self-weighing ate less fat and walked more blocks each day.[63] With adolescents, Alm and colleagues found that those who reported more frequent self-weighing ate less food, less calories, and followed more of a structured diet.[64] Qi and Dennis found that there was a significant increase in daily self-weighing in those that lost at least 5kg, and also found increases in self-monitoring of intake, restraint, and stimulus control with regards to eating behaviors.[65]

However, none of these studies examined the relationship between self-weighing and these behaviors using a prospective or temporal relationship. Understanding the mediating mechanisms through which more frequent self-weighing impacts key behaviors is important to understanding how this behavior is effective for weight loss. Using mediation analysis will allow for a greater understanding of the causal relationship rather than just an association.[66]

III.H. Negative psychological consequences associated with self-weighing

Although more frequent self-weighing appears to be effective for weight loss, there remains concern about the possible negative psychological consequences associated with this behavior.[8] Previous research, mostly derived from psychological experiments that did not focus on weight control, suggests that awareness about body weight in general may be associated with greater body dissatisfaction[67] and depression.[68,69] These results seem to be heightened among those who report restrained eating.[70] Most of the evidence, however, was obtained from experiments with normal weight adults responding to false weight feedback at

one point in time about current weight status. Results indicate that individuals who were told they were overweight reported poorer psychological outcomes compared to those who were told their weight was normal.[71] Although compelling, the reaction to false feedback among normal weight individuals is not necessarily comparable to using the scale to self-monitor progress among overweight and obese adults looking to lose weight. Furthermore, these studies examined one time weighing and its impact on psychological state. This is not the same as using self-weighing as a self-monitoring tool for weight loss over time where habituation to this behavior might decrease the amount of value-laden judgment from the number on the scale.

To our knowledge, only one study has looked at the impact of daily self-weighing specifically, outside of a weight control intervention. Ogden and Whyman experimentally tested the impact of this behavior among normal weight, non-treatment seeking female college students (n=30) on a variety of psychological outcomes after 2 weeks of daily weighing against a no-weighing group. Results show that there was a significant difference between groups with regard to mood and self-esteem, with the intervention group reporting poorer outcomes.[69] However, this study evaluated the impact of daily weighing with a small sample size over a 2-week period, and included normal weight, young adult females who were not seeking weight loss treatment. These results are not necessarily applicable to a population of overweight and obese adults looking to lose weight, who would use daily weighing as a self-monitoring tool for long-term weight management.

O'Neil and Brown conducted a review of the claims regarding the negative consequences associated with self-weighing and found that self-weighing by obese and overweight adults trying to lose weight does not cause negative mood or body dissatisfaction,

[72] and there is also limited evidence that these states lead to poorer weight loss outcomes.[73] What is most important, they state, is that there might be negative effects of scale avoidance given the effectiveness of self-weighing for weight control. There appears to be no risk for adverse outcomes, rather potential improvements, when examining evidence from weight control interventions.

Welsh and colleagues examined differences in body dissatisfaction between those weighing weekly or daily and found that self-weighing frequency was not associated with greater body dissatisfaction, and in fact may have improved body satisfaction. They state that these results are possibly due to the hypothesis that self-weighing increases self-efficacy for weight loss, which would enhance body satisfaction.[60] With regard to outcomes associated with eating disorders, Gokee-LaRose and colleagues looked at the effect of a daily weighing intervention for weight loss among young adults and found no increased risk for development of eating disorders, negative body image, or mood disorders; rather, improvements were seen on all parameters.[5] Linde and colleagues examined whether there was an association between self-weighing and BMI among overweight adults with or without depression. They found that more frequent self-weighing and lower depression scores were associated with lower BMI, but that there was no interaction between depression and self-weighing, suggesting the effect of depression status does not vary by self-weighing frequency.[74] Similarly, among individuals enrolled in a weight loss maintenance intervention, more frequent self-weighing was associated with decreases in disinhibition and depressive symptoms. Furthermore, individuals who weighed daily were less likely to report binge-eating episodes.[75] These results suggest that self-weighing, regardless of frequency, does not pose a threat to adverse psychological outcomes; rather it can possibly help prevent negative

consequences in individuals trying to lose weight.

III.I. Summary and potential implications

In summary, obesity continues to be a very challenging public health problem. Creating effective and sustainable strategies to enhance weight reduction would have strong public health implications. Standard behavioral weight loss interventions include regular face-to-face contacts and detailed self-monitoring of diet and exercise behavior, however, the high intensity of these components may not be sustainable long-term. The literature suggests that a low intensity approach can be effective for producing clinically significant weight loss, especially when self-monitoring is a central component. This effectiveness may be enhanced with the addition of minimal contact or tailored feedback. Delivering this type of approach via the Internet can increase the potential for dissemination.

Previous evidence indicates that daily self-weighing may be more beneficial for weight loss, and weight control overall, compared to less frequent self-weighing. Similarly, more frequent weighing appears to be associated with positive changes in behavioral outcomes and without concern for psychological harm among overweight and obese adults looking to lose weight. Despite this, a recent review of the self-weighing literature stated, "At this time, the evidence base does not support endorsement of a precise self-weighing frequency and duration that has the most benefit for the most people."[7] Given that practitioners give varying recommendations of self-weighing frequency for weight loss,[76] having a randomized design to test the efficacy of daily self-weighing is vital. Additionally, only one study objectively measured self-weighing frequency. Using an objective measure would help prevent potential systematic measurement error with regards to recall because the reporting of self-weighing at one particular time point may not accurately reflect consistent behavior over a given period

of time.

In summary, more research is necessary to test lower intensity interventions delivered via the Internet that focus on self-regulation for weight loss via daily self-weighing This dissertation project will help address some of these gaps by evaluating the behavioral mechanisms through which daily weighing leads to weight loss, as well as the effect of a daily self-weighing intervention on weight loss and psychological outcomes using an experimental study design and inclusion of an objective measurements of self-weighing. Should daily self-weighing appear efficacious, and continue to show no adverse psychological outcomes, this simple self-monitoring strategy could be implemented on a large scale to increase weight loss success, which in turn would have strong implications for the prevalence of obesity on a population level.

CHAPTER IV

MECHANISMS LINKING DAILY SELF-WEIGHING AND WEIGHT LOSS AMONG OVERWEIGHT ADULTS

IV.A. Overview

Evidence indicates that daily self-weighing is associated with greater weight loss compared to less frequent weighing. This is likely via direct impact on behaviors that produce caloric deficits. However, these mechanisms have not been thoroughly tested. The purpose of this analysis was to examine whether diet and physical activity behaviors act as possible mediators between daily self-weighing and weight loss among participants enrolled in a 12-month Internet behavioral weight loss intervention.

The association between daily self-weighing and weight loss was analyzed using participants (n=158) from the HealtheLife Study: a randomized trial that compared group chats vs. individual email counseling for weight loss. Multiple mediation analysis was conducted using bootstrapping to assess whether caloric intake, eating behaviors, and physical activity act as mediators between daily self-weighing and weight loss at both 6 and 12 months. Using ANOVA, those who reported daily weighing often or always had greater percent weight loss compared to those that reported less frequent weighing at both 6 months [(8.27% (5.40) vs. 5.51% (5.41); p=.003] and 12 months [8.09% (7.81) vs. 4.60% (6.35); p=.004]. Multiple mediation analysis showed that for 6-month weight loss, eating and exercise behaviors acted as mediators between daily self-weighing and weight loss. Only

eating behaviors acted as a mediator for 12-month weight loss.

Results confirm that daily weighing is associated with greater weight loss compared to less frequent weighing. These findings also suggest that daily weighing leads to greater engagement in diet and physical activity behaviors associated with producing a caloric deficit, which in turns leads to weight loss.

IV.B. Introduction

Obesity continues to be one of the most important public health problems in the U.S given that 69% of adults in the U.S. are overweight or obese and 36% are obese.[1] Chronic diseases affected by obesity are of great concern.[29] Fortunately, risk for these health outcomes decreases with even small reductions in body weight.[35]

Evidence indicates that self-monitoring of weight is an effective weight control strategy.[7,26] This is supported by self-regulation theory, which posits that individuals self-monitor and self-evaluate when behavior change is necessary in response to some feedback. This feedback allows for a judgment that results in either positive reinforcement or punishment regarding the behaviors associated with that feedback.[11,12] In this instance, self-weighing is the self-regulatory behavior and the scale provides the feedback about how eating and exercise behaviors affect body weight. Given this, more frequent weighing will provide more proximal feedback, making it easier to connect specific behaviors with changes in body weight.[3]

The majority of evidence suggests that a dose response pattern is present with regard to self-weighing frequency and weight loss; daily weighing is associated with greater weight loss compared to weekly or less frequent weighing.[4,60] Although more frequent weighing appears to be associated with greater weight loss, few studies have examined the relationship

between daily self-weighing and eating and exercise behaviors that may lead to weight loss. Given that simply stepping on the scale will not produce weight loss, it is important to have an understanding of *how* this daily behavior leads to better weight control. To our knowledge, no studies have examined the mechanisms explaining the relationship between daily self-weighing and weight loss using mediation analysis. This type of analysis will allow for a better understanding of the causal relationship.[66]

This study involved a secondary analysis of data from the HealtheLife Study to examine the impact of daily self-weighing on weight loss and the mechanisms linking those variables over time within the context of a weight loss intervention. Consistent with previous research and self-regulation theory, it was hypothesized that individuals who reported daily self-weighing would have greater percent weight loss after 6 and 12 months compared to those that reported less frequent self-weighing. Furthermore, it was hypothesized that individuals who reported daily self-weighing would report greater engagement in eating and exercise behaviors associated with weight loss, which would then lead to greater weight loss at both 6 and 12 months compared to those that reported less frequent self-weighing.

IV.C. Methods

Sample

The data used for this analysis were from the HealtheLife Study, a 12-month Internet behavioral weight loss intervention conducted in Chapel Hill, NC and Providence, RI. The purpose of the HealtheLife Study (n=158) was to test the efficacy of two different Internet weight loss programs, with the goal of comparing group vs. individual delivery modalities of a standard behavioral weight loss intervention on percent weight loss at 12 months.[77] All groups were instructed to self-weigh at least weekly, with no specific emphasis on daily

weighing. All measures were obtained at baseline, 3, 6, and 12 months. The present analyses were conducted on those with available data for all measures at that follow-up. The sample for the weight loss analysis was 144 at 6 months and 141 at 12 months. For the mediation analysis, the sample was decreased to 127 for the 6-month data and 124 for the 12-month data.

Measures

Weight

Percent weight loss at 6 and 12 months was calculated from measured weights. Weights were measured in person, in hospital gowns without shoes using a digital scale.

Daily Self-weighing

The primary independent variable was daily self-weighing frequency over the past 3 months, which was assessed via the Eating Behavior Inventory question "*I weigh myself daily*." The Eating Behavior Inventory (EBI) is a 26-item questionnaire developed from a survey of behavioral treatment manuals with the goal of generating items that represented specific behaviors that had been empirically and theoretically implicated in weight loss.[9] The item regarding daily self-weighing has 5 response options that include *never/hardly ever, some of the time*, *about half of the time*, *much of the time*, and *always or almost always* with values of 1-5 attached to those responses. To better understand weighing frequency throughout the intervention, an average daily self-weighing score was calculated by averaging the 3 and 6-month measurements for the 6-month outcomes and the 3, 6, and 12-month measurements for the 12-month outcomes. Baseline values were excluded, as they were not affected by the intervention and therefore would possibly misrepresent the effect of daily self-weighing on weight loss within the context of a weight loss intervention. Average

daily self-weighing frequency was then dichotomized and categorized as *rarely/sometimes* (1-3.9), and *often/always* (4-5) in order to capture the effect differences between those that reported almost always doing this behavior compared to those that reported rarely or sometimes doing this behavior.

Eating and Exercise Behaviors

Caloric Intake

Caloric intake was measured using the Block Food Frequency Questionnaire (FFQ). This FFQ is a 98-item questionnaire that has been shown to be a moderately valid[78] and reliable measure[79] of total energy intake compared with more objective measures of food intake.

Eating Behaviors

Eating behaviors associated with weight loss were also assessed via the EBI over the previous 3 months. The questionnaire includes both positive and negative behaviors, and negative behaviors are reverse scored to allow for calculation of a total score and assessment of whether higher scores are associated with better outcomes. An example of a positive behavior includes *I refuse food offered to me by others* and an example of a negative behavior includes *I eat when I am not really hungry.* Previous studies have shown the EBI to have moderate-high test-retest reliability (r =0.74).[80] Evidence indicates that EBI scores increase at the end of weight loss intervention and higher scores are associated with better weight loss outcomes.[81] Total EBI scores were calculated with removal of the daily self-weighing question.

Energy Expenditure

Exercise habits were assessed using the Paffenbarger Exercise Habits Questionnaire, which captures leisure time physical activity. Data were analyzed as total energy expenditure from physical activity per week.[82] This questionnaire has moderate to high test-retest reliability (r =0.72),[83] and has been used in previous weight loss interventions to capture changes in physical activity.[84]

Additional covariates considered for inclusion in the models that might act as confounders are age, sex, and race/ethnicity.

Statistical Analyses

Given no differences in weight loss (data not shown), both intervention groups were collapsed into one group for the purposes of this analysis. ANOVA was conducted to examine the relationship between the dichotomous daily self-weighing variable and the continuous measure of percent weight loss at both 6 and 12 months. No imputations for missing data were conducted and participants with any missing values were assumed to be missing at random. Log transformations were made for continuous variables showing a non-normal distribution. Energy expenditure from physical activity was the only variable that required a log transformation. Weight loss over time was expressed as percent of baseline weight lost.

Multiple mediation analysis was conducted using the methods of MacKinnon[85] and Preacher and Hayes[86] to assess the mediating effects of eating and exercise behaviors between daily self-weighing and weight loss controlling for appropriate covariates (age, sex, race/ethnicity) and baseline values of the mediators to assess changes over time. This method allowed for analysis of one mediator controlling for the effect of the other mediators,

with additional control of covariates that might be associated with the variables in the model but were not mediators. For 6-month percent weight loss we examined daily self-weighing at 3 months and its impact on the mediator measured at 6 months. This was done to account for temporality as each measurement reflected behavior over the past 3 months. Similarly for 12-month weight loss, we examined daily self-weighing at 6 months with the mediator at 12 months. This analysis initially included a series of regression analyses to assess the significance between the *a, b, c,* and *c'* paths (Figure 4). Path *c* represents the *total effect*, which is the relationship between the independent variable and the dependent variable. Path *a* represents the relationship between the independent variable and the mediator, path *b* is the relationship between the mediator and the dependent variable controlling for the independent variable, and path *c'*, the *direct effect*, is the relationship between the independent variable and the dependent variable controlling for the mediators.[87] Point estimates are presented as unstandardized beta coefficients.

Bootstrapping was then used to assess the significance of mediated effect, also known as the *indirect effect*. This is a more robust method for assessing the indirect effect as is does not require a normal distribution to be present, which is typically assumed for other tests of the indirect effect, namely the Sobel test.[86,87] Bootstrapping allowed for assessment of whether the indirect effects (a*b) were significantly different from zero by creating multiple sampling distributions (5000) and using these estimates to calculate the point estimate for the indirect effect. The standard error from the point estimate allowed for calculation of a 95% confidence interval; if zero was not contained in the confidence interval, then the indirect effect was significant and mediation was present.[86,87] A p-value of <0.05 was used to assess significance for all tests. All analyses were performed using SPSS (Version 19, Chicago, IL).

IV.D. Results

Table 1 contains sample characteristics. Participants were on average 46.2±8.6 years old, obese (BMI: 31.7± 4.2 kg/m^2), predominantly female (83%) and White (87%).

Main outcomes

Figure 5 presents self-weighing frequency among the participants. Over the past 3 months, 24.1% of participants reported *often or always* daily self-weighing at baseline, while 39.2% and 37.3% reported *often or always* daily weighing at 6 and 12 months respectively. Figure 6 presents the weight loss data by self-weighing frequency. Individuals who reported *often or always* daily self-weighing had greater percent weight loss compared to those that reported less frequent self-weighing at both 6 months [(8.27% (5.40) vs. 5.51% (5.41); p=.003] and 12 months [8.09% (7.81) vs. 4.60% (6.35); p=.004]

Mediation Outcomes

Table 2 shows the indirect effects from the multiple mediation models for each of the mediators at both time points. At 6 months, the effect of daily weighing *often or always* on weight loss was marginally significant (path c: $\beta = 1.81$ +/- 0.93 $p = .054$). For eating behaviors (EBI), daily weighing was significantly associated with higher EBI score [path a1: $\beta = 5.24$ +/- 2.1, $p = .01$] and EBI score was significantly associated with greater weight loss (path b1: $\beta = .12$ +/- .04, $p = .002$). For energy expenditure (PA), daily weighing was significantly associated with greater engagement in physical activity (path a3: $\beta = .32$ +/- .16, $p = .04$) and physical activity was significantly associated with greater weight loss (path b3: $\beta = 1.2$ +/- .51, $p = .02$). There were no significant associations for caloric intake. The effect of daily weighing on weight loss was attenuated and non-significant when caloric intake, EBI and PA were entered into the model (path c1': $\beta = 0.88$ +/- .89, $p = .33$). This suggests full

mediation. A significant indirect effect was seen for both eating behaviors and physical activity at 6 months, indicating that these variables significantly mediated the relationship between daily self-weighing and weight loss [EBI: β = 0.64 (95% CI: .16, 1.45); p <.05; PA: β = 0.39 (95% CI: .02, 1.15); p <.05]. The indirect effect for caloric intake was non-significant [β = -0.09 (95% CI: -0.73, 0.09); p >.05];

At 12 months, the effect of daily weighing often/always on weight loss was significant (path c: β = 3.70 +/- 1.26 p = .004). For eating behaviors, daily weighing was significantly associated with higher EBI score (path a1: β = 5.72 +/- 2.1, p = .007) and EBI score was significantly associated with greater weight loss (path b1: β = .18 +/- .05, p = .001). For energy expenditure, daily weighing was not significantly associated with greater engagement in physical activity (path a3: β = .14 +/- .20, p = .49) and PA was also not significantly associated with weight loss (path b3: β = .56 +/- .57, p = .32). Similar to the 6-month outcomes, there were no significant associations for caloric intake. The effect of daily weighing on weight loss was attenuated but remained significant when EBI, caloric intake, and PA score were entered into the model (path c1': β = 2.42 +/- 1.2, p = .047). This suggests partial mediation. For 12 months, only eating behaviors produced a significant indirect effect [β = 1.26 (95% CI: .30, 3.04); p <.05]. The indirect effects for physical activity and caloric intake at 12 months were non-significant [PA: β = .07 (95% CI: -.14, .68); p >.05; Caloric Intake: β =.15 (95% CI: -0.08, 1.0); p >.05]. Thus, when conducting multiple mediation analysis, both eating behaviors and physical activity helped explain the relationship between daily self-weighing and weight loss at 6 months, but at 12-months only eating behaviors acted as a mediator. Caloric intake did not mediate the relationship at either time point.

IV.E. Discussion

Consistent with previous research, we found that daily self-weighing was associated with greater weight loss compared to less frequent weighing among overweight individuals enrolled in a weight loss intervention. This analysis sought to add to the evidence base with an examination of the mechanisms explaining that relationship using mediation analysis. We found that those who reported daily self-weighing more often were more likely to report greater engagement in eating and exercise behaviors associated with producing a caloric deficit. This, in turn, led to greater percent weight loss at 6 months compared to those that reported daily weighing less often.

At 12 months, only changes in eating behaviors explained how daily weighing led to greater weight loss. The lack of mediation findings for physical activity at 12 months may be because energy expenditure decreased between 6-12 months in all participants, and there was a small amount of weight regain during this time period. Caloric intake was not associated with daily weighing or weight loss. The reason for this may be because food frequency questionnaires provide a better representation of overall dietary patterns and are a less precise measure of caloric intake.[88] What is shown, however, is that those who reported daily weighing more consistently were more likely to engage in dietary behaviors associated with weight loss, as measured by the EBI. This suggests that daily weighing may lead to greater self-regulation of eating behaviors that are encouraged during weight loss interventions to produce caloric deficits (e.g., *I leave food on my plate, I decide ahead of time what I will eat for meals and snacks*). While the present analysis controlled for the temporal factors, we don't know when these behavior changes truly occurred and whether daily weighing is a part of a constellation of behavior changes that occur simultaneously.

