Physical activity, self-weighing, and absenteeism in a worksite weight gain prevention intervention: The HealthWorks trial

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Dedication

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Abstract

INTRODUCTION: Rising obesity rates are a threat to the American public's health. To date, however, few studies have used an environment focused weight gain prevention intervention approach, which is arguably more appropriate than individual weight loss counseling interventions. The HealthWorks trial recently implemented a worksite environment intervention (e.g., modifications to cafeterias/vending, activity social environment) aimed at reducing weight gain over two years among adults.

METHODS: This dissertation includes three secondary data analyses from the broader HealthWorks trial in order to: (1) determine if baseline physical activity level is associated with enrollment in worksite walking club events, (2) assess if self-weighing frequency is associated with weight maintenance, and (3) assess if weight change is associated with workplace absenteeism. Physical activity and self-weighing were two of the key lifestyle changes targeted in the HealthWorks trial and reduced workplace absenteeism was one of the economic outcomes believed to result from a successful intervention. Six worksites (N=1,747 individuals) were randomized to either a treatment or control arm. Multivariate regression models were used for all analyses.

RESULTS: In paper #1, baseline physical activity level was not a significant predictor of worksite walking club participation, but several covariates (i.e., age, sex, social support, worksite) remained in the final models as significant predictors. In paper #2, there was a significant interaction between follow-up self-weighing frequency and baseline BMI category. Specifically, adjusted weight change ranged from a mean±SE -4.5±0.8 kg among obese daily self-weighers to 2.2±0.4 kg for participants at a healthy BMI who reported self-weighing monthly or less. In paper #3, weight change was not a significant predictor of workplace absenteeism, but several covariates (i.e., sex, depression, smoking, BMI) remained in the final models as significant predictors of workplace absenteeism.

CONCLUSIONS: The collective findings suggest that over two years: (1) worksite walking clubs are generally appealing across varying levels of physical activity, (2) self-weighing may be most beneficial for obese individuals who increase their self-weighing frequency over time, and (3) weight loss may not meaningfully decrease workplace illness absence days. More intense efforts on the primary prevention of weight gain that decreases the proportion of newly obese employees, perhaps via broad-based physical activity programs and stronger emphases on frequent self-weighing, may be necessary to achieve long-term weight change and economic benefits for employers.

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Chapter I. Specific Aims

An escalating obesity rate threatens the American public's health. To combat this, environmental changes will likely be needed to improve food services and opportunities for physical activity. The worksite presents a unique opportunity to modify the food and physical activity environment and influence individuals' daily choices in ways that are more conducive to preventing weight gain and improving overall health. The primary aim of the HealthWorks study was to evaluate the efficacy of a multi-component, environment oriented intervention in reducing weight gain over two years among working adults. The intervention included modifications to: worksite cafeterias/vending, social/physical activity environment, and informational environments. Six worksites were randomized to either a treatment or control group. The primary study outcome of interest was weight change among participants from baseline to 24-month follow-up. It was hypothesized that the intervention would result in reduced intake of targeted foods, increased physical activity, and reduced weight gain across the 24 months of observation among employees in intervention versus control worksites.

This dissertation includes three secondary data analyses from the broader HealthWorks study in order to gauge the degree to which various targeted intervention exposures predicted outcomes related to the study's primary aims described above. The following specific aims will be addressed in these three separate analyses:

1) Determine if baseline physical activity level is associated with enrollment in worksite walking club events.
2) Assess if self-weighing frequency is associated with weight change.
3) Assess if weight change is associated with workplace absenteeism.

The respective hypotheses are that: (1) higher levels of baseline physical activity will be associated with enrolling in worksite walking club events relative to lower levels of baseline physical activity, (2) weekly or daily self-weighing frequency will be associated with greater weight maintenance relative to monthly or less self-weighing frequency, and (3) weight loss will be associated with less workplace absenteeism relative to weight gain.

Chapter II. Introduction

Excess body weight persistently plagues the American public's health.[1, 2] About 34% of adults age 20-74 years are clinically obese (i.e., body mass index [BMI] ≥30 kg/m^2) in the United States.[2, 3] Obesity is associated with a moderately increased risk of premature mortality[4] and a consistently strong risk of incident high blood pressure,[5] dyslipidemia,[6] type 2 diabetes,[7] and certain forms of cancer.[8] In terms of overall chronic disease risk, obesity is essentially equivalent to an additional 20 years of aging.[9] Even more concerning is the fact that the obesity epidemic shows few signs of abatement. Obesity prevalence has at least doubled over the past three decades, with the largest increases observed in the more severe forms of obesity (i.e., BMI ≥40 kg/m^2).[3, 10] Current trends suggest that, on average, American adults gain an estimated 1 kg per year.[11] At this rate of increase, over half of all American adults will be clinically obese by 2030, creating a potentially calamitous, unsustainable demand for healthcare services and subsequent burden for healthcare payers.[12]

It seems commonplace for health professionals and the mainstream press to call for weight loss as the solution to the rising prevalence of obesity. It is perhaps not surprising that most adults have attempted to diet to lose weight at some point in their life.[13] Such efforts have much intuitive appeal given the background epidemiological trends of obesity, but unfortunately, current evidence suggests only limited efficacy for behavioral weight loss interventions as a strong, long-term population-level obesity management strategy. At best, it is estimated that only about 15% of overweight individuals who intentionally lose 5 kg or more of their body weight will successfully keep it off beyond 5 years.[14, 15] Ample evidence from systematic literature reviews[16, 17] and meta-analyses[18, 19] on the topic of long-term weight management support the assertion that weight loss followed by long-term avoidance of weight regain, though possible, is elusive for all but the most dedicated few individuals. Franz and colleagues[19] found a highly predictable weigh regain curve across most all common weight management therapies, including:

- Lifestyle Therapy (i.e., diet and exercise) – On average, lifestyle therapy results in a 7-10% weight loss over the first 6 months. Jeffery, et al.[20] concluded that about 40% of the initial weight loss is regained after the first year and weight returns to a level near baseline within four years.
- Pharmacotherapy – Though few long-term studies exist, drug treatment (combined with lifestyle therapy) typically results in at least a 10% weight loss over the first six months.[21] Weight regain is generally more gradual compared to lifestyle therapy, but occurs quickly if/when the drugs are discontinued.
- Surgery – Obesity surgery has the best long-term weight loss profile in that the average individual can expect to lose 20-45% of their preoperative weight over the first year[22] and 60-75% of such individuals maintain this weight loss long-term.[23] Surgery, however, is not considered a viable public health strategy because it is reserved for very few individuals due to the long-term complications, high costs, and stringent dietary restrictions.

Relatively little is known about why weight loss and weight maintenance are such elastic phenomena, but investigators consistently cite poor long-term adherence to weight management behaviors coupled with physiological barriers, such as lowered resting metabolic rate and increased adipose lipoprotein lipase activity, as likely contributors.[24] In addition, obesogenic environmental cues may make ongoing adherence to diet and exercise more difficult. In light of these hypotheses, there is widespread scientific consensus based on empirical evidence that relapse is basically the norm following most weight loss therapies.

The case for weight gain prevention

Based on the shortcomings of traditional weight loss therapies, others have advocated for a more pragmatic focus of intervention efforts designed to control excess body weight.[11, 25, 26] The target of such efforts is urged to be on the prevention of weight gain across the entire population versus weight loss for those at the highest medical risk. Meaningful stabilization of population level obesity is hypothesized to begin at even modest levels of behavior change sufficient to produce a 100 kcal/day deficit through increased physical activity and/or caloric restriction.[11] The steadily rising prevalence of obesity in the U.S. is believed to be due to small, persistent changes in the environment that have shifted energy balance (i.e., calories consumed versus calories burned) toward the positive. The cause of this shifting energy balance is multifactorial,[27] but seems to be particularly driven by expanded access to high-calorie convenience foods and technological advances that have reduced the amount of physical activity required for routine transportation (e.g., commuting to work) and occupational activities (replaced by sedentary behaviors such as television watching and automobiles).

A handful of studies have been published that focused specifically on weight gain prevention. A recent systematic literature review was completed by Lemmens and colleagues[28] that examined the efficacy of adult weight gain prevention trials conducted since 1998. Nine randomized trials were included in the review, with four studies demonstrating statistically significant weight change advantages of the intervention group over comparison groups and five studies showing no such advantage. Overall conclusions on the effectiveness of weight gain prevention studies were inconclusive due to the heterogeneity of study characteristics (e.g., follow-up was 0.25-8 years and sample sizes ranged from 40-48,835 participants), but the three interventions with the largest effect sizes (median weight advantage for the intervention group ~3 kg over 1 year) included professional follow-up support options and a focus on regular physical activity in conjunction with moderating caloric intake and portion sizes. This is consistent with evidence that implicates that regular physical activity is perhaps the most influential behavioral marker of weight loss maintenance.[20, 29] Studies with more intense professional contact and shorter follow-up periods generally showed more pronounced body weight advantages relative to interventions without a professional contact component and/or with longer follow-up periods. Because such interventions are more expensive to conduct given their more intense level of professional-participant contact, they may have limited potential to reach large segments of the population.

The Pound of Prevention study from the University of Minnesota[30] was the first study funded by the National Institutes of Health on population-wide weight gain prevention. Interventions in that study consisted of monthly educational newsletters targeting reduced energy consumption, regular exercise, and frequent self-weighing, along with access to complementary community programs including a brief weight loss coaching course, physical activity seminars, 1 month free membership to a community exercise facility, walking groups, and home-based walking competitions. In addition, an enhanced intervention group was entered into a monthly $100 prize drawing incentive for returning monthly postcards included with the newsletter that asked questions on behavior change progress. Results at year 3 of this study indicated a slight, though non-significant, weight change advantage for the two intervention arms over the control arm. Secondary analyses revealed significant weight change advantages for participants that adopted the three primary target behaviors (i.e., reduced calories, increased physical activity, frequent self-weighing) relative to participants who did not.[31]

Given the ubiquity of the obesity epidemic and the background forces expanding it in the general population, the most realistic near-term goal for a large group may well be weight gain prevention and not weight loss.[11] In other words, at the community level at least, the goal should be to maintain the weight the population is currently at and stop weight from increasing up by the expected 1 kg/year. There is at least some evidence that weight gain prevention interventions can be effective,[28] but studies to date have largely relied on individual education/counseling approaches with equivocal results overall. As such, they lack scalability to larger populations due to their high implementation costs. It seems that an intervention approach that includes stronger components to modify the physical and social environment would likely be more feasible for larger populations and potentially touch more individuals with new behavioral contingencies designed to stabilize weight gain.

Chapter III. Overview of the HealthWorks Study

Design, purpose, and general procedures

The three analyses conducted as part of this dissertation were completed using data from the larger group randomized-controlled trial, HealthWorks. The purpose of the broader HealthWorks study was to evaluate the effectiveness of a multi-component package of environmental interventions on physical activity, eating behaviors, and body weight over 24 months among working adults. HealthWorks was delivered in the worksite setting primarily due to the large amount of time spent at work by many individuals in a given week and the associated opportunities to make sustained changes in the environments there that influence physical activity and nutrition.[32]

Three worksites were randomized to a weight gain prevention intervention arm and three worksites were randomized to a no-treatment control arm. Each arm consisted of worksites from the Minneapolis-St. Paul metropolitan area and worksite was the unit of randomization. The primary outcome of interest in HealthWorks was change in body weight and it was hypothesized that average weight gain over 2 years would be less in the intervention condition relative to the control condition. Also, it was hypothesized that intervention worksites would report reduced intake of targeted high calorie foods, increased physical activity, and increased weight control behaviors (e.g., self-weighing) compared to control worksites. Measures were taken at baseline and again at 24-month follow-up. Study procedures were approved in advance by the University of Minnesota Institutional Review Board. Informed consent was obtained from all individual participants at the baseline assessment.

Participants and recruitment

Worksites. The worksite recruitment period lasted approximately 18 months and was conducted by first purchasing a list of area worksites from a local marketing company. Worksites of 250-1000 employees were preliminarily identified, enumerated, and contacted by telephone for a brief screening to determine interest and assess basic eligibility criteria (see below). An initial letter was then sent to the human resources director that described the project in more detail. A follow-up telephone call was made to the human resources director to verify eligibility with extended screening (i.e., to assess presence of worksite wellness activities or potential for expansion, downsizing or relocation within the next several years), explain more details of study procedures, and invite participation in the study if warranted. For interested worksites, an informational meeting was held to discuss the project and its associated requirements with senior leadership. Finally, the administrative director would sign a written acknowledgement of understanding of the expectations and benefits of participating in the study. Specific study eligibility requirements for participating worksites were: (1) ≥250 employees, (2) willingness to provide a worksite liaison to help coordinate study activities, (3) onsite food services, (4) onsite stairways and elevators, (5) willingness to allow modification of the food service environment, (6) willingness to implement the physical activity components of the intervention, (7) willingness to allow evaluation surveys onsite at baseline and 24 months, (8) willingness to provide a worksite advisory group to help coordinate the project, and (9) willingness to be randomized to treatment or control conditions. Participating companies represented a mix of industries including finance/insurance, healthcare, lifestyle/beauty, higher education, and energy. Though these were all large worksites with relatively large workforces, it is not known the degree to which the participating worksites represented all Minneapolis-St. Paul metropolitan area employers.

Individuals. Within each participating worksite, study eligibility requirements for individual participants were: (1) at least 50% full time equivalent position, (2) day shift, (3) present onsite for at least half of work position, and (4) willingness to complete study assessments. Individual employee recruitment was conducted over a 4-week period and included sending a site-wide announcement inviting participation and up to 9 proactive telephone calls from study staff further inviting study participation (based on an a priori list of eligible employees obtained from the employer). A study participant flow diagram is outlined in Figure 1. Across all six participating worksites, the estimated total available workforce was 2,700 individual employees, of which 2,428 met the inclusion criteria for individual participants. Of these, 1,747 (72% of all eligible employees) enrolled in the HealthWorks trial and completed baseline assessments, and 1,407 (81% of all enrollees) completed the 24-month follow-up assessment. Overall follow-up rates were unremarkable between intervention (81%) and control (80%) arms, and across all six worksites ranged 74-84%. Of note, 256 of the 340 HealthWorks participants who were unavailable at the 24-month follow-up had left employment at the participating worksite. Thus the follow-up rate among participants who were still employed at the participating worksites during the entire two year study timeframe was actually 94%. Individual-level information was not available to compare study enrollees versus non-enrollees.

