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The Association Between Physical Activity, Sitting, and Sleep on 1-Year Change in Weight and Waist Circumference in CPS-3 Validation Cohort Study

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Miami University of Ohio
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Abstract

The Association Between Physical Activity, Sitting, and Sleep on 1-Year Change in Weight and Waist Circumference in CPS-3 Validation Cohort Study

By Mary Allison Geibel

The purpose of this study was to assess the association between moderate/vigorous physical activity, sitting time, and sleep patterns on 1-year change in weight and waist circumference within the Cancer Prevention Study-3 (CPS-3) Cohort between 2015 and 2016. Each of these activities, individually, has been associated with changes in body composition over long-term durations in previous studies, but this study offered a unique opportunity to study these factors collectively in a diverse cohort of men and women over a 1-year period. 664 eligible participants completed a pre-survey at the beginning and a post-survey at the end of a 1-year follow up duration, including questions on self-reported weight, waist circumference (WC), physical activity, sitting time, and sleep duration. Multivariable polytomous logistic regression models were used with physical activity, sitting time, or sleep individually, adjusted for age, sex, BMI, and further mutually adjusted for all remaining exposures.

There was a significant association between proportion of the day spent sitting and weight gain (OR=1.18, 95% confidence interval (CI): 1.03, 1.35), proportion of the day spent sitting and WC loss (OR=0.82, 95% CI: 0.72, 0.94), as well as between >8 hours sleep duration and weight gain (OR=0.51, 95% CI: 0.26, 0.99). All other associations considered were not statistically significant. There was a positive association between the highest levels of physical activity and weight loss/waist loss ($OR_{weight\ loss}$=1.47, 95% CI: 0.74, 2.92, OR_{WC}=1.53, 95% CI: 0.83, 2.84)), and between the highest levels of TV sitting time and weight gain (OR=1.45, 95% CI: 0.82, 2.56). Though there are directional trends in many of these associations, they were widely non-significant. These findings suggest no convincing evidence of an association between 1-year weight change or waist circumference change with physical activity, sitting time, or sleep duration, though this may be explained by uncontrolled factors within this study or a general lack of power to detect such associations.

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Chapter I: Background

Obesity has risen in the United States to epidemic levels, drawing serious concern for the burden of obesity-associated chronic diseases and the prognosis of life expectancy. The prevalence of obesity is double what it used to be in 1980, but has remained relatively stable around 36.5% since 2011 (1-3). The prevalence of obesity differs by sex, age, and race/ethnicity, with the highest proportion of obesity in adults aged 40-59 years (40.2%) and adults over the age of 60 years (37.0%) (3). Obesity more commonly affects women than men (38.3% *versus* 34.3%) and is more prevalent in Hispanic and non-Hispanic black adults (42.5% and 48.1%, respectively) compared to non-Hispanic white adults (34.5%) (3).

Obesity is one of the largest preventable risk factors for chronic disease and also is a tremendous financial drain to the United States healthcare system (4). Obesity places substantial burden on the health and economy of the United States, through the elevated risk of chronic diseases, decreased productivity at work, mental health disparities, and aggravation of the general state of the economy. The cost of obesity to the healthcare sector is projected in the range of $147 to $210 billions per year (4). Additionally, an obese adult is estimated to spend 42% more on direct healthcare costs than a non-obese adult (5).

Overweight and obesity are associated with an increased risk for development of type II diabetes, cardiovascular disease, hypertension, and at least 13 types of cancer with sufficient evidence as judged by the International Agency for Research on Cancer (IARC) review group. These cancers include breast, corpus uteri, ovary, colorectrum, gallbladder, kidney, liver, pancreas, esophagus, thyroid, meningioma, gastric cardia, and multiple myeloma (2, 6).

While being overweight and obese is associated with an increased risk for chronic disease, the specific distribution of fat in the body may also play a vital role. Excess weight retained specifically around the abdomen and the waist, known as abdominal adiposity, may be more pertinent to adverse health outcomes than general adiposity. Abdominal adiposity plays an important role in insulin resistance, adipose tissue hypoxia, promotion of chronic inflammation and alterations in adipokine production (7, 8). Abdominal adiposity has been associated with a higher risk for pancreatic, endometrial, and colorectal cancers (2, 9). A prospective study of women the US (N=44,636) found that women in the highest waist circumference quintile as compared to women in the lowest waist circumference quintile had a relative risk for all-cause mortality of 1.79 (95% CI: 1.47, 1.98), a relative risk for cardiovascular disease (CVD) mortality of 1.99 (95% CI: 1.44, 2.73), and a relative risk for cancer mortality of 1.63 (95% CI: 1.32, 2.01), with all associations independent of body mass index (BMI) (10). Additionally, a pooled analysis on waist circumference, BMI, and all-cause mortality in 650,000 adults found that for each 5 cm increase in waist circumference, the risk for all-cause mortality increased by 7% for men and by 9% for women (11). A meta-analysis considering 239 prospective cohort studies throughout Europe, Asia, Australia, New Zealand, and North America found an increased risk of all-cause mortality among individuals with a BMI 30-35 kg/m^2 (HR=1.45, 95% CI: 1.41, 1.48), among individuals with a BMI 35-40 kg/m^2 (HR=1.94, 95% CI: 1.87, 2.01), and among individuals with a BMI 40-60 kg/m^2 (HR=2.76, 95% CI: 2.60, 2.92), showing the dose response relationship of increasing BMI with higher risks for mortality (12). Therefore, obesity related to chronic disease is best measured by a combination of both BMI and waist circumference (7).

Physical Activity

It has long been recognized that physical activity has a beneficial impact on the incidence and mortality of many chronic diseases including cardiovascular disease, diabetes, stroke, and various types of cancer including colon and postmenopausal breast cancer (2). Physical activity has consistently been associated with reduced overall mortality and cancer recurrence (9, 13). Multiple biologic mechanisms explaining this association have been proposed including the direct benefit of exercise on weight change and the indirect biological impact through the stabilization of hormones and insulin levels (7, 9, 14). The 2008 Physical Activity Guidelines for Americans recommends that adults partake in at least 150 minutes per week of moderate intensity or 75 minutes of vigorous activity, spread throughout the week (2, 13). In 2014, only 50% of individuals in the United States met the recommended levels for aerobic activity, with 30% of adults reporting no leisure-time activity (2).

Physical activity exhibits different effects based on temporality, as well as with diverse demographic characteristics, creating a complex relationship between physical activity and weight loss. Associations between physical activity and weight have been shown to differ by sociodemographic factors such as race, sex, and age. For example, a longitudinal study comparing 10-year weight change and physical activity between Swedish women and United States women found that 10-year percent weight change was the largest among overweight/obese women who were 30 years old from both countries (15).

Physical activity has the potential to drastically improve the prognosis of health outcomes by promoting healthy weight loss. Even a minor weight loss (5-10% body fat) in obese individuals can elicit positive health benefits including lowered blood pressure and a reduction in abdominal fat (9). Dose-response relationships between physical activity and improved health outcomes have been reported, and substantial evidence supports health benefits, even with sub-optimal levels of physical activity (7, 16). In a prior study examining physical activity and 9-month weight change, low amounts of moderate intensity activity was associated with average weight loss of 1.3 kg (SD=2.2, p-value<0.05), low amounts of vigorous intensity activity was associated with average weight loss of 1.1 kg (SD=2.2, p-value>0.05), and high amounts of vigorous intensity activity was associated with average weight loss of 3.5 kg (SD=2.8, p-value<0.05), over the study period compared to inactivity (7).

Several studies have examined long-term (7-year or 10-year) weight change in relation to physical activity, but little research has been done on shorter duration (one-year) of weight change in adults (15, 17). However, examining one-year weight change has implicit value, as one-year change reflects the likelihood of longer-term weight maintenance (5+ years) (18), possibly because there are more modest, and maintainable amounts of weight loss over a one-year period.

Sedentary Behavior

There is a wealth of research that investigates differing intensities of physical activity in relation to weight change, but more research is needed to compare the effect of sedentary behavior versus moderate/vigorous physical activity (MVPA). This research can be utilized to construct guidelines for the prevention of weight gain, with a mechanism of displacement of sedentary time with physical activity. For example, to displace 2 hours of sedentary time with 2 hours of light activity would increase energy expenditure by around 2 metabolic equivalents (MET) hours/day, comparable to that of walking for 30 minutes/day (19). It is very important to differentiate between light physical activity and sedentary time in terms of metabolic equivalents (METs). METs are a ratio of the energy consumed during a given activity relative to a baseline measure of energy consumed while laying still at rest. What distinguishes the two forms is that sedentary behavior involves sitting and low energy expenditure (1.0-1.5 METs), whereas light intensity activities involve standing and relatively higher energy expenditure (<2.9 METs) (19).

Several studies have evaluated the influence of MVPA against lower levels of energy expenditure (<3 METs) assigned as sedentary behavior, however this neglects the key differences between light intensity activity and actual sedentary time. Light physical activity does compromise a large proportion of the "active part" of a person's day. However, the overwhelming majority of an average adults day is spent in a sedentary state of sitting or reclining during waking hours (energy expenditure <1.5 METs) (20). The requirement to engage in physical activity of any kind has been reduced and sedentary behaviors have been enforced through the development of modern technology, the dynamics of workplace infrastructure, and the alteration in modes of communication (19). Some examples of sedentary time during waking hours include time spent watching TV, playing video games, sitting at the computer (recreationally or in the workplace), and in automobile transportation.

Sedentary time has been closely tied to increased weight gain, increased risk for chronic diseases, and even a 49% increased risk of premature mortality (20). These associations between time sitting and obesity are shown to be independent of physical activity level, insinuating that sedentary time is distinctly different from physical activity in terms of weight change (7, 21). Adverse health outcomes due to extended sitting time are also more pronounced in already overweight or obese individuals (15). For example, one longitudinal study over the course of 9 years found that sitting for 5-6 hours per day compared to less than 3 hours per day was associated with an increase in BMI over time of 0.51 kg/m^2 (95% CI: 0.45, 0.57) for participants at the cohort's baseline 50^{th} percentile of BMI, compared to an increase in BMI of 1.11 kg/m^2 (95% CI: 0.96, 1.26) at the 90^{th} percentile of BMI (22). On the physiologic level, prolonged bouts of sitting have suggested a loss of contractile stimulation, resulting in reduced uptake of glucose and reduced activity of lipoprotein lipase (LPL), a key compound involved with the production of good cholesterol [high density lipoprotein (HDL)] and triglyceride uptake (23). The alterations in LPL activity can be remedied by low intensity physical activity such as standing, because such activity contracts postural muscles (19).

In order to sustain a balanced and healthy lifestyle, it is recommended to limit sedentary time throughout the day in forms such as screen-based entertainment or at least to impede on long durations of sitting (24). Breaking up periods of sedentary time with light intensity activities (10 minutes or less), such as taking out the trash or going to the grocery store can improve metabolic biomarkers (19). One study found that irrespective of the total time spent in a sedentary position or the amount of physical activity during a day, increasing the frequency of breaks in periods of sedentary time was associated with decreases in BMI, waist circumference, and metabolic biomarker outcomes such as triglyceride and glucose levels (24). For example, individuals in the lowest quartile for breaks in sedentary time had, on average, a 5.95 cm larger waist circumference and 0.88 mmol/L higher 2-hour plasma glucose than individuals in the highest quartile (p-values 0.025 and 0.019, respectively) (24).

In fact, some studies suggest that there is a stronger association between weight change and sedentary time compared to physical activity (1, 25). For example, in a 7-year weight change study, researchers reported that the odds of gaining weight were 47% higher for non-overweight women at baseline who sat for 6 hours/day compared with non-overweight women who sat less than 3 hours/day (OR=1.47, 95% CI: 1.21, 1.79), and this association is independent of low levels of physical activity (15, 17). Researchers in this study found that the effect of sedentary behavior could not be explained simply by low levels of physical activity, and the small protective association between elevated levels of physical activity and weight gain (OR=0.89, 95% CI: 0.75, 1.06) was not due only to low levels of sedentary behavior [12]. There is a growing body of evidence showing that reducing the amount of time spent sitting, regardless of the amount of physical activity, may also improve the metabolic consequences of obesity (20). One such study found that while increasing physical activity did not reduce central body fat compared to peripheral body fat, physical inactivity enabled a substantial increase in central body fat accumulation (7).

It is relevant to determine the association between sedentary time and physical activity, because some studies have revealed that increases in MVPA actually led to increased sedentary time throughout the day, as a result of individuals feeling satisfied with meeting the physical activity guidelines (20). This allows for the co-existence of highly sedentary and highly active individuals. One population based study concluded that a more meaningful measure of sedentary time is as a percentage of the day rather than the number of minutes spent sitting, attesting to the proposed importance of displacing sedentary time with physical activity (26). Though many epidemiologic studies that promote weight maintenance support recommendations to increase physical activity levels, it is uncertain what influence these guidelines impart on time spent sitting throughout the day, that may hold more stake in body composition and weight change.