Prior to this study, limited evidence examined the link between self-weighing frequency and diet and physical activity behaviors, as well as other behaviors associated with weight control. Linde and colleagues examined differences in baseline characteristics of individuals who reported greater than or equal to weekly weighing compared to those who reported less than weekly weighing. The results indicated that those who reported at least weekly self-weighing ate less fat and walked more blocks each day.[63] With adolescents, Alm and colleagues found that those who reported more frequent self-weighing ate less food, less calories, and followed a structured diet.[64] Qi and Dennis found that there was a significant increase in daily self-weighing in those that lost 5kg, and also found increases in self-monitoring of intake, restraint, and stimulus control with regards to eating behaviors.[65] Consistent with our findings, these results suggest that daily weighing is associated with dietary strategies for weight loss. However, these previous analyses were conducted cross-sectionally, making it unclear as to whether the more frequent weighing caused individuals engage in weight loss behaviors or if greater engagement in these behaviors and greater weight loss led to more frequent weighing. The present analysis provides more temporal evidence regarding the mechanisms between daily weighing and weight loss.

Limitations

This study has some limitations that are worth mentioning. As a secondary data analysis, we were limited to a self-report, one-item measure of daily self-weighing that assessed the frequency of daily weighing and not overall self-weighing frequency. Our sample was predominantly female and White, and the intervention was delivered solely via the Internet. This limits the generalizability of the results to other populations and delivery modalities. Furthermore, we included participants in this analysis with complete data, thereby

limiting the sample size. However, the sample size of was still large enough to conduct mediation analysis using bootstrapping.[89]

Strengths

Despite these limitations, these analyses have several strengths. Previous research examining self-weighing with both behavioral and weight outcomes suffered from a lack of understanding regarding temporality, where both variables were measured simultaneously. This makes it difficult to determine whether daily weighing led to greater weight loss or greater weight loss led to more frequent weighing. Although not as ideal as an experimental manipulation, the longitudinal data in this study accounted for temporality by examining the variables at multiple times throughout the study period, which suggest that perhaps daily weighing preceded changes in eating and exercise behaviors, as well as weight loss.

None of the previous evidence examined the relationship between self-weighing and these behaviors using mediation analysis, which adds to the evidence base with robust methods. Despite this, more experimental research manipulating daily self-weighing is necessary to provide a greater understanding as to whether daily weighing causes weight loss and the mechanisms explaining that relationship. Furthermore, it will be important to utilize an objective measure of self-weighing to better capture the impact of self-weighing frequency on weight loss

IV.F. Conclusions

This study suggests that daily weighing leads to weight loss via changes to behaviors that can produce a caloric deficit compared to less frequent weighing. Daily weighing was particularly effective for self-regulation of eating behaviors associated with weight loss. Daily self-weighing is a simple weight control strategy that, if implemented on a larger scale,

could have strong public health implications with regards to overweight and obesity. Future studies using an experimental design are necessary to determine the causal relationship between daily weighing and weight loss.

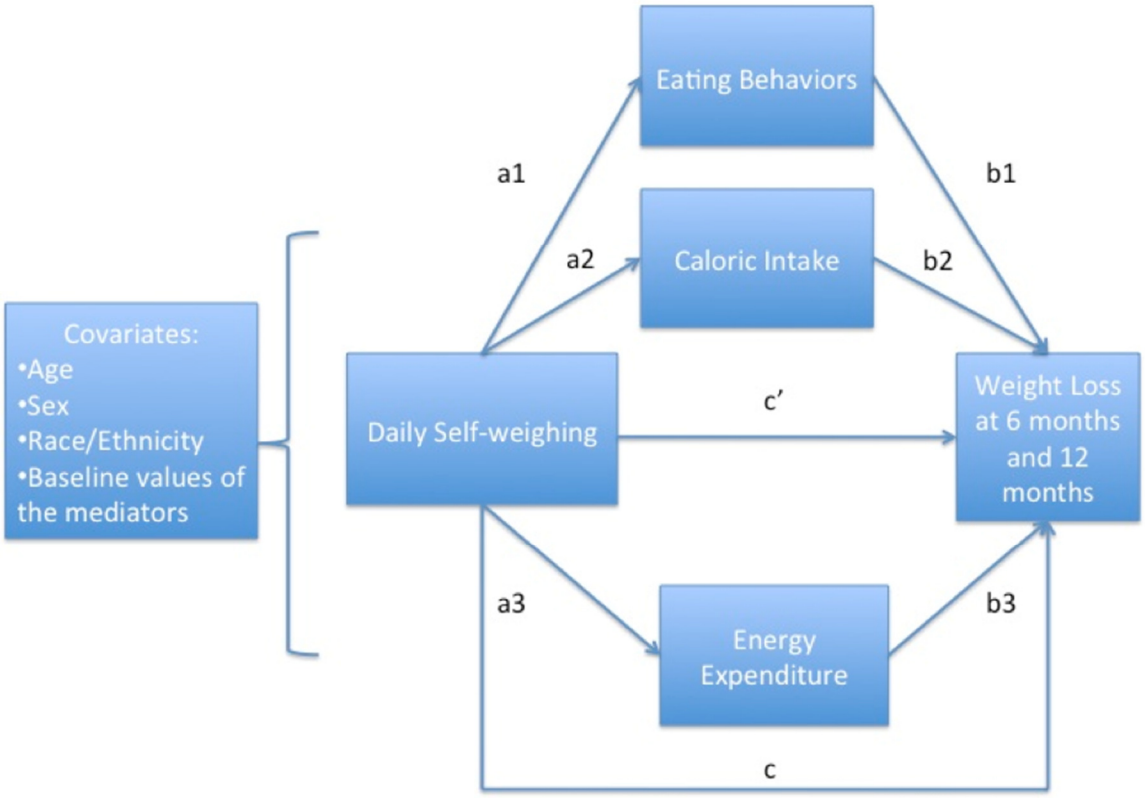


Figure 4: Multiple Mediation Model

Table 1: Descriptive baseline characteristics of participants in the HealtheLife Study of those included and excluded from the analytical sample at 12 months (n=158)

Baseline measure	**Included (n = 141)**	**Excluded (n = 17)**	**p-value**
Age (years)	46.2 ± 8.6	45.1 ± 10.8	0.605
BMI (kg/m^2)	31.7 ± 4.2	31.9 ± 3.9	0.860
Sex			
Male	24 (17%)	4 (23%)	0.353
Female	117 (83%)	13 (77%)	
Race/ethnicity			
White, non-Hispanic	123 (87%)	15 (88%)	0.633
Not White, or Hispanic	18 (13%)	2 (12%)	
Daily self-weighing frequency			
Often/Always	35 (25%)	3 (18%)	0.377
Rarely/Sometimes	106 (75%)	14 (82%)	

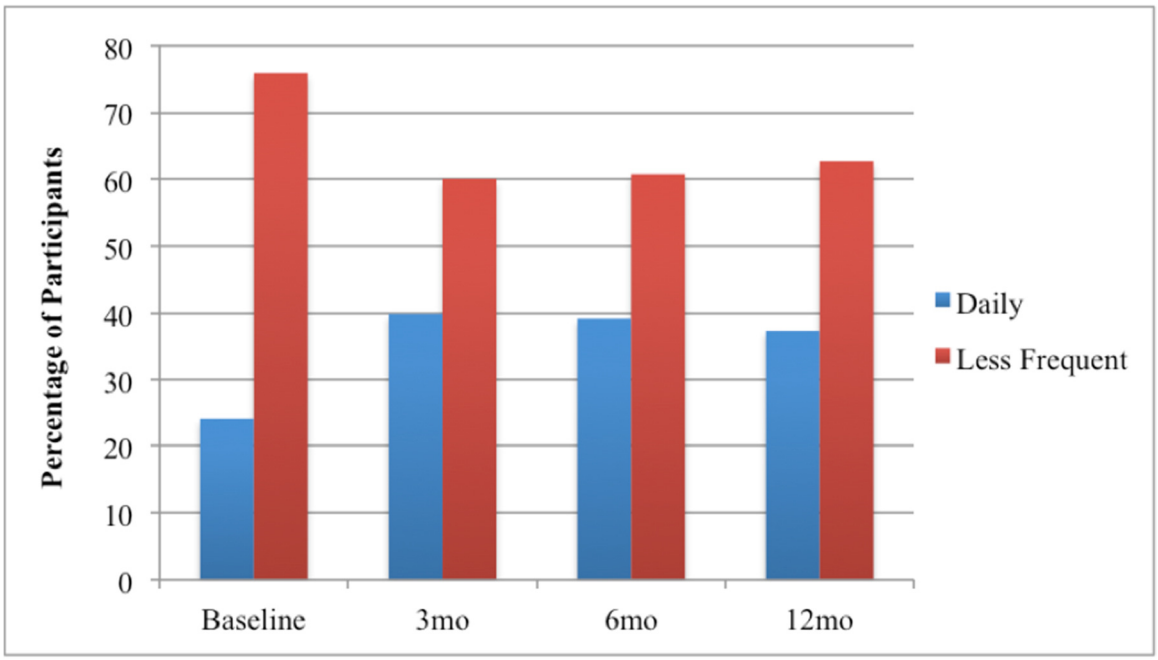


Figure 5: Self-weighing frequency among study participants at all time points

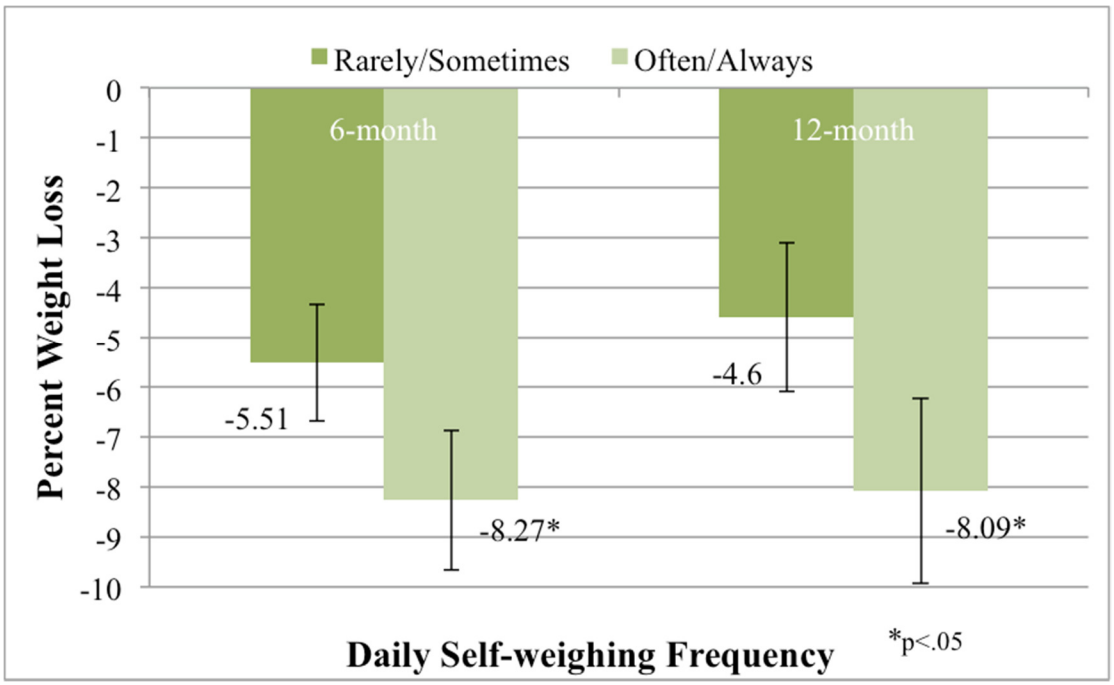


Figure 6: Weight loss by self-weighing frequency (6 months: n=144; 12 months: n=141)

Table 2: Indirect effects of daily self-weighing on weight loss at 6 and 12 months through changes in caloric intake, eating behaviors, and physical activity

	Point Estimate	95% CI*	
		Lower Bound	Upper Bound
Indirect Effects at 6 months			
Eating Behaviors	.642	.159	1.455
Caloric Intake	-.090	-.732	.091
Physical Activity	.386	.025	1.151
Indirect Effects at 12 months			
Eating Behaviors	1.058	.239	2.896
Caloric Intake	.147	-.081	1.011
Physical Activity	.078	-.160	.692

[a] Multiple Mediation Analysis; 5000 bootstrap samples.

[b] Confidence intervals containing zero are interpreted as not significant.

[c] N = 127 at 6 months and 124 at 12 months;

CHAPTER V

THE EFFICACY OF A DAILY SELF-WEIGHING WEIGHT LOSS INTERVENTION USING SMART SCALES AND EMAIL

V.A. Overview

Limited experimental evidence has examined the impact of daily self-weighing on weight loss among overweight adults. Overweight and obese men and women (n=91) were randomly assigned to a daily self-weighing intervention or delayed control group. The 6-month intervention included a cellular-connected "smart" scale for daily weighing, web-based graph of weight loss, and weekly emails with tailored feedback and lessons on behavioral weight control. Weight was measured in clinic at 3 and 6 months. Smart scales provided an objective measure of self-weighing frequency. At all time points, caloric intake and expenditure, and perceptions of daily self-weighing were measured.

Using intent-to-treat analyses with linear mixed models, the intervention group lost significantly more weight compared to the control group [Mean (95%CI); 3 months: -4.41%(-5.5, -3.3) vs. -0.37%(-1.5, .76); 6 months: -6.55%(-7.7, -5.4) vs. -0.35%(-1.5, .79); group x time interaction: $p<.001$]. At 6 months, a greater percentage of the intervention group achieved 5% (42.6% vs. 6.8%; $p<.0001$) and 10% (27.7% vs. 0%; $p<.0001$) weight loss. On average, the intervention group self-weighed more days/week (6.1±1.1 vs. 1.1±1.5; $p<.0001$) and consumed fewer calories/day compared to the control group [Mean (95% CI); 6 months: 1509 (1291, 1728) vs. 1856 (1637, 2074); group x time interaction: $p=.006$]. Among

intervention participants, daily self-weighing was perceived as an easy, positive and helpful behavior. These results indicate that an intervention focusing on daily self-weighing can produce clinically significant weight loss, as well as positive changes in behavioral outcomes. This further establishes daily self-weighing as a feasible and effective weight loss strategy.

V.B. Introduction

Recent estimates indicate that 69% of Americans are overweight or obese.[1] This has major implications for the incidence and prevalence of chronic diseases such as heart disease and diabetes,[29] as well as some cancers.[32] Evidence indicates that even 5-10% weight losses can reduce risk factors for these diseases.[39-41] Standard behavioral weight loss interventions that include frequent face-to-face interactions with a trained weight loss counselor and detailed self-monitoring of diet and physical activity behaviors produce on average about 7-10% weight loss after 6-12 months,[2,38,43] however, the intensive nature of these interventions limits their potential for dissemination. This indicates a need for effective, lower intensity programs that reduce the burden of frequent face-to-face contacts and increases the potential for broader public health impact and reach.

One of the most effective strategies within most weight loss interventions is self-monitoring of diet, physical activity, and weight.[26,90] Self-monitoring provides personal accountability and allows for greater awareness of how behaviors are impacting weight.[27] The mechanism of self-monitoring is suggested by Kanfer's Model of self-regulation: self-monitoring provides feedback that allows for greater awareness, which can lead to greater self-efficacy, self-control, and self-initiated reinforcement.[28] Kanfer posits that individuals self-evaluate by comparing the feedback to the performance criterion, which allows for a

judgment to be made that either results in positive reinforcement or a lack of reinforcement for specific behaviors.[11,12]

Despite being effective and theoretically grounded, detailed self-monitoring of diet and physical activity behaviors is difficult to sustain. Burke and colleagues found that adherence to self-monitoring protocols declines dramatically over time during participation in a behavioral treatment program for weight loss.[91,92] Furthermore, qualitative evidence indicates that the labor intensive nature of self-monitoring leads to feelings of being overwhelmed, frustrated, and defeated.[93] Given poor adherence, a need exists for interventions that test simple and sustainable types of self-monitoring strategies.

Self-weighing is a simple self-monitoring behavior that has been shown to be useful for self-regulation of body weight.[94] Self-weighing provides feedback suggestive of how eating and exercise behaviors are impacting weight, and acts as a tool to allow individuals to make small adjustments to these behaviors to affect energy balance. Based on self-regulation theory, daily weighing is optimal over less frequent weighing because the feedback is more proximal, making it easier to attribute changes in weight to specific diet and physical activity behaviors. This allows for better self-regulation as small changes in body weight can be identified and resolved, likely leading to greater self-efficacy and empowerment over one's ability to regulate their body weight.[3]

A recent review of the self-weighing literature indicates that daily self-weighing is associated with greater weight loss compared to less frequent weighing.[7] The seminal study by Linde and colleagues found that individuals who reported daily self-weighing saw a significantly greater reduction in body mass index compared to those who reported weekly or never weighing.[4] Welsh and colleagues also examined the impact of self-weighing on weight

loss within a phone-based weight loss intervention and found a similar dose response pattern.[60]

Both of these studies, however, examined daily weighing and weight loss post hoc using an observational study design making it impossible to ascertain if the weight losses seen were a result of daily weighing or if losing weight led to more frequent weighing. Furthermore, a retrospective self-report measure of self-weighing frequency was used, which may have introduced systematic recall bias. Experimental evidence does indicate that daily self-weighing is effective for self-regulation of body weight during weight loss maintenance.[62] However, there is limited experimental evidence examining whether daily self-weighing is effective for weight loss, when coupled with a lower intensity intervention.[5,61]

The purpose of the WEIGH Study (Weighing Every day to Improve and Gain Health) was to improve on previous evidence and test whether a lower intensity, and potentially sustainable, intervention focusing on daily self-weighing can produce significantly greater weight loss compared to a delayed intervention control group. In order to test a lower intensity approach, we included no regular face-to-face contact, relied solely on tailored feedback, and did not emphasize self-monitoring of diet and physical activity behaviors. An objective measure of self-weighing frequency was utilized to provide an accurate assessment of this behavior. We hypothesized that the group receiving the intervention would have greater percent weight loss at 3 and 6 months compared to a delayed control group, as well as more positive changes in diet and physical activity behaviors.

V.C. Methods

Participants

Inclusion criteria included men and women ages 18-60 with a body mass index (BMI) between 25-40 kg/m^2 and a maximum weight of 330 lbs. (the maximum weight allowable on the scales provided). Participants were also required to have access to the Internet to allow for weight tracking. Exclusion criteria included having a pre-existing medical condition (i.e., myocardial infarction within the past 2 years, cancer diagnosis (non-skin) within the past 5 years, uncontrolled high blood pressure, unstable thyroid disease, current treatment for psychiatric disorder other than depression, hospitalization for depression within the past year, or history of eating disorder), pregnant or nursing within the past 6 months or planning to become pregnant, currently undergoing treatment for substance abuse, or planning to move out of the area. Individuals were also excluded if, within the past 6 months, they participated in a structured weight-loss program or lost and kept off at least 10 lbs. of their body weight.

Recruitment

Participants were recruited via 1) an advertisement on a university listserv, 2) flyers posted around UNC Chapel Hill, and 3) flyers posted in medical offices in the Chapel Hill, NC area. Those who were eligible and interested were invited to an orientation session where they were provided with more details about the study and informed consent was obtained. Baseline measures were obtained prior to randomization being revealed to participants by blinded evaluation staff. Data were collected between February 2011 and November 2011 in Chapel Hill, NC. The University of North Carolina at Chapel Hill Institutional Review Board approved and monitored the study (clinicaltrials.gov Identifier: NCT01369004). Participants received $25 as an incentive for completion of follow-up

assessments at 3 and 6 months.