Intervention components

Intervention activities of the HealthWorks study primarily focused on environmental changes to the work setting designed to support regular physical activity, reduced caloric consumption, and weight control behaviors such as self-weighing. All intervention activities were developed in coordination with the worksite advisory group. The intervention components were organized within three conceptual groupings, including physical environment, social environment, and informational environment. Physical environment intervention components included: food/beverage modifications, stairwell enhancements, pedometers, and scale access. Social environment intervention components included: worksite advisory groups, and peer-led worksite walking clubs. Informational environment intervention components included: worksite publicity (announcements and signage), monthly healthy living newsletters, and website recording individual progress in weight and behavior change.

Theoretical framework and conceptual model. The HealthWorks study intervention package was primarily informed by Social Cognitive Theory, which describes behavior as being a function of reciprocal determinism between the environment and intrapersonal factors.[33] More specifically, behavioral choices are based on a given individual's expected outcomes to be gained from the choice, as well as their confidence in their ability to successfully perform the behavior (particularly under difficult circumstances). Environmental factors influence both expectations and confidence, and thus information from the environment about likely rewards motivates decisions to attempt and/or persist with efforts over time. The environmental principles guiding behavioral choice have been amply demonstrated with respect to both eating and exercise. People prefer foods that are rewardingly palatable. They are also heavily influenced by constraints on food choices determined by availability and costs. Similarly, preferred methods for spending leisure time are those that are intrinsically rewarding and easily accessible.

The essential conceptual logic of the HealthWorks intervention was to first encourage individuals to participate in programs and expose them to environmental prompts and contingencies. The conceptual idea that drove the study's aims was that helpful behavior changes (i.e., decreased consumption of energy dense foods, increased physical activity levels, increased self-weighing) would be a function of exposure to the study intervention components. These behavior changes, if adopted and maintained on a sufficient scale, would then cause a net zero weight change in the treatment arm, while a net weight gain would naturally occur in the control arm (as expected in the general population). Furthermore, the net zero weight change in the intervention arm would lead to economic benefits, including decreases in (or stabilization of) workplace absenteeism and medical care utilization relative to increases in these variables in the control arm. The three proposed analyses in this dissertation paper parallel components of the HealthWorks intervention logic model.

Food and beverage modifications. The food and beverage intervention component targeted worksite cafeterias and vending machines to offer more healthy foods and less unhealthy foods, as defined in Appendix A. The goal of the cafeteria intervention was to encourage lower energy intake among cafeteria users by changing the availability and prices, and by implementing promotional signage/labeling for the foods and beverages in the cafeteria. The goals for each of these components were to: (1) increase the percent of the foods/beverages available that meet the healthy criteria defined above to 50%, (2) decrease prices on healthy foods and beverages by 15% and increase prices on less healthful foods by 15%, and (3) label healthy foods and provide point-of-purchase nutrition information about all foods/beverages in the cafeteria.

The cafeteria intervention was implemented continuously for 2 years in each site. To increase healthy food availability, cafeteria foods were first inventoried and evaluated. Intervention staff worked with food service staff to identify foods/beverages that could be added or dropped to bring the overall food and beverage product mix to 50% healthy foods. Intervention staff also worked with food distributors and manufacturers to facilitate ordering of new foods that meet the healthy criteria. Research staff worked with food service staff to ensure that such foods were consistently ordered, stocked and placed in the cafeteria. Portion size was addressed in the context of defining healthy foods and increasing their availability. Portion sizes were evaluated for every food and beverage available in the cafeteria. Portion size goals included making small sizes available for all food and beverage products, and reducing the availability of extra large sizes. The second cafeteria intervention component consisted of pricing adjustments to promote healthy food sales, to be determined in collaboration with food service staff, with the aim of providing an incentive for purchasing healthier foods and a disincentive against purchasing less healthy foods. The third cafeteria intervention component was point-of-purchase promotions and labeling. Healthy foods and beverages were labeled to indicate that they met healthful criteria. Point-of-purchase nutrition information (total energy) was provided on menu boards and small signs near to foods and beverages. A lump sum financial incentive was offered to each site to facilitate staff training and engagement in food service changes for the study.

The goal of the vending machine intervention was to encourage the purchase of healthful vending machine beverages and snacks and discourage the purchase of less healthful vending machine beverages and snacks. The study goal for availability of snacks in vending machines is less than a 50/50 ratio between the two. Smaller portion sizes were offered wherever possible and extra-large sizes were discouraged. Pricing adjustments were recommended to favor healthier food choices (i.e., raising the price of less healthy snacks by 15%, and lowering the price of healthy snacks by 15%). Incentives for accurate placement of beverages were offered to route drivers who achieved consistent beverage and snack placement. Route drivers were offered $10 per week per machine for accurate placement of lower fat/energy vending products. An incentive of $1000 per year per intervention worksite was given to the vending services company servicing each intervention worksite to offset any additional work required by the study.

Stairwell enhancements. Enhancements to stairwells included signage posted at each stairwell entrance to identify and remind employees of the availability of the stairwell, and artwork and music inside the stairwell to increase the attractiveness of the stairwell space. Artwork consisted of posters (e.g., art reproductions, movie posters, inspirational message posters) on the walls and landings of each floor; art placement was allowed at two sites. Two sites allowed music to be played on cassette recorders secured with locked cables in the stairwells. Employees at those sites could offer music suggestions through a drop-box onsite or through e-mail to the intervention coordinator.

Pedometers. Pedometers were made available at no cost to all employees in intervention worksites. In addition, to encourage the application of pedometers toward increased physical activity, participants had free access to the America on the Move website program (http://aom3.americaonthemove.org/Home.aspx). This program was developed by scientists at the America on the Move Foundation in Colorado. The program includes goal-setting planners, daily emails, pedometer step tracking tools, virtual community support, group challenge contests, feature articles, and access to health professionals to ask questions.

Scale access. To promote regular self-weighing, environmental modifications were made to improve scale access. Four balance beam scales were placed at various locations in worksite buildings that were easily accessible and frequently used, such as rest rooms. Each scale location also included an opportunity for anonymously reporting progress in weight control. A station was set up with a short data form for employees to record a private code number, the date of weigh-in, and their body weight. Employees could then drop their information into a locked box. Feedback on aggregate level trends in the number of people using the scales and cumulative weight changes were reported in the monthly healthy living newsletters.

Worksite walking clubs. These were offered at each intervention worksite and were worksite- or building-wide clubs that promoted regular walking among employees through a series of club events. Research staff served as club organizers and recruited two or more individual employees from each worksite floor or department. Recruited tenants then served as department organizers, liaisons, and promotional point-persons. Walking club participants completed a basic membership form. Membership was free and the only requirement was being employed at the worksite. Group walking events were held in the form of a seasonal challenge program, typically lasting 6 to 8 weeks, and included a daily organized group walk at work during the walking club challenge timeframe, along with feedback on group performance (e.g., participation, miles accumulated). Employees who enrolled in the walking club events received free t-shirts, visors, and walking logbooks to assist with tracking. Team competitions and charity walks were organized for some events, with small incentives for teams that logged the most miles within specified time periods. At each worksite, there were 6 or 7 total walking club events offered over the course of the two year study.

Worksite publicity and newsletters. This involved active promotion and marketing of the food and beverage intervention components throughout the two year study. Specifically, awareness of these interventions was targeted through posters, table tents, fliers, and other signage. In addition, a monthly newsletter included behavioral messages to promote regular self-weighing, exercise for 30 minutes per day, and limiting portion sizes/energy intake, high-fat food intake, and sugar-sweetened beverage intake. Hot topics in the field of obesity prevention were also highlighted such as glycemic index and worldwide prevalence updates. Also included was information about the environmental components of the project, other community resources, and recipes. Newsletters were distributed to employees individually, by work mailbox or email.

Chapter IV. Paper #1: Physical Activity and Program Participation

Background

Purpose

Paper #1 involved a secondary analysis of data from the HealthWorks trial. The purpose was to answer the following research question, “does baseline physical activity level predict participation in worksite walking club events?” The hypothesis was that higher levels of baseline physical activity would be associated with participation in at least one worksite walking club event over two years, relative to lower levels of baseline physical activity.

Preliminary studies on physical activity level and program participation

A high level of physical activity is perhaps the strongest behavioral factor associated with weight gain prevention.[34] A very large (n=34,079) 15-year prospective cohort study of female adults found that regular physical activity (~1 hour daily) was the strongest predictor of primary weight gain prevention.[35] This relationship is consistent with findings from the National Weight Control Registry (NWCR), a cohort of over 6,000 individuals who have maintained ≥30 pounds weight loss for one year or more.[14] NWCR members expend an average of 400 kcal daily (~1 hour daily), mainly through walking. This level of physical activity is achieved by less than 40 percent of the general adult population,[1] which is believed to at least partially explain the tendency of American adults to steadily gain weight over time.[11] There may also be a dual feedback loop affecting this process in that experimentally manipulated weight gain (through overfeeding) over short time periods has been causally linked to decreases in leisure-time walking.[36] Also of note, regular physical activity is associated with at least some health benefits (e.g., controlled lipids, improved glycemic control), even in the absence of weight changes.[37, 38]

There is consistently strong evidence for the effectiveness of worksite-based physical activity programs. A recent meta-analysis examined the health and behavioral effects of workplace physical activity interventions. That study included 38,231 participants from 138 reports and indicated a mean overall effect size of d=0.57 for post-study oxygen consumption levels ($VO2_{max}$) in favor of treatment group participants over controls.[39] This translated into a $VO2_{max}$ mean of 37.7 mL/kg/min for treatment subjects relative to 34.2 mL/kg/min for control subjects, or about a 10% advantage in physical fitness for those exposed to worksite physical activity programs. Similarly, findings from this meta-analysis also indicated that participants in worksite physical activity programs were nearly 8% more physically active (e.g., higher pedometer step counts, higher physical activity questionnaire scores) than control participants (effect size d=0.21). Narrative literature reviews on this topic have arrived at very similar, though slightly more optimistic and less analytically precise, conclusions that physical activity interventions based largely at the worksite and on company time increase overall physical activity level.[40, 41]

There seems to be general scientific agreement that: (1) more physically active employees are less likely to gain weight, and (2) worksite physical activity programs improve physical activity levels for the employees they reach. In regard to the latter point, much less is known about what individual factors influence participation in worksite physical activity programs. Widespread participation in a formal physical activity program, though not required for a given workforce to become more active, is considered to be a helpful strategy to broaden weight gain prevention or health improvement efforts across an entire workforce. But few published research studies have examined the determinants of participation in worksite physical activity programs. Many researchers have intimated that physical activity programs, and indeed health promotion programs in general, are biased toward attracting individuals who do not need them (or do not need them nearly as much as others) because they are already healthy and sufficiently active.[42, 43]

A recent systematic literature review paper examined the determinants of participation specifically in worksite health promotion programs. It cited mixed findings on baseline physical activity or physical fitness levels as significant (prospective) predictors of program participation.[44] Demographic variables were the overwhelming focus of all reviewed studies in that paper and only two studies examined baseline physical activity levels. In a prospective cohort study of 2,290 employees at a petrochemical company, Lewis and colleagues[45] found that participants at low fitness risk (unspecified, assumed to be regularly physically active) per a worksite health risk assessment had a 45% higher odds of signing up for a multi-component health promotion program (that included a major focus on physical activity). These same participants also had 2.5 times higher odds of using the company fitness center relative to employees at high fitness risk (unspecified, but assumed to be inactive), suggesting that physical activity programs were primarily used by employees who were already sufficiently active. In contrast, a small prospective cohort study by Heaney et al.[46] found that new female employees of an insurance company that reported being physically active less than 1 day per week at baseline had 2.4 times higher odds of joining the company fitness center over their first year of employment relative to new female employees who reported being active more than 2 days per week at baseline. This study suggested that physical activity programs were primarily used by employees who were not sufficiently active.

Summary of research gaps

Only two studies were found that examined the degree to which baseline physical activity level among employees predicts participation in worksite physical activity programs. These studies cited differing conclusions on the direction of the relationship between baseline physical activity level and program participation. Another important note is that these studies generally defined program participation as signing up to use a company fitness center, thus it remains unclear the degree to which baseline physical activity may influence participation in programs with broader appeal. In particular, there are no known studies to date that have examined predictors of participation in worksite walking programs, the most preferred form of physical activity among working age adults.[47]

There remains a need to establish the relationship between baseline physical activity level and walking program participation in order to help improve recruitment and/or retention efforts for these programs. In order to maximize their reach, intervention designers need to understand how to better market such programs for recruitment purposes toward targeted groups that are more difficult to attract. Also, knowing this information may help optimize program curriculum in terms of informing how much emphasis should be placed on physical activity maintenance versus physical activity adoption. The HealthWorks study presents a relatively uncommon opportunity to examine this research question because baseline physical activity levels, as well as other covariates, were collected on all study enrollees, including those that did and did not participate in the study's worksite walking club program.

Methods

Eligible participants

For analytical purposes (described in detail below in the *Statistical analyses* section), only study participants assigned to the intervention arm, with complete baseline and 24-month follow-up data (for all examined variables), not pregnant, and not given birth during the trial or within one year prior to the enrollment date were considered eligible (n=642).

Measures

Measures were collected at baseline and 24-month follow-up. Categories of measures collected as part of the full HealthWorks study included self-reported: demographics, physical activity, routine health habits, food habits, social support, nutrition/exercise environment, and medical history. In addition, clinical measures were taken for anthropometrics and direct observations were collected at each worksite for stair use and onsite program participation. For the purposes of this paper, two primary predictors and one outcome, as well as several covariates, were examined as described below.

Independent variable. The independent variable was overall physical activity level at baseline. Physical activity was assessed using a slightly modified version of the International Physical Activity Questionnaire (IPAQ),[48] as was done by French and colleagues in a comparable worksite-based study.[49] Specifically, it included 10 items asking questions about walking, sitting, and vigorous and moderate physical activities performed at home, work, and leisure time settings. Participants responded with how many days per week they typically did such activities (frequency) and for how long per day (duration). Per the IPAQ scoring guidelines,[50] overall physical activity level is calculated and reported in metabolic unit equivalent minutes per week (MET-min/wk). The MET-min/wk can be roughly translated as the rate of energy consumption of all physical activities performed during a given week relative to the rate of energy consumption if no physical activities were performed during that given week (i.e., at rest). In the IPAQ, this measure is calculated by summing the MET-min/wk for all reported walking, moderate, and vigorous physical activities. The IPAQ has well established test-retest reliability in several settings (median Spearman's rho=0.80) and acceptable criterion validity against accelerometer counts (median Spearman's rho=0.30) as a self-reported physical activity measure.[51] Note that physical activity was expected to have a large range and standard deviation, thus for analytical purposes, it was modeled in units of 10 MET-min/wk (versus the standard 1 MET-min/wk) in order to improve interpretability of parameter estimates. It was then back-transformed to standard units for discussion purposes.

