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Stages of Behavior Change and Longitudinal Weight Trends in Atlanta Veterans

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B.S.
Gonzaga University
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Thesis Committee Chair: Lisa Staimez, PhD MPH

An abstract of
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Abstract

Stages of Behavior Change and Longitudinal Weight Trends in Atlanta Veterans
By Kanoelehua Ho

Objective: The aim of this study was to investigate associations of stage of behavior change across four weight-related behaviors (dietary calorie reduction, fruit and vegetable intake, dietary fat reduction, and physical activity) with longitudinal weight change among Veterans at the Atlanta VA.

Methods: Data from two linked data sources were used. The Screening for Diabetes and Prediabetes in Primary Care study assessed stages of behavior change for all participants at baseline collected between 2009-2012. Overweight participants with follow up care at the VA, with at least 2 recorded weights in primary care health records through December 2020, were included in the present analysis. Associations between stage of change and longitudinal weight changes, measured using body mass index (BMI), were analyzed, adjusted for other demographic (age, race, sex) and baseline clinical factors (diabetes status, family history of diabetes, and obesity status).

Results: A total of 886 individuals reported being overweight with complete stage of change and weight data; a majority of participants were clinically defined as obese (66.8%, BMI $\geq$ 30 kg/m^2), but actively trying to make healthy behavior changes. Controlling for age and diabetes status, BMI significantly decreased ($p<0.05$) among participants in the action stage of change. However, the rate of decrease was not significantly different between the stages of change; except for fat reduction where reduction in BMI for participants in the precontemplation and contemplation stages was significantly greater compared to those in the action stage. The annual rate of decrease in BMI was significantly faster among participants who were 65 and older and among those with diabetes.

Conclusions: The BMI of participants who were actively trying to make diet and exercise changes did not decrease at a faster rate compared to those who were not trying. Older individuals, and those with diabetes, are losing more weight compared to younger individuals without diabetes. Further research is required to determine the benefits of utilizing a stage of change assessment when initiating weight loss efforts.

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Chapter I: Background Literature Review

OBESITY IN THE UNITED STATES

Obesity is defined by the World Health Organization (2020) as an abnormal or excessive accumulation of fat, especially located in adipose tissue. It is characterized by a body mass index greater than 30 kg/m^2 and has become one of the most prevalent diseases plaguing the United States today. The prevalence of obesity in the United States, and around the world, has steadily risen over the last 40 years. In 2018, approximately 42.4% of American adults were estimated to be obese (BMI ≥ 30), 31.1% were overweight (BMI = 25-29) and 9% were severely obese (BMI ≥ 40) [2 3]. The prevalence of obesity in adults has risen almost 50% in only the last 20 years, and the prevalence of severe obesity has almost doubled [2]. The magnitude of this public health crisis is further exacerbated by obesity being associated with higher risk of morbidity and mortality from dozens of other conditions, including type 2 diabetes mellitus [4].

OBESITY AND TYPE II DIABETES

Type 2 diabetes mellitus is one of a group of disorders characterized by an elevation in blood glucose levels. It develops if the body becomes resistant to insulin and can no longer produce enough insulin to overcome this resistance. According to the Centers for Disease Control and Prevention, diabetes is the 7^{th} leading cause of death in the U.S., but this figure may be underreported as 1 in 5 people are estimated to have undiagnosed diabetes [5]. The percent of US adults with diagnosed diabetes almost tripled between 1980 and 2014, and type 2 diabetes is the most common form, accounting for over 90% of cases [6 7]. The association of obesity with diabetes is well documented, and the rise in obesity has been correlated to a parallel rise in type 2 diabetes. These increases are predicted to continue and projections estimate that the percent of U.S. adults with diagnosed diabetes will reach as high as 33% by 2050 [8]. Furthermore,

longitudinal studies found that a longer duration of obesity was associated with a substantially higher risk of diabetes. Specifically, the CARDIA study, which followed adult men and women for 18-30 years, found that each additional year of obesity resulted in a 4% higher risk of developing diabetes [9]. Additional research in the Beijing Blood Pressure Cohort Study, which followed children for over 20 years, found that the odds of developing diabetes among obese children who remained obese into adulthood were over four times the odds of non-obese children (OR=4.3; 95%CI 2.2, 8.1).