Sleep Duration

Aside from physical activity and sedentary behavior, numerous epidemiology studies have also found an inverse association between sleep duration and the development of chronic diseases such as obesity, depression, cardiovascular disease, diabetes, and even some types of cancer (1, 27, 28). The National Sleep Foundation currently recommends that the average adult between the ages of 26-64 years get between 7-9 hours of sleep per night to remain in good metabolic and energy expenditure health (29). Sleep duration has risen as a novel risk factor for obesity alongside more commonly considered dietary and physical activity related factors. The amount of sleep per night maintains strong connections with behavioral and molecular mechanisms that promote fat retention. For example, one prior study found that less than 6 hours of sleep was associated with a higher BMI (1).

On the metabolic level, sleep deprivation has the capability to alter hormone levels and neuroendocrine function associated with diet and physical activity (1). Sleep curtailment can also impact immunity, which influences chronic disease development and life expectancy. Sleep duration has been shown to impact the secretion of hormones involved with metabolism and glucose processing (1). Fatigue inflates the amount of the stress hormone, cortisol, as well as insulin, to deplete glucose tolerance, leading to heightened fat retention (1). Leptin levels are subsequently lowered, where leptin normally supports the feeling of being satiated and promotes increased energy expenditure during exercise and non-exercise activities (1). Furthermore, sleep restriction has been shown to increase levels of the hormone ghrelin, known to promote hunger (1). In addition to these molecular manifestations, obesity is tied to sleep quality with conditions like obstructive sleep apnea (OSA). Among the average United States population, the prevalence of OSA is 24% in men and 9% in women, but these numbers rise to a staggering 93.6% in men and 73.5% in women among severely obese individuals (30).

Sleep relates to obesity not only on the molecular level through regulation of hormones and biomarkers, but also on the behavioral scale to influence feeding patterns and physical energy expenditure. The modern day society further emphasizes work and activity during hours extended into the night time, which inevitably costs the individual sleep time (1). Staying awake until late hours of the night promotes late night eating and lower energy levels the next day for physical activity, instilling a high calorie diet and sedentary tendencies. A meta-analysis of 50 epidemiologic studies found that individuals sustaining less than five hours of sleep per night had 55% higher odds of being obese (OR=1.55, 95% CI= 1.43, 1.68), with each additional hour of sleep per night decreasing BMI by 0.35 kg/m^2 (1). This effect is differential in diverse sub-populations as one cohort study found that the negative effects of sleep duration on BMI was highest among obese individuals (OR=3.12 with individuals ≥40 kg/m^2 with <6 h of sleep) (31). There have been few studies to confirm a prospective relationship between sleep duration and obesity, so the causal directionality is still widely debated. Though sleep is the gold standard of sedentary time, it is likely the only sedentary activity that is beneficial for the health of humans in regards to weight maintenance.

Due to the differential prevalence of obesity in non-white, females, and older individuals, it is also extremely important for the application of public health research to encompass a demographically diverse population. Previous epidemiologic studies have focused their research on one geographic location, one sex, or a limited range of ages to draw conclusions about the relation of physical activity to weight maintenance. Thus, to examine the association between physical activity (moderate/vigorous, and light intensity), sedentary time, and sleep duration in relation to one-year weight and waist circumference change, we conducted a study in the Cancer

Prevention Study-3 (CPS-3) physical activity validation sub-study. This cohort consists of racially diverse men and women, with ages ranging from 31-72 years.

There is evidence to support that physical activity, sedentary time, and sleep may influence weight change, which could in turn impact the risk of numerous chronic diseases including cancer. To address the gaps in the current literature, the CPS-3 physical activity validation sub-study offers a good opportunity to examine these factors independently and in combination in relation to one-year weight and waist circumference change in a racially and ethnically diverse population of men and women. Such lifestyle alterations may exhibit health benefits to aid in the prevention of chronic diseases, and this knowledge can be utilized to further tailor community prevention measures and determine specifically which kinds of activity versus inactivity may help promote more successful weight maintenance.

Chapter II: Methods

Data Source and Study Population

Data were collected within the Cancer Prevention Study-3 (CPS-3) cohort, a prospective cohort study focused on cancer prevention and understanding the lifestyle, genetic, and environmental factors that cause cancer. Recruitment took place from 2006-2013 across the United States and Puerto Rico to enroll men and women between the ages of 30 and 65 years and no personal history of cancer (excluding non-melanoma skin cancer). Participants completed an enrollment survey at recruitment and a baseline survey within a couple months at home. The survey included questions on medical history, anthropometry, physical activity, drug and alcohol use, and basic demographics. In May 2015, the first routine follow-up survey on lifestyle and medical history was mailed to the entire CPS-3 population. Approximately 3 months prior to the first mailing of the 2015 follow-up survey, a random subset of 10,000 participants (among approximately 255,000 CPS-3 participants who would be sent the 2015 follow-up survey) were invited to participate in a physical activity validation sub-study. The goal was to enroll a total of 750 participants with over-sampling for minority and male participants. Thus, 4,000 white women and 2,000 each among white men, African American men and women, and Hispanic men and women were invited to ultimately include 300 white women, 150 white men, 150 Hispanic men and women, and 150 African American men and women in the validation study. Upon receiving the invitation and agreeing to participate in the sub-study, participants signed an informed consent and provided information on availability for the upcoming year. Participants were then mailed the 2015 follow-up survey and "activated" in the sub-study upon receipt of the completed survey. After being activated, participants completed a 4-page pre-survey at the start of the validation study and completed the same 4-page post-survey at the end of the one-year validation study period. This survey included questions related to weight, self-measured waist circumference, physical activity (light, moderate, vigorous, and walking specifically), sitting time, and sleep. Of the 751 participants who agreed to participate in the validation study, 737 completed participation through the final post-study survey and were eligible for baseline inclusion in this analysis (98.1% completion rate).

Exposure Assessment

The primary exposures of interest came from the self-reported responses on the post-survey as these values reflect the average activities over the past year that the weight and waist circumference change was measured.

Moderate/vigorous physical activity (MVPA) is a metric that is used to capture physical activity, excluding light activities such as standing. MVPA is also used to tailor physical activity guidelines to maintain proper health as it captures the MET values during exercise. The physical activity grid in the surveys asked: "During the past year, estimate how many hours per week and months per year you spent in each of the following activities." Activities were categorized as

“None,” “<1 hours per week,” “1-2 hours per week,” “3 hours per week,” “4-6 hours per week,” or “7+ hours per week,” and further “1-3 months per year,” “4-6 months per year,” “7-9 months per year,” or “10-12 months per year.” Average hours per week throughout the year of each activity were calculated individually, and MVPA was calculated as the sum of total aerobic activity in MET-hours/week (walking, jogging, running, biking, swimming, tennis aerobics, elliptical, sports, dancing).

Generic MET values were assigned to each specific activity according to the Compendium of Physical Activities to summarize the reported activity in MET- hours/week (32). This summary of activity was assigned based on MET values to dampen the tendency of participants to over-report physical activity. The recommended guidelines are at least 150 minutes/week of moderate activity and at least 75 minutes/week of vigorous activity (2). Thus, MVPA was divided into four categories according to adherence to the recommended guidelines (0-<7.5 MET hrs/week=”Inactive or active, below guidelines,” 7.5-<15 MET hrs/week=”1-<2X guidelines,” 15-<30 MET hrs/week=”2-<4X guidelines,” >30 MET hrs/week=”≥4X guidelines”).

The daily activity grid, which provided measures for sitting time and sleep quantity, asked the participants to estimate over the past year the number of hours per day they spent on typical weekdays and weekends in each of the following activities. “Please average your seasonal physical activities over the entire year. Try to account for all 24 hours per day.” Total sitting time was the sum of sitting and sitting while watching TV (hours/day), ranging from 0-11+ hours on a typical weekday and a typical weekend day (averaged by 5 weekdays and 2 weekend days). Sleep duration is also reported in terms of the number of hours/day, ranging from 0-11+ hours on a typical weekday and a typical weekend day (averaged by 5 weekdays and 2 weekend days).

Secondary exposures in this analysis include the proportion of daily sitting time out of total wake time, as well as restriction of total sitting time to only TV sitting time. The proportion of the day spent sitting was calculated as the total time sitting divided by the total time spent awake from the daily activity grid. Time spent sitting in front of the TV was also considered on its own because this specific type of sitting could be associated with certain adverse dietary behaviors such as lower consumption of fruits and vegetables, higher consumption of fast food and energy dense snacks, and excessive caloric intake (33).

Both types of sitting were divided into sex dependent quartiles according to the distribution within the sample, and sleep quantity was divided into <7 hours of sleep per night, 7-8 hours of sleep per night, or >8 hours of sleep per night during a typical week, based on the recommendation to sustain 7-8 hours of sleep per night to maintain proper health (29).

Combination variables to account for two-way exposures combined high and low categories of MVPA, sitting time, and sleep. Low MVPA was assigned to participants who fell into the ‘Inactive/active, below guidelines,’ or ‘1-<2X guidelines’ categories. High MVPA was assigned to participants who fell into the ‘2-<4X guidelines,’ or ‘>4X guidelines’ categories. Low sitting was assigned to quarters 1 and 2 for TV sitting time, and high sitting was assigned to quarters 3 and 4 for TV sitting time. Low sleep category consisted of participants who maintained 8 or fewer hours of sleep/night, and high sleep category consisted of participants with greater than 8 hours of sleep/night. These dichotomous exposures were combined to create 3 variables: MVPA-sitting, MVPA-sleep, and sleep-sitting, each with 4 combinations of high and low variables.

Outcome Assessment

Participants were sent a tape measure (cm only) and detailed instructions on how to measure their current waist circumference and report their current weight (lbs.). Weight change was categorized into weight gain (+ >2 kg), weight maintenance (a change of ±2 kg), and weight loss (- >2 kg) from the pre-survey to the post-survey. Waist circumference change was also categorized into waist gain, waist maintenance (a change of ±1 cm), and waist loss from the pre-survey to the post-survey. For the data collection phase, there was in depth follow up with participants if weight or waist circumference responses on either survey were missing or invalid to ensure quality data for the self-report.

Statistical Analyses

Participants were excluded from analysis if they had missing outcome or exposure data, were currently pregnant women at the 2015 Follow Up Survey, above and below the top and bottom 1% of weight and waist circumference change distributions, or underweight (BMI <18 kg/m^2). The latter exclusion was done because there were very few underweight participants (N=6), and having a very low BMI may be associated with uncontrolled factors such as acute illnesses. The criteria for exclusion from the analytic cohort is displayed in detail in Figure 1. Of the original 751 pre-surveys sent out, 14 participants were excluded for missing surveys (pre-survey or post-survey), 7 participants for missing data on weight or waist circumference, 3 participants for missing exposure data, 14 women for pregnant at baseline, 43 participants with a weight or waist circumference change in the top or bottom 1% of the distribution, and 6 participants whose BMI was categorized as "Underweight" (BMI <18.5 kg/m^2). After exclusions, the final analytic cohort consisted of 664 participants (88.4% inclusion).

Multivariable logistic regression modeling was used to estimate the association of physical activity, sitting time, and sleep with changes in weight or waist circumference. Categorized weight and waist circumference change were entered into polytomous logistic regression models with 'maintenance' as the reference category for both measurements. Three classes of models will be constructed for each combination of the outcomes and relevant exposures. Model 1 is sex and age adjusted, Model 2 is sex and age adjusted, along with the set of variables determined to be confounders. Model 3 builds upon Model 2 with further adjustment for the remaining two exposures to mutually adjust for all activities. In addition, an interaction assessment included relevant interaction terms in Model 2. Lastly, Model 2 was recreated with 2-

way combination exposure variables, such that high and low categories of MVPA, sleep, and sitting will be combined to serve as the primary exposure variable.

Potential confounders were assessed *a priori* according to previously published literature and biologic plausibility using a 10% change in estimate rule to determine the final set of variables that adequately control for confounding. The confounding assessment compared models including individual covariates to the minimally adjusted model, controlling for age and sex as shown in Supplementary Table S1 and Table S2. For both weight change and waist circumference change, BMI was the only covariate that satisfied 10% rule for confounding assessment. Thus, the minimally adjusted model (Model 1 controlling for age and sex), fully adjusted model (Model 2 controlling for age, sex, and BMI), and the mutually adjusted model (Model 3, the fully adjusted model with further control for the remaining two exposures). Likelihood ratio tests were used to evaluate interaction between age, sex, BMI, education, and race with each exposure. The p-values for interaction compares cross-products from fully adjusted model (age, sex, BMI, interaction term) against the reduced model (age, sex, BMI).

Potential confounders besides age and sex include race, education, employment level, BMI, and diet quality. Sex, employment status, and dietary variables were taken from the 2015 follow up survey. Height, race, and education were collected from the baseline survey. Current age was recorded at the time of the post survey. Race was divided into White, African American, and Hispanic. Education was divided into high and low categories, with high education consisting of any college education and low education consisted of high school and below. Employment was categorized into full time, part time, homemaker or retired, and unemployed. BMI was calculated as weight (kg) at the pre-survey divided by the squared height (m^2) from the baseline survey. BMI was divided into five levels: 18-<22.5 kg/m^2, 22.5-<25 kg/m^2, 25-<30 kg/m^2, 30-<35 kg/m^2, and 35+ kg/m^2. Dietary quality was summarized as the weekly consumption of sugar sweetened beverages, alcohol, fruits and vegetables, and fast food servings. Fruits/vegetables and fast food were divided into sex-dependent quartiles according to the distribution within the cohort. Sugar sweetened beverages and alcohol were divided into three sex dependent categories as no consumption, low consumption, and high consumption. Effect modification between each exposure with BMI, education, race, age, and sex individually were considered with likelihood ratio statistics and individual chunk tests.