Dependent variable. The dependent variable was participation in worksite walking club events offered as part of the HealthWorks study. More specifically, for the purposes of analysis, HealthWorks subjects were dichotomized into one of two categories, including (1) enrollee: enrolled in ≥1 walking club events, and (2) non-enrollee: enrolled in 0 walking club events. Note that each participating worksite had 6 or 7 walking club events offered over the course of the two year study.

Covariates. Covariates considered for inclusion were baseline: demographics (i.e., age, sex, race/ethnicity, education, marital status), worksite, smoking, diabetes, high blood pressure, depression, perceived pounds needed to gain before attempting weight loss, coworker social support for physical activity, and BMI. Coworker social support for physical activity was measured with a single item that asked participants to rate on a 6-point scale (ranging from not supportive to very supportive) how supportive their coworkers are of efforts to be more physically active. For BMI, weight was measured using a calibrated digital scale (participants wore light street clothes and no shoes) and height was measured using a wall-mounted ruler. The BMI metric was calculated by dividing weight in kg by height in meters squared. There was little direct empirical guidance to inform the selection of covariates. Only the Heaney, et al.[46] study utilized a multivariate model, and found sex, education, high blood pressure, and BMI to be significant (adjusted) predictors of workplace fitness facility use. Other covariates considered for this analysis were selected based on their availability in the HealthWorks dataset and the clinical suspicion that they may be related to both baseline physical activity level and peer walking club participation. Each considered covariate was initially examined to determine whether or not it would be tested for potential inclusion in the final model. This was done by examining the univariate associations between each considered covariate, the independent variable, and the dependent variable. Because these univariate analyses were only needed to initially identify covariates that would be tested in final models, less protection against a type I error was deemed necessary. Any covariate that was found to have a p-value <0.100 in its association with the independent or dependent variables was considered for inclusion into the final regression models.

Statistical analyses

All analytical procedures were conducted using SAS Version 9.2 (Cary, NC). Only the intervention arm of the HealthWorks study was utilized in this analysis because they were the only worksites that had access to walking club events. No imputations were made for missing variables and a complete-case framework was utilized in that participants with missing values for any predictor variable or outcome measure were listwise excluded.

A multivariate logistic regression model (PROC LOGISTIC) was used to examine the association between baseline physical activity and walking club event participation. The outcome in this analysis, walking club participation, was modeled as a dichotomous variable as defined above (i.e., enrollee vs. non-enrollee [reference category]). The primary predictor, baseline overall physical activity level, was modeled continuously. First, a basic model was created to examine the crude relationship between baseline physical activity and walking club event participation. Next, effect modification was examined by creating a two-way interaction term between baseline physical activity and each covariate (separately), and entering it into the crude model. Also, a quadratic interaction for baseline physical activity was tested. Interaction terms with a p-value less than 0.05 were retained in subsequent models. Any remaining covariates that were not found to be effect modifiers were then entered separately into the reduced model to check for their utility as an independent predictor or a confounder. Specifically, any covariate term with a p-value less than 0.05 (i.e., was an independent predictor) or that that changed the reduced modeled baseline physical activity parameter estimate by more than 10 percent (i.e., was a confounder) was retained in the final model.

Results

Of the 1,747 enrollees, 752 were assigned to the intervention arm. Of these 642 (85%) met all eligibility criteria for inclusion in this analysis. Table 1 outlines the descriptive characteristics of the included and excluded analytical samples, as well as the entire HealthWorks intervention arm sample. HealthWorks participants could generally be described as primarily White, middle-aged, females, being slightly healthier than the general American population in regard to the prevalence of smoking and chronic medical conditions. Missing follow-up data was primarily due to participants leaving employment at one of the worksites that participated in the HealthWorks study. Differences in baseline characteristics were statistically indistinguishable between the 642 participants from the intervention arm that were included in the analytical dataset relative to the remaining 110 participants that left the workforce or declined study follow-up. Three exceptions were age, marital status, and worksite (see Table 1). Participants who were younger at baseline, married, or were employed at worksite #2 were significantly more likely to be excluded.

In regard to the primary dependent and independent variables in the analytical sample, 322 (50%) participants enrolled in ≥1 walking club events (i.e., were enrollees) and mean±sd overall physical activity was 3,424.8±2,814.5 MET-min/wk. As outlined in Table 2, initial crude examinations of the considered baseline covariates found that age, sex, marital status, worksite, diabetes, depression, coworker social support, and BMI were suitable to be tested for inclusion in the final model. Race/ethnicity, education, smoking, perceived pounds needed to gain before attempting weight loss, and high blood pressure were not further considered as covariates in any models because they were not associated with either the outcome or predictor variable.

The initial crude model indicated that baseline physical activity level (β±se<-0.001±<0.001, df=1, χ^2=0.27, p=0.607) was not significantly associated with participation in walking club events. The direction of this relationship was essentially "flat", indicating no discernible relationship between these two variables. Further modeling for effect modification revealed no significant interactions between any of the considered covariates. However, age, sex, worksite, and coworker social support were found to be independent predictors of participation in walking club events. The final multivariate regression model with all included beta terms and directions of association for this analysis is summarized in Table 3. Participants who were older, female, and/or had more coworker social support had a significantly higher odds of participation in walking club events relative to participants who younger, males, and/or had less coworker social support, respectively. In addition, participants who were employed at worksite #3 had significantly lower odds of participation in walking club events relative to participants who were employed at worksite #2 or worksite #6. The strongest single covariate predictor in the final multivariate model was male sex. After holding all other predictors constant, men had 75% lower odds of participation in walking club events relative to women (i.e., the odds of participation for men was only 25% that of the odds of participation for women).

Discussion

There was essentially no relationship between baseline physical activity level and participation in worksite walking club events in the HealthWorks study. This finding differed from two previous studies in this area, with one indicating that higher levels of baseline physical activity increased the odds of (physical activity) program participation,[45] and the other indicating that higher levels of baseline physical activity decreased the odds of program participation.[46] This may be at least partially explained by what constituted "program participation" in other studies. The Lewis, et al.[45] study defined participation as signing up for a multi-component health promotion program and utilization of the company fitness center. The Heaney, et al.[46] study defined participation as utilization of the company fitness center. In particular, fitness center use may constitute a relatively narrow option in that it is appealing to employees who are interested in adopting or maintaining engagement in formal, structured exercises that typically involve the use of machines or other apparatus (e.g., stationary bike, lifting weights). The HealthWorks study was the first to date that specifically examined the impact of baseline physical activity on participation in walking programs, which would seem to have broader appeal given that walking is consistently cited as the most popular form of physical activity among adults.[47, 52]

The findings observed in this analysis may be considered in a positive light in that previous research has indicated that health promotion programs, including physical activity programs, tend to attract few people and that there is a pervasive bias in the types of individuals that do participate. The population reach of any given physical activity is rarely known or published.[53] In the HealthWorks study, one-half of all study enrollees who had access to the walking club events participated in at least one of them. This 50% reach rate seems to be higher than the reach rates reported in other recent (Internet-based) worksite physical activity programs[54, 55] and may serve as a reasonable benchmark to compare the recruitment success of future worksite physical activity program to. The pervasive question, however, is in regard to who “shows up” to such programs? Research trials that are focused on physical activity interventions tend to attract individuals with higher household income and education,[43] and program participants are generally believed to have fewer health risks than non-participants.[42] There may be a difference between enrolling in a trial and enrolling in a specific program, but in the HealthWorks study, education was not related to walking club participation (income was not measured). Furthermore, the physical activity level between walking club participants and non-participants was indistinguishable. As such, it may be that walking club events are appealing across varying strata of physical activity and/or fitness.

However, there were observed limits to the appeal of the walking club events in the HealthWorks study. Males in particular were least apt to enroll in them, which is well established in physical activity trial research[43] and broader population health programming.[42] Also, employees who reported lower levels of workplace social support for physical activity had a lower odds of enrolling in a walking club event as compared to employees who reported higher levels of workplace social support. This is a novel finding in regard to program participation, though some research has identified social support in general as a predictor of exercise adherence and program retention in worksite populations.[56, 57] Interestingly, one of the worksites had a participation rate in the walking club events that was about one-third lower than the other two worksites (i.e., 39% participation in worksite #3 vs. 58% in worksite #2 and 56% in worksite #6). Worksite was retained as a significant predictor in the final model independent of age, sex, and social support, and it is unclear what it was about worksite #3 in particular that resulted in a much lower rate of participation in the walking clubs. It was a private insurance company, whereas the other two companies were in the fields of public education and non-profit healthcare services. The degree to which organizational or industry culture/environment may have played a role in walking club participation in the HealthWorks study was unknown.

There were several methodological strengths in this analysis. Because it involved a sub-program (i.e., walking clubs) of the full intervention cohort, it permitted evaluating how the sub-program participants differed from non-participants. After accounting for study enrollment and analytical eligibility criteria, the final analytical sample included 62% of the entire workforce (that was eligible to enroll in HealthWorks) across all three combined intervention worksites. Having access to matching predictor variables from both participants and non-participants is uncommon in prospective intervention studies, therefore this analysis helps researchers understand some commonly suspected, but understudied, predictors of volunteer bias in physical activity programs. Participation in the walking club events was a directly observed outcome variable not subject to self-report biases.

The most significant limitation to internal validity was the reliance on self-reported physical activity. Though the IPAQ is now commonly used in the published scientific literature and has reliability and validity statistics comparable to other self-reported physical activity instruments,[51] it provides estimates with a high degree of variability or error, which may make it less sensitive from an analytical perspective as compared to more objective measures of physical activity (e.g., pedometers, accelerometers). The dependent variable, walking club participation, was dichotomous.

Because the available number of walking club events held at any given worksite was small, with a maximum of 7, no attempts were made to model walking club participation as a count variable (i.e., “dose” of walking club events). Thus, the degree to which participating in any one worksite walking events translated into participating in multiple walking club events was not explored. Other limitations included the fact that participants with missing data were excluded and there was some evidence that drop-outs were not missing at random. In addition, the sample size was relatively large compared to other studies that have prospectively examined predictors of worksite physical activity program participation, but still limited for stratified analyses designed to detect interactions. Overall, the results indicated that the worksite walking programs in HealthWorks attracted a sizeable fraction of employees to participate, with baseline physical activity level showing little or no influence on that participation.

Chapter V. Paper #2: Self-weighing and Weight Change

Background

Purpose

Paper #2 involved two secondary analyses of data from the HealthWorks trial. The purpose was to answer the following general research question, "does self-weighing frequency predict weight maintenance over two years?" The hypothesis was that weekly or daily self-weighing frequency would be associated with greater weight maintenance (including weight loss) relative to monthly or less self-weighing frequency over two years.

Preliminary studies on self-weighing and weight maintenance

Self-monitoring of body weight, or self-weighing, has received the least (and perhaps most controversial[58, 59]) attention in the scientific literature as a useful behavioral self-management strategy for weight control. It is proposed to work via behavioral self-regulation in that an individual who self-weighs often will stay more focused on (and sensitive to) changes in their body weight, even subtle ones to their body composition as well. This theoretically creates more opportunities for internal reinforcement of small accomplishments in regard to weight loss or weight maintenance. Thus the individual is also empowered to quickly identify lapses in their progress and adjust their behavior accordingly to maintain body weight homeostasis or redirect their efforts entirely. National guidelines on the treatment of obesity[1] recommend regular self-weighing for weight loss, with little specific direction on "how regular" self-weighing should be, particularly for differing goals of weight management.

One systematic literature review has been conducted on the topic of self-weighing and concluded that higher frequencies of self-weighing are indeed associated with favorable weight status, both in terms of greater weight loss and less weight (re)gain, relative to lower frequencies of self-weighing.[60] However, only one study in this review examined the impact of frequent self-weighing in the context of a weight gain prevention focused randomized-controlled trial over a long timeframe.[30] Follow-up analyses from this study by Linde, et al.[62] found that participants who self-weighed daily (-0.8 kg/m^2) or weekly (0.3 kg/m^2) held a statistically significant BMI change advantage relative to participants who self-weighed monthly (0.8 kg/m^2), semi-monthly (0.8 kg/m^2), or never (1.1 kg/m^2) over a period of two years.

Evidence from less rigorous analyses in different populations has also indicated benefits of frequent self-weighing for the avoidance of weight gain. Secondary analyses of a randomized-controlled trial by Wing and colleagues[63] revealed that within an Internet-based intervention group, a significantly smaller proportion of participants who self-weighed daily (40%) regained ≥2.3 kg over 18 months follow-up relative to participants who did not self-weigh daily (68%). Another randomized-controlled trial by Levitsky and colleagues[64] found that college females in a self-weighing intervention group (0.1 kg) gained significantly less weight relative to controls (3.1 kg) who did not track weight over 10 weeks during a freshman semester. Three cross-sectional studies have indicated a significant advantage of more frequent self-weighing for weight maintenance. Two nationally representative samples found that 60%[65] and 80%,[66] respectively, more respondents who were successful at preventing weight regain following weight loss reported weekly or daily self-weighing (relative to participants that regained weight). Linde and colleagues[67] observed that women in a large heath plan sample who reported daily self-weighing were almost 2 kg/m^2 less in body mass relative to women who reported never self-weighing.

Summary of research gaps

Very few large scale studies of environmental-oriented interventions targeting weight gain prevention in worksites have been conducted. In particular, no studies to date have specifically examined the utility of frequent self-weighing for weight maintenance exclusively in worksite populations, where the ability to promote large scale increases in self-weighing through environmental intervention is arguably the strongest.

This is an important unfilled gap in the literature because self-weighing is a commonly recommended component of weight loss and weight maintenance programs.[1] Also, despite self-weighing being key endorsed component of weight management programs, very little is known about what sub-groups of individuals, if any, stand to benefit most from this strategy.[60] This is likely because few previous studies had adequately powered sample sizes or an a priori focus to statistically examine for interactions between self-weighing frequency and suspected covariates. As such, it seems timely to examine self-frequency in a large worksite cohort with a long-term follow-up that is large enough to potentially detect some of the smaller sub-groups where self-weighing frequency is particularly beneficial. This may help further refine recommendations on optimal levels of self-weighing frequency.

Methods

Eligible participants

For analytical purposes (described in detail below in the *Statistical analyses* section), only study participants with complete baseline and 24-month follow-up data (for all examined variables), not pregnant, and not given birth during the trial or within one year prior to the enrollment date were considered eligible (n=1,222).

Measures

Measures were collected at baseline and 24-month follow-up. Categories of measures collected as part of the full HealthWorks study included self-reported: demographics, physical activity, routine health habits, food habits, social support, nutrition/exercise environment, and medical history. In addition, clinical measures were taken for anthropometrics and direct observations were collected at each worksite for stair use and onsite program participation. For the purposes of this paper, two similar analyses were performed as described below. The independent variable and examined covariates were the same in both analyses, but the dependent variable was modeled in two different ways, slightly different in each analysis.