The relationship between weight and diabetes is further supported by multiple studies demonstrating the relationship between weight loss and type 2 diabetes improvement or remission (ceasing all diabetic medication). Schauer et al. found that, in a cohort of patients with type 2 diabetes who underwent bariatric surgery between 1997 and 2002, surgically induced weight loss resulted in either significant improvement of both fasting plasma glucose and HbA1c (17%) or complete remission (83%) in all 191 patients assessed [10]. Similar results from the Swedish Obese Subjects Trial, a prospective matched cohort study, showed that type 2 diabetes remission was achieved in 72.3% of individuals who achieved surgical weight loss, compared to only 16.4% of individuals who did not receive bariatric surgery [11]. Results from non-surgical weight loss programs have also shown significant results. In the Diabetes Remission Clinical Trial (DiRECT), the intervention group was placed on a physician-monitored low calorie (825–853 kcal/day) liquid diet for 3-5 months followed by a food re-introduction phase of 2-8 weeks and an ongoing structured food program for long-term weight loss maintenance. The trial showed that diabetes remission varied by weight loss recorded at 12 months – 86% of participants who lost 15 kg or more were able to achieve remission compared to only 7% among participants who lost 0-5 kg [12].

WEIGHT LOSS INTERVENTIONS

It is clear that weight loss results in significant health improvements, especially among those with type 2 diabetes. However, long term weight maintenance following participation in extreme non-surgical diet modification programs, like DiRECT, remains difficult to achieve. Results from lifestyle modification programs have shown greater success in reducing weight and the risk of type 2 diabetes long term [13 14]. Lifestyle modification programs focus on more than just diet, usually incorporating both physical activity and behavior therapy aspects as well. In the Look AHEAD Study, Wadden et al. found that after 4 years, participants who were enrolled in an intensive lifestyle modification intervention lost significantly more weight than those who received traditional care (4.7% vs 1.1%). Further, more participants who received the intervention lost ≥5% (46% vs. 25%) and ≥10% (23% vs. 10%) of initial weight [14]. Lifestyle modification programs have also been shown to effectively reduce the incidence of type 2 diabetes in obese individuals. In a randomized control trial, Knowler et al. found that among obese, non-diabetic individuals with elevated plasma glucose levels, those who participated in an intensive lifestyle intervention program had reduced incidence of type 2 diabetes by 58% over 2.8 years compared with those who received standard lifestyle recommendations [13].

Despite these promising studies, weight loss management long term is minimal and inconsistent, even among those who participate in lifestyle interventions. Half of lifestyle intervention participants, if not more, may not be able to achieve intentional weight loss long term [15]. This is primarily due to the multifactorial nature of weight loss and maintenance which has been associated with many factors such as a history of weight cycling, internal motivation, self-efficacy, and psychological strength and stability [16]. Therefore, it is important to identify additional behavioral characteristics associated with successful weight reduction and

maintenance. One key characteristic that may affect success, and requires additional exploration, is an individual's readiness to change which has been measured using the transtheoretical model of behavior change.

THE TRANSTHEORETICAL MODEL AND STAGES OF CHANGE THEORY

The transtheoretical model, developed by Prochaska and DiClemente (1982), describes a temporal model of behavior change characterized by five distinct stages - precontemplation, contemplation, preparation, action, and maintenance [17]. Individuals in the **precontemplation** stage are not intending to take any action within the next six months and avoid learning about or discussing their dangerous behaviors. Individuals may be in this stage because they have been discouraged due to previous attempts to change or may just be uninformed of the dangers of their behavior. Marked by an intent to change in the next six months, individuals in the **contemplation** stage are more aware of both the pros and cons of changing during contemplation and therefore may get stuck in this stage for long periods of time. Once individuals decide to make a change in the immediate future, within one month, they move into the **preparation** stage where they have typically taken some preliminary actions such as making a plan, seeking out educational resources and support, or discussing the topic with their physician. Preparation moves into the **action** stage when individuals make observable, intentional changes to their behavior over a six month period. Finally, the **maintenance** stage is where individuals are actively working to prevent relapse but are no longer making progressive behavior changes, and can last up to five years.