Exploratory data analyses summarized selected characteristics both in the total cohort and stratified by sex. Categorical variables were reported as N(%) and continuous variables were reported as mean(standard deviation). Chi-squared tests for categorical variables and t-tests for continuous variables were used to test for significant differences (p-value<0.05) in selected characteristics between males and females. Furthermore, sensitivity analyses reproduced Models 1, 2, and 3 among non-diabetic participants, non-smoking participants, or participants who had no past bariatric surgery to assess any significant changes in the effect estimates. History of bariatric surgery, diabetes diagnosis, and smoking status all came from the 2015 Follow Up Survey. There were not enough diabetic (n=37), smoking (n=14), or participants with past bariatric surgery (n=14) to utilize these variables as stable confounders, so they were instead considered in the sensitivity analysis. All statistical tests were two sided with significance level considered as $p<0.05$ and all regression analyses were conducted using SAS software version 9.4 (SAS Institute, Cary, NC, USA).

Chapter III: Results

Selected characteristics of the validation study cohort overall and by sex are shown in Table 1. There were 382 women and 282 men included in this analysis. 67.0% of the cohort was White, 18.2% was Black or African American, and 14.76% was Hispanic. The average age of the study participants was 52.76 years (SD=10.00 years). The majority of participants (75.9%) had a BMI that was considered overweight or normal weight (<30 kg/m^2), and 273(41.1%) of participants were considered ‘Normal weight’ (BMI<25 kg/m^2). For both men and women, the majority of the participants fell into the two highest categories for MVPA, with 121(31.7%) women in the ‘2-<4x guidelines’ category, 147(38.5%) women in the ‘≥4x guidelines’ category, 71(21.6%) men in the ‘2-<4x guidelines’ category, and 138(48.9%) men in the ‘≥4x guidelines’ category. Males and females differed significantly in regards to employment status, BMI, type 2 diabetes status, sugar sweetened beverage consumption, and sleep duration (Table 1).

Regarding changes in body composition throughout the follow up period, 60.1% of participants maintained their weight during the year period (± 2kg), while 16.7% lost weight and 23.2% gained weight. Among those who lost weight, the average weight loss was 4.3 kg (SD=1.9 kg), and among those who gained weight, the average weight gain was 3.9 kg (SD=2.1 kg). Additionally, 26.2% of participants maintained their waist circumference during the year (± 1cm), while 44.6% had a lower waist circumference and 29.2% had a higher waist circumference at follow up. Among participants who lost waist circumference during the follow up period, the average waist loss was -5.7 cm (SD=3.4 cm) and among those who gained waist circumference, the average waist gain was 4.5 cm (SD=2.6 cm). The correlation between weight and waist circumference was 0.89485 (p-value<0.0001).

In the assessment of physical activity (PA) with changes in body composition, PA was positively associated with weight/waist circumference loss, though these relationships were not statistically significant. Physical activity was not associated with weight/waist circumference gain (Tables 2 and 3). There was no significant association between physical activity and weight loss, however, the odds of weight loss were greater with the highest level of physical activity (OR=1.47, 95% CI: 0.74, 2.92). In addition, physical activity was not significantly associated with waist circumference loss, though the odds of decreasing waist circumference was greater at the highest level of physical activity as shown in Model 3 (OR=1.53, 95% CI: 0.83, 2.84). In terms of waist circumference gain, there was a 14% lower odds of waist gain if individuals were ≥4x MVPA guidelines (95% CI: 0.46, 1.64). In the interaction assessment, there were no statistically significant interactions between MVPA and age, sex, race, BMI, or education (Table 4 and Table 5).

Time spent sitting in front of a TV was positively associated with weight gain. For example, the odds of weight gain increased from 1.05 to 1.45 from the second quartile of sitting time to the highest quartile of sitting time, with the lowest quartile of TV sitting as the reference (Table 2). TV sitting time was negatively associated with waist circumference loss (At the highest levels of sitting, OR=0.69, 95% CI: 0.39, 1.21), but the association was null with weight loss (OR=1.02, 95% CI: 0.52, 2.01). Of all interactions considered, the interaction between BMI (≤25 kg/m^2 or >25 kg/m^2) and TV sitting time in the categorical weight change model was the only statistically significant p-interaction (p-value=0.014). There were several tests for interaction, so this significant interaction may only be due to chance. Table 6 stratifies the weight change model results among the two levels of BMI. However, though the OR estimates change between levels of TV sitting time, all associations are null with considerably wide confidence intervals.

The models in Table 2 and Table 3 show the odds of weight or waist circumference change for a 10% increase in the proportion of the day spent sitting. Sitting proportion was associated with weight gain (OR=1.18, 95% CI: 1.03, 1.35), but was not associated with weight loss (OR=1.09 95% CI: 0.94, 1.27). Increased proportion of the day spent sitting was protective against the odds of waist circumference loss (OR=0.82, 95% CI: 0.72, 0.94). Additionally, there was a no significant association between proportion of the day spent sitting on waist circumference gain (OR=0.94 (0.82, 1.09). Supplementary to TV sitting time and proportion of the day spent sitting, we also explored total sitting time, but found no significant associations with weight change or waist circumference change. There were no statistically significant interactions between proportion of the day spent sitting and age, sex, race, BMI, or education (Table 4 and Table 5).

Participants who had more hours of sleep per night (>8 hours per night) were less likely to gain weight (OR=0.51, 95% CI: 0.26, 0.99). The odds of weight loss also decreased with more sleep per night, but this was a non-significant relationship (OR=0.54, 95% CI: 0.26, 1.11). In terms of waist change, there was no significant association between sleep and waist loss or waist gain, when comparing >8 hours of sleep per night to <7 hours of sleep per night (Table 3). Furthermore, there were no statistically significant interactions between sleep and age, sex, race, BMI, or education (Table 4 and Table 5).

Combination models were used to combine two way exposures in fully adjusted models with categorical weight change and waist circumference change. The results of this analysis are shown in Table 7. High MVPA-low sitting, high MVPA-high sleep, and high sleep-low sitting served as reference categories in each combination model respectively. Though the OR estimates varied according to the levels of the combination exposures, all confidence intervals were quite broad and contained the null (OR=1.00). Low MVPA and high sleep was protective against waist circumference loss, and this was the only statistically significant association observed with the combination models (OR=0.27, 95% CI: 0.09, 0.82)), though this significant relationship out of the many relationships tested, may only be due to chance.

Lastly, sensitivity analyses reassessed the output of Table 2 and Table 3 among non-smoking (N=650), non-diabetic (N=627), or participants without a history of bariatric surgery (N=650) as shown in Tables 8-11. Each restricted population showed comparable results to those observed in the total analytic cohort (N=664) for the hierarchy of models considered with weight change and waist circumference change (Tables 2 and 3).

Chapter IV: Discussion

Overall, the results from this 1-year follow up study suggest there is no convincing evidence of an association between physical activity, sitting time, or sleep duration and weight or waist circumference change. Though non-significant, MVPA increased the odds of weight loss and waist circumference loss. MVPA also decreased the odds of waist circumference gains in the cohort. Total sitting time displayed no significant associations with weight change or waist circumference change, while sitting time restricted to just TV sitting time showed a non-significant positive association with weight gain. In terms of loss, there was no association between TV sitting time and weight loss, but there was a non-significant negative association between TV sitting time and decreases in waist circumference measurements. As an alternative metric to sitting time, proportion of the day spent sitting was positively associated with weight gain and negatively associated with the odds waist circumference loss. When considering sleep duration, >8 hours of sleep per night decreased the odds of weight gain, but held no strong association with weight loss or any changes in waist circumference. None of the above associations differed meaningfully by age, sex, race, education, or BMI.

Although these findings lack statistical significance, many of the directional associations can be explained through prior research or general biologic plausibility. There are a variety of prior studies and biologic rationalizations that have attempted to deduce and explain the associations between physical activity, sedentary behavior, sleep duration and changes in body composition.

Prior literature has supported a dose-response relationship between physical activity and weight loss (7, 16, 17, 34). Physical activity in a daily manner protects specifically against abdominal obesity, as we saw in our study (35). One review found that in studies that lasted <16 weeks, there was a dose-response between physical activity and weight loss, when diet was controlled. They did not find a similar dose-response effect in studies that were >24 weeks, which may explain the insufficient association witnessed in our study (16).

In some cases, physical activity is not enough to balance the increasing levels of sedentary time, in addition to excessive caloric intake (14). In fact, this same review reported that although physical activity can drastically increase energy expenditure, the benefits of physical activity are negligible without dietary alterations and decreased sitting time (14). There is a biologic theory that weight gain occurs due to an imbalance in greater caloric intake than energy expenditure (14), as shown in a physical activity intervention study that found individuals with a negative energy balance lost weight (7). The biologic justification for this claim is that out of pure survival mechanisms in the case of starvation, excess energy consumed through food must be stored as triglycerides in adipose tissue. Adipose tissues can expand substantially to accommodate excessive caloric intake, contributing to increases in BMI and waist circumference. One review states that small imbalances in energy intake, as little as 10 extra calories per day, can result in a 0.45 kg weight gain each year (14). If our study were able to accurately quantify total caloric intake and energy expenditure through closely regulated physical activity, we would have gained a better picture of energy intake *versus* energy expenditure, and further be able to elucidate a well-defined picture of weight and waist circumference maintenance.

Another argument to consider is that it is possible that physical activity could reduce percent body fat, but show no reflection in a loss of BMI. However, if this were the case, we would expect to see a more prominent decrease in waist circumference change with increasing levels of physical activity, which were also null associations in our analysis. Future research could integrate alternative metrics of obesity to capture this reduction in percent body fat, such as body fat percentage, waist to hip ratio, skin-fold thickness, etc.

Past studies have considered multiple types of sitting exposures rather than generalizing sedentary time to total time spent sitting. In our study, total sitting was not related to any changes in weight or waist circumference, which aligns with prior research that sitting time was insufficient to explain why TV time increased BMI (36). Several proposed mechanisms in this relationship with TV sitting include misalignment with circadian sleep and wake cycles due to

TV watching near bed time (37) as well as the relationship between television viewing and snacking at night (38). For example, TV sitting time has been linked to several adverse dietary habits, as shown in a European cross-sectional study which found that more time spent in front of a television was associated with lower fruit and vegetable intake, higher consumption of sugar-sweetened beverages, and higher consumption of fast food (36). This is of great importance because television sitting time has been reported the most common sedentary activity during leisure time (22). Our analysis was strengthened with multiple sitting exposures, as few studies have considered a sitting exposure as the proportion of the wake day spent sitting like we were able to in our analysis.

Several studies also found that the relationship between TV sitting time and BMI is most prominent at the highest levels of BMI, such as one prospective study which found that at the 90th percentile for BMI, 3-4 hours/day of TV viewing was associated with a 2.11 kg/m^2 increase in BMI compared to 0.41 kg/m^2 increase in BMI at the 50th percentile (22). Though BMI was not a significant effect modifier of TV sitting time and weight change within our study, it was the only confounder out of the covariates we considered, and thus plays a role in the association between sitting time and weight change.

Many studies investigating the association between sitting time and BMI or weight changes were conducted as cross-sectional and therefore lacked temporality considerations in the association (19, 36, 39). The literature on prospective relationships between sitting and obesity is not consistent, as an occupational British cohort study found no prospective or cross-sectional relationship between five indicators of sedentary time (work-related sitting time, TV-viewing time, non-TV leisure sitting time, total leisure-time sitting, and total sitting time) (40). Although proportion of the day spent sitting was associated with weight gain and waist loss, and TV sitting was associated with weight gain, the trends were not convincing overall. There are several similarities between this study and the British cohort study, in that they acknowledged limitations of an unusually active cohort with high levels reported of walking (40). In our study, self-reported MVPA was substantially inflated with nearly 70% of the cohort above 2x physical activity guidelines, and 42% above 4x physical activity guidelines. There are a couple possibilities that may have contributed to very high levels of activity in this cohort. Participants who voluntarily sign up for cancer prevention studies are likely to be more health conscious and sustain higher levels of activity. In addition, we considered that there may have been misreporting of physical activity, such as participants may have reported leisure time walking in the physical activity grid (i.e. walking to work, the grocery store, etc.), when the grid was intended to capture specific activities that were done for exercise purposes.