Independent variable. The independent variable was self-weighing frequency. It was assessed at both baseline and 24-month follow-up using a single-item, self-reported measure that asked "How often do you weigh yourself?" There were seven ordinal response options that included: never, about once a year or less, every couple of months, once a month, once a week, once a day, or more than once a day. This form of assessing self-weighing frequency has been used in large randomized-controlled trials[30, 68] and is widely accepted in the published scientific literature,[60] but no formal validity studies have been published that correlate self-reported to directly observed self-weighing frequency. For purposes of analysis, the 24-month self-weighing frequency measure was used as the primary predictor variable and was collapsed into three categories, including: (1) Monthly or less, (2) Weekly, or (3) Daily. These three categories were based on the non-linear association observed between self-weighing frequency and weight change in secondary analyses from two large randomized-controlled trials,[62] as well as conclusions from a recent systematic literature review paper[60] where weekly self-weighing was the point at which weight change benefits meaningfully occurred and daily self-weighing offered a modest, statistically significant benefit over weekly self-weighing.

Dependent variables. The dependent variable was body weight change, modeled slightly different in each analysis. Body weight was measured for all participants at baseline and 24-month follow-up using a calibrated digital scale by a trained study staff person. Participants were weighed in light street clothing and without shoes. Weight was recorded to the nearest 0.1 kg. For purposes of analysis, weight change was modeled both continuously and as a dichotomous variable based on the difference in body weight (i.e., change score) between baseline and 24-month follow-up. Dichotomous categories were: (1) weight maintainers: individuals who weighed ≤1 kg of their baseline weight at the 24-month follow-up (i.e., lost weight or gained ≤1 kg), and (2) weight gainers: individuals who gained >1 kg of their baseline weight at the 24-month follow-up.

The dichotomous categories used to define weight maintenance in this study were modeled after those used by Gordon-Larsen and colleagues[69] and others,[70, 71] with the ≤1 kg threshold generally reflecting the expected mean annualized weight gain in American adults.[11] As outlined in a recent review paper by Stevens et al.,[72] however, the definition of weight maintenance is an unsettled topic in the scientific literature. These authors recommended a threshold of <3% weight gain from baseline as a clinically meaningful cut-point based on the notion that this level of weight change is larger than the expected short-term variation in body weight (secondary to fluctuations in normal fluid balance and measurement error), but within the bounds of what is recognized as a biologically meaningful weight gain. Stevens et al. acknowledge, however, that there is not scientific consensus on what is “normal variation” or what is “biologically meaningful” when it comes to weight gain. Given this ambiguity and the fact that the HealthWorks study was essentially designed to achieve 0 kg weight gain in the intervention condition, it was determined that the most conservative cut-point for weight maintenance (i.e., 1 kg) observed from the Stevens, et al. review paper would be most appropriate for analytical purposes in this study.

Covariates. Covariates considered for inclusion were baseline: demographics (i.e., age, sex, race/ethnicity, education, marital status), randomized condition, self-weighing frequency, smoking, diabetes, high blood pressure, depression, number of weight loss attempts in the past two years, perceived pounds needed to gain before attempting weight loss, number of scales in the home, and BMI. For BMI, height was measured to the nearest millimeter using a wall-mounted ruler and the BMI metric was calculated by dividing weight in kg by height in meters squared. Participants were assigned to one of three BMI categories, including: obese: $\geq$30.0 kg/m^2, overweight: 25.0-29.9 kg/m^2, and healthy weight: <25.0 kg/m^2. Few previous studies analyzing the association between self-weighing frequency and weight change utilized multivariate models,[60] and those that did typically found no statistically or clinically significant covariates to report,[62, 73] or analyzed self-weighing only with other self-monitoring covariates.[66] As such, there was little direct empirical guidance to inform the selection of covariates. Covariates considered for this analysis were selected based on their availability in the HealthWorks dataset and whether or not they were examined in previous studies (from the preliminary studies sub-section of the Background section of this paper) or the clinical suspicion that they may be related to both self-weighing frequency and body weight change. Each considered covariate was initially examined to determine whether or not it would be tested for potential inclusion in the final model for both Analysis #1 and Analysis #2. This was done by examining the univariate association between each considered covariate, the independent variable, and the dependent variables. Because these univariate analyses were only needed to initially identify covariates that would be tested in final models, less protection against a type I error was deemed necessary. Any covariate that was found to have a p-value <0.100 in its association with the independent or dependent variables was considered for inclusion into the final regression models.

Statistical analyses

All analytical procedures were conducted using SAS Version 9.2 (Cary, NC). Because the intervention and control groups were statistically indistinguishable in terms of weight change (data not shown), these two groups were combined in this analysis in order to improve power. Two different analytic approaches were used to predict body weight and are described below. In both analyses, no imputations were made for missing variables and a complete-case framework was utilized in that participants with missing values for any predictor variable or outcome measure were listwise excluded.

Analysis #1. In the first analysis, a multivariate general linear regression model (PROC GLM) was used to examine the association between self-weighing frequency categories and body weight change. The outcome in this analysis, body weight change, was modeled as a continuous variable. The primary predictor in this analysis, self-weighing frequency at the 24-month follow-up, was modeled categorically as described above with the “Monthly or less” group used as the reference category. First, a basic model was created to examine the crude relationship between self-weighing frequency categories and weight change. Next, effect modification was examined by creating a two-way interaction term between self-weighing frequency and each covariate (separately), and entering it into the crude model. Interaction terms with a p-value less than 0.05 were retained in subsequent models. Any remaining covariates that were not found to be effect modifiers were then entered separately into the reduced model to check for their utility as an independent predictor or a confounder. Specifically, any covariate term with a p-value less than 0.05 (i.e., was an independent predictor) or that that changed the reduced modeled self-weighing frequency parameter estimate by more than 10 percent (i.e., was a confounder) was retained in the final model.

Analysis #2. The second analysis generally used identical procedures as were performed in Analysis #1. In this analysis, however, a multivariate logistic regression model (PROC LOGISTIC) was used to examine the association between self-weighing frequency categories and body weight change. The outcome in this analysis, body weight change, was modeled as a dichotomous variable (i.e., weight maintainer vs. weight gainer) using the definition described previously. This second analysis was done to complement the first analysis and to aid in the clinical interpretation of the relationship between self-weighing frequency and body weight change.

Results

Of the 1,747 enrollees, 1,222 (70%) met the eligibility criteria for this analysis. Table 4 outlines the descriptive characteristics of the included and excluded analytical samples, as well as the entire HealthWorks sample. HealthWorks participants could generally be described as primarily White, middle-aged, females, being slightly healthier than the general American population in regard to the prevalence of smoking and chronic medical conditions. Missing follow-up data was primarily due to participants leaving employment at one of the worksites that participated in the HealthWorks study. Differences in baseline characteristics were statistically indistinguishable between the group included in the analytical dataset and the remaining 525 participants that left the workforce or declined study follow-up, with the exceptions of age, sex, hypertension, and depression (see Table 4). Participants who were younger at baseline, female, reported having depression, or were normotensive were somewhat more likely to be excluded.

In regard to the primary independent and dependent variables in the analytical sample, mean±sd weight change between baseline and 24-month follow-up was 0.65±6.06 kg, 642 (53%) participants gained ≤1 kg of body weight relative to baseline (i.e., were weight maintainers), and the proportion of participants in each self-weighing frequency category at the 24-month follow-up was: monthly or less (55%), weekly (28%), and daily or more (17%). As outlined in Table 5, initial crude examinations of the considered baseline covariates found that age, race/ethnicity, education, marital status, randomized condition, baseline self-weighing frequency, smoking, diabetes, high blood pressure, number of weight loss attempts in the past two years, perceived pounds needed to gain before attempting weight loss, number of scales in the home, and BMI were suitable to be tested for inclusion in the final analytical models. Sex and depression were not further considered as covariates in any models because they were not associated with any outcome or predictor measures.

Analysis #1: Weight change outcome modeled as a continuous variable

The initial crude model indicated that both daily (β±se=-1.79±0.48, t=3.76, $p<0.001$) and weekly (β±se=-0.92±0.40, t=2.29, p=0.022) self-weighing at the 24-month follow-up were significantly associated with weight change. At the 24-month follow-up, participants who reported self-weighing daily and participants that reported self-weighing weekly lost about 1.8 kg and 0.9 kg, respectively, more than participants who reported self-weighing monthly. Further modeling for effect modification revealed a significant interaction between follow-up self-weighing frequency and baseline BMI category (F=2.29, df=4, p=.050), as well as significant main effects for BMI category (F=12.45, df=2, $p<.001$), baseline self-weighing frequency (F=15.73, df=2, $p<.001$), and follow-up self-weighing frequency (F=22.20, df=2, $p<.001$). The final multivariate regression model with all included beta terms and directions of association for this analysis is displayed in Table 6. To aid in the interpretation of these findings, Figure 2 graphs the least-squares adjusted weight change by each category of self-weighing frequency and baseline BMI category. The direction of the interaction indicated that the greatest weight loss was observed for participants who were obese at baseline and reported self-weighing daily at the 24-month follow-up (mean±se -4.5±0.8 kg). In contrast, the largest weight gain was observed for participants who were at a healthy BMI at baseline and reported self-weighing monthly at the 24-month follow-up (2.2±0.4 kg).

Analysis #2: Weight change outcome modeled as a dichotomous variable

The initial crude model indicated that both daily (β±se=0.45±0.16, χ^2=7.77, p=0.005) and weekly (β±se=0.38±0.13, χ^2=8.12, p=0.004) self-weighing at the 24-month follow-up were significantly associated with weight maintenance. Relative to participants that self-weighed monthly, participants that self-weighed daily had 56% higher odds of being a weight maintainer and participants that self-weighed weekly had 47% higher odds of being a weight maintainer. Further modeling for effect modification revealed a significant interaction between baseline and follow-up self-weighing frequency (χ^2=11.28, df=4, p=.024), as well as significant main effects for baseline self-weighing frequency (χ^2=7.21, df=2, p=.027), follow-up self-weighing frequency (χ^2=14.51, df=2, p<.001), and age (χ^2=4.06, df=1, p=.044). The final multivariate regression model with all included beta terms and directions of association for this analysis is displayed in Table 7. To aid in the interpretation of these results, Table 8 outlines the adjusted odds ratio of being a weight maintainer by each self-weighing frequency category at both baseline and follow-up. The direction of the interaction indicated that the largest association was observed for participants who self-weighed weekly at baseline and daily at follow-up (i.e., increased self-weighing frequency over time). This group had a 2.86 times higher adjusted odds of being a weight maintainer relative to participants who self-weighed monthly at both baseline and follow-up. In contrast, participants who self-weighed weekly at baseline and monthly at follow-up (i.e., decreased self-weighing frequency over time) had 46% lower adjusted odds of being a weight maintainer relative to participants who self-weighed monthly at both baseline and follow-up.

Discussion

Consistent with previous research,[60] more frequent self-weighing was associated with a more favorable weight change profile in the HealthWorks trial. The two analyses illuminated slightly different effect modifiers that have not been observed in previous research. In the first analysis, weight change was modeled as a continuous variable and its association with self-weighing frequency was modified by baseline BMI category. Specifically, the impact of self-weighing frequency was most pronounced among obese participants. Daily self-weighers lost weight across all BMI categories, but obese participants who reported daily self-weighing clearly lost the most weight over two years relative to all other combinations of baseline BMI category and self-weighing frequency. As would be expected in the general American adult population,[11] monthly self-weighers gained nearly 2 kg on average over two years, with little distinction between BMI categories at that monthly level of self-weighing. This suggests that more frequent self-weighing may indeed stem the tide of expected weight gain and that more frequent self-weighing may be particularly beneficial at higher levels of BMI.

The general findings from Analysis #1 were supported in Analysis #2, which examined weight change as a dichotomous outcome of participants being either weigh maintainers or weight gainers at study end. This is arguably a more clinically meaningful outcome in a weight maintenance trial, but because those that lost weight were included in the weight maintainer category, Analysis #2 was likely less sensitive to detecting small sub-group associations relative to Analysis #1. Despite this, an interaction was observed between baseline and 24-month follow-up self-weighing frequencies in Analysis #2 and this was noteworthy for several reasons. Main effect findings revealed that self-weighing frequency at the 24-month follow-up was associated with weight maintenance in the direction consistent with Analysis #1. This was not the case, however, when looking at the baseline self-weighing frequency main effect. More frequent self-weighing at baseline was actually associated with lower adjusted odds of weight maintenance by study end. This may suggest that it is actually the change in self-weighing frequency over time that is most telling with regard to weight maintenance (at least when it is modeled as a dichotomous variable). Participants that started out at a lower level of self-weighing frequency but then moved up to a higher level generally increased their odds of weight maintenance by about two-fold. In contrast, participants that started out a higher level of self-weighing frequency but then moved down to a lower level generally decreased their odds of weight maintenance success by about 25%. Participants who remained stable at any level of baseline self-weighing frequency generally saw no change in their odds of weight maintenance over two years. Some precedence for this pattern may also be evident in the Butryn, et al.[73] cohort study in that participants who increased their self-weighing frequency (unspecified magnitude) over one year gained 2.5 kg less body weight as compared to participants who decreased their self-weighing frequency over the same timeframe.

The collective findings from both analyses may have implications for program designers. More frequent self-weighing seems to be most beneficial for the individuals that are assumed to need it most; namely those that are obese and self-weighing weighing very infrequently at the start of the program. A persistent question in regard to weight management program design involves what the optimal level of self-weighing frequency should be. Some have suggested that a blanket recommendation of "at least weekly" is the closest to evidence informed advice researchers can currently give.[60, 74] In light of the findings observed in the current research, this recommendation can perhaps be further refined or tailored. Given that the vast majority of participants reported weighing themselves monthly or less in the HealthWorks trial and assuming the HealthWorks sample represents the broader adult population, perhaps the most relevant and realistic self-weighing advice should be to increase one's self-weighing frequency to at least weekly for weight maintenance. However, if weight loss is the goal, particularly for obese individuals, increasing one's self-weighing frequency to daily may be optimal.

From a methodological perspective, these analyses had several strengths. Sample sizes in published weight management literature rarely exceed 1,000 participants and it is not uncommon for attrition rates to exceed 50% in studies with longer follow-up timeframes.[19] HealthWorks had a relatively long 2-year follow-up timeframe and recruited over 1,700 participants, with 70% of all enrollees retained in these analyses. Two separate approaches were used to characterize the outcome variable, with each giving a slightly different, though largely complementary, point of view. Most notably, there were enough participants in this study to adjust for other independent predictors and detect some important interactions had previously been unknown or unstudied in other self-weighing research. This adds to the evidence base in this area and could potentially refine recommendations on the optimal level of self-weighing.