Prochaska and Velicer (1997) describe three additional factors that help guide individuals through the five stages: The Processes of Change, Decisional Balance, and Self-Efficiency [18]. First, processes of change consist of 10 processes that describe both the internal and external

actions that must occur in order to move from one stage to the next. Next, decisional balance is an individual's understanding and evaluation of the pros and cons of making the change. Lastly, self-efficacy is the individual's belief in themselves to make the change. While the transtheoretical model was originally described for the application of smoking cessation, transtheoretical model-based interventions have been applied to weight related behaviors such as physical activity and dietary improvements, as well as weight control, with varying levels of success [19 20].

EFFECTS OF TRANSTHEORETICAL-BASED INTERVENTIONS ON DIET

The effectiveness of stage-based interventions on dietary changes has primarily been applied to behavior changes regarding the reduction of dietary fat, calorie intake, and increase of fruits and vegetables. Short-term (1-24 months) randomized control trials comparing transtheoretical model-based interventions to usual care have shown some positive results, specifically in reducing dietary fat. Menezes, Mingoti, and Lopes (2015) conducted a randomized control trial where participants were either provided usual nutrition counseling or transtheoretical model-based counseling. They found that participants in the intervention group were able to successfully reduce their consumption of fried food and overall calorie intake, while no significant changes were observed in the control group [21]. However, the follow up time was very short, at only six months. In a longer randomized control trial conducted in the Netherlands, Van der Veen et al (2002) found that total and saturated fat in-take declined significantly more among individuals receiving the intervention of stage-based nutrition counseling compared to the control group at both 6 and 12 months. However, a significant difference in total calorie intake between the two groups was only observed at 6 months [22]. Similarly, Steptoe et al. (1999) also found that individuals randomized to receive a stage-based health counseling were more

successful at reducing dietary fat intake at both 4 and 12 months of follow up [23]. Additionally, results from the ALIVE program, a four month randomized control trial where intervention participants were emailed transtheoretical model-based information, the consumption of fruits and vegetables increased significantly and compared to the control group [24]. The difference between the two groups was maintained for an additional four months after the intervention. These results suggest that transtheoretical model stage-based counseling does have a short term effect on dietary change behaviors.

EFFECTS OF TRANSTHEORETICAL MODEL-BASED INTERVENTIONS ON PHYSICAL ACTIVITY

Transtheoretical model-based interventions have also been shown to be effective for short term changes in physical activity behaviors. Two observational studies have shown a significant increase in self-reported physical activity after receiving transtheoretical model-based counseling. Kim and Kang (2020) found that middle aged obese Korean women who participated in a four month transtheoretical model-based counseling program were able to consistently increase their physical activity throughout the four month period, but post intervention results were not recorded [25]. Additionally, Riebe et al. (2005) found that men and women who underwent a six month clinic based weight loss program according to the transtheoretical model were able to maintain an increase of physical activity, even after 24 months [26]. In addition to dietary improvements, Steptoe et al. (1999) and Sternfeld et al. (2009) also found significant differences between the intervention and control groups for physical activity at 12 and 8 months, respectively. Similar to dietary changes, transtheoretical model-based interventions appear to have at least a short-term effect on physical activity.

EFFECTS OF TRANSTHEORETICAL MODEL-BASED INTERVENTIONS ON WEIGHT

While weight-related behaviors appear to be positively affected by transtheoretical model-based interventions in the short term, studies assessing the effectiveness of transtheoretical model-based interventions on biological weight change, especially long term, are variable. A recent randomized control trial involving adult women in Brazil assessed the effects of stage-based individual counseling compared standard group level health education. They found that the difference in weight loss and BMI between the two groups at baseline and at 6 months was statistically significant at -1.4 kg (95% CI -2.5, 0.3, p-value 0.01) and -0.5 kg (95% CI -0.9, -0.5; p-value 0.03), respectively [27]. Similar results from the Vivamos Activos program, a randomized control trial assessing the effectiveness of transtheoretical modeled case management and community health worker services compared to usual care, showed a significant difference in weight loss between the two groups at 6 months [28]. However, longer term differences at 12 months and 24 months were not significant in this trial. Similar randomized control trials comparing the effects of usual care to transtheoretical model and stage-based interventions did not see significant differences between the control and intervention groups with a short follow up time of 1-4 months [29] or a longer follow-up time of 24 months [30]. This data suggests that transtheoretical model-based interventions may be more effective at addressing specific weight-related behavior changes, but less effective at addressing complex behaviors outcomes such as weight change. However, these studies did not describe the distribution of the stage of change between the intervention and control groups, or the potential effects the distribution of stage of change may have had on results. Therefore, it is not clear how a participant's readiness to change could have affected the outcomes in each group.