There have been several individual studies and meta-analyses that have considered sleep duration and weight change in adults and children. The overall consensus from these studies is that there is an association between weight gain and low sleep duration, with one meta-analysis of 36 populations reported increased odds of obesity (BMI >30kg/m^2) among adults who slept <5 hours per night (OR=1.55, 95% CI: 1.43, 1.68) (28). Another meta-analysis of 50 prospective cohort studies found a significant association between <6 hours of sleep per night and an increased risk for obesity (1). Our study found a decreased odds of weight gain among participants who got >8 hours of sleep per night compared to <7 hours of sleep per night (OR=0.51, 0.26, 0.99), though the association was non-significant, yet protective for weight loss (OR=0.54, 95% CI: 0.26, 1.11). The associations were null with waist change, but few prior studies have considered the influence of sleep duration on changes in waist circumference. One cross-sectional study that utilized the National Health and Nutrition Examination Survey (NHANES) for 13,742 participants found that shorter sleepers (<6 hours) had a waist circumference 3.4 cm (SD=1.0) greater than longer sleepers (>10 hours) (41), though this study did not consider waist circumference change over time, as we investigated, and therefore could not establish any temporality in the association. In fact, the previously mentioned meta-analysis of 36 populations (28) and several individual prospective studies (42-44) were not able to support a prospective relationship with sleep and obesity due to inconsistency of results. One prospective study in >60,000 women showed trivial hazard ratios of 1.15 and 1.06 for women sleeping <5 and <6 hours per night (27).

The consensus on sleep duration and obesity has not been firmly established, as some meta-analyses found null associations between sleep and weight in 8 out of 17 cross-sectional adult studies and 2 out of 6 longitudinal adult studies (45). Failure to establish a prospective relationship with a negative relationship at baseline suggests an associative relationship rather than a causative one per se. The relationship has been proposed as null, negative linear, as well as U-shaped with a minimum at 7-7.5 hours/night (45). Prospective studies have found more variability with deducing the relationship between long sleepers and obesity as opposed to the relationship with short sleepers (45). Within this study, we did find a decreased odds of weight gain among participants who got >8 hours of sleep. The remainder of associations with sleep were null, which may be explained because of the narrow categories of sleep duration (>7 hours, 7-8 hours, >8 hours), while prior studies found an increased risk for weight gain below 5 or 6 hours of sleep and categorized long sleepers as >10 hours of sleep (41).

Overall, the CPS-3 Validation Study provided a great resource to investigate the effects of physical activity, sitting time, and sleep related to 1-year changes in weight and waist circumference change in a racially diverse subcohort of men and women. Our study could consider mutual adjustment for physical activity, sitting time, and sleep, as well as combination exposures at varying levels of 2-way exposures. By oversampling for African American and Hispanic participants, we were able include racial diversity among both men and women. There was a very high retention rate and thus protection against selection bias, with only 10 participants lost to follow-up by failing to return either the pre-survey or the post-survey (98.7% retention). Additionally, there was very thorough follow up with participants who were missing data or recorded invalid responses for anthropometric measurements to ensure quality data in the study.

Though the subcohort offered many strengths, there are undeniable limitations that may have contributed to the null results of the study. To start, this subcohort lacks substantial heterogeneity, as participants were highly educated, predominately non-smokers, very physically active, and had relatively low BMI's. Another very pertinent limitation is the small amount of weight fluctuation and changes in waist circumference during a 1-year period. It is quite possible that the insignificant change in weight and waist circumference and homogeneity in the participant's exposure distributions may have unpowered our study's ability to detect an association with physical activity or sitting time. The lack of power in this study, largely caused by a limited range of weight change and waist circumference change in this cohort is arguably the most important limitation of this study, contributing to the null results from the analysis. The Cancer Prevention Study II Nutrition Cohort found among 18,583 women, there was no association between physical activity or sedentary behavior and 5-9 pound weight gain (17). Additionally, there was only an association with a 10 pound weight gain among non-overweight women at baseline (BMI<25.0 kg/m^2) (OR=0.88, 95% CI: 0.77, 0.99) (17). Though this study differs from the Cancer Prevention Study III Cohort in terms of only female participants and a longer duration, what is important to note is the lack of association observed with a <10-pound weight change. A 10-pound weight gain is equivalent to a 4.5 kg weight gain, where the average weight gain among participants who gained weight in our study was only 3.9 kg.

Additionally, there were possible issues with over reporting physical activity for specific activities such as walking, which may explain why such a large proportion of the cohort was above 2x the physical activity guidelines. However, there were efforts to dampen the tendency to over-report activity, such as inclusion of MET hrs/week in quantifying each specific type of physical activity. The walking variable included in the summary MVPA, as well as the question for total sitting are not yet validated, which may explain why total sitting showed no association with weight or waist circumference change. In terms of residual confounding, there are uncontrolled factors surrounding weight loss intentionality such as extreme dieting, acute illnesses, and exercise training (i.e. marathon) that could produce unintended associations between weight change and activity. Additionally, there was incomplete adjustment for total dietary energy intake, though the summary dietary variables from the 2015 follow up survey that we did include made no substantial impact on the associations. Though we made efforts to address these limitations during the analytic stages, uncontrollable lack of power and residual confounding may have contributed to the absence of associations observed in the results.

In conclusion, our findings suggest that, overall, there is no significant association between reported physical activity, sitting time, and sleep duration and changes in weight or waist circumference over the course of 1 year in the CPS-3 validation subcohort. Prior literature and biologic plausibility propose that there theoretically should be an association between activity and inactivity with weight and waist circumference change. Further research is necessary to provide a validated picture of energy intake and energy expenditure to assess if there exists any true association between physical activity and sedentary time with short term changes in body composition.

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Appendix (Tables and Figures)

Figure 1. Exclusion Criteria for Cohort Participants (N=751)

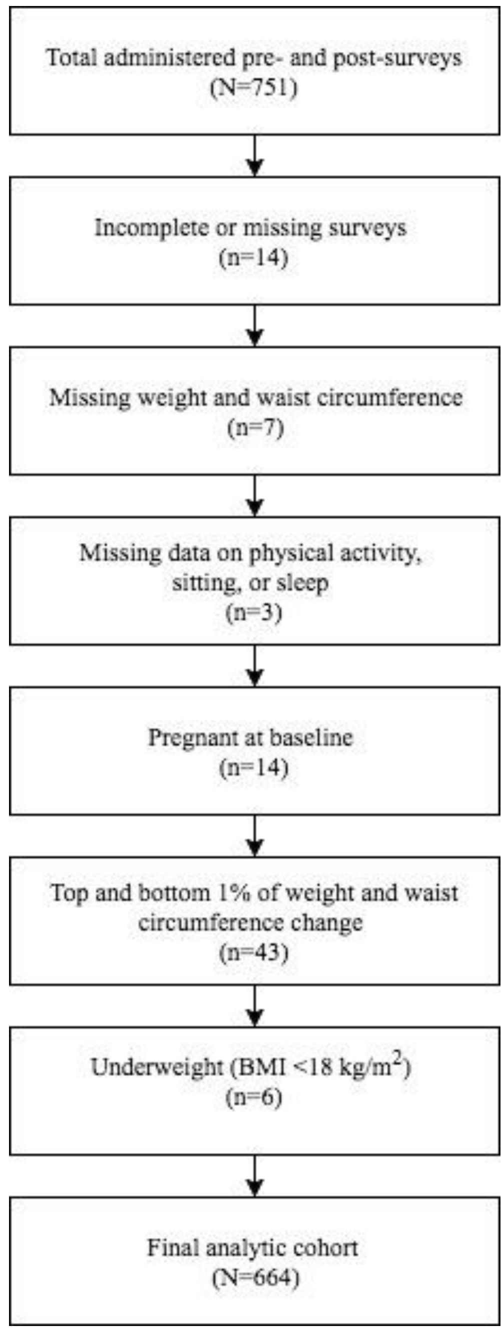

Table 1. Selected Characteristics in the Cohort Stratified by Sex (N=664)

	Total (N=664)		**Women (N=382)**		**Men (N=282)**		**p-value[b]**
Characteristic	**N**	**%**	**N**	**%**	**N**	**%**	
Age (years)[a]	52.8	10.0	52.3	9.8	53.4	10.3	0.186
Race							0.943
White	445	67.0	254	66.5	191	67.7	
Black or African American	121	18.2	71	18.6	50	17.7	
Hispanic	98	14.8	57	14.9	41	14.5	
Education							0.273
Any college education	487	73.3	274	71.7	213	75.5	
High school education or less	177	26.7	108	28.3	69	24.5	
Employment status							0.006
Any full time work	442	66.6	239	62.6	203	72.0	
Any part time work	75	11.3	56	14.7	19	6.7	
Homemaker/retired	128	19.3	78	20.4	50	17.7	
Unemployed	19	2.9	9	2.4	10	3.6	
Current smoker							0.262
Yes	14	2.1	6	1.6	8	2.8	
No	650	97.9	376	98.4	274	97.6	
Initial Body Mass Index (BMI) (kg/m²)							<0.0001
18.5-<22.5	107	16.1	78	20.4	29	10.3	
22.5-<25	166	25.0	100	26.2	66	23.4	
25-<30	231	34.8	111	29.1	120	42.6	
30-<35	106	16.0	52	13.6	54	19.2	
35+	54	8.1	41	10.7	13	4.6	
Type 2 Diabetes							0.031
Yes	37	5.6	15	3.9	22	7.8	
No/missing	627	94.4	367	96.1	260	92.2	
History of bariatric surgery							0.107
Yes	14	2.11	11	2.9	3	1.1	
No/missing	650	97.9	371	97.1	279	98.9	
Sugar sweetened beverages[d]							<0.0001
None	320	48.2	215	56.3	105	37.2	
Low Consumption	165	24.9	81	21.2	84	29.8	
High Consumption	179	27.0	86	22.5	93	33.0	
Alcohol[e]							0.456
None	184	27.7	113	29.6	71	25.2	
Low Consumption	239	36.0	134	35.1	105	37.2	
High Consumption	241	36.3	135	35.3	106	37.6	
Fruit/vegetables (servings/week)							0.994
Q1 (Men: 2-<27.5, Women: 0-<29)	163	24.6	94	24.6	69	24.5	
Q2 (Men: 27.5-<43, Women: 29-<46.5)	165	24.9	94	24.6	71	25.2	
Q3 (Men: 43-<62.5, Women: 46.5-<67)	168	25.3	98	25.7	70	24.8	
Q4 (Men: >62.5, Women: >67)	168	25.3	96	25.1	72	25.5	
Fast food (servings/week)							0.074

Q1 (Men: 0-<0.5, Women: 0-<0.5)	150	22.6	94	24.6	56	19.9	
Q2 (Men: 0.5-<1, Women: 0.5-<1)	147	22.1	84	22.0	63	22.3	
Q3 (Men: 1-<2, Women: 1-<1.5)	166	25.0	82	21.5	84	29.8	
Q4 (Men: >2, Women: >1.5)	201	30.3	122	31.9	79	28.0	
MVPA based on guidelines[c]							0.051
Inactive/Active, below guidelines	95	14.3	60	15.7	35	12.4	
1-<2X guidelines	92	13.9	54	14.1	38	13.5	
2X-<4X guidelines	192	28.9	121	31.7	71	25.2	
≥4X guidelines	285	42.9	147	38.5	138	48.9	
Total sitting time quartiles (hours/day)							0.194
Q1 (0-5.15)	160	24.1	90	23.6	70	24.8	
Q2 (5.15-7)	137	20.6	88	23.0	49	17.4	
Q3 (7-9.29)	194	29.2	102	26.7	92	32.6	
Q4 (>9.29)	173	26.1	102	26.7	71	25.2	
TV sitting time quartiles (hours/day)							0.288
Q1 (0-1.5)	151	22.7	88	23.0	63	22.3	
Q2 (1.5-2.07)	130	19.6	68	17.8	62	22.0	
Q3 (2.07-3.5)	170	25.6	107	28.0	63	22.3	
Q4 (>3.5)	213	32.1	119	31.2	94	33.3	
Sleep duration (hrs/night)							0.009
<7 hrs/night	244	36.8	124	32.5	120	42.6	
7-8 hrs/night	331	49.9	197	51.6	134	47.5	
>8 hrs/night	89	13.4	61	16.0	28	9.9	
Proportion of the day spent sitting[a]	0.4	0.2	0.4	0.2	0.5	0.2	0.452
Weight change (kg)[a]	0.2	3.0	0.4	2.9	0.0	3.1	0.118
Waist circumference change (cm)[a]	-1.2	5.1	-1.4	5.3	-1.1	4.9	0.441
1-year Weight change category							0.583
Weight loss	111	16.7	59	15.5	52	18.4	
Weight maintenance (±2 kg)	399	60.1	234	61.3	165	58.5	
Weight gain	154	23.2	89	23.3	65	23.1	
1-year Waist change category							0.585
Waist loss	296	44.6	176	46.1	120	42.6	
Waist maintenance (±1 cm)	174	26.2	95	24.9	79	28.0	
Waist gain	194	29.2	111	29.1	83	29.4	
Percent weight change[a]	0.3	3.6	0.5	3.8	0.1	3.4	0.103
WHO waist circumference recommendation[f]							0.076
Low risk (Men: <102 cm; Women: <88 cm)	393	59.2	215	56.3	178	63.1	
High risk (Men: >102 cm; Women: >88 cm)	271	40.8	167	43.7	104	36.9	