Perhaps the most significant limitation to internal validity was the reliance on a self-reported measure of self-weighing frequency. Though commonly used in the published scientific literature to assess self-weighing, no known validity work has been done in this area. As is the case in nearly all self-weighing studies to date, there remains a temporality issue in that the exposure and outcome are essentially measured (and are occurring) during a parallel timeframe and are not experimentally manipulated or static measures. As such, increased self-weighing frequency could have been either a cause or a consequence of weight change, even after covariate adjustment. Future research should attempt to experimentally manipulate self-weighing frequency in different controlled “doses”, both with and without other weight management strategies. Collapsing continuous variables into dichotomous categories, as was done in the second analysis for the weight change outcome variable, may result in residual confounding. Also, participants with missing data were listwise deleted from the analytical dataset, which again could bias effect estimates. Finally, by design, worksite was the unit of randomization in the HealthWorks study. However, the analyses in this paper proceeded under the assumptions of an observational dataset and used individuals as the unit of analysis. Statistical procedures to nest worksites within study arms may have arguably led to more precise standard error estimates, though study arm was not associated with weight change in any analyses. Taken collectively, the findings seemed to indicate that an increase in self-weighing frequency over time was associated with a net weight change benefit over two years.

Chapter VI. Paper #3: Weight Change and Workplace Absenteeism

Background

Purpose

Paper #3 involved two secondary analyses of data from the HealthWorks trial. The purpose was to answer the following general research question, "does weight change predict workplace absenteeism?" The hypothesis was that weight loss or weight maintenance would be associated with less workplace absenteeism relative to weight gain over two years.

Preliminary studies on weight maintenance and workplace absenteeism

The impact that weight gain prevention programs have on obesity-associated economic indicators such as healthcare service costs or lost workplace productivity is largely unclear. The latter indicator is of particular concern for private businesses in the U.S. because they tend to be the primary payers of healthcare for young and middle aged adults.[75] Current evidence generally indicates that a BMI in the overweight or obese category is associated with greater workplace absenteeism relative to a BMI in the healthy range.[76] The evidence supporting this relationship, however, is mainly cross-sectional. The largest and most recent study to date in this area found that a BMI $\geq$30 kg/m^2 was associated with a 25% higher odds of calling in sick $\geq$1 day per year relative to a BMI <25 kg/m^2 in a sample of Dutch employees.[77] This same study also found that participants with a BMI $\geq$30 kg/m^2 had a 55% higher odds of calling in sick $\geq$25 day per year relative to participants with a BMI <25 kg/m^2.

Prospective studies examining weight change and absenteeism are scarce and those that are available[78, 79] have typically examined the impact of a general health risk reduction program, versus body weight change specifically, on workplace absenteeism. Two prospective studies have examined the impact of a weight loss intervention package specifically on workplace absenteeism. Narbro and colleagues[80] observed 14% fewer sick days among 369 intervention participants in year 3 following bariatric surgery relative to a matched control group who was treated for obesity using a standard behavioral program. In time series analyses from the Healthy Worker Project,[81] which involved a combined weight loss and smoking cessation intervention, the intervention group reported a significant 3.7% net fewer sick days (in the previous month) after 2 years follow-up relative to the control group. Thus, there is evidence to indicate that weight loss interventions can improve workplace absenteeism, but no direct information on the relationship between workplace absenteeism and actual body weight change since these preliminary studies analyzed only the impact that weight loss intervention arms had (versus actual weight change as the independent variable).

Summary of research gaps

Poor health (of which obesity is a major component) is the principal driver of lost workplace productivity, which is up to three times more expensive than healthcare costs in a typical employee.[75] If weight gain prevention could be shown to help offset workplace productivity losses, employers would arguably be in a strong position to invest in and deliver such services quickly and on a large scale.

Given that worksites have a clear economic interest in improving the health of their workforce, quantifying the association between weight change and workplace absenteeism is an important unfilled gap in the literature that needs to be better understood. Furthermore, if the focus of obesity management initiatives is indeed to change more broadly toward preventing weight gain (versus promoting weight loss), businesses will also need to better understand if/how weight maintenance predicts less workplace absenteeism relative to weight gain in order to justify continued investment in weight management programming.

Methods

Eligible participants

For analytical purposes (described in detail below in the *Statistical analyses* section), only study participants with complete baseline and 24-month follow-up data (for all examined variables), not pregnant, and not given birth during the trial or within one year prior to the enrollment date were considered eligible (n=1,238).

Measures

Measures were collected at baseline and 24-month follow-up. Categories of measures collected as part of the full HealthWorks study included self-reported: demographics, physical activity, routine health habits, food habits, social support, nutrition/exercise environment, and medical history. In addition, clinical measures were taken for anthropometrics and direct observations were collected at each worksite for stair use and onsite program participation. For the purposes of this paper, two similar analyses were performed as described below. The dependent variable and examined covariates were the same in both analyses, but the independent variable was modeled in two different ways, slightly different in each analysis.

Independent variables. The primary independent variable in this analysis was change in weight between baseline and follow up, modeled slightly different in each analysis. Body weight was measured for all participants at baseline and 24-month follow-up using a calibrated digital scale by trained study personnel. Participants wore light street clothing and no shoes. Weight was recorded to the nearest 0.1 kg. For purposes of analysis, body weight change (i.e., 24-month weight minus baseline weight) was modeled both continuously and as a dichotomous variable that contrasted weight gainers with those not gaining weight. Dichotomous categories were (1) weight maintenance: individuals who gained <= 1.0 kg between baseline and 24-month follow-up, and (2) weight gain: individuals who gained > 1 kg between baseline and the 24-month follow-up. These dichotomous categories for weight maintenance were identical to those used in Paper #2, and thus also come with the caveats discussed in that section and as outlined in a recent review paper by Stevens, et al.[72]

Dependent variable. The dependent variable was workplace absenteeism. It was assessed at 24-month follow-up using a single-item, self-reported measure that asked "In the past two years, how many days have you missed work because of illness or injury?" The response option was numerically open-ended. Similar single-item forms of assessing workplace absenteeism have been used in other studies.[81-84] Revicki and colleagues[84] found their single-item absenteeism instrument correlated well with timecard records of workplace sickness absence (intraclass correlation=0.86).

Covariates. Analytical covariates considered for inclusion were baseline: age, sex, race/ethnicity, randomized condition, smoking, depression, diabetes, high blood pressure, and BMI. For BMI, height was measured to the nearest millimeter using a wall-mounted ruler and BMI was calculated by dividing weight in kg by height in meters squared. There was somewhat limited direct empirical guidance to inform the selection of candidate covariates to examine in multivariate modeling. This was mainly due to the fact that few studies examined the relationship between weight status and workplace absenteeism, and also because some studies did not disclose the parameter estimates for the covariates analyzed or did not use multivariate models. The research by Robroek and colleagues[77] implicated age, sex, smoking, and chronic diseases as the strongest independent predictors of workplace absenteeism in their multivariate cross-sectional analyses. These investigators also found that BMI was associated with workplace absenteeism in a non-linear fashion, thus a quadratic examination of baseline BMI was also included in the analysis. Other covariates considered for this analysis were selected based on their availability in the HealthWorks dataset and their clinical suspicion that they may be related to both body weight change and workplace absenteeism. Each considered covariate was initially examined to determine whether or not it would be tested for potential inclusion in the final model for both Analysis #1 and Analysis #2 (described in *Statistical analyses* section below). This was done by examining the univariate association between each considered covariate, the primary predictors, and the outcome. Because these univariate analyses were only needed to initially identify covariates that would be tested in final models, less protection against a type I error was deemed necessary. Any covariate that was found to have a p-value <0.100 in its association with the primary predictors or the outcome was considered for inclusion into the final regression models.

Statistical analyses

All analytical procedures were conducted using SAS Version 9.2 (Cary, NC). The intervention and control groups were statistically indistinguishable in terms of workplace absenteeism (data not shown), therefore these two groups were combined in this analysis in order to improve power. Two different analytic approaches were used to predict workplace absenteeism and are described below. In both analyses, no imputations were made for missing variables and a complete-case framework was utilized in that participants with missing values for any predictor variable or outcome measure were listwise excluded. As expected, the outcome variable, workplace absenteeism, was skewed to the right (see histogram in Figure 3) with approximately one-third of the sample reporting a value of 0 days. Because of this, negative binomial regression models were used in both analyses (described below) because they are designed to fit such distributions.[85] In addition, for analytical purposes, a 99% Winsorization technique[86] was applied to the outcome variable. This involved setting all observed values for workplace absenteeism below the 1st percentile to the 1st percentile score, while all data above the 99th percentile were set to the 99th percentile score. Essentially, this technique truncated 12 values for workplace absenteeism in this dataset so that no value exceeded 80 days. This Winsorization technique was performed as an alternative to trimming and to temper impacts of short-term disability that was likely experienced by a very small subset of the analytical sample.

Analysis #1. In the primary analysis, a general model (PROC GENMOD) that specified a negative binomial distribution was used to examine the association between workplace absenteeism and weight change. The outcome in this analysis, workplace absenteeism, was modeled as a continuous variable. The primary predictor in this analysis, weight change, was also modeled as a continuous variable. A basic model was first created to examine the crude relationship between weight change and workplace absenteeism. Next, effect modification was examined by creating a two-way interaction term between weight change and each covariate (separately), and entering it into the crude model. Also, a quadratic interaction for baseline physical activity was tested. In addition, quadratic interaction terms for both weight change and baseline BMI were tested. Interaction terms with a p-value less than 0.05 were retained in subsequent models. Any remaining covariates that were not found to be effect modifiers were then entered separately into the reduced model to check for their utility as an independent predictor or a confounder. Specifically, any covariate term with a p-value less than 0.05 (i.e., was an independent predictor) or that that changed the reduced modeled weight change frequency parameter estimate by more than 10 percent (i.e., was a confounder) was retained in the final model.

Analysis #2. In the secondary analysis, identical procedures were performed as in Analysis #1. In this analysis, however, the primary predictor, weight change, was modeled as a dichotomous variable (i.e., weight gain vs. weight maintenance) using the definition described previously. Weight maintenance was used as the reference category. This second analysis was done to complement the first analysis and to aid in the clinical interpretation of the relationship between weight change and workplace absenteeism.

Results

Of the 1,747 enrollees, 1,241 (71%) met the eligibility criteria for this analysis. Closer inspection of the primary predictor variable found that three participants lost ≥40 kg (~90 lb) during the study. These participants were excluded from the analytical dataset in order to control for extreme weight loss outliers that could skew conclusions from the regression analyses. Thus the final analytical sample included 1,238 individuals with complete data available. Table 9 outlines the descriptive characteristics of the included and excluded analytical samples, as well as the entire HealthWorks sample.

HealthWorks participants could generally be described as primarily White, middle-aged, females, being slightly healthier than the general American population in regard to the prevalence of smoking and chronic medical conditions. Missing follow-up data were primarily due to participants leaving employment at one of the worksites that participated in the HealthWorks study. Differences in baseline characteristics were statistically indistinguishable between the group included in the analytical dataset and the remaining 509 participants who left the workforce or declined study follow-up, with the exceptions of age, sex, depression, and hypertension (see Table 9). Participants who were younger at baseline, female, reported having depression, or were normotensive were somewhat more likely to be excluded.

In regard to the primary predictors and outcome, mean±sd weight change was 0.8±5.0 kg and the number of participants in the weight maintenance category was 649 (52%). Workplace absenteeism averaged 5.1±11.1 days over two years. Initial univariate examinations of the considered baseline covariates found that age, sex, smoking, diabetes, high blood pressure, depression, and BMI were suitable to be tested for inclusion in the final models (see Table 10). Race/ethnicity and randomized condition were not further considered as covariates in any multivariate models since there was no univariate association between them and any primary predictor or outcome variable.

Analysis #1: Weight change predictor modeled as a continuous variable

The initial crude model indicated that weight change (β±se=-0.003±0.009, df=1, χ^2=0.12, p=0.731) was not significantly associated with workplace absenteeism. The direction of this relationship, though very weak and not statistically significant, indicated that as weight increased, workplace absenteeism slightly decreased over the two-year study. Further modeling for effect modification revealed no significant interactions between any of the considered covariates. However, age, sex, smoking, depression, and BMI were found to be independent predictors of workplace absenteeism. The final multivariate regression model with all included beta terms and directions of associations for this analysis is summarized in Table 11. Workers who were current smokers, female, depressed, and/or had higher BMI had significantly more predicted illness absence days relative to workers who were non-smokers, males, non-depressed, and/or had lower BMI, respectively.

Analysis #2: Weight change predictor modeled as a dichotomous variable

Results from the secondary analysis paralleled the primary analysis. The initial crude model indicated that the weight gain category (β±se=0.138±0.091, df=1, χ^2=2.29, p=0.131) was not significantly associated with workplace absenteeism relative to the weight maintenance reference category. The direction of this relationship, though very weak and not statistically significant, indicated that as weight increased, the rate of workplace absenteeism slightly increased over the two-year study. Likewise, further modeling for effect modification revealed no significant interactions between the considered covariates, but age, sex, smoking, depression and BMI were found to be independent predictors of workplace absenteeism. The final multivariate regression model with all included beta terms and directions of associations for this analysis is displayed in Table 12.

Given its wide range in the analytical dataset (16.9 to 61.1 kg.m^2), the strongest single covariate predictor in both models was baseline BMI (at high levels). After holding all other predictors constant, each 1 kg/m^2 increase in baseline BMI was associated with a 3.1% increase in the mean number of workplace illness absence days. To aid in the interpretation of that finding, the final model-based relationship between baseline BMI and workplace absenteeism from Analysis #1 is graphically displayed in Figure 4. Of note, the average number of illness absence days among morbidly obese participants (i.e., BMI $\geq$40 kg/m^2) was approximately twice that of healthy weight participants (i.e., BMI <25 kg/m^2).

Discussion

The relationship between body weight change and workplace absenteeism was generally weak and not statistically significant in both models examined in the HealthWorks study. This finding was somewhat surprising in that it did not support the general direction of this relationship intimated by previous research.[80, 81] However, the HealthWorks study was the first to date that specifically examined the relationship between weight change and workplace absenteeism (both modeled as continuous variables) over two years.

Speculating on the reasons for the observed null findings with regard to weight change is challenging due to the very limited research in this area. Findings from the recently completed WAY to Health project also failed to find a significant relationship between weight loss, dichotomized at -5% of baseline weight, and workplace absenteeism (or medical expenditures) over one year.[87] That study focused solely on weight loss, however, and was only open to overweight and obese participants.