Study Design and Intervention Description

Participants were randomized to one of two treatment groups (Figure 1): A daily self-weighing intervention group or a delayed intervention control group. The 6-month intervention consisted of 4 main components: (1) cellular-connected "smart" scales for daily weighing; (2) web-based graph of weight trends overtime; (3) weekly tailored feedback via email on self-weighing frequency and weight loss progress; and (4) 22 weekly lessons on behavioral weight control via email. Intervention participants were instructed to weigh daily at the same time each day using the smart scales. The smart scale displayed current weight and sent it directly to a website (www.bodytrace.com) via the wireless cellular network. The scales did not rely on an individual's cell service, but rather were connected to the Body Trace website via a separate cell service embedded in the scales. This allowed participants to use the scales in any location that had cell service. Participants were able to view on the website a graph of weight trends overtime.

Weight and weighing data were accessible for each participant using a separate researcher interface. Each week a research assistant collected data on how often the participant weighed and their average and weekly weight loss. An algorithm was used to provide tailored feedback to each participant with the expected rate of weight loss at 0.5 lbs. per week and the expected self-weighing frequency at 6-7 days per week. The feedback was not individually written, but rather participants were placed in one of four groups each week based on their weight loss and self-weighing frequency over the past week, as well as average weight loss per week, and they received the message and recommended strategies appropriate for that category. They received messages reinforcing their current behaviors if

they were weighing daily and losing at least 0.5 lbs. per week. Conversely, the feedback for those that were not losing weight included more specific strategies for making changes to diet and physical activity behaviors.

Initially, participants attended a face-to-face group session that included measurement of baseline weight, procurement of smart scales, and a 30-minute discussion about calorie balance. The weekly emailed lessons on behavioral weight control provided further skills training strategies for making changes to diet and physical activity behaviors. The lessons were initially derived from the Diabetes Prevention Program[42] and adapted from other Internet-based and face-to-face weight loss interventions[59,95,96] to be tailored to the goals of this study. Lessons were both informational and behavioral, and included topics such as portion control, restaurant eating, structured exercise, problem solving, stimulus control, and relapse prevention. Participants were not encouraged to self-monitor diet and exercise, but were provided with recommendations to achieve a caloric intake of 1200-1500 calories per day and 150-200 minutes of moderate intensity exercise per week. Examples of calorie-controlled meal plans were also provided to help guide food choices. After the study was complete, intervention group participants were followed up at 9 months to assess weight loss maintenance. During this maintenance period, intervention participants retained the smart scales but were provided with no further feedback or lessons.

The delayed intervention control group was also provided with the scales at baseline for evaluation purposes only and instructed to maintain their current self-weighing habits. Control group participants received no intervention during the study period and were provided with a modified version of the program after 6 months. They were blinded to the focus of daily weighing during the 6-month period.

Measures

Demographics

At baseline, a variety of demographic variables were collected to help characterize the sample including age, gender, race/ethnicity, education, marital status, occupation status, and co-morbidities.

Anthropometrics

Height was collected at baseline using a wall-mounted stadiometer. Weight was measured to the nearest 0.2 lbs. using a digital scale wearing light clothes and no shoes at baseline, 3, and 6 months in the study center clinic. At 9 months, in order to assess maintenance effects within the intervention group, smart scale data were used to obtain an objective measure of weight after a 3-month period of no intervention.

Frequency of weighing

Self-weighing frequency was measured objectively in both groups via the smart scales throughout the study period. There were some technical problems with the scales that arose because of the reliance on cellular service to provide an objective measure of self-weighing frequency. However, such problems occurred in a small number of participants (n=4), and they were able find alternative places to weigh (e.g., work) to provide an objective measure of self-weighing frequency.

Diet

Caloric intake was measured via two, 24-hour recalls on one weekday and one weekend day using the Automated Self-Administered 24-Hour Dietary Recall (ASA-24) from the National Cancer Institute (NCI) at baseline, 3 and 6 months.[97] Interviewer-

administered 24-hour recalls have been shown to be a good estimate of changes in caloric intake using the automated multiple-pass method.[98]

Physical Activity

Exercise habits were assessed using the Paffenbarger Exercise Habits Questionnaire, which captures leisure time physical activity. Data were analyzed as energy expenditure from leisure time physical activity per week.[82] Evidence indicates that this questionnaire has moderate to high reliability,[83] and has been used in previous weight loss interventions to assess changes in physical activity.[84]

Daily Self-weighng Perceptions

Within the intervention group, perceptions about daily self-weighing were assessed via a questionnaire that was used in a previous daily self-weighing intervention for weight gain prevention.[99] Using an 8-point scale, where 8 was most favorable and 1 most unfavorable, participants were asked whether they found daily self-weighing to be easy to do, easy to remember, helpful, positive, and whether they were likely to continue doing it after completion of the study. Additionally, using a reverse-scored 8-point scale, participants were asked whether they found this behavior to be frustrating, anxiety provoking, or made them feel self-conscious. Average scores at 6 months were calculated.

Self-monitoring of diet and physical activity behaviors

Two self-report measures were used to assess self-monitoring of diet and physical activity behaviors at baseline, 3 and 6 months. The question asked was, "*Over the past 3 months, how often have you used the following strategies to try to manage your weight? Recorded or graphed your physical activity? Recorded or wrote down the type and quantity of food eaten?"* There were 5 response options that include *never/hardly ever, some of the*

time, *about half of the time*, *much of the time*, and *always or almost always* with values of 1-5 attached to those responses. Average scores for each time period were calculated and dichotomized to examine group differences in those that reported self-monitoring half the time or more versus less than half of the time.

Statistical Analysis

Chi-square tests and one-way ANOVAs were conducted to compare differences in baseline characteristics. Intent-to-treat analyses using linear mixed models with random intercept and maximum likelihood estimates were conducted to examine the effect of treatment on weight loss and behavioral outcomes between groups over time. Separate models for the different outcomes were conducted looking at the effects of time within each group, group effects, and group by time interactions. All participants were included in the analyses with the assumption that any missing values were missing at random. Bonferroni corrections were included to account for multiple time point comparisons. Percent weight loss was used as the primary outcome variable to account for baseline weight. ANOVA was used to look at other continuous outcomes and chi-square tests were used to look at differences in dichotomous measures. Transformations were conducted for variables that did not meet the assumptions of normality. Caloric expenditure from physical activity was the only variable that required a natural log transformation. Raw means are presented with statistical tests performed using the transformed data. Analyses were conducted using SPSS for Mac (Version 19, Chicago, IL). A cut-off value of alpha <0.05 was used to assess statistical significance.

V.D. Results

Enrollment and Retention

Figure 7 outlines the study enrollment and retention. A total of 326 potential participants were screened online and by phone and 135 were invited to an orientation session. Of those, 91 participants were randomized to either the daily self-weighing intervention group (n=47) or a delayed intervention control group (n=44). Participant retention for the primary dependent variable of percent weight loss was 98% at 3 months and 96% at 6 months with no differences between groups (3 months: p=.50; 6 months: p=1.00). Retention at 9 months was 96% for weight loss using smart scale data (intervention group only).

Baseline Characteristics

Table 3 highlights the baseline characteristics across study groups. On average, participants were 44±11 years old, obese (BMI: 32.15± 3.8kg/m^2) with an average weight of 90.5±15.2kg, female (75%), White (74%), college-educated (78%), and married (60%). About half the sample (46%) reported weighing less than weekly, 35% reported weighing weekly and 18% reported weighing daily over the past 3 months. About half of the sample reported self-monitoring diet less than half the time, and 83% reported self-monitoring physical activity less than half the time over the past 3 months. Baseline characteristics did not differ between groups on any variable with the exception of baseline weight (p=.008) and baseline BMI (p=.006), with the intervention group having higher average baseline weight and BMI. This difference was accounted for in the analysis by using percent weight loss as the main outcome variable.

Self-weighing Frequency

Figure 8 shows the average self-weighing frequency over time by study group using data derived from the smart scales. Over the 6-month study period, the intervention group self-weighed on average more days per week compared to the control group (6.1±1.1 vs. 1.1±1.5; p<.0001).

Weight Change

Weight loss over the study period was significantly different between groups (Figure 9). The intervention group lost on average more weight compared to the delayed control group at both 3 and 6 months [3 months: Mean (95%CI): -4.41%(-5.5, -3.3) vs. -0.37%(-1.5, .76); 6 months: Mean (95%CI): -6.55%(-7.7, -5.4) vs. -0.35%(-1.5, .79); group x time interaction: p<.001 at both time points]. Furthermore, a greater percentage of the intervention group achieved 5% (42.6% vs. 6.8%; p<.0001) and 10% (27.7% vs. 0%; p<.0001) weight loss at 6 months.

Change in weight from baseline to the 9-month follow-up (using smart scale data) in the intervention group was -7.10% ± 8.55%, and was -0.92% ± 3.32% between 6 and 9 months (during which time, the intervention group received no feedback or lessons).

Diet and Physical Activity Behaviors

Table 4 shows the differences in diet and physical activity behaviors over time between groups. At both 3 and 6 months, intervention participants consumed on average fewer calories per day compared to control participants [3 months: Mean (95%CI): 1719 (1510, 1929) vs. 2101 (1885, 2318); group x time interaction: p=.003; 6 months: Mean (95%CI): 1509 (1291, 1728) vs. 1856 (1637, 2074); group x time interaction: p=.006]. There were no differences between groups with regard to calories expended per week from physical

activity, although there was a trend towards greater physical activity over time among the intervention group, with the difference almost reaching statistical significance at 3 months (p=.052). At 6 months, the majority of participants across both groups reported self-monitoring diet and physical activity behaviors less than half of the time with no significant differences across groups, although there was a trend towards a greater proportion of the control group reporting that they self-monitored diet less than half the time [(Diet: Intervention (65%) vs. Control (83%); p=.055) (PA: Intervention (75%) vs. Control (81%); p=.54)].

Perceptions of Daily Self-weighing

At 6 months, daily self-weighing was perceived positively within the intervention group. On average, participants felt that daily self-weighing was easy to do (6.9±1.5), easy to remember (7.2±1.2), helpful (6.9±1.6), and positive (6.3±1.9) and they were likely to continue doing it after completion of the study (6.6±2.1). On average, they reported low scores for whether they found this behavior to be frustrating (2.4±1.6), anxiety provoking (3.1±1.8), or made them feel self-conscious (3.2±2.0).

V.E. Discussion

We found that a lower intensity intervention that included daily self-weighing, emailed tailored feedback and skills training with no regular face-to face-contact produced clinically significant weight losses of 13.6 lbs. on average, as well as reductions in caloric intake. Including an objective measure of self-weighing allowed for a robust assessment of self-weighing frequency and a greater understanding of the feasibility of daily self-weighing. Participants adhered to the daily self-weighing prescription and reported positive responses, indicating that daily weighing is a behavior that will likely continue to be used for self-

monitoring. Other studies that included daily weighing for weight control have found similar positive responses.[99,100]

Previous weight loss trials that included daily self-weighing have found similar effects as this study. Gokee-LaRose and colleagues examined the impact of an intensive behavioral self-regulation program that included daily self-weighing, weekly group sessions with a trained weight loss counselor, and instruction to self-monitor diet and physical activity behaviors. This group lost on average 14.4±12.1 lbs. after 20 weeks.[5] However, the intensive nature of this intervention may have overshadowed the effect of daily weighing, given that it included detailed self-monitoring of diet and physical activity behaviors and frequent face-to-face interactions. Our study found similar weight losses but included a less intensive approach that focused on daily weighing.

The 'Weight By Day' trial examined the impact of a weight loss intervention that included telephone-based counseling with a home-based weight tele-monitoring system that was used to provide individualized feedback regarding progress during counseling calls compared to a delayed start control group. Participants were encouraged to weigh daily, as well as self-monitor diet and physical activity behaviors. They found that intervention participants lost on average 7.5±1.3 lbs. after 6 months. Although similar to our study with its focus on daily weighing, they found smaller weight losses and had poorer adherence to daily self-weighing. Participants self-weighed only 50% of possible days over the 6-month period, which equates to each participant weighing approximately 3 days per week on average. We consistently reinforced daily weighing for self-regulation of behaviors, which resulted in 80% of participants in our study weighing at least 6 days per week and 96% weighing at least 5 days per week. Given this strong adherence, our findings provide a better

evaluation of the efficacy of a daily self-weighing intervention on weight loss.

Despite the low-intensive nature of this program, almost half of the participants in the intervention group achieved the 5% weight loss threshold that is associated with positive changes in risk factors for chronic disease. The percent that achieved 5% is comparable to larger gold-standard clinical trials,[38,43] and the average weight losses achieved are similar to more intensive interventions that included online counseling and detailed self-monitoring.[57,59] However, the main difference is that our study was able to achieve these levels with no regular face-to-face interaction, only group tailored feedback via email, and no requirement for detailed self-monitoring of diet and physical activity behaviors. This approach, with its focus on self-regulation via daily weighing, may be more sustainable outside the research setting and more easily disseminated than higher intensity interventions.

Because the study did not isolate the effect of daily weighing, it is not possible to determine the direct impact of this behavior on weight loss. Previous studies found little or no effects for daily weighing in the absence of feedback or skills trailing on how to utilize the scale as a tool for self-regulation.[62,100] These findings suggest that feedback around daily weighing is necessary for this strategy to be most effective and the results achieved in this study are likely a result of daily weighing in combination with the other components. Future studies using dismantling designs are warranted to obtain a better understanding of the isolated effect of daily weighing and whether individuals can benefit from daily self-weighing alone, independent of feedback or skills training.

Strengths and Limitations

The use of a randomized-controlled design allowed us to examine the impact on weight loss among individuals who were instructed to daily weigh, while previous post hoc

analyses examined the impact of this behavior among those that chose to daily self-weigh. The strong retention rate, inclusion of blinded evaluation staff, and use of intent-to-treat analyses strengthens our understanding of the effectiveness and feasibility of the intervention. Our study sample was highly educated and included only 25% minority and males, which limits generalizability of the results to other populations. Additional studies are necessary looking at more diverse samples, including those in various socioeconomic positions. Although we assessed weight loss maintenance at 3-months post intervention and found promising results for continued weight loss, future studies should examine whether these effects would be maintained over the long term.

V.F. Conclusions

Given the large percentage of Americans that are overweight or obese, there is a need to test the efficacy of weight loss interventions with high potential for sustainability and dissemination. This is important as a recent report from the U.S. Preventive Services Task Force indicates that lower-intensity interventions with limited face-to-face contact are not as effective as more intensive interventions.[101] In contrast to those findings, we found that an approach that included daily weighing along with tailored feedback and skills training can be effective for producing clinically meaningful weight loss. Our results further establish that daily self-weighing is an effective behavioral weight control strategy

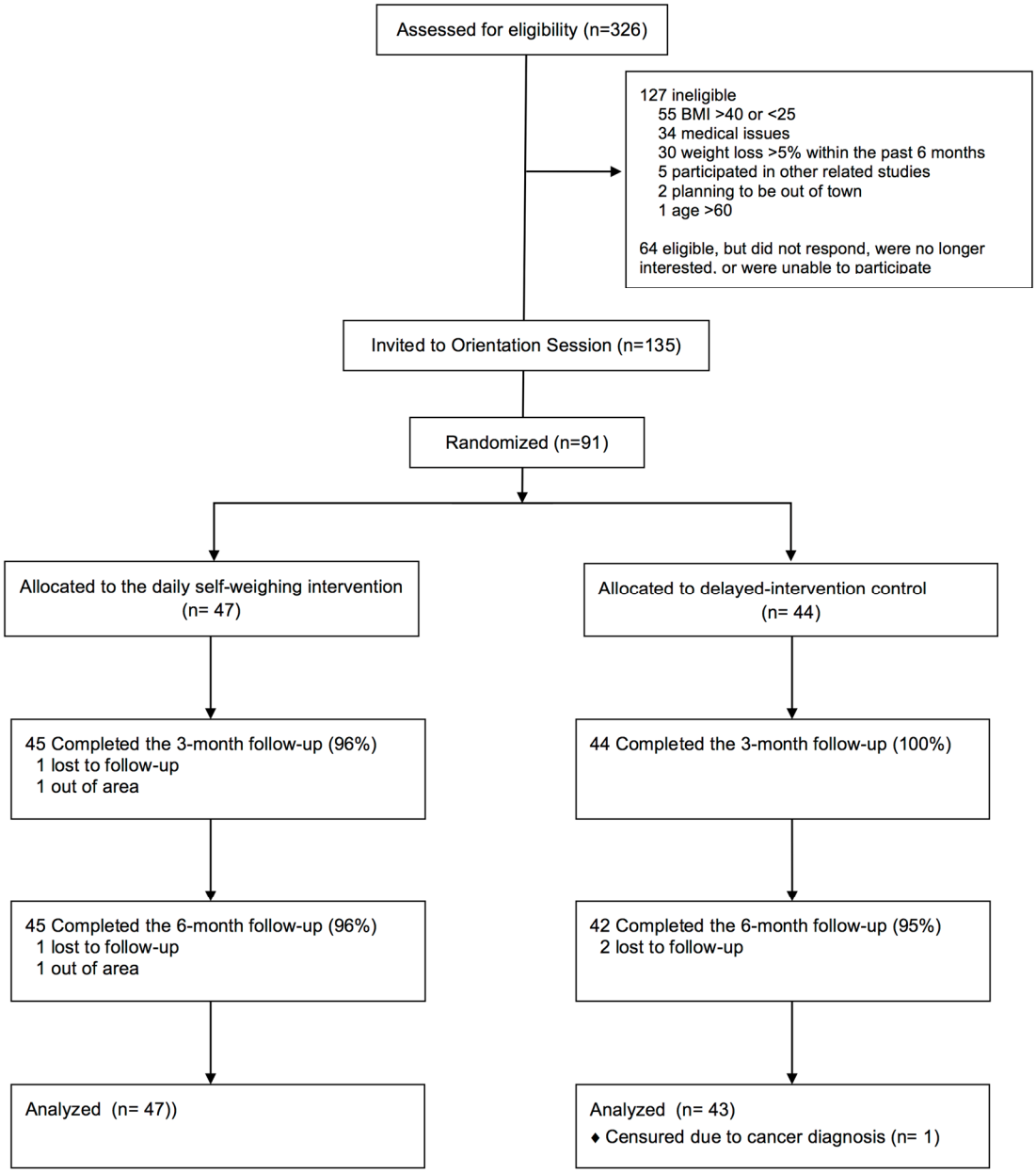


Figure 7: Study enrollment and retention diagram (CONSORT)

Table 3: WEIGH Study baseline characteristics by study group (n=91)

	Control	**Intervention**	**P-value**
n	44	47	
Age	44.7 (± 10.6)	43.0 (± 11.4)	0.45
Gender			0.31
Male	9 (21)	14 (30)	
Female	35 (80)	33 (70)	
Race/ethnicity			0.76
Black	8 (18)	6 (13)	
White	31 (71)	36 (77)	
Other	5 (11)	5 (10)	
Marital status			
Not married	17 (39)	19 (40)	0.86
Married	27 (61)	28 (60)	
Education			
High School, Vocational Training, or Partial College	9 (21)	11 (23)	0.73
College Graduate or Greater	35 (80)	36 (77)	
Weight (kg)	86.1 (± 13.4)	94.5 (± 15.8)	**.008**
BMI (kg/m^2)	31.05 (± 3.13)	33.18 (± 4.03)	**.006**
Self-weighing Frequency			0.12
Daily	11 (25)	5 (10.6)	
Several Times/Week	12 (27)	9 (20)	
One time/week	3 (7)	8 (17)	
Less than one time/week	18 (41)	24 (52)	
Self-monitoring Frequency of Diet and Physical Activity Behaviors			
Diet			
Less than Half the Time	21 (48)	28 (60)	.257
Physical Activity			
Less than Half the Time	37 (84)	39 (83)	.886