[a]Continuous variables reported as mean, standard deviation.
[b]P-value represents the comparison between men and women of given characteristic. T-test for continuous variables, chi-squared test for categorical variables.
[c]Guidelines for Moderate Vigorous Physical Activity (MVPA) from *Cancer Statistics* is 7.5 hours/week (1X).
[d]High consumption for men is ≥2 servings/day, low consumption is >0 but <2 servings/day. High consumption for women is ≥1.5 servings/day, low consumption is >0 and <1.5 servings/day.
[e]High consumption for men is ≥4.5 servings/day, low consumption is >0 but <4.5 servings/day. High consumption for women is ≥3 servings/day, low consumption is >0 and <3 servings/day.
[f]Waist recommendations from World Health Organization (WHO) are cut off at 102 cm for men and 88 cm for wome

Table 2. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Weight in CPS-3 Validation Study (N=664), 2015-2016

			Model 1	Model 2	Model 3
Primary Exposure	**Level**	**Change[a]**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Weight Loss**	0.97 (0.45, 2.12)	1.10 (0.49, 2.47)	1.14 (0.50, 2.60)
	2-<4X vs. inactive		0.80 (0.40, 1.58)	1.03 (0.51, 2.10)	1.05 (0.51, 2.18)
	≥4X vs. inactive		0.90 (0.48, 1.69)	1.42 (0.73, 2.77)	1.47 (0.74, 2.92)
	1-<2X vs. inactive	**Weight Gain**	1.03 (0.51, 2.05)	1.15 (0.56, 2.37)	1.15 (0.56, 2.39)
	2-<4X vs. inactive		1.04 (0.57, 1.87)	1.32 (0.71, 2.44)	1.33 (0.71, 2.49)
	≥4X vs. inactive		0.77 (0.43, 1.36)	1.12 (0.61, 2.05)	1.14 (0.61, 2.12)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Weight Loss**	0.59 (0.38, 0.94)	0.73 (0.46, 1.18)	0.71 (0.44, 1.15)
	>8 hrs vs. <7 hrs		0.56 (0.28, 1.11)	0.55 (0.27, 1.13)	0.54 (0.26, 1.11)
	7-8 hrs vs. hrs	**Weight Gain**	0.71 (0.48, 1.06)	0.88 (0.58, 1.34)	0.86 (0.57, 1.32)
	>8 hrs vs. <7 hrs		0.49 (0.26, 0.94)	0.51 (0.26, 0.99)	0.51 (0.26, 0.99)
Sitting Proportion	**10% increments**	**Weight Loss**	1.12 (0.98, 1.28)	1.05 (0.91, 1.21)	1.09 (0.94, 1.27)
	10% increments	**Weight Gain**	1.21 (1.07, 1.36)	1.15 (1.02, 1.31)	1.18 (1.03, 1.35)
TV Sitting Time	**Q2 vs. Q1**	**Weight Loss**	0.99 (0.49, 2.03)	0.87 (0.42, 1.80)	0.85 (0.41, 1.78)
	Q3 vs. Q1		2.12 (1.15, 3.89)	1.64 (0.87, 3.09)	1.73 (0.91, 3.27)
	Q4 vs. Q1		1.48 (0.79, 2.78)	0.97 (0.50, 1.90)	1.02 (0.52, 2.01)
	Q2 vs. Q1	**Weight Gain**	1.22 (0.67, 2.21)	1.10 (0.60, 2.04)	1.05 (0.56, 1.95)
	Q3 vs. Q1		1.36 (0.77, 2.39)	1.12 (0.63, 2.00)	1.12 (0.62, 2.02)
	Q4 vs. Q1		2.03 (1.19, 3.46)	1.47 (0.84, 2.58)	1.45 (0.82, 2.56)

[a]Compared to weight maintenance (±2 kg).

[b]Mutual adjustment for two alternative exposures. I.e., MVPA model adjusted for sleep and TV sitting. TV sitting used as main sitting exposure for adjustment.

Table 3. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Waist Circumference in CPS-3 Validation Study (N=664), 2015-2016

			Model 1	**Model 2**	**Model 3**
Primary Exposure	**Level**	**Change**[a]	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Waist Loss**	1.37 (0.66, 2.82)	1.40 (0.67, 2.92)	1.33 (0.63, 2.81)
	2-<4X vs. inactive		1.29 (0.69, 2.39)	1.48 (0.79, 2.79)	1.42 (0.75, 2.69)
	≥4X vs. inactive		1.28 (0.72, 2.29)	1.64 (0.90, 3.01)	1.53 (0.83, 2.84)
	1-<2X vs. inactive	**Waist Gain**	1.03 (0.48, 2.20)	1.06 (0.49, 2.28)	1.09 (0.50, 2.36)
	2-<4X vs. inactive		0.95 (0.50, 1.81)	1.06 (0.55, 2.04)	1.08 (0.56, 2.09)
	≥4X vs. inactive		0.73 (0.40, 1.34)	0.86 (0.46, 1.62)	0.86 (0.46, 1.64)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Waist Loss**	1.21 (0.80, 1.83)	1.36 (0.89, 2.08)	1.35 (0.88, 2.07)
	>8 hrs vs. <7 hrs		1.28 (0.69, 2.38)	1.28 (0.68, 2.40)	1.23 (0.65, 2.32)
	7-8 hrs vs. hrs	**Waist Gain**	0.81 (0.52, 1.27)	0.89 (0.56, 1.40)	0.89 (0.60, 1.40)
	>8 hrs vs. <7 hrs		1.04 (0.54, 2.03)	1.03 (0.53, 2.01)	0.97 (0.49, 1.90)
Sitting Proportion	**10% increments**	**Waist Loss**	0.85 (0.75, 0.96)	0.81 (0.71, 0.92)	0.82 (0.72, 0.94)
	10% increments	**Waist Gain**	1.00 (0.87, 1.14)	0.97 (0.84, 1.11)	0.94 (0.82, 1.09)
TV Sitting Time	**Q2 vs. Q1**	**Waist Loss**	0.89 (0.50, 1.57)	0.82 (0.46, 1.46)	0.84 (0.47, 1.51)
	Q3 vs. Q1		1.55 (0.89, 2.71)	1.31 (0.74, 2.31)	1.34 (0.75, 2.38)
	Q4 vs. Q1		0.84 (0.49, 1.42)	0.67 (0.38, 1.16)	0.69 (0.39, 1.21)
	Q2 vs. Q1	**Waist Gain**	0.79 (0.42, 1.48)	0.74 (0.39, 1.40)	0.72 (0.38, 1.37)
	Q3 vs. Q1		1.26 (0.69, 2.32)	1.11 (0.60, 2.07)	1.08 (0.58, 2.01)
	Q4 vs. Q1		0.99 (0.56, 1.75)	0.82 (0.46, 1.49)	0.80 (0.44, 1.44)

[a]Compared to waist maintenance (±1 cm).
[b]Mutual adjustment for two alternative exposures. For example, MVPA model adjusted for sleep and TV sitting. TV sitting used as the main sitting exposure for adjustment.

Table 4. Assessment of Effect Modification with 1-Year Weight Change by Previously Identified Plausible Demographic and Lifestyle Factors in the CPS-3 Validation Cohort (N=664)

Interaction Term	df[a]	p-int[b]
Age x MVPA	6	0.985
Age x TV sitting	6	0.621
Age x Sitting proportion	2	0.713
Age x Sleep	4	0.931
Sex x MVPA	6	0.186
Sex x TV sitting	6	0.716
Sex x Sitting proportion	2	0.898
Sex x Sleep	4	0.881
Race x MVPA	16	0.415
Race x TV sitting	16	0.592
Race x Sitting proportion	8	0.856
Race x Sleep	12	0.471
BMI x MVPA	24	0.094
BMI x TV sitting	24	0.089
BMI x Sitting proportion	8	0.947
BMI x Sleep	16	0.236
Education x MVPA	8	0.748
Education x TV sitting	8	0.843
Education x Sitting proportion	4	0.859
Education x Sleep	6	0.593

[a]Difference in degrees of freedom between full and reduced models
[b]P-value represents the chi-squared chunk test for interaction

Table 5. Assessment of Effect Modification with 1-Year Waist Circumference Change by Previously Identified Plausible Demographic and Lifestyle Factors in the CPS-3 Validation Cohort (N=664)

Interaction Term	df[a]	p-int[b]
Age x MVPA	6	0.640
Age x TV sitting	6	0.577
Age x Sitting proportion	2	0.640
Age x Sleep	4	0.864
Sex x MVPA	6	0.950
Sex x TV sitting	6	0.719
Sex x Sitting proportion	2	0.512
Sex x Sleep	4	0.676
Race x MVPA	16	0.396
Race x TV sitting	16	0.520
Race x Sitting proportion	8	0.709
Race x Sleep	12	0.235
BMI x MVPA	24	0.519
BMI x TV sitting	24	0.611
BMI x Sitting proportion	8	0.783
BMI x Sleep	16	0.015
Education x MVPA	8	0.201
Education x TV sitting	8	0.446
Education x Sitting proportion	4	0.883
Education x Sleep	6	0.216

[a]Difference in degrees of freedom between full and reduced models
[b]P-value represents the chi-squared chunk test for interaction

Table 6. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Weight, Stratified by BMI, in CPS-3 Validation Study (N=664), 2015-2016

			Starting Body Mass Index (BMI) (kg/m²)	
			≤25	**>25**
TV Sitting Time	**Q1**	**Weight Loss**	1.00 (ref)	1.00 (ref)
	Q2		1.17 (0.41, 3.39)	0.79 (0.30, 2.09)
	Q3		2.17 (0.82, 5.73)	1.64 (0.73, 3.69)
	Q4		0.14 (0.02, 1.17)	1.73 (0.77, 3.87)
	Q1	**Weight Gain**	1.00 (ref)	1.00 (ref)
	Q2		1.59 (0.61, 4.15)	0.89 (0.41, 1.96)
	Q3		2.42 (0.97, 6.00)	0.76 (0.36, 1.60)
	Q4		2.11 (0.87, 5.14)	1.53 (0.77, 3.03)

Table 7. ORs and 95% CIs for the Associations Between Combination Exposures of MVPA, Sitting, Sleep and Change in Weight and Waist Circumference in CPS-3 Validation Study (N=664), 2015-2016

Weight Change	Combination Exposure[a]	OR (95% CI)	Waist Change	OR (95% CI)
Weight Gain	High MVPA + Low sitting	1.00 (ref)	**Waist Gain**	1.00 (ref)
	High MVPA + High sitting	1.20 (0.75, 1.91)		1.31 (0.79, 2.16)
	Low MVPA + Low sitting	0.79 (0.37, 1.66)		1.68 (0.80, 3.56)
	Low MVPA + High sitting	1.12 (0.63, 1.99)		1.07 (0.57, 2.00)
Weight Loss	High MVPA + Low sitting	1.00 (ref)	**Waist Loss**	1.00 (ref)
	High MVPA + High sitting	1.23 (0.72, 2.10)		1.06 (0.67, 1.66)
	Low MVPA + Low sitting	0.56 (0.21, 1.46)		0.80 (0.38, 1.68)
	Low MVPA + High sitting	1.18 (0.62, 2.23)		0.76 (0.43, 1.34)
Weight Gain	High MVPA + High sleep	1.00 (ref)	**Waist Gain**	1.00 (ref)
	High MVPA + Low sleep	1.91 (0.87, 4.19)		0.62 (0.27, 1.41)
	Low MVPA + Low sleep	1.70 (0.73, 3.94)		0.77 (0.31, 1.90)
	Low MVPA + High sleep	1.04 (0.32, 3.44)		0.47 (0.15, 1.51)
Weight Loss	High MVPA + High sleep	1.00 (ref)	**Waist Loss**	1.00 (ref)
	High MVPA + Low sleep	1.57 (0.68, 3.65)		0.58 (0.27, 1.26)
	Low MVPA + Low sleep	1.33 (0.54, 3.28)		0.53 (0.23, 1.22)
	Low MVPA + High sleep	0.94 (0.26, 3.36)		0.27 (0.09, 0.82)
Weight Gain	High sleep + Low sitting	1.00 (ref)	**Waist Gain**	1.00 (ref)
	High sleep + High sitting	0.99 (0.29, 3.38)		1.31 (0.40, 4.31)
	Low sleep + Low sitting	1.54 (0.54, 4.37)		1.04 (0.39, 2.82)
	Low sleep + High sitting	2.00 (0.72, 5.56)		1.09 (0.41, 2.92)
Weight Loss	High sleep + Low sitting	1.00 (ref)	**Waist Loss**	1.00 (ref)
	High sleep + High sitting	1.52 (0.37, 6.34)		1.25 (0.42, 3.77)
	Low sleep + Low sitting	1.68 (0.46, 6.12)		1.09 (0.44, 2.72)
	Low sleep + High sitting	2.32 (0.66, 8.23)		1.06 (0.43, 2.62)

[a]High MVPA = '2-<4X guidelines' and '≥4X guidelines', Low MVPA = 'Inactive/Active, Below Guidelines' and '1-<2X guidelines.' High Sitting = Q3 and Q4, Low Sitting = Q1 and Q2. High Sleep = '>8 hours/night', Low Sleep = '<7 hours/night' and '7-8 hours/night.'