ASSOCIATION OF STAGE OF CHANGE WITH WEIGHT

There are only a few studies that have assessed the association of stage of change with successful weight reduction behaviors and weight loss outcomes. Johnson et al. (2008) performed a randomized control trial to compare the effects of individualized transtheoretical model-based education on stage of change progression for healthy eating and physical activity, and its effect on weight loss. Results showed more participants in the treatment group moved from pre-action stages in healthy eating and physical activity to action and maintenance stages compared to the control group; which was associated with a significantly greater weight loss (-2.1 kg; $p<0.05$) at 24 months among the treatment group [31]. Similarly, a randomized control trial conducted by Kjøllesdal, Hjellset, Bjorge, Holmboe-ottesen, and Wandel (2011) assessed the effects of stage of change on multiple weight related behaviors and found that individuals in the action stages for changing amount of dietary fat, eating more vegetables and having an intention to change weight at follow-up (7 months) were more likely than others to have lost weight. Both studies suggest that movement to the action/maintenance stage increases the likelihood of successful weight loss. However, in a randomized control trial assessing the effects of transtheoretical model-based intervention and stage of change on self-care behaviors for glycemic control, Jones et al. (2003) found that HbA1c after 12 months was significantly reduced in participants who reached the action/maintenance phase compared to those who were in a pre-action phase; but weight reduction was not statistically different between these two groups. Therefore, the evidence showing the effects of stage of change on weight are promising, but not conclusive.

LIMITATIONS OF PREVIOUS STUDIES

There is a lack of evidence showing the effects of transtheoretical model-based interventions and stage of change progression on weight-related behavior change and weight loss long term (>24 months). All of the studies are short term, ranging from only 1 month to a maximum of 24 months. Additionally, most studies do not assess the distribution of stage of change among the treatment and control groups, or measure the effects of progressing through the stage of change on weight loss. Among the three studies that did assess the effect of stage of change progression on weight [31-33], transtheoretical model-based counseling was the primary exposure, not stage of change. To our knowledge, no previous study has investigated the association of stage of change as the primary exposure on longitudinal weight changes. Further, the association of stage of change on weight has not been previously assessed among U.S. Veterans, a particularly high-risk population, suffering from higher rates of obesity and diabetes.

OBESITY AND DIABETES AT THE VA

Obesity and diabetes are of particular concern among Veterans in the U.S., a population of older, sedentary individuals, who are often from high minority and lower socioeconomic backgrounds. One study estimates that when comparing proportions, Veterans have a higher risk for being overweight/obese (RR = 1.102) and diabetic (RR = 1.500), compared to non-Veterans [34]. The prevalence of obesity and diabetes among Veterans, according to data from the US National Health and Nutrition Examination Survey from 2005 to 2014, is estimated to be 40.7% and 20.5% respectively [35]. Furthermore, a longitudinal study of weight trends in Veterans across the country found that more than a quarter of Veterans had diabetes and their weight, regardless of diabetes status, was significantly increasing over time ($p < 0.0001$) [36]. Studies

also show that the increase in obesity in Veterans was significantly associated with multiple health conditions and a sedentary lifestyle, negatively impacting overall quality of life [37].

SIGNIFICANCE OF THESIS

Obesity and diabetes are great public health concerns in the U.S., especially among Veterans, an older sedentary, overweight population. Weight loss has been associated with a reduced risk of type 2 diabetes and diabetes related complications. Due to the multifactorial nature of obesity, the success of weight loss interventions has been variable. Lifestyle and behavior modification trials, using transtheoretical model-based interventions, have demonstrated some efficacy in weight loss. However, current research shows only short-term (1-24 months) associations and results are variable. Some studies have shown that an individual's readiness to change may be a key factor in weight loss success, but it is not often taken into account in the current literature. This study will assess the associations of a Veteran's stage of change (precontemplation, contemplation, action, and maintenance) for making dietary and physical activity behavior changes with weight change over time using data from the VA Medical Center.