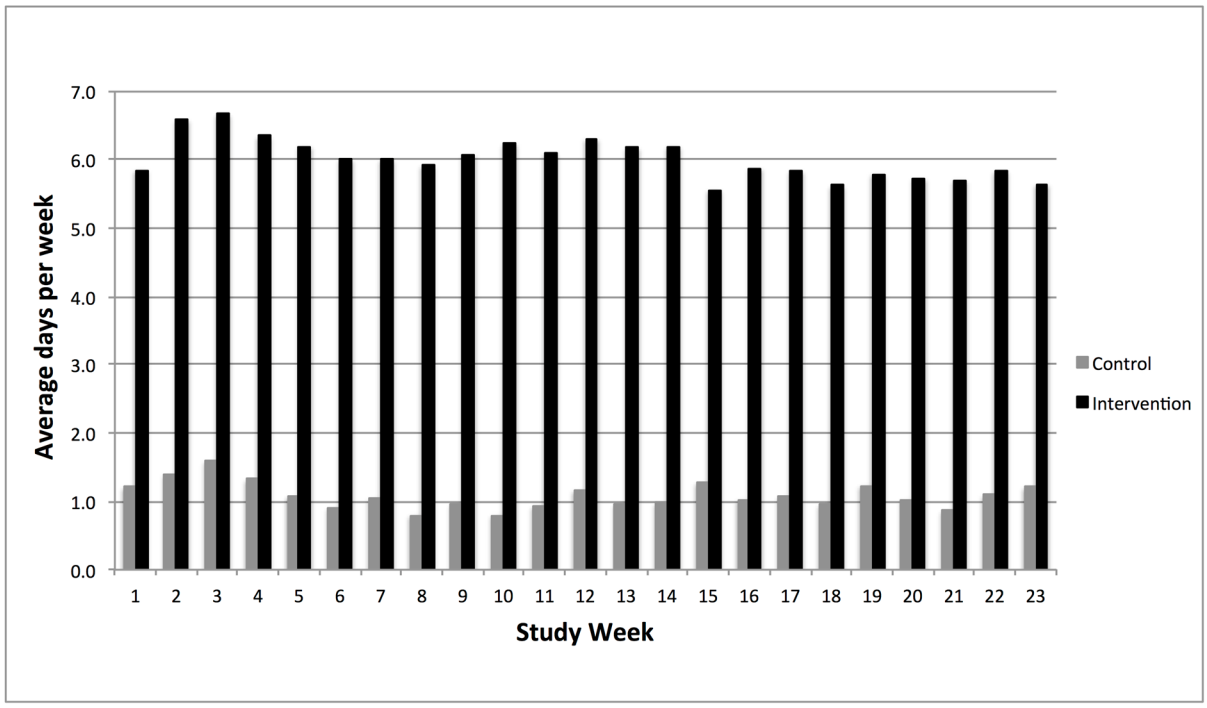


Figure 8: Self-weighing frequency by study week and study group

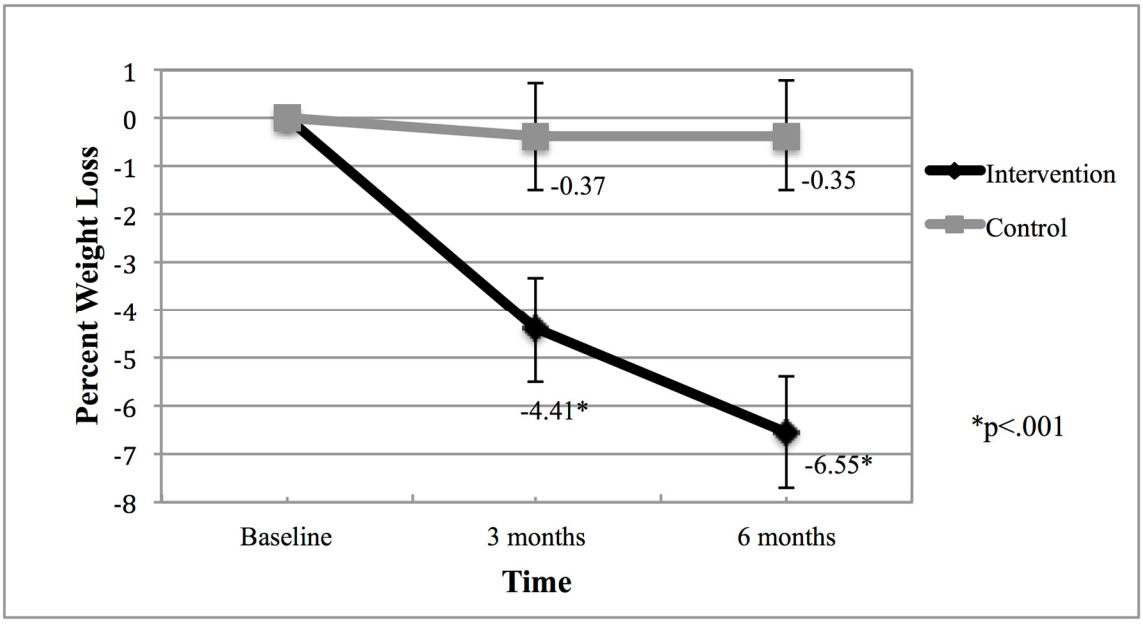


Figure 9: Weight loss over time by study group

Table 4: Average caloric intake and expenditure by study group

				P-value				
		Assessment Period		Time			Group x Time Interaction	
Outcome Variable and Group	BL (n=91)	3mo (n=82)	6mo (n=88)	3mo vs. BL	6mo vs. BL	Group	BL to 3mo	BL to 6mo
Caloric Intake								
Intervention	2014 (1808, 2220)	1719 (1510, 1929)	1509 (1293, 1725)	**.018**	**<.001**	.086	**.003**	**.006**
Control	1931 (1718, 2145)	2101 (1885, 2318)	1856 (1639, 2072)	.369	1.00			
Caloric Expenditure								
Intervention	832 (536, 1128)	1070 (769, 1371)	1068 (768, 1369)	.052	.523	.702	.155	.178
Control	759 (453, 1065)	933 (627, 1239)	737 (427, 1048)	1.00	1.00			

[1] Intention-to-treat, linear mixed models analysis with maximum likelihood estimation. Statistically significant p-values are shown in bold.

[2] All values are means, 95% CIs in parentheses.

[3] P-values for Caloric Expenditure are based on the natural log transformed variable. Raw means are presented.

[4] Abbreviations: BL = baseline; 3mo = 3 months; 6mo = 6 months

CHAPTER VI

DAILY SELF-WEIGHING DOES NOT CAUSE ADVERSE PSYCHOLOGICAL OUTCOMES AMONG OVERWEIGHT ADULTS LOOKING TO LOSE WEIGHT: RESULTS FROM A RANDOMIZED CONTROLLED TRIAL

VI.A. Overview

Despite evidence that daily weighing is effective for weight control, concerns remain regarding the potential for negative psychological consequences. The purpose of this analysis was to examine the impact of a 6-month daily self-weighing weight loss intervention on relevant psychological constructs. Ninety-one overweight and obese adults were randomly assigned to a daily self-weighing intervention group or a delayed intervention control group. Psychological outcomes were assessed at baseline, 3, and 6 months.

There were no significant differences between groups in depressive symptoms, anorectic cognitions, disinhibition, susceptibility to hunger, and binge eating. At 6 months, there was a significant group by time interaction for both body dissatisfaction ($p=.007$) and dietary restraint ($p<.001$) with the intervention group reporting lower body dissatisfaction and greater dietary restraint compared to the control group. Results indicate that a daily self-weighing weight loss intervention does not cause adverse psychological outcomes. This confirms that daily weighing is an effective and safe weight control strategy among overweight adults.

VI.B. Introduction

The high prevalence of overweight or obesity[1] indicates the need for effective and sustainable weight control strategies. One such strategy that has been shown to be associated with weight loss success is self-monitoring of body weight.[7] Based on self-regulation theory, self-weighing provides feedback on how eating and exercise behaviors are affecting weight and allows for adjustments to these behaviors to regulate body weight.[12] More frequent weighing may allow for better attributions between changes in body weight and specific behaviors because of the proximal nature of the feedback.[3] Accordingly, evidence indicates that daily weighing is more effective for weight loss compared to less frequent weighing.[4,60] Despite this effectiveness, there remains concern regarding potential adverse psychological outcomes as a result of this behavior.[8] A small study found, among normal weight, non-treatment seeking college females who were instructed to weigh daily for two weeks, poorer outcomes on mood and self-esteem compared to a control group who did not self-weigh.[69] However, these results are not necessarily applicable to a population of overweight and obese adults looking to lose weight, who would use daily weighing as a self-monitoring tool for long-term weight management.

O'Neil and Brown conducted a review of the evidence behind the claims that frequent self-weighing can lead to negative outcomes and found that there is limited evidence indicating, among obese and overweight individuals looking to lose weight, that self-weighing causes negative mood or body dissatisfaction.[72] Furthermore, there is limited evidence, that negative psychological states lead to poorer weight loss outcomes.[73] Despite showing no adverse outcomes, there are several limitations to the existing literature examining daily self-weighing and psychological outcomes within weight control

interventions. Most studies were conducted post hoc[60,74] and, therefore, prone to selection biases that make it difficult to test causal hypotheses. Because there might be differences in individuals who choose to weigh daily compared to those who choose to self-weigh less often, conclusions about the absence of negative outcomes from daily self-weighing are compromised. Furthermore, there are limitations to conclusions from the few experimental studies for weight control that included daily weighing as an intervention component, because most were intensive, face-to-face, multi-component interventions that might mitigate any negative effects of daily weighing on psychological outcomes.[5,75]

The purpose of this study was to utilize an experimental design to examine the impact on relevant psychological outcomes of a 6-month, low-intently weight loss intervention delivered via email that instructed overweight and obese adults to daily weigh using an e-scale that transmitted weights via the cellular network. The intervention focused on utilizing daily weighing for self-regulation of diet and physical activity behaviors, and, as reported elsewhere,[102] was found to be effective for weight loss. Our current analysis adds to the literature by providing a multidimensional view of the potential psychological costs of daily weighing using a randomized controlled design. We hypothesized that, at both 3 and 6 months, individuals in the daily self-weighing intervention group would report no differences in psychological outcomes compared to a delayed-intervention control group. We further hypothesized a positive relation between weight loss and psychological outcomes among intervention participants.

VI.C. Methods

Participant enrollment and retention

All participants were required to have access to the Internet in order to allow for weight tracking, be without any medical conditions that might affect participation, with no recent weight loss or plans to move out of the area. Regarding mental health, participants were excluded if they had been hospitalized for depression within the past year, had been diagnosed with bipolar disease or schizophrenia, or had a history of, or were currently receiving treatment for an eating disorder.

Participants were recruited predominantly through an advertisement on a university listserv and were screened for eligibility via online and telephone screeners. Participants (n=91) were then randomized to one of two treatment groups: a daily self-weighing intervention group (n=47) or a delayed intervention control group (n=44). All self-report measures were administered at baseline, 3, and 6 months via the Internet. One questionnaire (CESD) was administered in- person to reduce the potential for reactivity. Data were collected between February 2011 and August 2011 in Chapel Hill, NC. The University of North Carolina at Chapel Hill Institutional Review Board approved and monitored the study.

Study design and intervention description

The intervention consisted of daily weighing using a cellular-connected smart scale, weekly tailored feedback on self-weighing frequency and weight loss, and weekly emailed lessons on behavioral weight control. Participants were instructed to weigh daily and use the information from the scale to make adjustments to diet and physical activity behaviors to produce weight loss. All intervention materials reinforced daily self-weighing and encouraged participants to make connections between their diet and physical activity

behaviors and the number on the scale. The smart scale sent participant weights to a website for individualized weight graphs and provided self-weighing and weight loss data on each participant in a separate researcher interface that was used to provide tailored feedback. This feedback was delivered weekly to participants via email along with strategies for making changes to diet and physical activity behaviors.

The delayed intervention control group was also provided with smart scales for evaluation purposes only and instructed to maintain their current self-weighing habits. Control group participants received no intervention during the study period and were blinded to the focus on daily weighing.

Measures

The following variables were selected to assess both cognitive and behavioral outcomes: depressive symptoms, body satisfaction, anorectic cognitions, binge eating, dietary restraint, disinhibition, and susceptibility to hunger.

Body Satisfaction

Body satisfaction was measured using the 16-item Body Shape Questionnaire (BSQ-16). The BSQ-16 is a measure of attitudes regarding causes and consequences of body shape concern and body dissatisfaction, and has been shown to have high internal consistency (α=.93-.96) and be correlated with other measures of disordered eating attitudes.[103] Participants were asked a variety of questions regarding feelings about their appearance over the past 4 weeks with 6 response options ranging from always to never (e.g., *Have you been so worried about your shape that you have been feeling you ought to diet?).* Total scores were calculated and participants missing greater than 1 item were excluded (3 months: n=9; 6 months: n=3).

Depressive Symptoms

Depressive symptoms were measured using the 20-item Center for Epidemiologic Studies Depression Scale (CESD). This questionnaire has been shown to be a reliable (α=.85) and valid measure of depressive symptoms in the general population.[104,105] Participants were asked how often they felt a certain way over the past week with 4 response options ranging from rarely to all the time (*e.g., I was bothered by things that usually don't bother me*). Total scores ranged from 0 to 60. Higher scores indicate greater propensity towards depressive symptoms and scores ≥16 tend to be indicative of depression.[106] Participants missing one or more items were excluded from the analysis (3 months: n=2; 6 months: n=4).

Disordered Eating Cognitions and Behaviors

Disordered eating cognitions, patterns, and behaviors were assessed using the following measures. A 12-item, brief version of the Mizes Anorectic Cognitions Questionnaire (BMAC-Q) was used to assess dysfunctional cognitions related to fear of weight gain, self-control as the basis of self-esteem, and weight and eating behavior as the basis of approval. These cognitions have been shown to be associated with the onset of eating disorders and disordered eating.[107] Participants were asked to rate their beliefs and attitudes about eating and weight with 5 responses options ranging from strongly agree to strongly disagree (*e.g., If my weight goes up, my self-esteem goes down*). The BMAC-Q has been shown to be a reliable measure of eating disorder cognitions among non-clinical populations (α=.81) and higher scores are associated with more dysfunctional cognitions.[108] Total scores were calculated participants missing more than one item were excluded (3 months: n=9; 6 months: n=3).

The Questionnaire for Eating and Weight Patterns Revised (QEWP-R) was

administered to collect data about binge eating behaviors. This questionnaire has been shown to be a moderately reliable diagnostic tool (κ =.58) for binge eating disorder and can differentiate between clinical and non-clinical symptomatology.[109,110] The QEWP-R also assessed compensatory behaviors associated with binge eating, including vomiting, use of laxative, fasting, and excessive exercise; we were unable, however, to assess impact on these behaviors because only a small number of participants (n=7) reporting engaging in any of the behaviors at any time throughout the study. Therefore, we examined differences between groups on the likelihood of reporting any binge eating behavior within the past 6 months (*e.g., During the past six months, did you often eat within any two-hour period what most people would regard as an unusually large amount of food?)*. Participants missing a response to this question were excluded from the analysis (3 months: n=9; 6 months: n=3).

Dietary Restraint, Disinhibition, and Hunger

The 51-item Three-Factor Eating Questionnaire (TFE-Q) was used to measure cognitive dietary restraint (the degree to which individuals restrain from eating in order to lose or maintain weight), disinhibition (the degree to which individuals feel loss of control with eating) and susceptibility to hunger.[111] Participants were asked whether they agreed or not with a variety of statements assessing these constructs (*e.g., When I smell a sizzling steak or see a juicy piece of meat, I find it difficult to keep from eating, even if I have just finished a meal*). The TFE-Q has been shown to be a reliable measure among dieters (α=.79-.84) and all three dimensions have been shown to be associated with weight changes, such that higher restraint, lower disinhibition, and lower susceptibility to hunger are associated with greater weight loss.[111] Total scores for each of the constructs were calculated and greater scores are associated with higher levels of that specific construct. Participants missing more than one

item were excluded from analysis (3 months: n=9; 6 months: n=3).

Statistical Analysis

Chi-square tests and one-way ANOVAs were conducted to compare differences in baseline characteristics. Intent-to-treat analyses using linear mixed models with random intercept and maximum likelihood estimates were conducted to examine the effect of treatment on continuous outcomes between and within groups over time. Separate models for each of the outcomes examined the effects of group, time, and the group by time interaction for both time points. All participants were included in the analyses with the assumption that any missing values were missing at random. Bonferroni corrections were included to account for multiple time point comparisons. Any differences in baseline characteristics were controlled for by inclusion as a covariate in the model. Transformations were conducted for variables that did not meet the assumptions of normality. CESD score was the only variable that required a transformation. Raw means are presented with statistical tests performed using the transformed data. Generalized estimating equations were used to look at differences by treatment group over time in dichotomous outcomes and Fisher's exact chi-square tests were used to examine differences between groups in attrition. Analyses were conducted using SPSS for Mac (Version 19, Chicago, IL). A cut-off value of alpha <0.05 was used to assess statistical significance.

VI.D. Results

Table 5 highlights the baseline characteristics across study groups. Participants were on average 44±11 years old, obese (BMI: 32.15± 3.8kg/m^2), predominantly female (75%), White (74%), and college-educated (78%) with no history of depression/anxiety (88%) or tobacco use (90%). Baseline characteristics did not differ between groups on any variable

with the exception of baseline body mass index (BMI), with the intervention group having higher average baseline BMI.

Ninety-eight percent of participants completed the data collection visits that included in-clinic weights and completion of one paper questionnaire (CESD). Web-based questionnaires were completed by 90% of participants at 3 months and 97% at 6 months with no statistically significant differences between groups (3 months: p=.49; 6 months: p=.24). Main results have been published elsewhere,[102] but briefly, 80 % of intervention participants weighed on average at least 6 days per week and 96% weighed at least 5 days per week. At 6 months, the intervention group lost significantly more weight [Mean (95%CI): -14.06 lbs. (-17.3, -10.8) vs. -0.62 lbs. (-4.0, 2.8); group x time interaction: p<.001] and saw a greater reduction in BMI [Mean (95%CI): -2.16 kg/m^2 (-2.65, -1.67) vs. -0.09 kg/m^2 (-0.6, 0.4); group x time interaction: p<.001] compared to the control group.

Table 6 presents the means and standard errors for each of the measures for both groups over time, examining changes within each group and across groups over time using a group x time interaction. There were no significant group by time interactions at either time point for measures of depressive symptoms (3 months: p=.79; 6 months: p=.51), anorectic cognitions (3 months: p=.29; 6 months: p=.41), disinhibition (3 months: p=.23; 6 months: p=.12, and susceptibility to hunger (3 months: p=.07; 6 months: p=.19). For body dissatisfaction, there was a significant group by time interaction at 6 months (p=.007) and a marginally significant interaction at 3 months (p=.052) with the intervention group reporting lower scores at both time points. Similarly, at both 3 and 6 months, the intervention group reported significantly greater restraint compared to the control group (group by time interaction; p<.001 at both time points). At 3 months, there was a marginally significant

group x time interaction for susceptibility to hunger (p=.07) with the intervention group reporting lower susceptibility. Also observed was a significant decrease in disinhibition among intervention group participants at 6 months compared to baseline (p=.001). There were no significant changes within the control group.

Figure 10 shows the differences over time between groups with regard to the percentage of participants who reported any binge eating within the past 6 months. Overall, there was no significant group by time interaction (p=.15), although there was a trend towards a greater proportion of the control group reporting any binge eating within the past 6 months compared to the intervention group, with the difference almost reaching statistical significance between baseline and 6 months. (p=.07).