Nonetheless, it may be that the extremes of the weight change distribution in any given weight management study essentially “cancel out” the overall impact of weight change on workplace absenteeism. For example, it is typically theorized that individuals who gain a substantial amount of weight go on to experience the sequela of physical and emotional health conditions associated with excess body weight, which then translates into more days sick from work. However, a similar phenomenon may also operate for individuals who lose a substantial amount of weight. Such individuals may begin an intense exercise program that makes them prone to injury, or make rapid caloric reductions that reduce diet quality and compromise their immune system. Or in some cases, weight loss is precipitated by underlying disease processes (e.g., diabetes, cancer). More research is needed in this area to explain why such a phenomenon occurs.

The covariates in the HealthWorks study, however, were associated with workplace absenteeism in the expected direction and were nearly identical in both models. Participants who were female, depressed, current smokers, or at a higher BMI at baseline reported more illness absence days over two years, on average, relative to males, non-depressed, non-smokers, or lower BMI individuals, respectively. With the exception that age was not found to be a significant predictor of absenteeism, the significant covariates observed in the HealthWorks study were very consistent with several other studies,[75, 88] including the large cross-sectional study of over 10,000 Dutch employees.[77] It is theorized that poor health habits often cluster together and can be precipitated or maintained by negative emotional states, which can then lead to decrements in overall job productivity, particularly for females.[75, 88]

Higher levels of body mass stood out as the strongest predictor of workplace absenteeism. This is also consistent with previous research,[76, 77] but other studies to date have either not examined BMI as a continuous variable or examined few cut-points of excess body weight, presumably due to small sample sizes. HealthWorks participants at the highest levels of baseline BMI clearly had the highest rate of workplace absenteeism. To crudely translate this relationship in economic terms using two extremes (and assuming a gross salary of \$192/day, or \$50,000/annum), a morbidly obese employee with a BMI of 43 kg/m^2 would have an estimated \$914/y in absenteeism costs while a healthy weight employee with a BMI of 23 kg/m^2 would have an estimated \$492/y in absenteeism costs, or about half as much.

It could be argued that the HealthWorks study demonstrated that weight maintenance programs provide limited or no economic benefits for employers (purely from an absenteeism perspective – ignoring the full range of economic, social, and health benefits that were not examined in these analyses). A longer-term view is important, however, that takes into account the background epidemiologic trend of an increasingly overweight American workforce year over year, which in the absence of successful intervention, seems to be the norm.[11, 12] Compared to weight loss, weight maintenance likely remains a more achievable goal for a given population.[25, 26] Perhaps investments in worksite weight maintenance programs should be more heavily focused on primary prevention that is designed to stabilize the proportion of healthy weight or overweight employees who would otherwise eventually “progress” into the obese or morbidly obese BMI categories over time. Such programs may yield a better overall economic return-on-investment relative to worksite weight loss programs or worksite weight maintenance programs that are less effective due to their resources being spread too broadly.[89]

There were several methodological strengths in these analyses. The sample size was relatively large, though still limited to adequately test for all possible interactions. The attrition rate was acceptable relative to other weight management studies with longer term follow-up.[19] Over 75% of all eligible participants had complete data available for the analyses in this paper. Two separate approaches were used to characterize the predictor variable, each giving slightly different points of view, but with similar conclusions being drawn from both models. All analyses had the potential to account for confounding variables and detect at least some interactions between weight change and covariates.

The most significant limitation to internal validity was the reliance on self-reported measures of workplace absenteeism. Though commonly used in the published scientific literature, there is no known reliability studies on the single-item measure used in this study (though there are some validity studies). As is the case in many secondary data analyses such as this, there is also a temporality issue in that the exposure and outcome are essentially measured and occurring in a parallel timeframe and are not manipulated experimentally. As such, it is possible that reverse causation cold be at play whereby workplace absenteeism actually causes weight change, even after covariate adjustment. The second analysis that dichotomized weight change essentially lumped together both large and small weight gains, as well as large and small weight losses, into just two simplified categories. Though a quartile or tertile categorical representation of weight change would arguably be more statistically informative, the dichotomized approach gives what is perhaps a more easily understood “bottom line” analysis. Complemented by the first analysis where weight change was represented as observed in continuous variable format, the dichotomized representation of weight change essentially gives the opposite extreme where weight change is grouped into the fewest categories possible in order to determine if the conclusions changed with such an approach. Other limitations included the fact that participants with missing data were excluded and there was some evidence that drop-outs were not missing at random. In addition, the social support measure was an indirect, self assessment of the perceived level of support from coworkers for physical activities. More experimental research is needed to understand the association between weight change and productivity, as well as the other covariates that potentially confound that association.

Chapter VII. Conclusions

Obesity remains a significant challenge to the American public's health. Shifting the focus of weight management interventions toward weight gain prevention (rather than weight loss) may be a more realistic public health approach, but more work is needed to attract broad segments of the population to engage in and interact with interventions designed to help people eat fewer calories and become more physically active. Because adults generally spend about half of their waking hours at work in a given week, worksite-based environmental changes and programs may offer a more convenient, feasible, and replicable venue to reach larger segments of the population at a more affordable cost as compared to individualized or clinic-based programs.

Indeed, this was the overarching logic of the HealthWorks study. Findings from these dissertation analyses reveal some important lessons learned. Program participation (i.e., Paper #1) and absenteeism (i.e., Paper #3) are both critically important outcomes for employers to better understand what is driving them because it influences future investments made (or not made) in worksite health promotion initiatives. Self-weighing (i.e., Paper #2) is more of a within-program content strategy, but it is also important to understand how it influences weight gain prevention specifically in the worksite environment since it is an inexpensive behavior change strategy and worksites currently seem to focus much attention on controlling obesity in their workforce.

More specifically, researchers are well aware that the American public is not currently physically active enough to slow the rising prevalence of obesity.[11] Paper #1 indicated that worksite walking programs can indeed attract a sizeable fraction of a given workforce to participate, regardless of their physical activity level from the start. This is an encouraging finding because these sorts of programs focus on the most popular form of physical activity among U.S. adults, walking, and they are likely a good option to start up at other worksites. Yet there remain significant challenges to attract the “other half” of employees who did not participate, particularly young males with limited social support for physical activity. Future research should focus on how to improve aspects of physical activity program design and marketing so that recruitment among these harder to reach groups can be improved.

From Paper #2, it seemed clear that promoting an increase in self-weighing frequency may add a net weight change benefit over two years in a worksite population. More experimental studies are needed to determine the precise independent contribution of more refined levels of self-weighing frequencies on weight change, but future research should perhaps now also focus on examining self-weighing frequency as a dependent variable so that it can be better understood as a behavior in its own right (along with what program factors reinforce its regular practice). Self-weighing is a very straightforward, low-cost, self-management strategy that most of the American population can engage in easily given wide access to scales. Worksites in particular are well positioned to make environmentally oriented modifications to their work spaces that can increase the propensity for employees to self-monitor their weight and, if needed, take corrective action to head off the systemic weight gain so predictable in the American workforce today.

Perhaps most concerning about the weight gain epidemic in the United States is that it is projected to have major cost implications in the future as it relates to healthcare services and lost workplace productivity. It seems logical that successful weight gain prevention would eventually have a net impact on reducing workplace absenteeism (a major productivity cost for employers), but Paper #3 in this dissertation did not observe such an association over two years. More long-term experimental research is needed in this area to better understand the interplay between weight change and the significant disturbance variables such as baseline BMI, health habits, and various levels of workplace productivity (e.g., job impairment, short-term disability). If environmentally oriented weight gain prevention interventions such as those delivered in the HealthWorks study could be sustained over longer periods of time, they may eventually help to offset an employer's overall financial bottom line and be justifiable to invest in over larger volumes of the American workforce.

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Table 1. Descriptive baseline characteristics of the entire HealthWorks study intervention arm, as well as those included and excluded from the analytical sample in Paper #1.

Baseline measure	Intervention arm (all) (n = 752)	Included in analytical sample (n = 642)	Excluded from analytical sample (n = 110)	p
Age (y)	42.7 ±10.8	43.1 ±10.8	39.7 ±10.6	0.004
Sex				
Male	272 (36%)	242 (38%)	30 (27%)	0.061
Female	478 (64%)	400 (62%)	78 (71%)	
Not reported	2 (0%)	0 (0%)	2 (2%)	
Race/Ethnicity				
White, non-Hispanic	645 (86%)	565 (88%)	80 (73%)	0.296
Not White, or Hispanic	92 (12%)	77 (12%)	15 (14%)	
Not reported	15 (2%)	0 (0%)	15 (14%)	
Education level				
No college degree	288 (38%)	251 (39%)	37 (34%)	0.961
College degree or higher	448 (60%)	391 (61%)	57 (52%)	
Not reported	16 (2%)	0 (0%)	16 (15%)	
Marital status				
Married or living with partner	510 (68%)	433 (67%)	77 (70%)	0.027
Not married or living with partner	230 (31%)	209 (33%)	21 (19%)	
Not reported	12 (2%)	0 (0%)	12 (11%)	
Worksite				
#2	168 (22%)	130 (20%)	38 (35%)	0.004
#3	259 (34%)	227 (35%)	32 (29%)	
#6	325 (43%)	285 (44%)	40 (36%)	
Current cigarette smoker				
Yes	89 (12%)	76 (12%)	13 (12%)	0.554
No	646 (86%)	566 (88%)	80 (73%)	
Not reported	17 (2%)	0 (0%)	17 (15%)	
Medical conditions *				
Diabetes	24 (3%)	21 (3%)	3 (3%)	0.975
High blood pressure	154 (20%)	140 (22%)	14 (13%)	0.147
Depression	162 (22%)	138 (21%)	24 (22%)	0.268
Required weight gain for action (lb)	7.8 ±10.3	7.6 ±9.2	9.4 ±16.8	0.133
Social support (0-low to 5-high)	2.3 ±1.7	2.4 ±1.7	2.2 ±1.7	0.458
Body mass index (kg/m^2)	28.8 ±6.6	28.8 ±6.6	28.8 ±6.7	0.932

All values are reported as mean ±standard deviation or frequency (% of sample total).

* Variable does not sum to 100% of sample because participants could select multiple responses.

p=probability value, and corresponds to difference between included and excluded groups.

Table 2. Univariate, unadjusted association matrices between each considered covariate and the primary predictor, as well as the outcome variable, in Paper #1 (n=642).

Covariates	Predictor: Physical activity (MET-min/wk)	Outcome: Walking club (enrollee vs. non-enrollee)
Age * (y)	–3.586 (p<0.001)	1.026 (p=0.001)
Sex * (male vs. female)	197.965 (p=0.388)	0.246 (p<0.001)
Race/ethnicity (non-White or Hisp vs. White non-Hisp)	–261.038 (p=0.446)	1.151 (p=0.654)
Education (No college degree vs. college degree)	356.517 (p=0.117)	1.303 (p=0.102)
Marital status * (married/partner vs. not married/partner)	–398.110 (p=0.093)	1.083 (p=0.634)
Worksite * (#6 vs. #2)	–901.136 (p=0.002)	0.925 (p=0.717)
Worksite * (#3 vs. #2)	–425.049 (p=0.168)	0.464 (p=0.001)
Current cigarette smoker (yes vs. no)	–161.768 (p=0.638)	0.736 (p=0.212)
Diabetes * (yes vs. no)	–1,033.781 (p=0.098)	0.738 (p=0.498)
High blood pressure (yes vs. no)	–254.630 (p=0.344)	1.067 (p=0.734)
Depression * (yes vs. no)	–584.909 (p=0.030)	0.888 (p=0.537)
Required weight gain for action (lb)	16.546 (p=0.170)	0.988 (p=0.169)
Coworker social support * (0-low to 5-high)	38.592 (p=0.555)	1.144 p=0.004)
Body mass index * (kg/m^2)	–57.390 (p=0.001)	0.994 (p=0.602)

Values for the predictor are reported as physical activity in MET-min/wk (p-value). Negative values indicate that as the covariate increases (or relative to the reference category for categorical covariates), physical activity decreases.

Values for the outcome are reported as odds ratio (p-value) of being a walking club enrollee relative to a non-enrollee. Values less than 1 indicate that as the covariate increases (or relative to the reference category for categorical covariates), the odds of being a walking club enrollee decrease relative to a non-enrollee.

* Covariate considered for entry into the final multivariate models because associated p-value was <0.100 for predictor and/or outcome.

All covariates were collected at the baseline assessment.

Table 3. Final multivariate logistic regression model depicting the association between participation in worksite walking club events and baseline physical activity level, with significant covariates, in Paper #1.

Model predictors	Enrollee in walking club (vs. non-enrollee)				
	B	SE	OR	CI	p
n = 642					
Intercept	–0.514	0.480	---	---	0.284
Physical activity (MET-min/wk) *	< –0.001	<0.001	1.00	0.99-1.01	0.808
Age (y)	0.027	0.008	1.03	1.01-1.04	0.001
Sex					
Male	–1.376	0.183	0.25	0.18-0.36	<0.001
Female (ref)	---	---	---	---	---
Coworker social support (0-low to 5-high)	0.121	0.052	1.13	1.02-1.25	0.020
Worksite					
#6	–0.227	0.244	0.79	0.49-1.29	0.352
#3	–0.889	0.247	0.41	0.25-0.67	<0.001
#2 (ref)	---	---	---	---	---

B values are equal to (natural) logarithmic odds ratio of being an enrollee in ≥1 walking club event relative to the reference category. Positive values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the odds of being an enrollee increases. Negative values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the odds of being an enrollee decreases.

Other table column headings indicate: SE=standard error, OR=adjusted odds ratio, CI=95% confidence interval, and p=probability value.

* To aid in interpretation, the OR and CI for physical activity is per 10 MET-min/wk (versus 1 MET-min/wk).

Table 4. Descriptive baseline characteristics of the eligible sample, as well as those included and excluded from the analytical sample, in Paper #2.