The *Screening for Diabetes and Prediabetes in Primary Care* study was conducted at the Atlanta Veterans Administration Medical Center (VAMC), and provides a unique opportunity to assess the association of stage of change with longitudinal weight gain. The original study population consisted of 1,535 people without a previous diagnosis of diabetes, aged ≥45 years, with a BMI ≥25 kg/m^2 [38]. Participant's self-identified stage of change was assessed at baseline across four weight-related behaviors: dietary calorie reduction, dietary fat reduction, fruit and vegetable intake and physical activity. Additional baseline characteristics and follow up metrics

are available for all participants via the VA healthcare system, the largest integrated health care system in the United States.

SPECIFIC AIM AND HYPOTHESIS

Specific Aim: To investigate associations of stage of change across four weight-related behaviors (dietary calorie reduction, dietary fat reduction, fruit and vegetable intake and physical activity) with longitudinal weight change among Veterans at the Atlanta VA.

Hypothesis: A self-identified action stage of change will be associated with decreased weight gain over time compared to all other stages (precontemplation, contemplation and maintenance).

Chapter II: Stages of Behavior Change and Longitudinal Weight Trends in Atlanta Veterans

INTRODUCTION

Obesity has become one of the most prevalent diseases plaguing the United States today. Defined as a body mass index (BMI) greater than 30 kg/m^2, the prevalence of obesity in the United States, and around the world, has steadily risen over the last 40 years. In 2018, obesity was estimated to affect approximately 42.4% of American adults and 18.5% of American children [2 3]. The magnitude of this public health crisis is further exacerbated by obesity's association with higher risk of morbidity from dozens of other conditions, including type 2 diabetes mellitus [4].

Obesity and diabetes are of particular concern among Veterans in the U.S., a population found to be gaining significant weight over time [36]. Studies show that the prevalence of obesity and diabetes is higher among this population, and they experience an increased risk of developing both disorders [34 35]. The increasing prevalence of obesity, especially among the Veteran population, underscores the urgency in developing meaningful weight loss interventions

Lifestyle intervention programs are effective methods for reducing weight and the risk of type 2 diabetes [13 39]. However, long term results of these interventions are often minimal and inconsistent, and half, if not more are unable to achieve intentional weight loss long term [15]. This is primarily due to the multifactorial nature of weight loss and maintenance which has been associated with many factors such as a history of weight cycling, internal motivation, self-efficacy, and psychological strength and stability [16]. One key characteristic that may affect success is individual's readiness to change, which has been characterized using the transtheoretical model of behavior change. The transtheoretical model describes a temporal

model of behavior change characterized by five distinct stages - precontemplation, contemplation, preparation, action, and maintenance [17]. Existing research suggests that as individuals progress through each stage, their likelihood to partake in behaviors related to weight loss, such as healthy eating and exercise, increases [31 40]. However, the association between their initial readiness to change and long-term weight fluctuations tracked for greater than two years, has not been previously studied.

The Screening for Diabetes and Prediabetes in Primary Care study is a prospective study conducted at the Atlanta VA. Data collected during this study provides a unique opportunity to assess the association of stage of change with longitudinal weight changes among Veterans, a population with a heightened risk of obesity, diabetes and subsequent complications [34 35 37]. The purpose of this study was to investigate associations of stage of change across four weight-related behaviors (dietary calorie reduction, dietary fat reduction, fruit and vegetable intake and physical activity) with BMI changes over time among overweight individuals at the Atlanta VA.

METHODS

Participants

The Screening for Diabetes and Prediabetes in Primary Care was a prospective study which enrolled participants in 2009-2012 at the Atlanta VA Medical Center. Patients in VA waiting rooms and VA personnel were approached to participate if they appeared to be aged ≥45 years, with a BMI ≥25 kg/m^2, and were considered eligible if they did not have a previous diabetes diagnosis [38]. All participants were weighed, given a questionnaire developed according to the transtheoretical model, the Patient-centered Assessment and Counseling for Exercise and Nutrition (PACE+) program, and participated in a glucose challenge test at the

baseline visit. All participants who returned for a second visit, where an oral glucose tolerance test was performed, were included in that analysis [38].