Sensitivity analyses were conducted within the intervention group to examine differences in psychological outcomes between intervention participants who lost weight compared to those who did not. Meaningful weight loss was defined as at least 3% of initial body weight, as previous papers have suggested that weight changes below 3% are indicative of weight maintenance and may represent normal fluctuations in weight.[112] Intervention participants who lost at least 3% of their body weight (n=27) at 6 months had significantly lower body dissatisfaction (p=.019) and depressive symptoms (p=.01), and higher levels of dietary restraint (p=.003) compared to those who did not (n=20). Intervention participants who did not lose at least 3% reported no significant changes in body satisfaction or depressive symptoms over the 6-month period, suggesting that they were no worse off because of daily weighing despite showing no or low weight loss. Despite small or no weight change, intervention participants who did not lose 3% still reported a significant increase in dietary restraint between baseline and 6 months (p=.036).

VI.E. Discussion

These results indicate that a weight loss intervention that focused on daily self-weighing did not cause adverse psychological outcomes among overweight and obese adults. There were no significant differences between the intervention and control groups with regard to depressive symptoms, anorectic cognitions, disinhibition, and perceived susceptibility to hunger. However, intervention participants demonstrated greater improvements in body satisfaction and cognitions related to eating behaviors as compared to control participants. Moreover, there was a trend towards less binge eating among intervention participants as compared to control participants. These results add to the evidence base indicating that a self-regulation program that focuses on daily weighing can be effective for weight loss without concern for negative psychological consequences. The contribution of the findings is enhanced by the experimental study design.

Our findings of adverse psychological effects are consistent with previous research examining daily self-weighing and psychological outcomes. Using a cross-sectional design, Linde and colleagues found no association between depression and self-weighing, suggesting the effect of depression status does not vary by self-weighing frequency.[74] Similarly, Welsh and colleagues found no association between self-weighing frequency and body dissatisfaction.[60] The results of a self-regulation program that included daily weighing for weight loss among young adults indicated no increased risk for development of eating disorders, negative body image, or mood disorders.[5] Among participants enrolled in a self-regulation program for weight loss maintenance that focused on daily weighing, those who weighed daily were less likely to report binge-eating episodes compared to those who weighed less often.[75]

There are three important distinctions to note between our study and previous evidence concerning adverse outcomes associated with self-weighing. First, our intervention focused on daily self-weighing as an on-going self-monitoring tool to help self-regulate behaviors for weight loss. The intervention emphasized resisting the tendency to place judgment on the self as a reaction to the number on the scale. Rather, we emphasized the utility of the scale for simply providing information that could be useful to gauge progress in regulating eating and exercise behaviors when trying to lose weight. Participants were instructed to become aware of fluctuations in weight and attribute changes to specific eating and exercise behaviors.

Second, in contrast to previous studies, participants were instructed to weigh themselves daily. This minimizes potential selection biases, as previous post hoc analyses relied on recall of self-weighing frequency and examined effects among those who chose to weigh daily compared to those who chose to weigh less frequently. Lastly, given that almost all of the intervention participants weighed at least five days per week, this study provided the opportunity to examine whether more frequent self-weighing is associated with adverse outcomes. We found no negative consequences and some improvements, indicating that daily self-weighing is not harmful, but rather can be helpful for weight loss when used as a part of an intervention.

Refuting previous claims that self-weighing may lead to poorer body image,[8] we found that body satisfaction improved as a result of the intervention. Given that previous evidence links weight loss and body satisfaction,[113] the likely mechanism explaining this finding is that self-regulation via daily weighing led to greater weight loss, which improved body satisfaction. Indeed, we found that intervention participants who lost weight saw

improvement in body satisfaction compared to those who did not lose weight, further supporting this proposed mechanism. Importantly, among those who did not lose weight, daily weighing did not lead to increased body dissatisfaction.[60]

With regard to dietary cognitions, we found that cognitive restraint increased as a result of the intervention, with a trend towards a decrease in disinhibition and susceptibility to hunger over time. Similar results were found within a weight loss maintenance trial,[75] suggesting that weight loss and weight loss maintenance interventions that focus on daily weighing via greater self-regulation can produce positive changes in these constructs. Previous evidence indicates that increases in restraint and decreases in disinhibition and susceptibility to hunger are associated with weight loss success.[114] These results are expected given that most treatments for obesity are designed to produce such changes.[115] Our program was no exception as we provided skills training on topics such as stimulus control, problem solving, and portion control, and the intervention also encouraged participants to find individualized ways to decrease caloric intake using the scale to gauge whether any behavioral changes were effective for weight loss. Lastly, we found that there was a trend toward the intervention group reporting less binge eating. This finding is consistent with the weight loss maintenance evidence looking at this association[75] and suggests that a daily self-weighing intervention for weight loss does not promote binge eating.

Because daily self-weighing was not isolated in our intervention design, we cannot determine whether the effects seen were related to daily self-weighing or the other components within the intervention. However, daily weighing was the main focus of the intervention and all feedback and lessons reinforced this behavior for self-regulation. Future studies should examine the impact of this behavior alone on psychological outcomes. All

psychological outcomes were measured via self-report, which may introduce recall bias. Furthermore, this study examined whether this behavior is potentially harmful among a healthy overweight population with low levels of depression at baseline and no history of eating disorders. Therefore, the results we found are not generalizable to other populations that might be more predisposed to reporting adverse psychological outcomes.

VI.F. Conclusions

We found that an intervention that focused on daily self-weighing was effective for weight loss among overweight and obese adults and did not lead to negative psychological outcomes. Rather, this program was associated with improvements in body satisfaction and cognitions related to eating behavior. This indicates that daily self-weighing can be recommended as part of weight loss program without concerns for increases in depressive symptoms and disordered eating and cognitions.

Table 5: Baseline characteristics by study group for aim 3 (n=91)

	Control (n=44)	Intervention (n=47)	P-value
Age	44.7 (± 10.6)	43.0 (± 11.4)	0.45
Gender			0.31
Male	9 (21)	14 (30)	
Female	35 (80)	33 (70)	
Race/ethnicity			0.76
Black	8 (18)	6 (13)	
White	31 (71)	36 (77)	
Other	5 (11)	5 (10)	
College Degree	35 (80)	36 (77)	0.73
BMI (kg/m^2)	31.05 (± 3.13)	33.18 (± 4.03)	**0.006**
Self-weighing Frequency			0.12
Daily	11 (25)	5 (10.6)	
Several Times/Week	12 (27)	9 (20)	
One time/week	3 (7)	8 (17)	
Less than one time/week	18 (41)	24 (52)	
History of Depression or Anxiety	4 (9)	7 (15)	0.53
Any Tobacco Use	7 (16)	2 (4)	0.08

[a] Data are M (±SD) or *n* (%) unless otherwise indicated

Table 6: Average scores on psychological measures by study group and across time using linear mixed modeling

				P-value				
		Assessment Period		Time			Group x Time Interaction	
Outcome Variable and Group	Baseline (BL) (N=91)	3 months (N=82)	6 months (N=88)	3mo vs. BL	6mo vs. BL	Group	BL to 3mo	BL to 6mo
Depressive Symptoms								
Intervention	7.9 (1.3)	8.0 (1.3)	8.5 (1.3)	1.00	1.00	.359	.859	.228
Control	8.6 (1.3)	9.1 (1.3)	10.2 (1.3)	1.00	.561			
Anorectic Cognitions								
Intervention	32.9 (1.0)	32.5 (1.0)	31.7 (1.0)	1.00	.249	.794	.293	.406
Control	31.9 (1.0)	32.6 (1.1)	31.5 (1.0)	1.00	1.00			
Body Dissatisfaction								
Intervention	109.7 (4.7)	100.5 (4.8)	98.9 (4.8)	**.036**	**.008**	.490	.052	**.007**
Control	106.2 (4.9)	107.1 (4.9)	109.1 (4.9)	1.00	1.00			
Dietary Restraint								
Intervention	9.3 (0.59)	12.9 (0.60)	13.4 (0.60)	**<.001**	**<.001**	**.004**	**<.001**	**<.001**
Control	9.3 (0.60)	9.9 (0.62)	9.6 (0.61)	.400	1.00			
Disinhibition								
Intervention	8.3 (0.44)	7.5 (0.45)	7.0 (0.45)	.108	**.001**	.966	.225	.119
Control	7.8 (0.45)	7.7 (0.46)	7.3 (0.46)	1.00	.503			
Susceptibility to Hunger								
Intervention	5.7 (0.43)	5.2 (0.45)	4.9 (0.44)	.528	.134	**.011**	.065	.192
Control	6.5 (0.44)	7.0 (0.45)	6.4 (0.45)	.619	1.00			

[a]All values are Means (SE).

[b]Statistically significant P-values are shown in bold.

[c] Depressive Symptoms: N=89 at 3 months and 87 at 6 months. P-values derived from the transformed variable with raw means and standard errors presented.

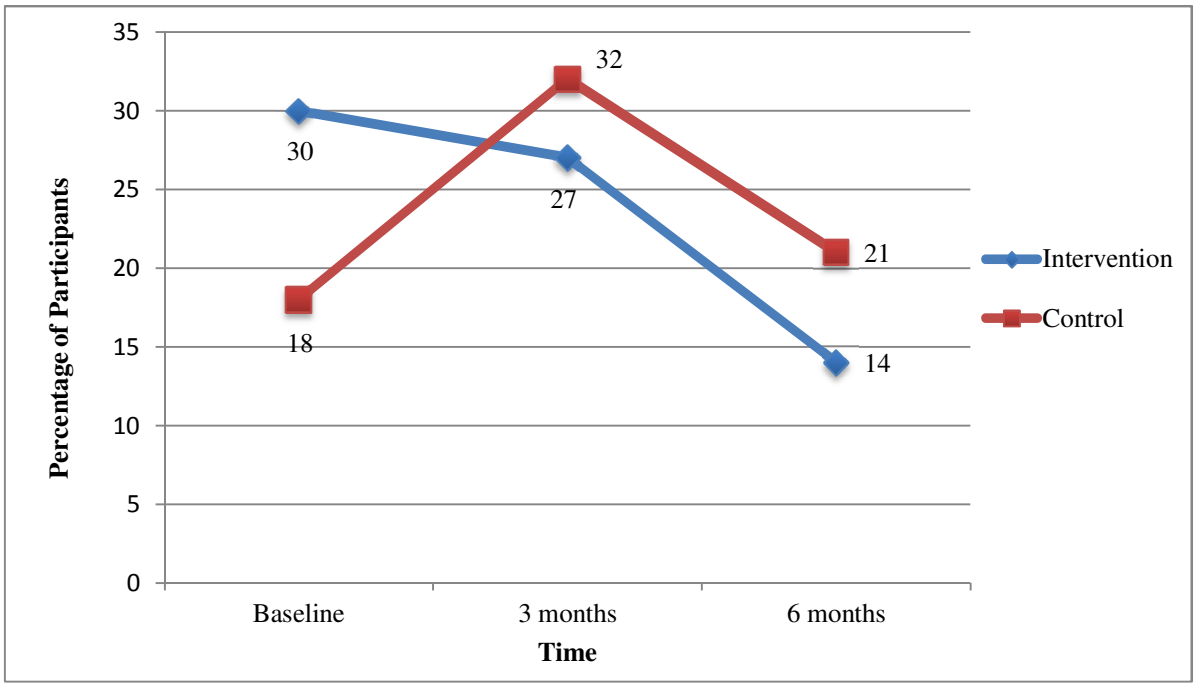


Figure 10: Percentage of participants reporting binge eating as a function of group and time

CHAPTER VII

SUMMARY OF FINDINGS AND RECOMMENDATIONS FOR FUTURE RESEARCH

VII.A. Summary of Findings

Overall, the results of this dissertation indicate that daily self-weighing is an effective and safe weight loss strategy among overweight and obese adults looking to lose weight. This research further contributes to the literature by showing that a 6-month low-intensity intervention that focuses on daily self-weighing without encouragement for detailed self-monitoring of diet and physical activity behaviors can produce weight losses that are comparable to that of more intensive interventions. Daily self-weighing is a simple, low-cost and potentially more sustainable self-monitoring behavior that has high potential for dissemination.

The information presented in this dissertation contributes to our understanding of the effect of daily self-weighing on weight loss in 3 ways: (1) by examining the mechanisms through which daily self-weighing leads to greater weight, (2) by comparing a low-intensity, daily self-weighing intervention among overweight and obese adults to a delayed intervention control group, and (3) by assessing the impact of the above intervention on psychological outcomes. The following sections summarize results and provide comparisons to the literature by specific aim, and discuss implications and future research recommendations.

Aim One

The primary purpose of aim one, found in chapter four, was to investigate the mechanisms linking daily self-weighing and weight loss. Previous evidence indicates an association between daily weighing and weight loss[4,60], however, few studies have examined its impact on eating and exercise behaviors [63-65] and to our knowledge, no studies have used mediation analyses to examine the mechanisms through which daily weighing leads to weight loss. Previous analyses examined the association between daily self-weighing and weight and behavioral outcomes cross-sectionally, which makes it difficult to infer whether daily weighing preceded behavioral changes for weight loss or if greater weight loss led to more frequent weighing. This study used longitudinal data and mediation analysis to examine this relationship, which allowed for more control over temporality and provided an understanding of the causal pathway through which this daily weighing leads to weight loss.

Results from aim one, consistent with previous observational analyses,[4,60] indicate that daily weighing is associated with greater weight loss compared to less frequent weighing. When exploring the mechanisms further, mediation analysis showed that daily weighing led to greater engagement in eating and exercise behaviors, which in turn led to greater weight loss at 6 months. At 12 months, only eating behaviors explained that relationship. This suggests that daily weighing may allow for greater self-regulation with regard to eating behaviors, such that individuals are able to make dietary changes each day based on reinforcement from the scale to produce weight loss. Daily weighers may be more consistent with adopting the strategies taught in weight loss interventions to change eating behaviors known to produce a caloric deficit (e.g., snacking after dinner). It is not known, however, whether adoption and consistent engagement in daily weighing precedes or is occurring concurrently with other behaviors, specifically the eating and exercise behaviors

measured in this analysis

These findings have implications for future research regarding recommendations for self-weighing frequency and the use of mediation analysis. Previous studies that examined the association between self-weighing frequency and weight loss found that a dose-response pattern was present with daily weighing being associated with greater weight loss compared to weekly weighing or monthly weighing.[4,60] Given the measure of self-weighing that was used in the analysis, it is not known whether those who reported less frequent weighing were weighing three times per week, weekly, monthly, or less often. The findings do indicate, however, that more consistent adoption of behavioral weight control strategies and greater weight losses were seen among those who reported doing this behavior more consistently.

Similar to the previous evidence, this aim examined the association between self-weighing and weight loss post hoc. There may be differences in those who choose to daily weigh compared to those that weigh less frequently that cannot be controlled for in this type of analysis. Although mediation analysis was used, the certainty of the temporality would be best understood if daily weighing was tested using an experimental design, as was conducted in aim 2 of this dissertation. Mediation analysis within intervention research provides a unique opportunity to examine causal pathways given the longitudinal nature of the data. However, it is not utilized often enough, particularly when examining both theoretical and behavioral processes.[116] This type of analysis will help better explain the mechanism through which the treatment or intervention components impact outcomes. Constructs from the theoretical frameworks guiding this dissertation were not examined in this analysis, but future research should examine the additional contributions of self-efficacy and motivation as potential mediators between daily weighing and weight loss.

Aim Two

Main Findings

The second aim, found in chapter five, examined the impact of a low-intensity, daily self-weighing intervention compared to a delayed intervention control group on weight loss at 6 months. The purpose of aim two was to investigate the effect of daily weighing using an experimental design, and to test a low-intensity intervention that focused on daily weighing, but did not encourage self-monitoring of diet and physical activity behaviors or include any face-to-face contact.

The intervention was effective for weight loss among overweight and obese adults looking to lose weight, with the intervention group losing on average 6.5% of initial body weight after 6 months. Similarly, almost half of the intervention participants achieved a weight loss threshold (>5%) that is associated with beneficial changes to risk factors for chronic disease. The control group saw no appreciable changes in weight (-0.35%) after 6 months. On average, the intervention group weighed 6 days per week, while the control group only weighed 1 day per week, indicating strong adherence to daily weighing within the intervention group. Interestingly, the control group, with no instruction for a specific self-weighing frequency, weighed on average weekly. In addition to changes in weight, the intervention group also consumed significantly fewer calories compared to the control group, and there was a trend towards an increase in physical activity at 3 months among intervention participants, although this did not reach statistical significance. These results are consistent with our findings in aim 1, which indicate that daily weighing is associated with greater weight loss likely via greater caloric deficits through changes to eating behaviors compared to less frequent weighing. The weight losses seen in this intervention are comparable to the results from more intensive interventions that did not focus on daily self-weighing, but

included greater feedback and detailed self-monitoring and were either delivered face-to-face or over the Internet.[38,43,57,59] This indicates that this type of approach may be just as effective, but maintains a higher potential for dissemination.

Potential Mechanisms

The possible mechanisms explaining these results are worth exploring. The focus on daily weighing for self-regulation likely contributed to the strong weight losses, as intervention participants were taught to become aware of typical day-to-day fluctuations in weight, and make attributions between changes in weight and eating and exercise behaviors, which was then used to make changes for weight loss. For example, participants may have observed that consumption of foods high in sodium leads to weight gain. This habituation to fluctuations may have limited reactivity to the scale and increased self-regulation, as participants became more aware of how behaviors impacted weight. Based on the theoretical frameworks informing this intervention, the scale provided reinforcement as to whether behavioral changes led to the expected weight loss. Participants received positive reinforcement for behaviors that were associated with weight loss and a lack of reinforcement for behaviors that led to weight gain. Such reinforcement might not be as apparent with detailed self-monitoring of diet and physical activity behaviors as these measures are less objective and underreporting is common, particularly among overweight and obese adults.[117] Similar effectiveness of daily weighing was found within a weight loss maintenance intervention that was informed by self-regulation theory and included feedback and skills training.[62] These findings, in conjunction with those of the WEIGH study, indicate that daily weighing is an effective self-regulation tool for both weight loss and weight loss maintenance. However, future research will be required to disentangle the benefits of daily

weighing alone without any companion skills training and feedback.

Previous experimental trials examining daily self-weighing for weight loss were conducted under intensive conditions, which included additional self-monitoring components and face-to-face contact or telephone counseling. These interventions were shown to be effective,[5,6] but that effectiveness may have been a result of self-monitoring of diet and physical activity behaviors. It is not known whether these interventions emphasized daily weighing for self-regulation as was conducted in this dissertation. Although our results are compelling regarding the efficacy of daily weighing in a lower intensity intervention focused on self-regulation, the benefit of daily weighing independent of other components has not been thoroughly examined.

A study by Linde and Jeffery examined the effectiveness of a fully self-directed approach that included daily weighing, self-monitoring of concrete goals (e.g., pedometer use, exercise bouts, dietary activities), and limited skills training on behavioral weight control. They found that participants weighed on average 5.3 days per week, indicating moderately high adherence to daily weighing. Daily weighing was also well received, but no significant or appreciable weight loss was achieved as a result of this intervention.[100] Furthermore, adherence to self-monitoring of other behaviors was poor (50% adherence rate), which further indicates that self-monitoring of diet and physical activity, even in a limited form, is not sustainable. Given the inclusion of daily weighing and the results achieved in this dissertation, as well as previous evidence suggesting that a self-directed approach can be effective,[48] some weight loss would have been expected. In contrast to the findings from this dissertation, potential explanations for the lack of findings may be due to less focus on daily weighing for self-regulation or not enough feedback or accountability.

The effect of accountability from the smart scales in the WEIGH study was not measured, but nonetheless, remained a part of the intervention. It is likely, however, that the accountability the smart scales provided had a greater impact than we anticipated. It is not known whether provision of simple bathroom scales would have produced similar results. This type of accountability may be all that is required to achieve clinically meaningful weight loss results, which is promising because typical face-to-face accountability can be costly and burdensome for participants.