Table 8. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Weight Among Non-smoking Participants (N=650)

			Model 1	**Model 2**	**Model 3**
Primary Exposure	**Level**	**Change**[a]	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Weight Loss**	1.06 (0.47, 2.38)	1.21 (0.52, 2.79)	1.25 (0.53, 2.94)
	2-<4X vs. inactive		0.93 (0.46, 1.89)	1.21 (0.58, 2.52)	1.23 (0.58, 2.60)
	≥4X vs. inactive		1.01 (0.53, 1.95)	1.60 (0.80, 3.20)	1.65 (0.81, 3.37)
	1-<2X vs. inactive	**Weight Gain**	1.10 (0.55, 2.20)	1.23 (0.60, 2.55)	1.23 (0.59, 2.58)
	2-<4X vs. inactive		1.10 (0.60, 1.99)	1.38 (0.74, 2.59)	1.41 (0.75, 2.68)
	≥4X vs. inactive		0.80 (0.45, 1.43)	1.16 (0.63, 2.15)	1.19 (0.64, 2.24)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Weight Loss**	0.57 (0.36, 0.91)	0.70 (0.43, 1.13)	0.68 (0.42, 1.10)
	>8 hrs vs. <7 hrs		0.58 (0.29, 1.15)	0.57 (0.28, 1.17)	0.57 (0.28, 1.16)
	7-8 hrs vs. hrs	**Weight Gain**	0.70 (0.47, 1.06)	0.86 (0.57, 1.32)	0.85 (0.55, 1.30)
	>8 hrs vs. <7 hrs		0.50 (0.26, 0.95)	0.53 (0.27, 1.03)	0.53 (0.27, 1.03)
Sitting Proportion	**10% increments**	**Weight Loss**	1.09 (0.95, 1.25)	1.03 (0.89, 1.18)	1.06 (0.91, 1.24)
	10% increments	**Weight Gain**	1.20 (1.06, 1.35)	1.14 (1.01, 1.30)	1.17 (1.02, 1.34)
TV Sitting Time	**Q2 vs. Q1**	**Weight Loss**	1.00 (0.49, 2.04)	0.89 (0.43, 1.84)	0.87 (0.42, 1.83)
	Q3 vs. Q1		1.96 (1.06, 3.63)	1.57 (0.83, 2.97)	1.64 (0.86, 3.12)
	Q4 vs. Q1		1.49 (0.79, 2.81)	0.99 (0.51, 1.94)	1.05 (0.53, 2.06)
	Q2 vs. Q1	**Weight Gain**	1.21 (0.66, 2.20)	1.11 (0.60, 2.06)	1.06 (0.57, 1.96)
	Q3 vs. Q1		1.28 (0.72, 2.27)	1.08 (0.60, 1.95)	1.07 (0.59, 1.95)
	Q4 vs. Q1		2.02 (1.18, 3.44)	1.46 (0.83, 2.56)	1.45 (0.82, 2.56)

[a]Compared to weight maintenance (±2 kg).
[b]Mutual adjustment for two alternative exposures. I.e., MVPA model adjusted for sleep and TV sitting. TV sitting used as main sitting exposure for adjustment.

Table 9. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Waist Circumference Among Non-smoking Participants (N=650)

			Model 1	**Model 2**	**Model 3**
Primary Exposure	**Level**	**Change[a]**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Waist Loss**	1.38 (0.66, 2.89)	1.39 (0.66, 2.94)	1.31 (0.61, 2.81)
	2-<4X vs. inactive		1.26 (0.67, 2.35)	1.42 (0.75, 2.69)	1.33 (0.69, 2.54)
	≥4X vs. inactive		1.24 (0.69, 2.24)	1.56 (0.85, 2.88)	1.44 (0.77, 2.68)
	1-<2X vs. inactive	**Waist Gain**	1.07 (0.50, 2.30)	1.09 (0.50, 2.38)	1.12 (0.51, 2.45)
	2-<4X vs. inactive		0.97 (0.50, 1.85)	1.08 (0.56, 2.09)	1.09 (0.56, 2.12)
	≥4X vs. inactive		0.70 (0.38, 1.30)	0.84 (0.45, 1.59)	0.84 (0.44, 1.60)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Waist Loss**	1.20 (0.79, 1.82)	1.34 (0.87, 2.06)	1.33 (0.86, 2.06)
	>8 hrs vs. <7 hrs		1.25 (0.67, 2.32)	1.24 (0.66, 2.33)	1.19 (0.63, 2.26)
	7-8 hrs vs. hrs	**Waist Gain**	0.81 (0.52, 1.26)	0.89 (0.56, 1.41)	0.89 (0.56, 1.42)
	>8 hrs vs. <7 hrs		1.04 (0.54, 2.02)	1.03 (0.53, 2.03)	0.97 (0.49, 1.90)
Sitting Proportion	**10% increments**	**Waist Loss**	0.86 (0.76, 0.97)	0.82 (0.72, 0.93)	0.82 (0.72, 0.94)
	10% increments	**Waist Gain**	1.00 (0.88, 1.15)	0.97 (0.84, 1.11)	0.94 (0.82, 1.09)
TV Sitting Time	**Q2 vs. Q1**	**Waist Loss**	0.86 (0.49, 1.52)	0.80 (0.45, 1.43)	0.82 (0.45, 1.47)
	Q3 vs. Q1		1.52 (0.86, 2.67)	1.30 (0.73, 2.31)	1.33 (0.74, 2.37)
	Q4 vs. Q1		0.82 (0.48, 1.39)	0.65 (0.37, 1.13)	0.67 (0.38, 1.18)
	Q2 vs. Q1	**Waist Gain**	0.80 (0.42, 1.50)	0.75 (0.40, 1.42)	0.73 (0.38, 1.38)
	Q3 vs. Q1		1.30 (0.70, 2.40)	1.15 (0.61, 2.14)	1.11 (0.59, 2.08)
	Q4 vs. Q1		1.01 (0.57, 1.79)	0.83 (0.46, 1.50)	0.79 (0.44, 1.45)

[a]Compared to waist maintenance (±1 cm).
[b]Mutual adjustment for two alternative exposures. For example, MVPA model adjusted for sleep and TV sitting. TV sitting used as the main sitting exposure for adjustment.

Table 10. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Weight Among Non-Diabetic Participants (N=627)

			Model 1	**Model 2**	**Model 3**
Primary Exposure	**Level**	**Change[a]**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Weight Loss**	1.07 (0.47, 2.42)	1.20 (0.52, 2.79)	1.20 (0.51, 2.84)
	2-<4X vs. inactive		0.84 (0.41, 1.73)	1.08 (0.52, 2.28)	1.07 (0.50, 2.29)
	≥4X vs. inactive		0.89 (0.46, 1.73)	1.44 (0.71, 2.93)	1.46 (0.70, 3.05)
	1-<2X vs. inactive	**Weight Gain**	1.07 (0.53, 2.17)	1.20 (0.58, 2.50)	1.16 (0.55, 2.45)
	2-<4X vs. inactive		1.01 (0.55, 1.85)	1.27 (0.67, 2.39)	1.25 (0.66, 2.39)
	≥4X vs. inactive		0.76 (0.42, 1.37)	1.12 (0.60, 2.09)	1.11 (0.59, 2.11)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Weight Loss**	0.60 (0.37, 0.96)	0.73 (0.45, 1.20)	0.70 (0.43, 1.15)
	>8 hrs vs. <7 hrs		0.50 (0.23, 1.06)	0.53 (0.24, 1.16)	0.51 (0.23, 1.12)
	7-8 hrs vs. hrs	**Weight Gain**	0.72 (0.48, 1.08)	0.88 (0.57, 1.35)	0.87 (0.57, 1.35)
	>8 hrs vs. <7 hrs		0.43 (0.22, 0.87)	0.48 (0.23, 0.97)	0.48 (0.23, 0.98)
Sitting Proportion	**10% increments**	**Weight Loss**	1.12 (0.98, 1.30)	1.06 (0.92, 1.23)	1.09 (0.94, 1.28)
	10% increments	**Weight Gain**	1.22 (1.08, 1.38)	1.16 (1.02, 1.32)	1.19 (1.04, 1.37)
TV Sitting Time	**Q2 vs. Q1**	**Weight Loss**	1.07 (0.52, 2.20)	0.95 (0.45, 1.98)	0.93 (0.44, 1.96)
	Q3 vs. Q1		2.14 (1.15, 3.99)	1.71 (0.90, 3.25)	1.82 (0.95, 3.50)
	Q4 vs. Q1		1.99 (1.16, 3.42)	0.94 (0.47, 1.90)	0.98 (0.48, 1.98)
	Q2 vs. Q1	**Weight Gain**	1.14 (0.62, 2.10)	1.05 (0.56, 1.95)	01.00 (0.53, 1.86)
	Q3 vs. Q1		1.33 (0.75, 2.35)	1.12 (0.63, 2.02)	1.14 (0.63, 2.05)
	Q4 vs. Q1		1.35 (0.69, 2.62)	1.50 (0.85, 2.6)	1.47 (0.83, 2.62)

[a]Compared to weight maintenance (±2 kg).
[b]Mutual adjustment for two alternative exposures. I.e., MVPA model adjusted for sleep and TV sitting. TV sitting used as main sitting exposure for adjustment.

Table 11. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Waist Circumference Among Non-Diabetic Participants (N=627)

			Model 1	**Model 2**	**Model 3**
Primary Exposures	**Level**	**Change**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj
MVPA	**1-<2X vs. inactive**	**Waist Loss**	1.21 (0.57, 2.55)	1.19 (0.56, 2.55)	1.13 (0.52, 2.44)
	2-<4X vs. inactive		1.29 (0.68, 2.45)	1.46 (0.76, 2.82)	1.38 (0.71, 2.69)
	≥4X vs. inactive		1.23 (0.67, 2.24)	1.54 (0.82, 2.89)	1.44 (0.76, 2.73)
	1-<2X vs. inactive	**Waist Gain**	0.92 (0.43, 1.98)	0.92 (0.42, 2.01)	0.94 (0.43, 2.07)
	2-<4X vs. inactive		0.89 (0.46, 1.72)	0.99 (0.51, 1.94)	1.01 (0.51, 1.99)
	≥4X vs. inactive		0.65 (0.35, 1.22)	0.78 (0.41, 1.48)	0.78 (0.40, 1.50)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Waist Loss**	1.11 (0.73, 1.69)	1.21 (0.78, 1.87)	1.20 (0.77, 1.86)
	>8 hrs vs. <7 hrs		1.07 (0.56, 2.05)	1.07 (0.55, 2.06)	1.01 (0.52, 1.97)
	7-8 hrs vs. <7 hrs	**Waist Gain**	0.75 (0.48, 1.19)	0.81 (0.51, 1.29)	0.82 (0.51, 1.31)
	>8 hrs vs. <7 hrs		0.92 (0.46, 1.84)	0.91 (0.45, 1.83)	0.84 (0.42, 1.70)
Sitting Proportion	**10% increments**	**Waist Loss**	0.85 (0.75, 0.97)	0.82 (0.72, 0.93)	0.82 (0.72, 0.94)
	10% increments	**Waist Gain**	1.02 (0.89, 1.16)	0.98 (0.85, 1.12)	0.96 (0.83, 1.11)
TV Sitting Time	**Q2 vs. Q1**	**Waist Loss**	0.94 (0.53, 1.68)	0.88 (0.49, 1.59)	0.90 (0.49, 1.62)
	Q3 vs. Q1		1.59 (0.90, 2.80)	1.36 (0.76, 2.41)	1.39 (0.78, 2.49)
	Q4 vs. Q1		0.74 (0.43, 1.28)	0.62 (0.35, 1.08)	0.64 (0.36, 1.12)
	Q2 vs. Q1	**Waist Gain**	0.82 (0.43, 1.55)	0.78 (0.41, 1.48)	0.75 (0.39, 1.43)
	Q3 vs. Q1		1.27 (0.69, 2.36)	1.12 (0.60, 2.10)	1.09 (0.58, 2.04)
	Q4 vs. Q1		1.01 (0.57, 1.80)	0.85 (0.47, 1.55)	0.82 (0.45, 1.49)

[a]Compared to waist maintenance (±1 cm).
[b]Mutual adjustment for two alternative exposures. For example, MVPA model adjusted for sleep and TV sitting. TV sitting used as the main sitting exposure for adjustment.