Baseline measure	All (n = 1,747)	Included in analytical sample (n = 1,222)	Excluded from analytical sample (n = 525)	p
Age (y)	42.9 ±10.7	44.2 ±10.3	39.5 ±11.1	<0.001
Sex				
Male	654 (37%)	479 (39%)	175 (33%)	0.033
Female	1,086 (62%)	743 (61%)	343 (65%)	
Not reported	7 (0%)	0 (0%)	7 (1%)	
Race/Ethnicity				
White, non-Hispanic	1,478 (85%)	1,071 (88%)	407 (78%)	0.052
Not White, or Hispanic	228 (13%)	151 (12%)	77 (15%)	
Not reported	41 (2%)	0 (0%)	41 (8%)	
Education level				
No college degree	667 (38%)	486 (40%)	181 (34%)	0.381
College degree or higher	1,038 (59%)	736 (60%)	302 (58%)	
Not reported	42 (2%)	0 (0%)	42 (8%)	
Marital status				
Married or living with partner	1,178 (67%)	829 (68%)	349 (66%)	0.281
Not married or living with partner	539 (31%)	393 (32%)	146 (28%)	
Not reported	30 (2%)	0 (0%)	30 (6%)	
Randomized study condition				
Intervention	752 (43%)	541 (44%)	211 (40%)	0.114
Control	995 (57%)	681 (56%)	314 (60%)	
Self-weighing frequency				
Daily or more	237 (14%)	160 (13%)	77 (15%)	
Weekly	448 (26%)	329 (27%)	119 (23%)	0.239
Monthly or less	1,013 (58%)	733 (60%)	281 (54%)	
Not reported	48 (3%)	0 (0%)	48 (9%)	
Current cigarette smoker				
Yes	239 (14%)	171 (14%)	68 (13%)	0.876
No	1,459 (84%)	1,051 (86%)	408 (78%)	
Not reported	49 (3%)	0 (0%)	49 (9%)	
Medical conditions *				
Diabetes	59 (3%)	46 (4%)	13 (2%)	0.309
High blood pressure	331 (19%)	257 (21%)	74 (14%)	0.011
Depression	403 (23%)	274 (22%)	129 (25%)	0.032
Weight loss attempts past 2 yrs (n)	3.0 ±8.6	2.9.0 ±8.0	3.3 ±9.9	0.424
Required weight gain for action (lb)	8.3 ±10.1	8.4 ±9.7	7.9 ±10.9	0.319
Scales in home (n)	0.8 ±0.5	0.8 ±0.5	0.8 ±0.5	0.564
Body mass index				
Obese: ≥30.0 kg/m^2	571 (33%)	401 (33%)	170 (32%)	
Overweight: 25.0-29.9 kg/m^2	630 (36%)	444 (36%)	186 (35%)	0.854
Healthy weight: <25.0 kg/m^2	546 (31%)	377 (31%)	169 (32%)	

All values are reported as mean ±standard deviation or frequency (% of sample total).

* Variable does not sum to 100% of sample because participants could select multiple responses.

p=probability value, and corresponds to difference between included and excluded groups.

Table 5. Univariate, unadjusted association matrices between each considered covariate and: (1) the primary predictor, and (2) the outcome variables in Paper #2 (n=1,222).

Covariates	Primary predictor: Self-weighing frequency at 24-month follow-up (weekly or more vs. monthly or less)	Analysis #1 Outcome: Weight change between baseline and 24-month follow-up (kg)	Analysis #2 Outcome: Weight change between baseline and 24-month follow-up (weight maintenance vs. weight gain)
Age * (y)	1.004 (p=0.463)	–0.033 (p=0.054)	1.010 (p=0.063)
Sex (male vs. female)	0.823 (p=0.100)	–0.547 (p=0.127)	1.106 (p=0.339)
Race/ethnicity * (non-White or Hisp vs. White non-Hisp)	0.731 (p=0.079)	–0.668 (p=0.205)	1.153 (p=0.417)
Education * (No college degree vs. college degree)	0.731 (p=0.079)	0.214 (p=0.546)	1.074 (p=0.121)
Marital status * (married/partner vs. not married/partner)	1.133 (p=0.313)	–0.664 (p=0.074)	1.243 (p=0.076)
Randomized study condition * (intervention vs. control)	1.257 (p=0.048)	0.373 (p=0.286)	0.933 (p=0.547)
Baseline self-weighing * (weekly or more vs. monthly or less)	11.238 (p<0.001)	0.594 (p=0.094)	0.873 (p=0.247)
Current cigarette smoker * (yes vs. no)	0.425 (p<0.001)	0.875 (p=0.080)	0.724 (p=0.051)
Diabetes * (yes vs. no)	0.521 (p=0.045)	–0.763 (p=0.403)	1.424 (p=0.251)
High blood pressure * (yes vs. no)	1.043 (p=0.765)	–0.710 (p=0.095)	1.103 (p=0.485)
Depression (yes vs. no)	0.866 (p=0.298)	0.658 (p=0.114)	0.845 (p=0.219)
Weight loss attempts past 2 yrs * (n)	1.027 (p=0.006)	–0.031 (p=0.149)	1.013 (p=0.117)
Required weight gain for action * (lb)	0.955 (p<0.001)	0.023 (p=0.190)	1.000 (p=0.956)
Scales in home * (n)	1.901 (p<0.001)	–0.052 (p=0.870)	1.071 (p=0.518)
Body mass index * (obese vs. not obese)	1.003 (p=0.982)	–1.497 (p<0.001)	1.132 (p=0.311)

Values for the primary predictor are reported as odds ratio (p-value) for a one-unit change (continuous) or relative to reference category (categorical). Values less than 1 indicate that as the covariate increases (or relative to the reference category for categorical covariates), the odds of weekly or more self-weighing decrease relative to monthly or less self-weighing.

Values for the Analysis #1 outcome are reported as weight change in kg (p-value). Negative values indicate that as the covariate increases (or relative to the reference category for categorical covariates), weight decreases.

Values for the Analysis #2 outcome are reported as odds ratio (p-value) of being a weight maintainer (i.e.,≤1 kg weight gain) relative to a weigh gainer. Values less than 1 indicate that as the covariate increases (or relative to the reference category for categorical covariates), the odds of weight maintenance decrease relative to weight gain.

* Covariate considered for entry into the final multivariate models (for both Analysis #1 and Analysis #2) because associated p-value was <0.100 for primary predictor and/or at least one outcome.

All covariates were collected at the baseline assessment.

Table 6. Final multivariate linear regression model depicting the association between weight change and follow-up self-weighing frequency, with significant interactions and covariates in Analysis #1, from Paper #2.

Model predictors	Weight change (kg)		
	β	SE	p
n = 1,222			
Intercept	1.331	0.411	0.001
Baseline body mass index			
Obese: ≥30.0 kg/m^2	–0.821	0.570	0.150
Overweight: 25.0-29.9 kg/m^2	–0.329	0.558	0.555
Healthy weight: <25.0 kg/m^2 (ref)	---	---	---
Baseline self-weighing frequency			
Daily or more	3.441	0.628	<0.001
Weekly	1.393	0.439	0.002
Monthly or less (ref)	---	---	---
Follow-up self-weighing frequency			
Daily or more	–2.353	0.935	0.012
Weekly	–1.373	0.727	0.059
Monthly or less (ref)	---	---	---
Interaction (baseline body mass index × follow-up self-weighing)			
Obese × Daily	–3.440	1.211	0.005
Obese × Weekly	–1.022	0.970	0.292
Overweight × Daily	–0.771	1.132	0.496
Overweight × Weekly	–0.033	0.973	0.973
Healthy weight × Monthly (ref)	---	---	---

B values are equal to weight change (kg). Positive values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), weight increases. Negative values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), weight decreases.

Other table column headings indicate: SE=standard error, and p=probability value.

Table 7. Final multivariate logistic regression model depicting the association between weight maintenance and follow-up self-weighing frequency, with significant interactions and covariates in Analysis #2, from Paper #2.

	Weight maintenance (vs. weight gain)				
Model predictors	*B*	SE	OR	CI	p
n = 1,222					
Intercept	–0.498	0.266	---	---	0.062
Age (y)	0.012	0.006	1.01	1.00-1.02	0.044
Baseline self-weighing frequency					
Daily or more	–0.314	0.547	0.73	0.25-2.14	0.566
Weekly	–0.610	0.230	0.54	0.35-0.85	0.008
Monthly or less (ref)	---	---	---	---	---
Follow-up self-weighing frequency					
Daily or more	0.297	0.331	1.35	0.70-2.58	0.370
Weekly	0.777	0.206	2.18	1.45-3.26	<0.001
Monthly or less (ref)	---	---	---	---	---
Interaction (baseline self-weighing × follow-up self-weighing)					
Daily × Daily	–0.059	0.215	0.94	0.62-1.44	0.950
Daily × Weekly	–0.142	0.318	0.87	0.47-1.62	0.655
Weekly × Daily	1.051	0.294	2.86	1.61-5.09	<0.001
Weekly × Weekly	0.050	0.177	1.05	0.74-1.49	0.778
Monthly × Monthly (ref)	---	---	---	---	---

B values are equal to (natural) logarithmic odds ratio of being a weight maintainer (i.e.,≤1 kg weight gain) relative to the reference category. Positive values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the odds of being a weight maintainer increases. Negative values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the odds of being a weight maintainer decreases.

Other table column headings indicate: SE=standard error, OR=adjusted odds ratio, CI=95% confidence interval, and p=probability value.

Table 8. Final model-based, adjusted probability and odds ratio of being a weight maintainer by each category of self-weighing frequency at baseline and follow-up from Paper #2 (n=1,222).

Baseline self-weighing	24-month follow-up self-weighing: Daily or more	Weekly	Monthly or less
Daily or more	n=103 (49%) OR=0.94 (0.62-1.44)	n=43 (47%) OR=0.87 (0.47-1.62)	n=14 (42%) OR = 0.73 (0.25-2.14)
Weekly	n=67 (74%) **OR=2.86** (1.61-5.09)	n=166 (51%) OR=1.05 (0.74-1.49)	n=96 (35%) **OR=0.54** (0.35-0.85)
Monthly or less	n=40 (58%) OR=1.35 (0.70-2.58)	n=132 (69%) **OR=2.18** (1.45-3.26)	n=561 (50%) OR=1.00 (ref)

Cell values are given as frequency count (adjusted probability of weight maintainer), adjusted odds ratio (95% confidence interval).
Odds ratios are adjusted for age. Bolded adjusted odds ratios are significantly different than the reference category ($p<0.05$).
Cell shadings indicate: none=stable self-weighing, light=increased self-weighing, and dark=decreased self-weighing.

Table 9. Descriptive baseline characteristics of the complete sample, as well as those included and excluded from the analytical sample, in Paper #3.

Baseline measure	All (n = 1,747)	Included in analytical sample (n = 1,238)	Excluded from analytical sample (n = 509)	p
Age (y)	42.9 ±10.7	44.2 ±10.2	39.4 ±11.2	<0.001
Sex				
Male	654 (37%)	484 (39%)	170 (33%)	0.041
Female	1,086 (62%)	754 (61%)	332 (65%)	
Not reported	7 (0%)	0 (0%)	7 (1%)	
Race/Ethnicity				
White, non-Hispanic	1,478 (85%)	1,083 (87%)	395 (78%)	0.100
Not White, or Hispanic	228 (13%)	155 (13%)	73 (14%)	
Not reported	41 (2%)	0 (0%)	41 (8%)	
Randomized study condition				
Intervention	752 (43%)	546 (44%)	206 (40%)	0.164
Control	995 (57%)	692 (56%)	303 (60%)	
Current cigarette smoker				
Yes	239 (14%)	174 (14%)	65 (13%)	0.968
No	1,459 (84%)	1,064 (86%)	395 (78%)	
Not reported	49 (3%)	0 (0%)	49 (10%)	
Medical conditions *				
Diabetes	59 (3%)	47 (4%)	12 (2%)	0.246
High blood pressure	331 (19%)	263 (21%)	68 (13%)	0.003
Depression	403 (23%)	274 (22%)	129 (25%)	0.008
Body mass index (kg/m^2)	28.5 ±6.3	28.4 ±6.2	28.5 ±6.6	0.867

All values are reported as mean ±standard deviation or frequency (% of sample total).

* Variable does not sum to 100% of sample because participants could select multiple responses.

p=probability value, and corresponds to difference between included and excluded groups.

Table 10. Univariate, unadjusted association matrices between each considered covariate and: (1) the primary predictors, and (2) the outcome variable in Paper #3 (n=1,238).

Covariates	Analysis #1 predictor Weight change between baseline and 24-month follow-up (kg)	Analysis #2 predictor Weight change between baseline and 24-month follow-up (weight maintenance vs. weight gain)	Outcome Workplace absenteeism (days over two years)
Age * (y)	–0.033 (p=0.018)	1.012 (p=0.038)	–0.001 (p=0.815)
Sex * (male vs. female)	–0.376 (p=0.199)	1.089 (p=0.465)	–0.487 (p<0.001)
Race/ethnicity (non-White or Hisp vs. White non-Hisp)	–0.542 (p=0.209)	1.117 (p=0.521)	–0.109 (p=0.430)
Randomized study condition (intervention vs. control)	0.222 (p=0.440)	0.971 (p=0.798)	–0.065 (p=0.481)
Current cigarette smoker * (yes vs. no)	0.927 (p=0.024)	0.665 (p=0.013)	0.524 (p<0.001)
Diabetes * (yes vs. no)	–1.008 (p=0.177)	1.484 (p=0.197)	0.436 (p=0.063)
High blood pressure * (yes vs. no)	–0.450 (p=0.197)	1.083 (p=0.566)	0.212 (p=0.055)
Depression * (yes vs. no)	0.714 (p=0.038)	0.850 (p=0.236)	0.672 (p<0.001)
Body mass index * (kg/m^2)	–0.088 (p<0.001)	1.014 (p=0.123)	0.023 (p=0.001)

Values for the Analysis #1 primary predictor are reported as weight change in kg (p-value). Negative values indicate that as the covariate increases (or relative to the reference category for categorical covariates), weight decreases.

Values for the Analysis #2 primary predictor are reported as odds ratio (p-value) of weight maintenance (i.e., ≤1 kg weight gain) relative to weight gain for a one-unit change (continuous covariate) or relative to reference category (categorical covariate). Values less than 1 indicate that as the covariate increases (or relative to the reference category for categorical covariates), the odds of weight maintenance decrease relative to weight gain.

Values for the outcome are reported as workplace illness absence (days over two years). Negative values indicate that as the covariate increases (or relative to the reference category for categorical covariates), workplace absenteeism decreases.

* Covariate considered for entry into the final multivariate models (for both Analysis #1 and Analysis #2) because associated p-value was <0.100 for primary predictor and/or at least one outcome.

All covariates were collected at the baseline assessment.

Table 11. Final multivariate negative binomial regression model depicting the association between workplace absenteeism and weight change (modeled continuously) with significant covariates in Analysis #1, from Paper #3.

	Workplace absenteeism (d)		
Model predictors	β	SE	p
n = 1,238			
Intercept	0.639	0.213	0.003
Weight change (kg)	–0.005	0.009	0.605
Male (ref = female)	–0.380	0.093	<0.001
Current smoking (ref = non smoker)	0.394	0.128	0.002
Depression (ref = no depression)	0.556	0.109	<0.001
Body mass index (kg/m^2)	0.031	0.007	<0.001

B values are equal to (natural) logarithmic rate ratio of workplace illness absence days, Positive values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the rate of workplace absenteeism increases. Negative values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the rate of workplace absenteeism decreases.

Other table column headings indicate: SE=standard error, and p=probability value.