The smart scale also provided individualized feedback for each participant in the form of a web-based weight loss graph. It was anticipated that the weight loss graph would provide participants with feedback regarding weight loss progress over time, which would reinforce helpful behaviors. As expected, within the intervention group, there was a significant correlation between logins to the website and weight loss (r=-.59; p<.0001), however, participants logged in weekly on average 8 out of the possible 24 weeks, indicating that this feature was not frequently utilized. The smart scale also provided the data for the tailored feedback via email on objective self-weighing and weight loss statistics. Specifically, participants received feedback on their self-weighing frequency over the past week, weight losses to date, and average weight loss over time. Although we cannot tease out the effect of the tailored feedback in how the intervention was designed, previous studies that included tailored feedback via email have shown to be effective for weight loss,[59] indicating that this is an important feature.

A recent review of self-monitoring evidence for weight loss called for more information about self-monitoring in general, specifically asking "for objective measures of adherence to self-monitoring, and for studies that establish the required dose of self-

monitoring for successful outcomes."[26] This dissertation responded to this by including smart scales in both study groups, thereby obtaining an objective measurement of self-weighing frequency. The scales used the cellular network to send weights to a researcher interface. This feature provided a better understanding of adherence to daily weighing and builds on previous evidence that relied on self-report measures. Self-report measures, in general, may introduce recall bias and may not accurately reflect consistent behavior over a given period of time. In contrast, the smart scales provided an accurate assessment of self-weighing frequency that does not rely on recall and was collected in real-time.

The "Weigh by Day" study utilized an objective measure of self-weighing via a scale that sent weights through a telephone line. The scale provided instant feedback to participants on current, previous, and target weights and was used for customized feedback on weight loss progress during biweekly telephone counseling calls.[6] However, results indicate poor adherence to daily weighing (50% of possible days), and smaller weight losses than what was found in this dissertation. Given that both the Weigh By Day and WEIGH studies provided objective feedback, accountability, and skills training, the differences in both adherence and weight loss are unclear. Potential explanations could be the strong focus on self-regulation and the consistent reinforcement of daily weighing or the weekly email contact that was included in this dissertation.

The objective assessment of self-weighing frequency in the WEIGH study showed that 80% of participants weighed on average at least 6 days per week. This finding is important because it indicates that participants were able to consistently adopt daily self-weighing. Furthermore, adherence did not decline towards the end of an intervention, as has been shown with self-monitoring of diet and physical activity behaviors. Burke and

colleagues conducted an intervention that compared the use of personalized digital assistants to paper diaries for self-monitoring and found a significant decline in self-monitoring regardless of modality, with only one-third of participants continuing to use paper diaries at the end of 6 months.[92] Regarding perceptions about daily weighing, we found that daily weighing was perceived as a positive and helpful behavior that was easy to remember and easy to do. Participants did not report that they felt daily self-weighing was particularly frustrating, anxiety provoking or negatively impacting their self-esteem. Other studies have found similar positive responses to daily weighing, even in the absence of weight loss.[99,100] These positive responses are in contrast to previous evidence examining traditional self-monitoring where participants report that it is difficult and labor intensive.[93]

Despite not encouraging self-monitoring of other behaviors, approximately one-third of intervention participants reported keeping a diet record more than half the time at 6 months as compared to 17% in the control group. The amount of detail and consistency of this self-monitoring is not known, as the measure to assess self-monitoring behaviors included two items asking how often participants recorded or graphed their physical activity or wrote down the type and quantity of food eaten. For the 30% that reported self-monitoring other behaviors more than half the time, it is not known if the weight losses achieved are attributed to daily weighing or other self-monitoring. Given the intervention design, it is not possible to separate out the effects of self-monitoring of other behaviors and daily weighing. This is worth further exploration in future research.

Regarding the most optimal dose of self-weighing for weight loss, it is interesting that the study resulted in a natural daily vs. weekly comparison between groups, with greater weight losses seen in the daily weighing group. This is consistent with previous observational

evidence indicating a dose response relationship between self-weighing frequency and weight loss.[4,60] It is not possible, however, to make any causal inferences regarding the differences in daily vs. weekly weighing because of how the intervention was the designed, as the control group did not receive the feedback or lessons. One study tested at an experimental manipulation of self-weighing frequency to compare daily vs. weekly weighing and found no significant differences between groups in weight loss after 10 weeks. The lack of an effect by self-weighing frequency was likely because this was tested within a study that included a standard behavioral weight control intervention in both groups. The intervention, regardless of self-weighing frequency, may have been enough to produce weight loss and therefore, any effect differences as a result of self-weighing would not be detected. This intervention also included detailed self-monitoring of diet and physical activity behaviors, which is already known to be effective.

In general, these proposed mechanisms are speculative, as we did not isolate daily weighing from the other potential competing components. We did find that participants continued to lose weight for 3 months after the intervention period was over (-0.92% ± 3.32% between 6-9 months); during which time, the intervention group weighed on average 4-5 days per week, but received no feedback or lessons. This indicates that perhaps daily weighing in the absence of other intervention components can be effective for weight loss. More research examining this long-term is needed.

Regardless, the WEIGH study was found to be efficacious for producing clinically significant weight loss at 6 months. What is promising about these results is that this type of approach is potentially more sustainable and has greater potential for dissemination. The sustainability of daily weighing long-term is not known, however, data indicate that daily

weighing is associated with successful weight loss maintenance.[47,62] The comparative sustainability of daily weighing to other forms of monitoring is not known empirically, however, research does show positive responses to daily weighing,[99,100] while detailed self-monitoring is considered to be difficult and labor intensive.[93] Examining differences in these two self-monitoring behaviors is a top priority, as it will provide information as to whether daily weighing is more or less effective compared to other forms of self-monitoring for weight loss and weight loss maintenance.

Aim Three

Main Findings

The third aim, found in chapter six, sought to examine the effect of the daily self-weighing intervention in aim two compared to controls on relevant psychological outcomes. This is important as some skepticism remains regarding the potential negative consequences of self-weighing in general.[8] The outcomes selected included depressive symptoms, anorectic cognitions, body satisfaction, binge eating and other disordered eating behaviors, as well as changes in cognitive dietary restraint, disinhibition, and perceived susceptibility to hunger.

Results from these analyses indicate that there were no differences between groups on most of these outcomes. The exceptions included body satisfaction and dietary restraint; with the intervention group reporting significantly lower body dissatisfaction, and greater cognitive restraint with regard to dietary behaviors compared to the control group. There was also a trend toward fewer binge eaters among the intervention group compared to the control group, with this difference almost reaching statistical significance. Other positive changes noted within the intervention group were related to disinhibition and susceptibility to hunger at various time points within the intervention. No significant improvements over time

were found within the control group.

Potential Mechanisms

Further exploration into these outcomes is necessary. Regarding the positive changes in body satisfaction and dietary restraint seen within the intervention, additional analyses showed that these outcomes were correlated with weight loss. These results were expected as lower body dissatisfaction and higher restraint are consistently found with greater weight loss.[113,114] The likely mechanism is that the intervention, which focused on daily weighing, increased dietary restraint, which then led to weight loss. This weight loss, in turn, led to greater body satisfaction. Standard behavioral weight loss interventions seek to produce greater dietary restraint because is a known predictor of reducing caloric intake, which in turn leads to greater weight loss.[115] Consistent with the strong weight losses seen in this study, the intervention group reported lower caloric intake compared to controls.

While there were no group differences in the remaining psychological constructs and average scores did not indicate any negative effects, it was possible that daily weighing among those who lost weight was positive, but that daily weighing might be adverse among those who did not lose weight. To explore this further, sensitivity analyses were conducted within the intervention group to examine differences between those who lost at least 3% of their initial body weight and those who did not. Results show, as expected, that body satisfaction and restraint were higher among those who lost weight, however, what is interesting is that improvements in depressive symptoms were also seen among intervention participants that lost at least 3% of their body weight. Similar improvements in depressive symptoms were seen in another weight loss intervention that included daily weighing.[5] What is important is that there were no adverse changes in any of the psychological outcomes

among intervention participants who weighed daily but did not lose weight. This indicates that daily weighing in the absence of weight loss does not lead to poorer psychological outcomes.

When examining daily weighing compared to less frequent weighing, previous analyses showed no effect of self-weighing frequency on body dissatisfaction[60] or depressive symptoms,[74,75] and no increased risk for development of eating disorders, negative body image, or mood disorders.[5] Similarly, daily weighing was associated with decreases in disinhibition and a reduced risk for binge eating.[75] These findings are consistent with our results; however, we were able to make these inferences using an experimental design where individuals were instructed to daily weigh and examine whether daily weighing, in the absence of weight loss, leads to adverse outcomes.

What is not known from this dissertation and previous research is the effect of daily weighing on these psychological outcomes independent of other intervention components, especially without on-going support or reinforcement. This intervention sought to habituate participants to the scale and increase awareness about fluctuations and attributions between behaviors and weight changes. This may contribute to the lack of adverse findings that we found among daily weighers who did not lose weight. Future research examining the impact of daily weighing alone on the potential for negative psychological outcomes is important. Participants in the WEIGH study were overweight and obese adults seeking weight loss treatment, so the impact of daily weighing cannot be generalized to normal weight adults trying to prevent weight gain.

VII.B. Implications of Findings

Based on self-regulation theory and social cognitive theory, self-monitoring is

important for weight control, but sustainability of current self-monitoring strategies remains difficult. What this research project sought to assess was whether daily weighing as a simple, and potentially more sustainable, self-monitoring behavior could be effective for weight loss. Research on daily weighing is timely as a recent review of the self-weighing literature concluded that, "the evidence base does not support endorsement of a precise self-weighing frequency and duration that has the most benefit for the most people."[7] This dissertation sought to help fill that gap by examining the impact of daily self-weighing with a strong study design.

The results of aim one are compelling as they indicate that those who reported daily weighing had greater changes in diet and physical activity behaviors compared those who weighed less frequently. Our use of mediation analysis provided insight into the causal relationship, which adds to the evidence base with stronger, more robust methods. Given the results, future research should continue to examine the mechanisms linking self-regulation behaviors and weight loss outcomes using this type of analysis. Aim 2 showed, using an experimental design, that a low-intensity intervention that focused on daily weighing can be effective for producing clinically meaningful weight loss. Giving varying recommendations on self-weighing from researchers and practitioners[76], this study was important for further solidifying the efficacy of daily self-weighing. More research is necessary to build on these findings by examining the benefit of daily weighing alone, testing the differential effects of daily vs. weekly weighing, and whether there is any additional benefit of daily weighing compared to self-monitoring of diet and physical activity behaviors. Aim 3 found that instructing participants to daily weigh did not lead to adverse psychological outcomes; rather it improved body satisfaction and dietary restraint. These outcomes are important, as some

have claimed that this behavior may be detrimental to psychological health.[8,69] Given these findings, practitioners and researchers can recommend daily weighing for weight loss among overweight and obese adults without concern for psychological harm.

Given the high recidivism of weight gain post treatment,[44] it is important to test the efficacy of weight loss interventions that are sustainable and have high potential for dissemination. These results from this dissertation indicate that daily weighing is an effective behavioral strategy for weight loss among overweight and obese adults that also leads to improvements in behavioral outcomes and does not appear to cause psychological harm. Daily self-weighing is a self-monitoring behavior that simply requires access to a scale and is, therefore, a low-cost strategy that could have broad reach. Particularly at a population level, the effect of daily self-weighing could have a beneficial impact on the prevalence of obesity. This dissertation is just a starting point for future research looking at the impact of this daily behavior on weight loss.

VII.C. Recommendations for Future Research

Although this dissertation sought to add to the literature by investigating the impact of daily weighing using mediation analyses and an experimental study design, more research is necessary to further understand the benefits of this simple self-monitoring behavior. Future recommendations and research needs are outlined below.

Conducting mediation analysis in aim 1 improved on previous research that examined the association between self-weighing and behavioral outcomes and allowed for an understanding of the path through which daily weighing leads to greater weight loss as compared to less frequent weighing. Future studies utilizing this analysis approach in intervention research are necessary to examine the causal relationships between variables,

and provide an understanding regarding behaviors that are most effective for weight control. Additionally, future research examining theoretical mediators (e.g., self-efficacy, motivation) is important to further explain the mechanisms between daily self-weighing and self-regulation. The WEIGH study collected data on theoretical constructs, however, examining the impact of daily weighing on psychological outcomes was deemed more important for this dissertation to further indicate that this behavior is not harmful for overweight and obese adults looking to lose weight. Future analyses will be conducted to examine the impact of the intervention on self-efficacy for both eating and exercise behaviors and whether these constructs act as potential mediators between treatment group and weight loss.

The strong weight losses found in both aims 1 and 2 were likely attributed to daily self-weighing as a self-regulation tool. From this research and previous studies, however, the effects of daily weighing cannot be separated from other intervention components. Future research should utilize dismantling designs to isolate daily weighing in order to gain an understanding of the benefits of daily weighing in the absence of other components. A potential 3-group study design could include a group receiving the intervention, as described in aim two, a group provided with the smart scale and instructed to daily weigh (with no feedback or lessons) and a group provided with a standard bathroom scale and instructed to daily weigh, which would control for the effects of the accountability that the smart scale provides.

Based on self-regulation theory, seeing day-to-day changes in body weight may allow for greater attribution between behaviors and weight, while weighing less frequently makes it more difficult to connect behaviors and weight changes. As the theory indicates, this dissertation found that daily weighing was effective for weight control compared to less

frequent weighing. However, currently most practitioners and commercial weight control programs (e.g., Weight Watchers) recommend no more than weekly weighing[118] because physiologically it should take a week to produce a true loss of one pound of body weight. Given this, future studies should examine whether there is additional benefit to daily weighing compared to weekly weighing by isolating that one variable and holding all other components constant. Evaluating the effect of varying self-weighing frequencies would be best understood if tested under low-intensity conditions, as to not overshadow the effect of self-weighing frequency.

One of the arguments supporting this research project was that detailed self-monitoring of diet and physical activity behaviors, although effective for weight loss, is not sustainable. Daily monitoring has always been recommend for better self-awareness of how behaviors impact weight.[119] This dissertation sought to provide insight into the impact of daily weighing as an alternative to traditional self-monitoring strategies by testing a weight loss intervention that focused solely on daily self-weighing and did not encourage self-monitoring of diet and physical activity behaviors. Although there was a trend towards greater self-monitoring among the intervention group compared to the control group, the majority of participants in both groups reported self-monitoring these behaviors less than half the time. This suggests that this intervention produced clinically significant weight loss in the absence of intensive self-monitoring. This was not experimentally tested, however, and future studies should examine the differential impact of varying levels of self-monitoring intensity. A potential study design might include a group receiving the WEIGH intervention compared to a group receiving the WEIGH intervention plus detailed self-monitoring of diet and physical activity behaviors. This design would isolate the impact of self-monitoring and

indicate whether there is any additional benefit for weight loss to including this behavior.

Although the feedback provided in the intervention was tailored, it was not labor intensive, as it simply required an email to be physically sent by intervention staff. Future studies could test the use of automated feedback to further streamline the process, thereby limiting cost and increasing efficiency. Furthermore, although we did investigate maintenance effects within the intervention by examining any changes in weight after 3-months of no intervention, it is not known whether these results would be maintained long-term. The efficacy of daily self-weighing on weight loss maintenance has been established,[47,62] but future research should examine maintenance effects after receiving a weight loss intervention that focused on daily self-weighing.

Lastly, the outcomes of this research show that a low-intensive intervention that includes daily weighing can be effective for weight loss. Low intensity was defined as minimal face-to-face contact, and no requirement for detailed self-monitoring. Researchers should continue to examine this type of approach, as it is low-cost, has greater potential for dissemination and is more self-directed, potentially increasing sustainability. The intervention in aim 2 was conducted under controlled conditions in a research setting. Future studies should examine the effect of this intervention in other settings (e.g., primary care), which may offer an existing infrastructure for delivery of a self-regulation intervention that includes daily weighing. Given that the program centered on remote weight monitoring, Registered Dietitians or other health professionals in the primary care setting could potentially deliver the emailed feedback, which would decrease the burden and reliance on face-to-face contact to obtain an objective measure of weight. Evaluating the impact of a lower-intensity approach in primary care settings could enhance dissemination potential,

especially given the recent call for such programs by the U.S. Preventive Services Task Force.[101] Finding ways to integrate this type of approach into this setting also has the potential for greater reach and would be desirable given already limited resources. Additionally, future research should test this intervention with more diverse populations; particularly lower-income, minority populations, where obesity is highly prevalent.[1]

VII. D. Conclusions

In summary, obesity continues to be a challenging public health problem that is associated with an increased risk for chronic disease. Testing effective and sustainable strategies to enhance weight reduction would have strong public health implications. This dissertation was innovative as it focused primarily on understanding the efficacy of daily self-weighing, a simple self-monitoring behavior that has been shown to be associated with better weight loss outcomes, but has never been rigorously tested using an experimental study design under low-intensity conditions. This research sought to understand the effects of this behavior with a better, more objective measurement of self-weighing and examine the impact of daily weighing on psychological health.

Taken together, the results of the three aims within this dissertation suggest that daily self-weighing is an effective weight loss strategy that leads to greater engagement in diet and physical activity behaviors, as well clinically meaningful changes in body weight. This behavior does not cause negative psychological outcomes among overweight and obese adults looking to lose weight. Given these findings, this simple self-monitoring strategy should be implemented on a large scale to increase weight loss success, which in turn could have strong implications for the prevalence of obesity on a population level. This dissertation presents compelling evidence regarding the efficacy and safety of this behavior among

overweight and obese adults, and provides a solid foundation for future research to further examine the benefits of daily self-weighing.

APPENDIX 1: EATING BEHAVIOR INVENTORY

Directions: Check the number that best describes your behavior during the last 3 months.