Table 12. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Weight Among Participants with No History of Bariatric Surgery (N=650)

			Model 1	**Model 2**	**Model 3**
Primary Exposure	**Level**	**Change[a]**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj[b]
MVPA	**1-<2X vs. inactive**	**Weight Loss**	0.99 (0.45, 2.17)	1.15 (0.510, 2.59)	1.19 (0.52, 2.72)
	2-<4X vs. inactive		0.73 (0.36, 1.45)	0.93 (0.450, 1.90)	0.94 (0.45, 1.96)
	≥4X vs. inactive		0.85 (0.45, 1.60)	1.34 (0.681, 2.63)	1.37 (0.68, 2.74)
	1-<2X vs. inactive	**Weight Gain**	1.04 (0.52, 2.11)	1.19 (0.572, 2.48)	1.17 (0.56, 2.45)
	2-<4X vs. inactive		1.04 (0.57, 1.90)	1.30 (0.696, 2.44)	1.30 (0.69, 2.45)
	≥4X vs. inactive		0.76 (0.43, 1.37)	1.10 (0.595, 2.05)	1.12 (0.60, 2.10)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Weight Loss**	0.61 (0.38, 0.96)	0.75 (0.465, 1.22)	0.74 (0.45, 1.20)
	>8 hrs vs. <7 hrs		0.55 (0.27, 1.11)	0.54 (0.256, 1.12)	0.52 (0.25, 1.10)
	7-8 hrs vs. hrs	**Weight Gain**	0.75 (0.50, 1.12)	0.92 (0.600, 1.42)	0.91 (0.59, 1.40)
	>8 hrs vs. <7 hrs		0.53 (0.28, 1.01)	0.55 (0.279, 1.07)	0.53 (0.27, 1.05)
Sitting Proportion	**10% increments**	**Weight Loss**	1.13 (0.98, 1.30)	1.06 (0.921, 1.23)	1.10 (0.95, 1.28)
	10% increments	**Weight Gain**	1.20 (1.06, 1.35)	1.14 (1.007, 1.30)	1.17 (1.02, 1.34)
TV Sitting Time	**Q2 vs. Q1**	**Weight Loss**	1.05 (0.51, 2.16)	0.92 (0.440, 1.92)	0.92 (0.44, 1.93)
	Q3 vs. Q1		2.22 (1.20, 4.13)	1.76 (0.927, 3.35)	1.85 (0.97, 3.55)
	Q4 vs. Q1		1.52 (0.80, 2.90)	1.00 (0.502, 1.98)	1.05 (0.53, 2.11)
	Q2 vs. Q1	**Weight Gain**	1.13 (0.62, 2.07)	1.03 (0.554, 1.92)	0.99 (0.53, 1.85)
	Q3 vs. Q1		1.39 (0.79, 2.44)	1.17 (0.651, 2.09)	1.17 (0.65, 2.11)
	Q4 vs. Q1		1.99 (1.16, 3.41)	1.45 (0.819, 2.55)	1.43 (0.81, 2.55)

[a]Compared to weight maintenance (±2 kg).
[b]Mutual adjustment for two alternative exposures. I.e., MVPA model adjusted for sleep and TV sitting. TV sitting used as main sitting exposure for adjustment.

Table 13. ORs and 95% CIs for the Associations Between MVPA, Sitting, Sleep and Change in Waist Circumference Among Participants with No History of Bariatric Surgery (N=650)

			Model 1	**Model 2**	**Model 3**
Primary Exposures	**Level**	**Change**	Sex + Age adj	Sex + Age + BMI adj	Model 2 + mutual adj
MVPA	**1-<2X vs. inactive**	**Waist Loss**	1.28 (0.62, 2.66)	1.33 (0.63, 2.79)	1.28 (0.60, 2.72)
	2-<4X vs. inactive		1.21 (0.65, 2.25)	1.38 (0.73, 2.62)	1.32 (0.69, 2.52)
	≥4X vs. inactive		1.18 (0.66, 2.13)	1.52 (0.83, 2.79)	1.40 (0.75, 2.60)
	1-<2X vs. inactive	**Waist Gain**	0.94 (0.44, 2.04)	0.97 (0.45, 2.12)	1.01 (0.46, 2.20)
	2-<4X vs. inactive		0.93 (0.48, 1.77)	1.02 (0.53, 1.98)	1.04 (0.54, 2.03)
	≥4X vs. inactive		0.71 (0.38, 1.31)	0.83 (0.44, 1.58)	0.83 (0.44, 1.58)
Sleep Quantity	**7-8 hrs vs. <7 hrs**	**Waist Loss**	1.23 (0.81, 1.86)	1.38 (0.90, 2.12)	1.38 (0.90, 2.13)
	>8 hrs vs. <7 hrs		1.25 (0.67, 2.33)	1.23 (0.65, 2.33)	1.19 (0.63, 2.27)
	7-8 hrs vs. <7 hrs	**Waist Gain**	0.81 (0.52, 1.28)	0.88 (0.55, 1.39)	0.88 (0.56, 1.40)
	>8 hrs vs. <7 hrs		1.07 (0.55, 2.08)	1.04 (0.53, 2.05)	0.98 (0.50, 1.93)
Sitting Proportion	**10% increments**	**Waist Loss**	0.85 (0.75, 0.96)	0.81 (0.71, 0.92)	0.82 (0.71, 0.93)
	10% increments	**Waist Gain**	0.99 (0.87, 1.13)	0.96 (0.84, 1.10)	0.94 (0.81, 1.08)
TV Sitting Time	**Q2 vs. Q1**	**Waist Loss**	0.88 (0.50, 1.57)	0.82 (0.46, 1.47)	0.84 (0.46, 1.50)
	Q3 vs. Q1		1.54 (0.88, 2.70)	1.31 (0.74, 2.32)	1.34 (0.75, 2.38)
	Q4 vs. Q1		0.83 (0.48, 1.41)	0.65 (0.37, 1.14)	0.67 (0.38, 1.17)
	Q2 vs. Q1	**Waist Gain**	0.77 (0.41, 1.44)	0.73 (0.38, 1.37)	0.71 (0.37, 1.34)
	Q3 vs. Q1		1.24 (0.67, 2.28)	1.10 (0.59, 2.05)	1.07 (0.57, 1.99)
	Q4 vs. Q1		0.97 (0.55, 1.72)	0.81 (0.45, 1.47)	0.78 (0.43, 1.43)

[a]Compared to waist maintenance (±1 cm).
[b]Mutual adjustment for two alternative exposures. For example, MVPA model adjusted for sleep and TV sitting. TV sitting used as the main sitting exposure for adjustment.

Supplemental Tables and Figures

Table S1. Assessment of Confounding for Association Between Physical Activity, Sitting, and Sleep with Categorical Weight Change (ORs and 95% CIs) (N=664)

Model	Change[a]	1-<2X MVPA vs. Inactive	2-<4X MVPA vs. Inactive	≥4X MVPA vs. Inactive	Total sit Q2 vs. Q1	Total sit Q3 vs. Q1	Total sit Q4 vs. Q1	TV sit Q2 vs. Q1	TV sit Q3 vs. Q1	TV sit Q4 vs. Q1
Minimally adjusted	**Weight Loss**	0.97 (0.45, 2.12)	0.80 (0.40, 1.58)	0.90 (0.48, 1.69)	1.45 (0.75, 2.80)	1.38 (0.75, 2.54)	1.97 (1.06, 3.64)	0.99 (0.49, 2.03)	2.12 (1.15, 3.89)	1.48 (0.79, 2.78)
	Weight Gain	1.03 (0.51, 2.05)	1.04 (0.57, 1.87)	0.77 (0.43, 1.36)	0.94 (0.52, 1.70)	1.22 (0.73, 2.06)	1.78 (1.05, 3.00)	1.22 (0.67, 2.21)	1.36 (0.77, 2.39)	2.03 (1.19, 3.46)
Potential Confounders[b]										
Race	**Weight Loss**	0.93 (0.42, 2.04)	0.80 (0.40, 1.59)	0.90 (0.48, 1.70)	1.44 (0.74, 2.77)	1.34 (0.73, 2.48)	1.89 (1.02, 3.51)	0.99 (0.49, 2.02)	2.01 (1.09, 3.72)	1.41 (0.75, 2.65)
	Weight Gain	1.01 (0.51, 2.03)	1.04 (0.57, 1.87)	0.76 (0.43, 1.36)	0.93 (0.52, 1.69)	1.21 (0.72, 2.05)	1.76 (1.04, 2.98)	1.22 (0.67, 2.21)	1.34 (0.76, 2.37)	2.01 (1.17, 3.43)
BMI	**Weight Loss**	1.10 (0.49, 2.47)	1.03 (0.51, 2.10)	1.42 (0.73, 2.77)	1.46 (0.74, 2.85)	1.28 (0.68, 2.40)	1.47 (0.78, 2.80)	0.87 (0.42, 1.80)	1.64 (0.87, 3.09)	0.97 (0.50, 1.90)
	Weight Gain	1.15 (0.56, 2.37)	1.32 (0.71, 2.44)	1.12 (0.61, 2.05)	0.94 (0.51, 1.72)	1.13 (0.66, 1.92)	1.42 (0.82, 2.45)	1.10 (0.60, 2.04)	1.12 (0.63, 2.00)	1.47 (0.84, 2.58)
Education	**Weight Loss**	0.97 (0.44, 2.12)	0.80 (0.40, 1.58)	0.89 (0.47, 1.68)	1.44 (0.74, 2.79)	1.38 (0.75, 2.54)	1.97 (1.06, 3.64)	0.99 (0.49, 2.03)	2.12 (1.15, 3.89)	1.50 (0.79, 2.83)
	Weight Gain	1.04 (0.52, 2.09)	1.05 (0.58, 1.89)	0.78 (0.44, 1.38)	0.96 (0.53, 1.73)	1.22 (0.73, 2.06)	1.78 (1.05, 3.00)	1.21 (0.67, 2.21)	1.36 (0.77, 2.39)	2.00 (1.16, 3.42)
Employment	**Weight Loss**	1.03 (0.47, 2.25)	0.85 (0.42, 1.69)	0.92 (0.49, 1.74)	1.45 (0.74, 2.81)	1.35 (0.73, 2.49)	1.86 (0.99, 3.49)	1.01 (0.49, 2.06)	2.05 (1.12, 3.78)	1.49 (0.78, 2.82)
	Weight Gain	1.08 (0.54, 2.17)	1.10 (0.61, 2.00)	0.79 (0.44, 1.41)	0.94 (0.52, 1.71)	1.19 (0.70, 2.02)	1.69 (0.99, 3.49)	1.25 (0.69, 2.29)	1.32 (0.75, 2.33)	2.04 (1.19, 3.51)
Sugar sweetened beverages	**Weight Loss**	1.02 (0.47, 2.24)	0.86 (0.43, 1.71)	0.96 (0.51, 1.82)	1.51 (0.78, 2.91)	1.42 (0.77, 2.63)	2.02 (1.09, 3.75)	0.93 (0.46, 1.91)	2.05 (1.11, 3.78)	1.38 (0.73, 2.60)
	Weight Gain	1.02 (0.51, 2.04)	1.03 (0.57, 1.87)	0.76 (0.43, 1.35)	0.94 (0.52, 1.70)	1.22 (0.73, 2.06)	1.79 (1.06, 3.02)	1.22 (0.67, 2.22)	1.36 (0.77, 2.40)	2.04 (1.19, 3.49)
Alcohol	**Weight Loss**	1.01 (0.46, 2.22)	0.86 (0.43, 1.72)	0.97 (0.51, 1.84)	1.47 (0.76, 2.83)	1.35 (0.73, 2.49)	1.87 (1.00, 3.47)	0.99 (0.49, 2.03)	2.08 (1.13, 3.82)	1.45 (0.77, 2.72)
	Weight Gain	1.05 (0.52, 2.10)	1.10 (0.61, 2.00)	0.81 (0.45, 1.44)	0.94 (0.52, 1.69)	1.22 (0.72, 2.05)	1.72 (1.01, 2.91)	1.21 (0.66, 2.20)	1.35 (0.76, 2.37)	2.00 (1.17, 3.42)
Fruit and vegetables	**Weight Loss**	0.96 (0.44, 2.10)	0.79 (0.40, 1.58)	0.92 (0.49, 1.75)	1.45 (0.75, 2.80)	1.40 (0.76, 2.59)	1.95 (1.05, 3.61)	1.00 (0.49, 2.05)	2.14 (1.16, 3.94)	1.48 (0.78, 2.78)
	Weight Gain	1.00 (0.50, 2.00)	1.02 (0.56, 1.84)	0.73 (0.41, 1.30)	0.93 (0.51, 1.68)	1.26 (0.75, 2.13)	1.82 (1.07, 3.08)	1.23 (0.68, 2.25)	1.37 (0.78, 2.43)	2.08 (1.22, 3.56)
Fast food	**Weight Loss**	0.97 (0.44, 2.11)	0.82 (0.41, 1.64)	0.94 (0.50, 1.78)	1.46 (0.76, 2.83)	1.35 (0.73, 2.50)	1.90 (1.02, 3.54)	0.97 (0.47, 1.98)	1.98 (1.07, 3.67)	1.34 (0.74, 2.64)
	Weight Gain	1.03 (0.52, 2.06)	1.08 (0.60, 1.96)	0.80 (0.45, 1.43)	0.91 (0.50, 1.65)	1.19 (0.71, 2.01)	1.69 (0.99, 2.86)	1.24 (0.68, 2.26)	1.34 (0.76, 2.37)	1.40 (0.74, 2.64)