Participants were included in the present analysis if they had follow up data between baseline and December 2020. Participants were excluded if they did not have at least two primary care visits where weight was collected after baseline (n = 57), a weight measurement recorded on or prior to baseline (n=9), or if their weight was measured over a year prior to baseline (n = 8). Additionally, those who did not complete the PACE+ questionnaire at baseline (n = 27) or chose not to answer (n = 10) were excluded. Lastly, in order to reduce inherent differences within the population, those who self-identified as not overweight and not gaining weight were excluded (n = 538). Thus, 886 individuals remained eligible for this current study.

Longitudinal Study Design and Measures

The primary outcome of interest was weight change over time measured using BMI. BMI was calculated by dividing weight (kilograms) by height (meters) squared. Only weights recorded at primary care visits were used.

The exposure variable consisted of participant's self-identified readiness to change collected through the PACE+ derived questionnaire. The primary exposure of interest was readiness to make dietary calorie reductions. Participants were asked to choose the phrase that corresponded most accurately to their current status of (1) being overweight or gaining weight, (2) intention to reduce calorie intake, and (3) when changes in calorie intake are expected to begin or, if already begun, the regularity of the effort (See Figure 2. for specific stage of change questions). Only participants that reported being overweight or gaining weight were included in the present analysis; those who self-identified as being neither overweight nor gaining weight and those who chose "Did not answer" were not the target of the present analysis and were

excluded. Participants were categorized into three groups according to their calorie reduction status: pre-contemplation, contemplation, and action. The pre-contemplation group did not intend to reduce their calorie intake within six months, the contemplation group was thinking about consistently reducing calorie intake within six months, and the action group was trying to make a serious effort to reduce calorie intake.

The PACE+ derived questionnaire was used to assess participant's stage of change for two additional behaviors related to diet: fruit and vegetable intake and dietary fat reduction. Participants were asked to choose the phrase that corresponded most accurately to their current status of (1) intention to eat 5 servings per day of fruits and vegetables or a low-fat diet and (2) when changes were expected to begin or, if already begun, the regularity of the effort (See Figure 2. for specific stage of change questions). For both behaviors, participants were categorized into four groups according to their fruit and vegetable intake and fat reduction statuses: pre-contemplation, contemplation, action, and maintenance. For the fat reduction behavior, the pre-contemplation group did not eat a low-fat diet and did not intend to start within six months, the contemplation group did not eat a low-fat diet but was thinking about starting within six months, the action group was trying to eat a low-fat diet and the maintenance group was eating a consistently low-fat diet. Similarly for the fruit and vegetable intake behavior, the pre-contemplation group ate fewer than five servings per day of fruits and vegetables and did not intend to start eating more fruits and vegetables within six months, the contemplation group ate fewer than five servings per day of fruits and vegetables but was thinking about starting to eat more within six months, the action group was trying to eat five servings of fruits and vegetables each day, and the maintenance group was consistently eating five or more servings per day of fruits and vegetables.

Lastly, participant's readiness to increase physical activity was assessed using the PACE+ derived questionnaire and were also categorized into four stages: pre-contemplation, contemplation, action, and maintenance. The pre-contemplation group did not exercise regularly and did not intend to start within six months, the contemplation group did not exercise regularly but was thinking of starting within six months, the action group was trying to or consistently exercising for less than six months, and the maintenance group was exercising regularly for six months or longer (Figure 2.).

Covariates for this study included baseline BMI, baseline age, race, sex (male/female), self-reported family history of diabetes in a first degree relative (yes/no), obesity status at baseline and diabetes status at baseline. Baseline age was analyzed both as a continuous variable and as a dichotomous variable ('0' for age $<$ 65 and '1' for age $\geq$ 65). Diabetes status at baseline was analyzed as three categories based on standard definitions for diabetes [fasting glucose ≥126 mg/dl (7.0 mmol/l) or OGTT 2-h glucose ≥200 mg/dl (11.1mmol/l)], prediabetes [impaired glucose tolerance (OGTT 2-h glucose 140–199 mg/dl or 7.8– 11.0 mmol/l) and impaired fasting glucose (FPG 100-125 mg/dl)], and normal glucose tolerance [fasting plasma glucose <100 mg/dl (5.6 mmol/l), OGTT 2-h glucose <140 mg/dl (7.8 mmol/l)] [38]. Obesity status at baseline was also analyzed as three categories according to the Centers for Disease Control and Prevention definitions of normal body weight (18.5 ≤ BMI < 25), overweight (25 ≤ BMI < 30), and obesity 30 ≤ BMI) [41]. Race was analyzed as three categories White, Black, and Other (Hispanic, Asian, Native Hawaiian/Pacific Islander, and Other).