	Never or Hardly ever	Some of the time	About half of the time	Much of the time	Always or almost always
A. I carefully watch the quantity of food that I eat.	☐1	☐2	☐3	☐4	☐5
B. I eat foods that I believe will aid me in losing weight.	☐1	☐2	☐3	☐4	☐5
C. I keep 1 or 2 raw vegetables available for snacks.	☐1	☐2	☐3	☐4	☐5
D. I record the type and quantity of food which I eat.	☐1	☐2	☐3	☐4	☐5
E. I weigh myself daily.	☐1	☐2	☐3	☐4	☐5
F. I refuse food offered to me by others.	☐1	☐2	☐3	☐4	☐5
G. I eat quickly compared to most other people.	☐1	☐2	☐3	☐4	☐5
H. I consciously try to slow down my eating rate.	☐1	☐2	☐3	☐4	☐5
I. I eat at only one place in my home.	☐1	☐2	☐3	☐4	☐5
J. I use the same placemat and other utensils for each meal.	☐1	☐2	☐3	☐4	☐5
K. I eat and just can't seem to stop.	☐1	☐2	☐3	☐4	☐5
L. I eat in the middle of the night.	☐1	☐2	☐3	☐4	☐5
M. I snack after supper.	☐1	☐2	☐3	☐4	☐5
N. My emotions cause me to eat.	☐1	☐2	☐3	☐4	☐5
O. I buy ready-to-eat snack foods for myself.	☐1	☐2	☐3	☐4	☐5
P. I shop when I'm hungry.	☐1	☐2	☐3	☐4	☐5
Q. I shop from a list.	☐1	☐2	☐3	☐4	☐5
R. I leave food on my plate.	☐1	☐2	☐3	☐4	☐5
S. I serve food family style (serve from bowls on table).	☐1	☐2	☐3	☐4	☐5
T. I watch TV, read, work, or do other things while I eat.	☐1	☐2	☐3	☐4	☐5
U. If I'm served too much, I leave food on my plate.	☐1	☐2	☐3	☐4	☐5
V. Generally, while I'm at home, I leave the table as soon as I finish eating.	☐1	☐2	☐3	☐4	☐5
W. I keep a graph of my weight.	☐1	☐2	☐3	☐4	☐5
X. I eat when I'm not really hungry.	☐1	☐2	☐3	☐4	☐5
Y. I store food in containers where it is not readily visible or in a closed cupboard.	☐1	☐2	☐3	☐4	☐5
Z. I decide ahead of time what I will eat for meals and snacks.	☐1	☐2	☐3	☐4	☐5

APPENDIX 2: QUESTIONNAIRE ON DAILY SELF-WEIGHING PERCEPTIONS

1. **Over the past 3 months, how difficult was it to weigh yourself everyday?**

1	2	3	4	5	6	7	8
Very easy							*Very difficult*

2. **Over the past 3 months, how difficult was it to remember to weigh yourself everyday?**

1	2	3	4	5	6	7	8
Very easy							*Very difficult*

3. **Over the past 3 months, how helpful did you find daily self-weighing?**

1	2	3	4	5	6	7	8
Very helpful							*Not helpful at all*

4. **Over the past 3 months, I found weighing myself everyday to be:**

1	2	3	4	5	6	7	8
Very positive							*Very negative*

5. **Over the past 3 months, how frustrating was it to weigh yourself everyday?**

1	2	3	4	5	6	7	8
Very frustrating							*Not frustrating at all*

6. **Over the past 3 months, how anxious did you feel because of weighing yourself everyday?**

1	2	3	4	5	6	7	8
Very anxious							*Not anxious at all*

7. **Over the past 3 months, how self-conscious did you feel because of weighing yourself everyday?**

1	2	3	4	5	6	7	8
Very self-conscious							*Not self-conscious at all*

8. **Over the past 3 months, I found weighing myself everyday to be:**

1	2	3	4	5	6	7	8
Very positive							*Very negative*

9. **How likely are you to weigh yourself daily after this program ends?**

1	2	3	4	5	6	7	8
Very unlikely							*Very likely*

APPENDIX 3: CENTER FOR EPIDEMIOLOGIC STUDIES DEPRESSION SCALE

Please indicate how often you have felt this way DURING THE PAST WEEK: (check one for each statement)

		None or Rarely (less than 1 day)	Some of the time (1-2 days)	Occasionally (3-4 days)	Most of the time (5-7 days)
1.	I was bothered by things that usually don't bother me.	☐1	☐2	☐3	☐4
2.	I did not feel like eating; my appetite was poor.	☐1	☐2	☐3	☐4
3.	I felt that I could not shake off the blues even with help from my family or friends.	☐1	☐2	☐3	☐4
4.	I felt that I was just as good as other people.	☐1	☐2	☐3	☐4
5.	I had trouble keeping my mind on what I was doing.	☐1	☐2	☐3	☐4
6.	I felt depressed.	☐1	☐2	☐3	☐4
7.	I felt that everything I did was an effort.	☐1	☐2	☐3	☐4
8.	I felt hopeful about the future.	☐1	☐2	☐3	☐4
9.	I thought my life had been a failure.	☐1	☐2	☐3	☐4
10.	I felt fearful.	☐1	☐2	☐3	☐4
11.	My sleep was restless.	☐1	☐2	☐3	☐4
12.	I was happy.	☐1	☐2	☐3	☐4
13.	I talked less than usual.	☐1	☐2	☐3	☐4
14.	I felt lonely.	☐1	☐2	☐3	☐4
15.	People were unfriendly.	☐1	☐2	☐3	☐4
16.	I enjoyed life.	☐1	☐2	☐3	☐4
17.	I had crying spells.	☐1	☐2	☐3	☐4
18.	I felt sad.	☐1	☐2	☐3	☐4
19.	I felt that people disliked me.	☐1	☐2	☐3	☐4
20.	I could not get going.	☐1	☐2	☐3	☐4

APPENDIX 4: BRIEF MIZES ANORECTIC COGNITIONS QUESTIONNAIRE

Directions: This is an inventory of beliefs and attitudes about eating and weight. There are a number of statements with which you may tend to agree or disagree. On your answer sheet there is one of five possible answers for each item. For each statement, you should mark off the box that corresponds with your own reaction to the item.

	Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1. I am proud of myself when I control my urge to eat	☐1	☐2	☐3	☐4	☐5
2. If my weight goes up, my self-esteem goes down	☐1	☐2	☐3	☐4	☐5
3. Having a second serving of a high calorie food I really like does not make me feel guilty	☐1	☐2	☐3	☐4	☐5
4. I rarely criticize myself if I have let my weight go up a few pounds	☐1	☐2	☐3	☐4	☐5
5. My friends will like me regardless of how much I weigh	☐1	☐2	☐3	☐4	☐5
6. People like you because of your personality, not whether you are overweight or not	☐1	☐2	☐3	☐4	☐5
7. All members of the opposite sex want a mate who has a perfect, thin body	☐1	☐2	☐3	☐4	☐5
8. Members of the opposite sex are more interested in "who" you are rather than whether or not you are thin	☐1	☐2	☐3	☐4	☐5
9. No matter how much I weigh, fats, sweets, bread, and cereal are bad food because they always turn into fat	☐1	☐2	☐3	☐4	☐5
10. If I eat a sweet, it will be converted instantly into stomach fat	☐1	☐2	☐3	☐4	☐5
11. I can't enjoy anything because it will be taken away	☐1	☐2	☐3	☐4	☐5
12. If I gain one pound, I'll go on and gain a hundred pounds, so I must keep precise control of my weight, food, and exercise	☐1	☐2	☐3	☐4	☐5

APPENDIX 5: BODY SHAPE QUESTIONNAIRE

We should like to know how you have been feeling about your appearance over the **PAST FOUR WEEKS**. Please read each question and circle the appropriate number to the right. Please answer all the questions.

OVER THE PAST FOUR WEEKS:	Never	Rarely	Sometimes	Often	Very often	Always
1. Have you been so worried about your shape that you have been feeling you ought to diet?.....	1	2	3	4	5	6
2. Have you been afraid that you might become fat (or fatter)?.....	1	2	3	4	5	6
3. Has feeling full (e.g. after eating a large meal) made you feel fat?.....	1	2	3	4	5	6
4. Have you noticed the shape of other women and felt that your own shape compared unfavourably?.....	1	2	3	4	5	6
5. Has thinking about your shape interfered with your ability to concentrate (e.g. while watching television, reading, listening to conversations)?.....	1	2	3	4	5	6
6. Has being naked, such as when taking a bath, made you feel fat?.....	1	2	3	4	5	6
7. Have you imagined cutting off fleshy areas of your body?.....	1	2	3	4	5	6
8. Have you not gone out to social occasions (e.g. parties) because you have felt bad about your shape?.....	1	2	3	4	5	6
9. Have you felt excessively large and rounded?.....	1	2	3	4	5	6

10.	Have you thought that you are in the shape you are because you lack self-control?..... .	1	2	3	4	5	6
11.	Have you worried about other people seeing rolls of fat around your waist or stomach?.....	1	2	3	4	5	6
12.	When in company have your worried about taking up too much room (e.g. sitting on a sofa, or a bus seat)?.....	1	2	3	4	5	6
13.	Has seeing your reflection (e.g. in a mirror or shop window) made you feel bad about your shape?.....	1	2	3	4	5	6
14.	Have you pinched areas of your body to see how much fat there is?.....	1	2	3	4	5	6
15.	Have you avoided situations where people could see your body (e.g. communal changing rooms or swimming baths)?.....	1	2	3	4	5	6
16.	Have you been particularly self-conscious about your shape when in the company of other people?.....	1	2	3	4	5	6

APPENDIX 6: THREE-FACTOR EATING QUESTIONNAIRE

Directions: Read each of the following 36 statements carefully. If you agree with the statement, or feel that it is true as applied to you mark the box marked next to **"T" (true)**. If you disagree with the statement, or feel that it is false as applied to you, mark the box next to **"F" (false)**. Be certain to answer every question.		
1. When I smell a sizzling steak or see a juicy piece of meat, I find it difficult to keep from eating, even if I have just finished a meal.	T☐ 1	F☐ 2
2. I usually eat too much at social occasions, like parties and picnics.	T☐ 1	F☐ 2
3. I am usually so hungry that I eat more than three times a day.	T☐ 1	F☐ 2
4. When I have eaten my quota of calories, I am usually good about not eating any more.	T☐ 1	F☐ 2
5. Dieting is so hard for me because I just get too hungry.	T☐ 1	F☐ 2
6. I deliberately take small helpings as a means of controlling my weight.	T☐ 1	F☐ 2
7. Sometimes things just taste so good that I keep on eating even when I am no longer hungry.	T☐ 1	F☐ 2
8. Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat.	T☐ 1	F☐ 2
9. When I feel anxious, I find myself eating.	T☐ 1	F☐ 2
10. Life is too short to worry about dieting.	T☐ 1	F☐ 2
11. Since my weight goes up and down, I have gone on reducing diets more than once.	T☐ 1	F☐ 2
12. I often feel so hungry that I just have to eat something.	T☐ 1	F☐ 2
13. When I am with someone who is overeating, I usually overeat too.	T☐ 1	F☐ 2
14. I have a pretty good idea of the number of calories in common foods.	T☐ 1	F☐ 2
15. Sometimes when I start eating, I just can't seem to stop.	T☐ 1	F☐ 2
16. It is not difficult for me to leave something on my plate.	T☐ 1	F☐ 2

17. At certain times of the day, I get hungry because I have gotten used to eating then.	T☐ 1	F☐ 2
18. While on a diet, if I eat a food that is not allowed, I consciously eat less for a period of time to make up for it.	T☐ 1	F☐ 2
19. Being with someone who is eating often makes me hungry enough to eat also.	T☐ 1	F☐ 2
20. When I feel blue, I often overeat.	T☐ 1	F☐ 2
21. I enjoy eating too much to spoil it by counting calories or watching my weight.	T☐ 1	F☐ 2
22. When I see a real delicacy, I often get so hungry that I have to eat right away.	T☐ 1	F☐ 2
23. I often stop eating when I am not really full as a conscious means of limiting the amount that I eat.	T☐ 1	F☐ 2
24. I get so hungry that my stomach often seems like a bottomless pit.	T☐ 1	F☐ 2
25. My weight has hardly changed at all in the last ten years.	T☐ 1	F☐ 2
26. I am always hungry so it is hard for me to stop eating before I finish the food on my plate.	T☐ 1	F☐ 2
27. When I feel lonely, I console myself by eating.	T☐ 1	F☐ 2
28. I consciously hold back at meals in order not to gain weight.	T☐ 1	F☐ 2
29. I sometimes get very hungry late in the evening or at night.	T☐ 1	F☐ 2
30. I eat anything I want, any time I want.	T☐ 1	F☐ 2
31. Without even thinking about it, I take a long time to eat.	T☐ 1	F☐ 2
32. I count calories as a conscious means of controlling my weight.	T☐ 1	F☐ 2
33. I do not eat some foods because they make me fat.	T☐ 1	F☐ 2
34. I am always hungry enough to eat at any time.	T☐ 1	F☐ 2
35. I pay a great deal of attention to changes in my figure.	T☐ 1	F☐ 2
36. While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods.	T☐ 1	F☐ 2

Directions: Each question in this section is followed by a number of answer options. After reading each question carefully, choose the one option which most applies to you, and place an "X" in the box.				
37. How often are you dieting in a conscious effort to control your weight?	☐ 1 Rarely	☐ 2 Sometimes	☐ 3 Usually	☐ 4 Always
38. Would a weight fluctuation of 5 pounds affect the way you live your life?	☐ 1 Not at all	☐ 2 Slightly	☐ 3 Moderately	☐ 4 Very Much
39. How often do you feel hungry?	☐ 1 Only at Meal times	☐ 2 Sometimes between meals	☐ 3 Often between meals	☐ 4 Almost Always
40. Do your feelings of guilt about overeating help you to control your food intake?	☐ 1 Never	☐ 2 Rarely	☐ 3 Often	☐ 4 Always
41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?	☐ 1 Easy	☐ 2 Slightly Difficult	☐ 3 Moderately Difficult	☐ 4 Very Difficult
42. How conscious are you of what you are eating?	☐ 1 Not at all	☐ 2 Slightly	☐ 3 Moderately	☐ 4 Very Much
43. How frequently do you avoid "stocking up" on tempting foods?	☐ 1 Almost never	☐ 2 Seldom	☐ 3 Usually	☐ 4 Almost Always
44. How likely are you to shop for low calorie foods?	☐ 1 Unlikely	☐ 2 Slightly Likely	☐ 3 Moderately Likely	☐ 4 Very Likely
45. Do you eat sensibly in front of others and splurge alone?	☐ 1 Never	☐ 2 Rarely	☐ 3 Often	☐ 4 Always

46. How likely are you to consciously eat slowly in order to cut down on how much you eat?	☐ 1 Unlikely	☐ 2 Slightly Likely	☐ 3 Moderately Likely	☐ 4 Very Likely
47. How often do you skip dessert because you are no longer hungry?	☐ 1 Almost never	☐ 2 Seldom	☐ 3 At least once a week	☐ 4 Almost every day
48. How likely are you to consciously eat less than you want?	☐ 1 Unlikely	☐ 2 Slightly likely	☐ 3 Moderately likely	☐ 4 Very likely
49. Do you go on eating binges even though you are not hungry?	☐ 1 Never	☐ 2 Rarely	☐ 3 Sometimes	☐ 4 At least once a week
50. To what extent does this statement describe your eating behavior? *"I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising to start dieting again tomorrow."*	☐ 1 Not like me	☐ 2 Little like me	☐ 3 Pretty good description of me	☐ 4 Describes me perfectly
51. On a scale of 1 to 6, where 1 means no restraint in eating (eat whatever you want, whenever you want it) and 6 means total restraint (constantly limiting food intake and never "giving in"), what number would you give yourself?	☐ 1. Eat whatever you want, whenever you want it ☐ 2. Usually eat whatever you want, whenever you want it ☐ 3. Often eat whatever you want, whenever you want it ☐ 4. Often limit food intake, but often "give in" ☐ 5. Usually limit food intake, rarely "give in" ☐ 6. Constantly limiting food intake, never "giving in"			

APPENDIX 7: EXAMPLE OF SCREEN SHOT (WWW.BODYTRACE.COM)

APPENDIX 8: EXAMPLE OF EMAIL WITH TAILORED FEEDBACK

Hello «First_name»,

Congrats on completing your 1st month in the WEIGH Study!

You are doing an excellent job making sure to weigh everyday! By now, you have been doing it for 4 weeks and it is becoming a daily habit – just like brushing your teeth! Take a moment to reflect on how adding this daily behavior has changed your diet and physical activity behaviors. Do you think differently about how your choices are impacting your weight? Remember to continue to notice if you meet a new low weight – this is a good indicator of your progress! Keep up the good work!

After 4 weeks in the program, you have made great progress with your weight loss. As of yesterday, you have lost **«wt_lost_todate» lbs.**, which is an average of **«Avg_wkly_loss» lbs. per week.** These results indicate that you have made some great changes to your eating and exercise behaviors to help tip the energy balance equation towards weight loss. Take a moment to reward yourself for your accomplishments – see this week's lesson on making SMART goals!

Thinking about last week's lesson on food labels and liquid calories - Did you find yourself reading more food labels? Did you discover that you were "drinking your calories?" These two strategies can be very helpful when trying to determine where extra calories might be sneaking into your diet.

This week's lesson (attached) focuses on coming up with small, short-term goals that will help you achieve your ultimate goal of weight loss. It can be overwhelming to think about how you will achieve your weight loss, but breaking it down into these small goals will help. Please take time to review it and work on setting weekly goals to help you achieve success.

Keep weighing everyday and we'll check in with you again next week.

-Dori

APPENDIX 9: LIST OF BEHAVIORAL WEIGHT CONTROL LESSONS

1. Getting Started
2. How to be a Calorie Detective - Understanding Portions and Healthy Food Choices
3. Developing and Implementing your Exercise Program
4. Using Food Labels and Avoid Liquid Calories
5. Making SMART Goals
6. Being Active as a Way of Life
7. Eating Outside the Home
8. Role of Thoughts
9. Stimulus Control – Taking Charge of What's Around You
10. Problem Solving
11. Barriers to Exercise
12. Slippery Slope of Weight Management
13. Preparing Foods at Home and Supermarket Shopping - Plus Recipes
14. Dealing with Vacation/Events
15. Urge Surfing – Understanding Food Cravings
16. Exercise Equivalents
17. Stress Management
18. Ways to Stay Motivated
19. Weight Loss Plateaus
20. Social Support
21. Factors that Contribute to Long-term Success – How Successful Weight Losers Do It!
22. Evaluating Your Progress and Planning for the Future

APPENDIX 10: EXAMPLE OF BEHAVIORAL WEIGHT CONTROL LESSON

WEIGH Study
Weighing to Improve and Gain Health

Getting Started with the WEIGH Study: **We**ighing to **I**mprove and **G**ain **H**ealth

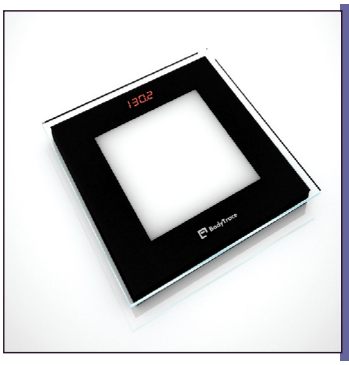
Welcome to the WEIGH Study. Over the next few months, you will learn how to use daily weighing as a tool to guide your eating and exercise choices. By weighing everyday, you will become more aware of what you are eating and how much exercise you are doing, and be able to make adjustments to help you lose weight.

Main Program Components

1. Weigh yourself everyday on your brand new Smart Scale first thing in the morning!
2. Review your weight graph at www.bodytrace.com.

See the **MY WEIGH** handout for your login and password

3. Read the weekly emailed lessons with information about strategies for losing weight
4. Review the weekly emailed feedback about your daily weighing and weight loss progress.



Quick Fact:

Did you know that daily weighing is one of the secrets of successful weight losers? In the National Weight Control Registry (made up of thousands of people who have lost at least 30 lbs. and kept if off for at least 1 year), over 75% of individuals weigh themselves regularly. This allows them to make quick adjustments to maintain weight loss.

REFERENCES

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of Obesity and Trends in Body Mass Index Among US Children and Adolescents, 1999-2010. *JAMA.* 2012;307(5):483-490.

2. Sarwer DB, von Sydow Green A, Vetter ML, Wadden TA. Behavior therapy for obesity: where are we now? *Current Opinion in Endocrinology, Diabetes and Obesity.* 2009;16(5):347.

3. Boutelle K. Weighing the evidence: benefits of regular weight monitoring for weight control. *Journal of nutrition education and behavior.* 2006;38(3):131.

4. Linde JA, Jeffery RW, French SA, Pronk NP, Boyle RG. Self-weighing in weight gain prevention and weight loss trials. *Annals of Behavioral Medicine.* 2005;30(3):210-216.

5. Gokee-Larose J, Gorin AA, Wing RR. Behavioral self-regulation for weight loss in young adults: a randomized controlled trial. *Int J Behav Nutr Phys Act.* 2009;6:10.

6. VanWormer JJ, Martinez AM, Benson GA, et al. Telephone counseling and home telemonitoring: the Weigh by Day Trial. *American journal of health behavior.* Jul-Aug 2009;33(4):445-454.

7. Vanwormer JJ, French SA, Pereira MA, Welsh EM. The impact of regular self-weighing on weight management: a systematic literature review. *Int J Behav Nutr Phys Act.* 2008;5:54.

8. Dionne MM, Yeudall F. Monitoring of Weight in Weight Loss Programs: A Double-Edged Sword? *Journal of Nutrition Education and Behavior.* 2005;37(6):315-318.

9. Noar SM, Zimmerman RS. Health Behavior Theory and cumulative knowledge regarding health behaviors: are we moving in the right direction? *Health Educ Res.* Jun 2005;20(3):275-290.

10. Bandura A. Health promotion by social cognitive means. *Health education & behavior : the official publication of the Society for Public Health Education.* Apr 2004;31(2):143-164.

11. Kanfer FH. Self-monitoring: Methodological limitations and clinical applications. *Journal of consulting and clinical psychology.* 1970;35(2):148-152.

12. Kanfer FH, Karoly P. Self-control: A behavioristic excursion into the lion's den. *Behavior Therapy.* 1972;3(3):389-416.