Table 12. Final multivariate negative binomial regression model depicting the association between workplace absenteeism and weight change (modeled dichotomously) with significant covariates in Analysis #2, from Paper #3.

	Workplace absenteeism (d)		
Model predictors	*β*	SE	p
n = 1,238			
Intercept	0.585	0.216	0.007
Weight gain (ref = weight maintenance)	0.107	0.088	0.227
Male (ref = female)	–0.382	0.093	<0.001
Current smoking (ref = non smoker)	0.383	0.129	0.003
Depression (ref = no depression)	0.549	0.109	<0.001
Body mass index (kg/m^2)	0.031	0.007	<0.001

B values are equal to (natural) logarithmic rate ratio of workplace illness absence days, Positive values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the rate of workplace absenteeism increases. Negative values indicate that as the predictor variable increases (relative to the reference category for categorical predictors or a 1-unit increase for continuous predictors), the rate of workplace absenteeism decreases.

Other table column headings indicate: SE=standard error, and p=probability value.

Figure 1. Worksite and participant recruitment and follow-up in the HealthWorks study.

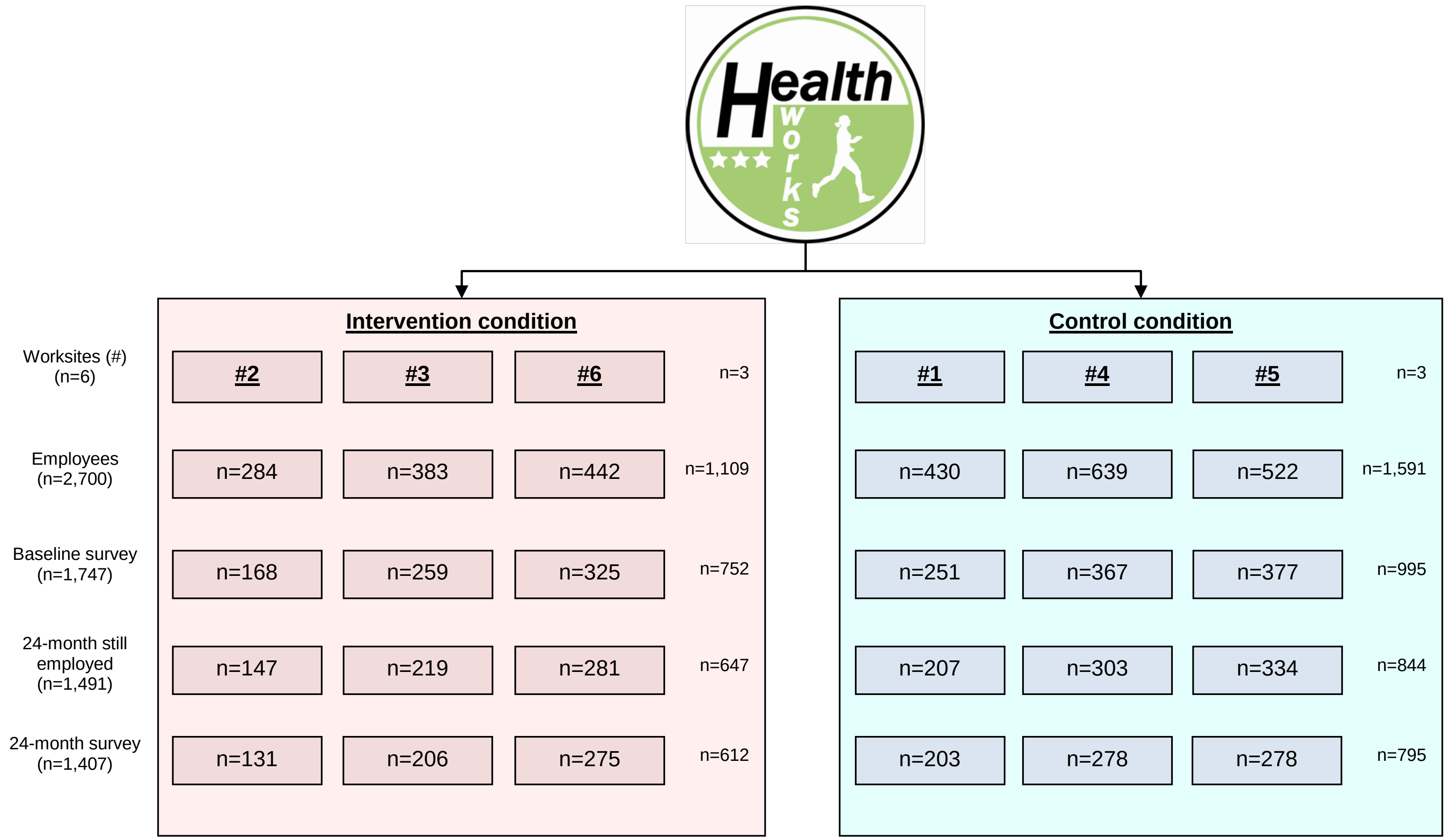
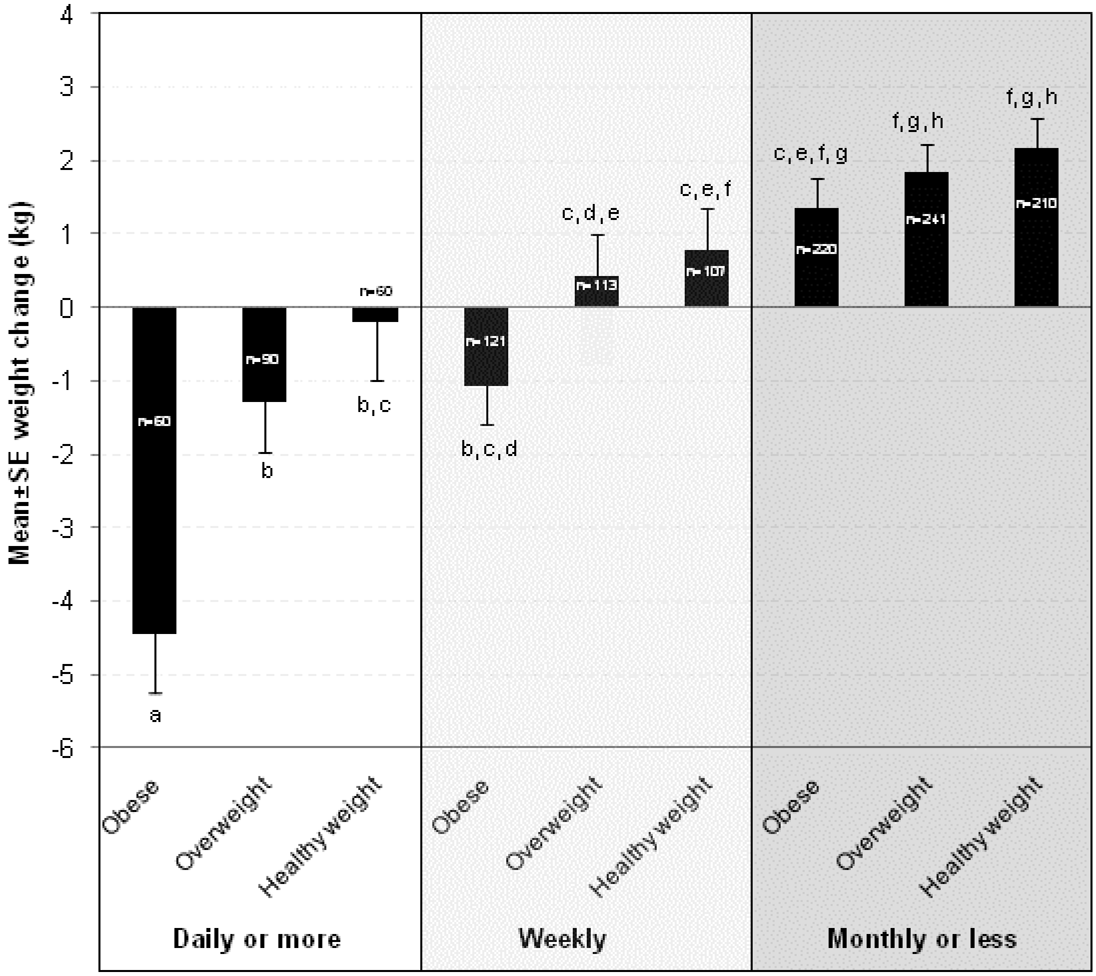


Figure 2. Least-square adjusted weight change by follow-up self-weighing frequency and baseline body mass index categories in Analysis #1, from Paper #2 (n=1,222).



Weight change scores with different subscripts are significantly different from one another (p<0.05).
Adjusted for baseline self-weighing frequency category.

Figure 3. Workplace illness absence over two years in the HealthWorks study.

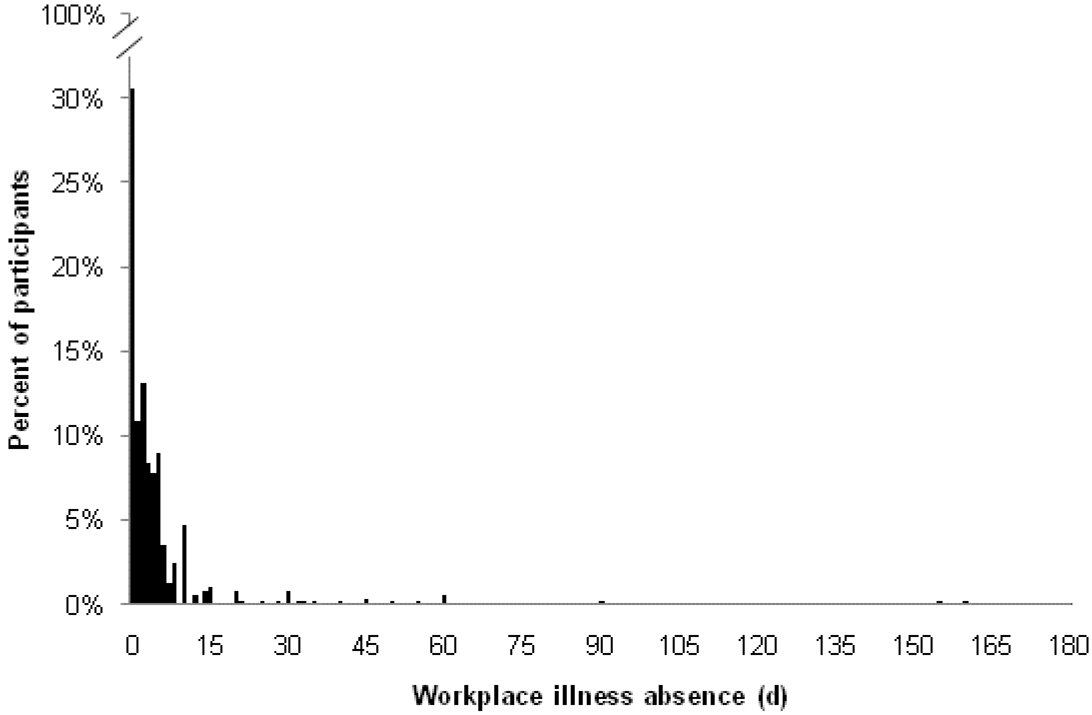
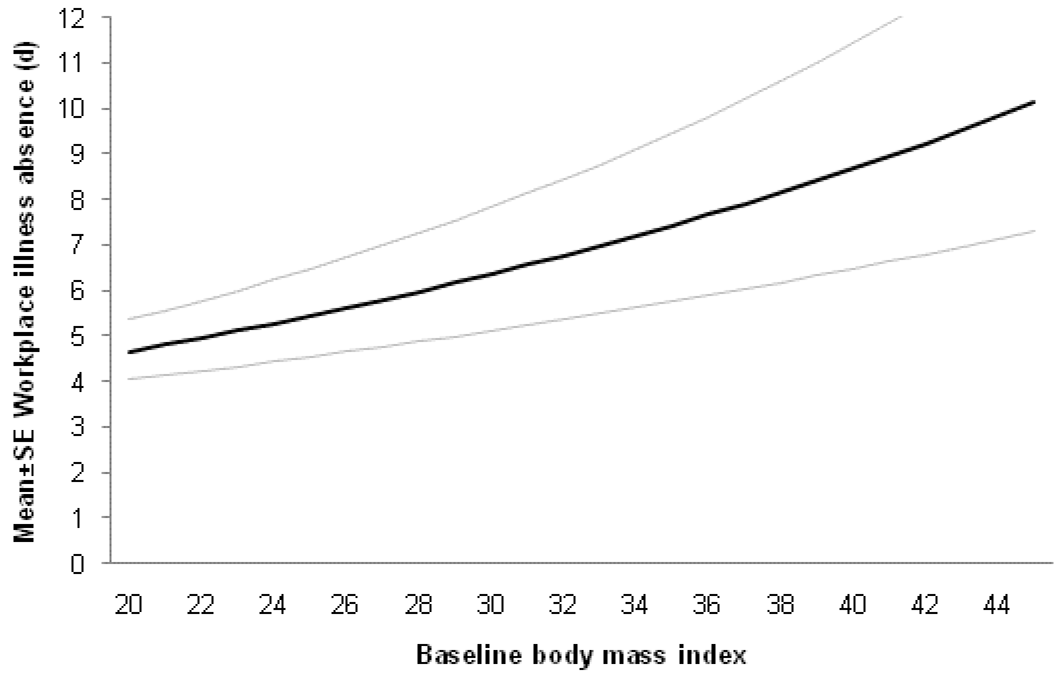


Figure 4. Two-year model-estimated workplace illness absence days by baseline body mass index in Paper #3 (n=1,238).



Dark line is mean, light lines are SE of mean.
Adjusted for sex, smoking, and depression

Appendix A: Criteria for defining healthy foods

The definition of healthy foods used in the HealthWorks study was based on nutrition guidelines developed by a national consensus panel established to develop recommendations for nutrient standards for competitive foods in California school districts. These standards were developed based on sound nutritional information, national recommendations, and with consideration for practical implementation in school food service settings. Criteria for defining healthy foods considered three elements in particular, including: 1) type of food item (e.g., entree, snack, side, beverage), 2) energy content, and 3) portion size. Calorie criteria were adapted from the California Healthy School guidelines (see: http://www.cde.ca.gov/ls/nu/he/compfoodsreq.asp). Healthy beverages were defined as having ≤150 kcal per package, including water, low-fat milk, 50% or greater fruit/vegetable juice (with no added sweeteners), and unsweetened tea or coffee. Larger sizes of non-diet soft drinks, sugar-sweetened sports drinks, or fruit drinks were not considered healthy beverages. Entrees, sides, and snack foods were evaluated in terms of total energy or weight per item sold (not serving size). Healthy entrees were considered to be ≤500 kcal per item, sides ≤250 kcal per item, and snacks ≤150 kcal per item.