Data Analysis

Baseline characteristics were examined in the entire study population and across the stages of change (for all four behaviors) using analysis of variance (ANOVA) for continuous

variables and chi-square statistics for categorical variables. Mean BMI was calculated per year for each participant and charted over time overall and stratified by stage of change to graphically visualize longitudinal BMI change. To assess the association of stage of change with BMI as a continuous variable over time, longitudinal models were fit using full maximum likelihood estimation and random effects for the intercept and time (measured as years since baseline). Covariance structures were evaluated by comparing the AIC, AICc, and BIC (Akaike Information Criterion, Corrected Akaike Information Criterion, Bayesian Information Criterion) and an unstructured error covariance structure provided the best fit. Participants in the 'action' stage were used as the referent group. All analyses were performed using SAS Enterprise Guide 8.2 (Cary, NC, USA).

Forward model selection was performed, starting with the basic model of BMI as the outcome and years of follow-up as the predictor. Next, the exposure variable, stage of change, was added to the model, along with the interaction of stage of change and years of follow-up. Baseline variables (age, diabetes status, BMI, race, family history of diabetes and sex) were added to the model one at a time along with their interactions with time. If the interaction term with time was not significant, the variable and its interaction with time were dropped from the model before adding the next covariate. This model selection strategy was used across all four behaviors.

This study was approved by the Emory University Institutional Review Board and the Atlanta VA Medical Center Research and Development Committee.

RESULTS

Participant Characteristics

Among 886 participants at baseline, mean weight of participants was 102.9 kg (SD 17.6), with a mean BMI of 32.5 kg/m^2 (SD 4.9). Nearly all participants were obese (66.8%) or overweight (30.7%), with only 2.5% of the population having a normal BMI status. The mean age of all participants was 55.1 years (SD 10.35). Diabetes and prediabetes was newly detected in 11.7% and 44.5% of participants at baseline, respectively. Participants were primarily male (92.2%) and nearly three-quarters of the sample identified as Black (72.1%), with a little over one quarter self-identifying as White (26.2%) or Other (1.6%). Approximately half of the population had a parent or sibling with diabetes (47.9%).

The distribution of baseline characteristics across stages of change for each behavior are represented in **Tables 1a-1d**. Most participants were in the action stage of change for all behaviors, with percent in the action phase ranging from 47% for fruit intake to 61% for calorie intake behavior. Baseline weight for the whole sample was 102.9 kg and did not appear to differ between the three stages of calorie reduction change (p=0.148), but mean BMI was slightly higher among those in the action stage (p=0.045) at 32.9 kg/m^2±0.21, compared to the contemplation (BMI=32.0 kg/m^2±0.29) and precontemplation (BMI=32.1 kg/m^2±0.6) stages. For the fat reduction behavior, those in the action stage were heavier with an average weight of 104.3 kg and mean BMI of 33.0 kg/m^2±0.23; while those in the precontemplation stage were lightest with an average weight of 98.3 kg and mean BMI of 31.1 kg/m^2±0.48 (p=0.0008 for weight; p=0.006 for BMI). Neither mean weight nor BMI appeared to differ between the four stages for fruit and vegetable intake and exercise.

Age differences by stage of change varied depending on behavior examined. For stages of calorie and fat reduction changes, those in precontemplation were significantly older (p=0.007 and 0.001, respectively). In contrast, for fruit and vegetable intake and exercise behaviors, those in the maintenance stage of change were oldest (p=0.001 for both). Women were more likely than men to be actively trying to make behavior changes, except for exercise change, where the difference by gender was not significant. Participants across the stages were similar with respect to diabetes status, BMI category, race, and family history of diabetes.

Graphically, there appeared to be no change in mean BMI over time (**Figure 3**). However, when stratified by stage of change, there are slight differences between the stages (**Figure 4**). Specifically, mean BMI for participants in the action and maintenance stages appeared to be decreasing; while it appeared to increase in participants in the precontemplation and contemplation phases.