Table S1. (Continued)

Model	Change[a]	Siting Prop.	Sleep (7-8 vs. <7 hrs)	Sleep (>8 vs. <7 hrs)
Minimally adjusted	**Weight Loss**	1.12 (0.98, 1.28)	0.59 (0.38, 0.94)	0.56 (0.28, 1.11)
	Weight Gain	1.21 (1.07, 1.36)	0.71 (0.48, 1.06)	0.49 (0.26, 0.94)
Potential Confounders[b]				
Race	**Weight Loss**	1.11 (0.97, 1.28)	0.63 (0.39, 1.01)	0.59 (0.30, 1.19)
	Weight Gain	1.21 (1.07, 1.36)	0.72 (0.47, 1.08)	0.49 (0.26, 0.95)
BMI	**Weight Loss**	1.05 (0.91, 1.21)	0.73 (0.46, 1.18)	0.55 (0.27, 1.13)
	Weight Gain	1.15 (1.02, 1.31)	0.88 (0.58, 1.34)	0.51 (0.26, 0.99)
Education	**Weight Loss**	1.21 (1.07, 1.37)	0.59 (0.37, 0.93)	0.56 (0.28, 1.11)
	Weight Gain	1.12 (0.98, 1.28)	0.72 (0.48, 1.09)	0.50 (0.26, 0.94)
Employment	**Weight Loss**	1.10 (1.05, 1.35)	0.61 (0.38, 0.96)	0.57 (0.29, 1.14)
	Weight Gain	1.19 (1.05, 1.35)	0.72 (0.48, 1.08)	0.50 (0.26, 0.96)
Sugar sweetened beverages	**Weight Loss**	1.13 (0.98, 1.29)	0.61 (0.39, 0.97)	0.58 (0.29, 1.15)
	Weight Gain	1.21 (1.07, 1.37)	0.71 (0.47, 1.06)	0.49 (0.26, 0.94)
Alcohol	**Weight Loss**	1.11 (0.96, 1.27)	0.61 (0.39, 0.97)	0.57 (0.29, 1.15)
	Weight Gain	1.20 (1.06, 1.36)	0.72 (0.48, 1.07)	0.49 (0.26, 0.93)
Fruit and vegetables	**Weight Loss**	1.12 (0.97, 1.28)	0.59 (0.37, 0.93)	0.55 (0.27, 1.09)
	Weight Gain	1.23 (1.08, 1.39)	0.71 (0.47, 1.06)	0.50 (0.26, 0.95)
Fast food	**Weight Loss**	1.11 (0.97, 1.28)	0.59 (0.37, 0.93)	0.56 (0.28, 1.12)
	Weight Gain	1.20 (1.06, 1.35)	0.71 (0.48, 1.07)	0.49 (0.26, 0.93)

[a]Weight maintenance (±2 kg) is the reference category for weight loss and weight gain in the polytomous logistic regression models.
[b]Potential confounders were entered into minimally adjusted models as individual covariates to assess if each estimate fell outside 10% of the minimally adjusted estimate.

Table S2. Assessment of Confounding for Association Between Physical Activity, Sitting, and Sleep with Categorical Waist Change (ORs and 95% CIs) (N=664)

Model	Change[a]	1-<2X MVPA vs. Inactive	2-<4X MVPA vs. Inactive	≥4X MVPA vs. Inactive	Total sit Q2 vs. Q1	Total sit Q3 vs. Q1	Total sit Q4 vs. Q1	TV sit Q2 vs. Q1	TV sit Q3 vs. Q1	TV sit Q4 vs. Q1
Minimally adjusted	**Weight**	1.36	1.28	1.28	0.54	0.54	0.57	0.88	1.55	0.83
	Loss	(0.66, 2.81)	(0.69, 2.38)	(0.71, 2.28)	(0.31, 0.96)	(0.31, 0.93)	(0.33, 0.99)	(0.50, 1.56)	(0.88, 2.71)	(0.49, 1.42)
	Weight	1.00	0.95	0.72	0.55	0.95	0.76	0.78	1.26	0.98
	Gain	(0.48, 2.19)	(0.50, 1.80)	(0.39, 1.39)	(0.28, 1.05)	(0.52, 1.70)	(0.41, 1.40)	(0.41, 1.47)	(0.68, 2.32)	(0.56, 1.74)
Potential Confounders[b]										
Race	**Weight**	1.29	1.30	1.31	0.54	0.52	0.54	0.87	1.44	0.77
	Loss	(0.62, 2.68)	(0.70, 2.42)	(0.73, 2.36)	(0.30, 0.96)	(0.30, 0.89)	(0.31, 0.94)	(0.49, 1.55)	(0.81, 2.53)	(0.45, 1.32)
	Weight	1.01	0.95	0.72	0.54	0.93	0.74	0.78	1.23	0.96
	Gain	(0.47, 2.16)	(0.50, 1.80)	(0.39, 1.33)	(0.28, 1.04)	(0.52, 1.68)	(0.40, 1.37)	(0.41, 1.47)	(0.66, 2.27)	(0.54, 1.71)
BMI	**Weight**	1.39	1.48	1.64	0.54	0.50	0.48	0.81	1.30	0.66
	Loss	(0.66, 2.91)	(0.78, 2.79)	(0.89, 3.00)	(0.30, 0.97)	(0.28, 0.87)	(0.27, 0.85)	(0.45, 1.46)	(0.73, 2.31)	(0.38, 1.15)
	Weight	1.06	1.06	0.86	0.54	0.89	0.66	0.74	1.11	0.82
	Gain	(0.49, 2.28)	(0.55, 2.04)	(0.46, 1.62)	(0.28, 1.05)	(0.49, 1.60)	(0.35, 1.23)	(0.39, 1.40)	(0.59, 2.06)	(0.45, 1.48)
Education	**Weight**	1.39	1.30	1.30	0.56	0.54	0.57	0.88	1.55	0.79
	Loss	(0.67, 2.89)	(0.70, 2.42)	(0.73, 2.34)	(0.31, 1.00)	(0.31, 0.93)	(0.33, 0.99)	(0.49, 1.56)	(0.88, 2.71)	(0.46, 1.35)
	Weight	1.04	0.96	0.73	0.55	0.94	0.76	0.78	1.26	0.95
	Gain	(0.48, 2.23)	(0.50, 1.82)	(0.40, 1.35)	(0.29, 1.07)	(0.52, 1.70)	(0.41, 1.40)	(0.41, 1.47)	(0.68, 2.32)	(0.53, 1.70)
Employment	**Weight**	1.33	1.26	1.26	0.52	0.53	0.55	0.89	1.57	0.83
	Loss	(0.64, 2.76)	(0.67, 2.34)	(0.70, 2.26)	(0.29, 0.93)	(0.30, 0.91)	(0.31, 0.96)	(0.50, 1.58)	(0.89, 2.75)	(0.48, 1.43)
	Weight	1.02	0.94	0.71	0.51	0.91	0.71	0.78	1.25	1.04
	Gain	(0.48, 2.20)	(0.49, 1.79)	(0.38, 1.32)	(0.26, 1.00)	(0.50, 1.65)	(0.38, 1.33)	(0.41, 1.47)	(0.67, 2.30)	(0.58, 1.86)
Sugar sweetened beverages	**Weight**	1.43	1.37	1.36	0.56	0.55	0.58	0.81	1.50	0.76
	Loss	(0.69, 2.98)	(0.73, 2.57)	(0.75, 2.46)	(0.31, 0.99)	(0.32, 0.95)	(0.34, 1.02)	(0.45, 1.45)	(0.85, 2.63)	(0.44, 1.31)
	Weight	1.04	0.97	0.73	0.56	0.95	0.78	0.73	1.23	0.92
	Gain	(0.48, 2.24)	(0.50, 1.85)	(0.39, 1.36)	(0.29, 1.08)	(0.53, 1.72)	(0.42, 1.44)	(0.38, 1.38)	(0.67, 2.29)	(0.51, 1.63)
Alcohol	**Weight**	1.39	1.37	1.36	0.54	0.54	0.54	0.88	1.54	0.82
	Loss	(0.67, 2.89)	(0.73, 2.57)	(0.76, 2.46)	(0.30, 0.96)	(0.31, 0.93)	(0.31, 0.95)	(0.49, 1.56)	(0.88, 2.70)	(0.48, 1.40)
	Weight	1.05	1.02	0.78	0.54	0.94	0.71	0.77	1.25	0.97
	Gain	(0.49, 2.26)	(0.53, 1.96)	(0.42, 1.44)	(0.28, 1.05)	(0.52, 1.70)	(0.38, 1.32)	(0.41, 1.46)	(0.67, 2.30)	(0.54, 1.71)
Fruit and vegetables	**Weight**	1.34	1.28	1.25	0.53	0.55	0.57	0.88	1.53	0.84
	Loss	(0.64, 2.77)	(0.69, 2.38)	(0.69, 2.25)	(0.30, 0.94)	(0.32, 0.95)	(0.33, 0.99)	(0.49, 1.57)	(0.87, 2.69)	(0.49, 1.44)
	Weight	1.03	0.95	0.69	0.54	0.95	0.77	0.77	1.24	0.99
	Gain	(0.48, 2.20)	(0.50, 1.81)	(0.37, 1.28)	(0.28, 1.04)	(0.52, 1.71)	(0.42, 1.42)	(0.41, 1.45)	(0.67, 2.29)	(0.56, 1.76)
Fast food	**Weight**	1.35	1.27	1.30	0.55	0.54	0.57	0.87	1.49	0.82
	Loss	(0.65, 2.80)	(0.68, 2.36)	(0.72, 2.33)	(0.31, 0.98)	(0.31, 0.93)	(0.33, 1.00)	(0.48, 1.54)	(0.85, 2.63)	(0.48, 1.40)
	Weight	1.02	0.94	0.73	0.55	0.94	0.76	0.77	1.23	0.97
	Gain	(0.48, 2.18)	(0.49, 1.80)	(0.39, 1.35)	(0.28, 1.06)	(0.52, 1.70)	(0.41, 1.41)	(0.41, 1.46)	(0.66, 2.28)	(0.55, 1.73)

[a]Waist maintenance (±1 cm) is the reference category for waist loss and waist gain in the polytomous logistic regression models.

[b]Potential confounders were entered into minimally adjusted models as individual covariates to assess if each estimate fell outside 10% of the minimally adjusted estimate.

Table S2. (Continued)

Model	**Change[a]**	**Siting Prop.**	**Sleep (7-8 vs. <7 hrs)**	**Sleep (>8 vs. <7 hrs)**
Minimally adjusted	**Weight Loss**	0.85 (0.75, 0.96)	1.21 (0.80, 1.82)	1.28 (0.69, 2.37)
	Weight Gain	0.99 (0.87, 1.13)	0.81 (0.52, 1.26)	1.04 (0.53, 2.02)
Potential Confounders[b]				
Race	**Weight Loss**	0.84 (0.74, 0.95)	1.36 (0.89, 2.09)	1.42 (0.76, 2.67)
	Weight Gain	0.99 (0.87, 1.13)	0.84 (0.53, 1.33)	1.08 (0.55, 2.11)
BMI	**Weight Loss**	0.81 (0.71, 0.92)	1.36 (0.89, 2.08)	1.27 (0.68, 2.39)
	Weight Gain	0.96 (0.84, 1.10)	0.88 (0.56, 1.39)	1.03 (0.52, 2.01)
Education	**Weight Loss**	0.85 (0.75, 0.96)	1.25 (0.82, 1.89)	1.30 (0.70, 2.41)
	Weight Gain	1.00 (0.87, 1.14)	0.82 (0.52, 1.29)	1.05 (0.54, 2.03)
Employment	**Weight Loss**	0.84 (0.74, 0.95)	1.21 (0.80, 1.83)	1.27 (0.68, 2.36)
	Weight Gain	0.99 (0.86, 1.13)	0.82 (0.53, 1.29)	1.03 (0.53, 2.01)
Sugar sweetened beverages	**Weight Loss**	0.85 (0.75, 0.96)	1.25 (0.82, 1.89)	1.34 (0.72, 2.50)
	Weight Gain	1.00 (0.88, 1.14)	0.82 (0.52, 1.29)	1.09 (0.56, 2.13)
Alcohol	**Weight Loss**	0.83 (0.74, 0.95)	1.22 (0.80, 1.84)	1.26 (0.68, 2.34)
	Weight Gain	0.98 (0.86, 1.12)	0.82 (0.52, 1.28)	1.02 (0.52, 1.99)
Fruit and vegetables	**Weight Loss**	0.85 (0.75, 0.96)	1.19 (0.79, 1.80)	1.32 (0.71, 2.45)
	Weight Gain	1.00 (0.88, 1.15)	0.80 (0.51, 1.26)	1.07 (0.55, 2.09)
Fast food	**Weight Loss**	0.85 (0.75, 0.96)	1.17 (0.77, 1.77)	1.27 (0.68, 2.37)
	Weight Gain	0.99 (0.87, 1.14)	0.79 (0.51, 1.24)	1.04 (0.53, 2.02)