13. Baranowski T, Perry CL, Parcel GS. How individuals, environments, and health behavior interact2002:165-184.

14. Rothman AJ, Baldwin AS, Hertel AW. Self-regulation and behavior change: Disentangling behavioral initiation and behavioral maintenance. In: Vohs K, Baumeister R, eds. *The Handbook of Self-regulation*. New York, NY: Guilford Press; 2004:130–148.

15. Clark MM, Abrams DB, Niaura RS, Eaton CA, Rossi JS. Self-efficacy in weight management. *Journal of consulting and clinical psychology.* 1991;59(5):739-744.

16. Anderson ES, Winett RA, Wojcik JR. Self-regulation, self-efficacy, outcome expectations, and social support: Social cognitive theory and nutrition behavior. *Annals of Behavioral Medicine.* 2007;34(3):304-312.

17. Kitsantas A. The role of self-regulation strategies and self-efficacy perceptions in successful weight loss maintenance. *Psychology & Health.* 2000;15(6):811-820.

18. Linde JA, Rothman AJ, Baldwin AS, Jeffery RW. The impact of self-efficacy on behavior change and weight change among overweight participants in a weight loss trial. *Health Psychology.* 2006;25(3):282-291.

19. Mahoney MJ. Self-reward and self-monitoring techniques for weight control. *Behavior Therapy.* 1974;5(1):48-57.

20. Mahoney MJ, Moura NG, Wade TC. Relative efficacy of self-reward, self-punishment, and self-monitoring techniques for weight loss. *Journal of consulting and clinical psychology.* 1973;40(3):404-407.

21. Rosen LW. Self-control in the treatment of obesity. *Journal of Behavior Therapy and Experimental Psychiatry.* 1981;12(2):163-166.

22. Segal SP, Silverman C, Temkin T. Measuring empowerment in client-run self-help agencies. *Community mental health journal.* 1995;31(3):215-227.

23. Borkman T, Powell TJ. *Working with self-help*: NASW Press Silver Spring, MD; 1990.

24. Bandura A. Self-efficacy mechanism in physiological activation and health-promoting behavior. In: Madden J, Matthysse S, Barchas J, eds. *Adaptation, learning and affect*. New York: Raven Press; 1991:229-269.

25. Murawski ME, Milsom VA, Ross KM, et al. Problem solving, treatment adherence, and weight-loss outcome among women participating in lifestyle treatment for obesity. *Eating Behaviors.* 2009;10(3):146-151.

26. Burke LE, Wang J, Sevick MA. Self-monitoring in weight loss: a systematic review of the literature. *Journal of the American Dietetic Association.* 2011;111(1):92-102.

27. Baker RC, Kirschenbaum DS. Self-monitoring may be necessary for successful weight control. *Behavior Therapy.* 1993;24(3):377-394.

28. Carver CS, Scheier MF. *Attention and self-regulation: A control-theory approach to human behavior*. New York: Springer-Verlag 1981.

29. Field AE, Coakley EH, Must A, et al. Impact of overweight on the risk of developing common chronic diseases during a 10-year period. *Archives of Internal Medicine.* 2001;161(13):1581.

30. Wilson PWF, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. *Circulation.* 1998;97(18):1837.

31. Wilson PWF, Meigs JB, Sullivan L, Fox CS, Nathan DM, D'Agostino Sr RB. Prediction of incident diabetes mellitus in middle-aged adults: the Framingham Offspring Study. *Archives of Internal Medicine.* 2007;167(10):1068.

32. Wolin KY, Carson K, Colditz GA. Obesity and Cancer. *The oncologist.* 2010;15(6):556.

33. Manson JE, Bassuk SS, Hu FB, Stampfer MJ, Colditz GA, Willett WC. Estimating the number of deaths due to obesity: can the divergent findings be reconciled? *Journal of Women's Health.* 2007;16(2):168-176.

34. Finkelstein EA, Fiebelkorn IC, Wang G. State-level estimates of annual medical expenditures attributable to obesity. *Obesity research.* 2004;12(1):18-24.

35. Panel NOEIE. On the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults—the evidence report. *Obes Res.* 1998;6(suppl 2):51S-209S.

36. Wadden TA, West DS, Delahanty L, et al. The Look AHEAD study: a description of the lifestyle intervention and the evidence supporting it. *Obesity (Silver Spring).* 2006;14(5):737-752.

37. Wadden TA, Berkowitz RI, Womble LG, et al. Randomized trial of lifestyle modification and pharmacotherapy for obesity. *New England Journal of Medicine.* 2005;353(20):2111.

38. Pi-Sunyer X, Blackburn G, Brancati FL, et al. Reduction in weight and cardiovascular disease risk factors in individuals with type 2 diabetes: one-year results of the look AHEAD trial. *Diabetes Care.* Jun 2007;30(6):1374-1383.

39. Wing RR, Koeske R, Epstein LH, Nowalk MP, Gooding W, Becker D. Long-term effects of modest weight loss in type II diabetic patients. *Archives of Internal Medicine.* 1987;147(10):1749.

40. Stevens VJ, Corrigan SA, Obarzanek E, et al. Weight loss intervention in phase 1 of the Trials of Hypertension Prevention. *Archives of Internal Medicine.* 1993;153(7):849.

41. Dattilo AM, Kris-Etherton PM. Effects of weight reduction on blood lipids and lipoproteins: a meta-analysis. *American journal of clinical nutrition.* 1992;56(2):320.

42. Program DP. The Diabetes Prevention Program. Design and methods for a clinical trial in the prevention of type 2 diabetes. *Diabetes Care.* Apr 1999;22(4):623-634.

43. Knowler WC, Barrett-Connor E, Fowler SE, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med.* Feb 7 2002;346(6):393-403.

44. Perri MG, Corsica JA. Improving the maintenance of weight lost in behavioral treatment of obesity. In: Wadden TA, Stunkard AJ, eds. *Handbook of obesity treatment*. New York: The Guilford Press; 2002:357-379.

45. Wing RR. Long-term effects of a lifestyle intervention on weight and cardiovascular risk factors in individuals with type 2 diabetes mellitus: four-year results of the Look AHEAD trial. *Arch Intern Med.* Sep 27 2010;170(17):1566-1575.

46. Knowler WC, Fowler SE, Hamman RF, et al. 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. *Lancet.* Nov 14 2009;374(9702):1677-1686.

47. Wing RR, Phelan S. Long-term weight loss maintenance. *American Journal of Clinical Nutrition.* 2005;82(1):222S.

48. Black DR, Cameron R. Self-administered interventions: a health education strategy for improving population health. *Health education research.* 1997;12(4):531.

49. Glasgow RE, Rosen GM. Behavioral bibliotherapy: A review of self-help behavior therapy manuals. *Psychological bulletin.* 1978;85(1):1-23.

50. Latner JD. Self-help in the long-term treatment of obesity. *Obesity Reviews.* 2001;2(2):87-97.

51. Butryn ML, Phelan S, Wing RR. Self-guided approaches to weight loss. In: Latner JD, Wilson GT, eds. *Self-help approaches for obesity and eating disorders* New York: Guilford; 2007:3-20.

52. Miller WC, Eggert KE, Wallace JP, Lindeman AK, Jastremski C. Successful weight loss in a self-taught, self-administered program. *International Journal of Sports Medicine.* 1993;14:401-405.

53. Cameron R, MacDonald MA, Schlegel RP, et al. Toward the development of self-help health behaviour change programs: weight loss by correspondence. *Canadian journal of public health.Revue canadienne de sante publique.* 1990;81(4):275-279.

54. Lally P, Chipperfield A, Wardle J. Healthy habits: efficacy of simple advice on weight control based on a habit-formation model. *International journal of obesity.* 2007;32(4):700-707.

55. Brownell KD. *The LEARN program for weight management.* Dallas, TX: American Health; 2000.

56. Carels RA, Wott CB, Young KM, et al. Successful weight loss with self-help: A stepped-care approach. *Journal of Behavioral Medicine.* 2009;32(6):503-509.

57. Gold BC, Burke S, Pintauro S, Buzzell P, Harvey-Berino J. Weight loss on the web: A pilot study comparing a structured behavioral intervention to a commercial program. *Obesity (Silver Spring).* Jan 2007;15(1):155-164.

58. Tate DF, Wing RR, Winett RA. Using Internet technology to deliver a behavioral weight loss program. *JAMA.* Mar 7 2001;285(9):1172-1177.

59. Tate DF, Jackvony EH, Wing RR. A randomized trial comparing human e-mail counseling, computer-automated tailored counseling, and no counseling in an Internet weight loss program. *Archives of Internal Medicine.* 2006;166(15):1620.

60. Welsh EM, Sherwood NE, VanWormer JJ, Hotop AM, Jeffery RW. Is frequent self-weighing associated with poorer body satisfaction? Findings from a phone-based weight loss trial. *J Nutr Educ Behav.* Nov-Dec 2009;41(6):425-428.

61. VanWormer JJ, Martinez AM, Martinson BC, et al. Self-Weighing Promotes Weight Loss for Obese Adults. *American Journal of Preventive Medicine.* 2009;36(1):70-73.

62. Wing RR, Tate DF, Gorin AA, Raynor HA, Fava JL. A self-regulation program for maintenance of weight loss. *N Engl J Med.* Oct 12 2006;355(15):1563-1571.

63. Linde JA, Utter J, Jeffery RW, Sherwood NE, Pronk NP, Boyle RG. Specific food intake, fat and fiber intake, and behavioral correlates of BMI among overweight and obese members of a managed care organization. *Int J Behav Nutr Phys Act.* 2006;3:42.

64. Alm ME, Neumark-Sztainer D, Story M, Boutelle KN. Self-Weighing and Weight Control Behaviors Among Adolescents with a History of Overweight. *Journal of Adolescent Health.* 2009;44(5):424-430.

65. Qi BB, Dennis KE. The adoption of eating behaviors conducive to weight loss. *Eating Behaviors.* 2000;1(1):23-31.

66. MacKinnon DP. Analysis of mediating variables in prevention and intervention research. *NIDA research monograph.* 1994;139:127-153.

67. Dionne MM, Davis C. Body image variability: the influence of body-composition information and neuroticism on young women's body dissatisfaction. *Body image.* Dec 2004;1(4):335-349.

68. Ogden J, Evans C. The problem with weighing: effects on mood, self-esteem and body image. *Int J Obes Relat Metab Disord.* Mar 1996;20(3):272-277.

69. Ogden J, Whyman C. The effect of repeated weighing on psychological state. *European Eating Disorders Review.* 1997;5(2):121-130.

70. Tiggemann M. Dietary restraint as a predictor of reported weight loss and affect. *Psychological reports.* Dec 1994;75(3 Pt 2):1679-1682.

71. McFarlane T, Polivy J, Herman CP. Effects of false weight feedback on mood, self-evaluation, and food intake in restrained and unrestrained eaters. *Journal of abnormal psychology.* May 1998;107(2):312-318.

72. O'Neil PM, Brown JD. Weighing the evidence: benefits of regular weight monitoring for weight control. *Journal of Nutrition Education and Behavior.* 2005;37(6):319-322.

73. Heinberg LJ, Thompson JK, Matzon JL. Body image dissatisfaction as a motivator for healthy lifestyle change: Is some distress beneficial? In: Striegel Moore RH, L S, eds. *Eating Disorders: Innovative Directions in Research and Practice*. Washington, DC: American Psychological Association; 2001:215-232.

74. Linde JA, Jeffery RW, Finch EA, et al. Relation of body mass index to depression and weighing frequency in overweight women. *Preventive medicine.* 2007;45(1):75-79.

75. Wing RR, Tate DF, Gorin AA, Raynor HA, Fava JL, Machan J. STOP regain: are there negative effects of daily weighing? *J Consult Clin Psychol.* Aug 2007;75(4):652-656.

76. Phelan S, Nallari M, Darroch FE, Wing RR. What Do Physicians Recommend To Their Overweight and Obese Patients? *The Journal of the American Board of Family Medicine.* 2009;22(2):115.

77. Tate DF, Wing RR. The effects of group vs. invidual weight loss counseling delivered via the Internet: results from a randomized controlled trial. *In Preparation.* 2012.

78. Block G, Thompson FE, Hartman AM, Larkin FA, Guire KE. Comparison of two dietary questionnaires validated against multiple dietary records collected during a 1-year period. *Journal of the American Dietetic Association.* 1992;92(6):686-693.

79. Brown JL, Griebler R. Reliability of a short and long version of the block food frequency form for assessing changes in calcium intake. *J Am Diet Assoc.* Jul 1993;93(7):784-789.

80. O'Neil PM, Currey HS, Hirsch AA, et al. Development and Validation of the Eating Behavior Inventory. *Journal of Psychopathology and Behavioral Assessment.* 1979;1(2):123-132.

81. O'Neil PM, Rieder S. Utility and validity of the Eating Behavior Inventory in clinical obesity research: a review of the literature. *Obesity Reviews.* 2005;6(3):209-216.

82. Paffenbarger Jr RS, Wing AL, Hyde RT. Physical activity as an index of heart attack risk in college alumni. *American Journal of Epidemiology.* 1995;142(9):889.

83. Ainsworth BE, Leon AS, Richardson MT, Jacobs DR, Paffenbarger RS, Jr. Accuracy of the College Alumnus Physical Activity Questionnaire. *J Clin Epidemiol.* Dec 1993;46(12):1403-1411.

84. Choo J, Elci OU, Yang K, et al. Longitudinal relationship between physical activity and cardiometabolic factors in overweight and obese adults. *European journal of applied physiology.* Jan 2010;108(2):329-336.

85. MacKinnon DP, Krull JL, Lockwood CM. Equivalence of the mediation, confounding and suppression effect. *Prevention Science.* 2000;1(4):173-181.

86. Preacher KJ, Hayes AF. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods.* 2008;40(3):879.

87. Zhao X, Lynch JG, Chen Q. Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis. *J.Consumer.Research.* 2010;37.

88. Arab L, Tseng CH, Ang A, Jardack P. Validity of a multipass, web-based, 24-hour self-administered recall for assessment of total energy intake in blacks and whites. *Am J Epidemiol.* Dec 1 2011;174(11):1256-1265.

89. Shrout PE, Bolger N. Mediation in experimental and nonexperimental studies: new procedures and recommendations. *Psychological methods.* Dec 2002;7(4):422-445.

90. Stunkard AJ, Wadden TA. *Obesity: theory and therapy*: Raven press New York; 1993.

91. Burke LE, Choo J, Music E, et al. PREFER study: A randomized clinical trial testing treatment preference and two dietary options in behavioral weight management--rationale, design and baseline characteristics. *Contemporary clinical trials.* 2006;27(1):34-48.

92. Burke L, Elci O, Wang J, et al. Self-monitoring in behavioral weight loss treatment: SMART trial short-term results. *Obesity.* 2009;17(suppl 2):S273.

93. Burke LE, Swigart V, Warziski Turk M, Derro N, Ewing LJ. Experiences of Self-Monitoring: Successes and Struggles During Treatment for Weight Loss. *Qualitative health research.* 2009;19(6):815.

94. McGuire M, Wing R, Klem M, Hill J. Behavioral strategies of individuals who have maintained long-term weight losses. *Obesity research.* 1999;7(4):334.

95. Tate DF, Jackvony EH, Wing RR. Effects of Internet behavioral counseling on weight loss in adults at risk for type 2 diabetes: a randomized trial. *JAMA.* Apr 9 2003;289(14):1833-1836.

96. Jakicic JM, Tate DF, Lang W, et al. Effect of a stepped-care intervention approach on weight loss in adults: a randomized clinical trial. *JAMA.* Jun 27 2012;307(24):2617-2626.

97. Subar AF, Thompson FE, Potischman N, et al. Formative research of a quick list for an automated self-administered 24-hour dietary recall. *Journal of the American Dietetic Association.* 2007;107(6):1002-1007.

98. Tran KM, Johnson RK, Soultanakis RP, Matthews DE. In-person vs Telephone-administered Multiple-pass 24-hour Recalls in Women Validation with Doubly Labeled Water. *Journal of the American Dietetic Association.* 2000;100(7):777-783.

99. Gokee LaRose J, Tate DF, Gorin AA, Wing RR. Preventing weight gain in young adults: a randomized controlled pilot study. *Am J Prev Med.* Jul 2010;39(1):63-68.

100. Linde JA, Jeffery RW. Testing a brief self-directed behavioral weight control program. *Behavioral medicine (Washington, D.C.).* Apr 2011;37(2):47-53.

101. McTigue KM, Harris R, Hemphill B, et al. Screening and interventions for obesity in adults: summary of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med.* Dec 2 2003;139(11):933-949.

102. Steinberg DM, Tate DF, Bennett GG, Ennett S, Samuel-Hodge C, Ward DS. The efficacy of a daily self-weighing weight loss intervention using smart scales and email. *Obesity.* 2012;Under Review.

103. Evans C, Dolan B. Body Shape Questionnaire: derivation of shortened" alternate forms". *International Journal of Eating Disorders.* 1993;13:315-321.

104. Radloff LS. The CES-D scale: A self-report depression scale for research in the general population. *Applied psychological measurement.* 1977;1(3):385.

105. Ensel W. Measuring depression: The CES-D Scale. In: Lin N, Dean A, Ensel W, eds. *Social Support, Life Events and Depression*. New York: Academic Press; 1986:51-70.

106. Zich JM, Attkisson CC, Greenfield TK. Screening for depression in primary care clinics: the CES-D and the BDI. *The International Journal of Psychiatry in Medicine.* 1990;20(3):259-277.

107. Mizes JS, Christiano B, Madison J, Post G, Seime R, Varnado P. Development of the Mizes Anorectic Cognitions Questionnaire-Revised: Psychometric properties and factor structure in a large sample of eating disorder patients. *International Journal of Eating Disorders.* 2000;28(4):415-421.

108. Osman A, Chiros CE, Gutierrez PM, Kopper BA, Barrios FX. Factor structure and psychometric properties of the brief Mizes Anorectic Cognitions questionnaire. *Journal of clinical psychology.* 2001;57(6):785-799.

109. Spitzer RL, Devlin M, Walsh BT, et al. Binge eating disorder: A multisite field trial of the diagnostic criteria. *International Journal of Eating Disorders.* 1992;11(3):191-203.

110. Nangle DW, Johnson WG, Carr-Nangle RE, Engler LB. Binge eating disorder and the proposed DSM-IV criteria: psychometric analysis of the Questionnaire of Eating and Weight Patterns. *International Journal of Eating Disorders.* 1994;16(2):147-157.

111. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of psychosomatic research.* 1985;29(1):71-83.

112. Stevens J, Truesdale KP, McClain JE, Cai J. The definition of weight maintenance. *Int J Obes (Lond).* Mar 2006;30(3):391-399.

113. Foster GD, Wadden TA, Vogt RA. Body image in obese women before, during, and after weight loss treatment. *Health Psychology.* 1997;16(3):226.

114. Foster G, Wadden T, Swain R, Stunkard A, Platte P, Vogt R. The Eating Inventory in obese women: clinical correlates and relationship to weight loss. *Int J Obes Relat Metab Disord.* 1998;22(8):778.

115. Clark MM, Marcus BH, Pera V, Niaura RS. Changes in eating inventory scores following obesity treatment. *International Journal of Eating Disorders.* 1994;15(4):401-405.

116. Lewis BA, Marcus BH, Pate RR, Dunn AL. Psychosocial mediators of physical activity behavior among adults and children. *Am J Prev Med.* Aug 2002;23(2 Suppl):26-35.

117. Westerterp KR, Goris AHC. Validity of the assessment of dietary intake: problems of misreporting. *Current Opinion in Clinical Nutrition & Metabolic Care.* 2002;5(5):489.

118. Cooper Z, Fairburn CG. A new cognitive behavioural approach to the treatment of obesity. *Behav Res Ther.* May 2001;39(5):499-511.

119. Wing R. Behavioral approaches to the treatment of obesity. In: Bray GA, Bouchard C, James WPT, eds. *Handbook of Obesity*. New York: Marcel Dekker, Inc 1998:855–873.