Multilevel Modeling Stage of Change

Median follow-up time was 9 years (0.5-11.4 years). Over half of participants (59%) had follow-up times greater than the average (8.6 years± 2.0). Follow-up time was not significantly different across the stages of change for any of the behaviors.

Results from the model building process, which produced a similar selection of covariates for each behavior change, are presented in **Tables 2-5**. First, an unconditional model assessing BMI as the outcome, and time as the only predictor, was fit (Model 1), which showed mean BMI was significantly decreasing over time at a marginal rate of 0.053 kg/m^2 per year ($p<0.01$). Next, for each behavior, stage of change was added to Model 1 to assess how longitudinal BMI change varied by stage of change in unadjusted models (Models 2a-2d), which again showed that mean BMI was decreasing over time among those in the action stage of

change, however this decrease was only significant for the exercise behavior. In Models 3a-3d, age is added to Models older age (≥65 years) (Model 3a-3d), the magnitude of the rate of decrease for BMI per year increased and became significant for all behaviors. Additionally, there was a significant difference in the rate of change for BMI between the two age groups across all behaviors ($p<0.0001$). In Models 4a-4d, both older age and normal diabetes status was adjusted for and the rate of change for BMI was significantly different comparing those with diabetes to those without ($p<0.0001$). However, this difference was not significant comparing those with prediabetes to those with a normal diabetes status, thus the prediabetes and normal categories were combined for the final models (Models 5a-5d). The longitudinal effects of obesity status at baseline (Models 6a-6d), race (Models 7a-7d), family history of diabetes (Models 8a-8d) and sex (Models 9a-9d) on BMI over time were not statistically significant for any behavior and were thus dropped from the final model as both predictors of initial status and change. Final models for all behaviors assessed stage of change, dichotomous age, and dichotomous diabetes status as predictors of both initial status and longitudinal change in BMI.

Results for the final models, assessing the differential associations of stages of change as the primary exposure with longitudinal BMI change, controlling for age and diabetes status as predictors of both initial status and change, are presented in **Table 6**. BMI significantly decreased at a rate of 0.126 kg/m^2 per year ($p<0.05$) among participants in the action stage of change for calorie reduction. However, participants in the precontemplation and contemplation stages for calorie reduction did not experience significantly different changes in BMI over time. Similar results were seen for fruit and vegetable intake; BMI significantly decreased at a rate of 0.155 kg/m^2 per year ($p<0.01$) among participants in the action stage. However, participants in the precontemplation, contemplation and maintenance stages for fruit and vegetable intake did

not experience significantly different changes in BMI over time. For fat reduction, BMI significantly decreased at a rate of 0.121 kg/m^2 per year ($p<0.05$) among participants in the action stage. The annual rate of decrease in BMI among participants in the precontemplation ($p<0.05$) and contemplation ($p<0.01$) stages was significantly greater compared to those in the action; however no difference was seen between maintenance and action stages. Lastly, BMI significantly decreased at a rate of 0.172 kg/m^2 per year ($p<0.001$) among participants in the action stage of change for exercise. However, participants in the precontemplation, contemplation and maintenance stages for exercise did not experience significantly different changes in BMI over time. Secondary results revealed that the annual rate of decrease in BMI was significantly faster among participants who were 65 and older and among those with diabetes.

DISCUSSION

This study investigated the associations of stage of change across four weight-related behaviors with longitudinal weight changes among overweight individuals in the Atlanta VA. Previous literature suggests that as individuals progress through each stage, their likelihood to partake in behaviors related to weight loss, such as healthy eating and exercise, increases [31 40]. Our primary aim was to assess whether individuals who were actively trying to make healthy changes would experience increased weight loss long term compared to their counterparts. Our primary findings are: (1) most participants were actively trying to make healthy behavior changes, (2) BMI was decreasing among individuals who were trying to make changes, but these individuals were not more successful at weight loss than their counterparts, (3) stage of change for fat reduction was most strongly associated with BMI changes, but

individuals actively making changes were less successful compared to those not trying, and (4) BMI was decreasing faster among older participants and those with diabetes.

The results of the bivariate analysis showed that most participants were actively trying to improve both diet and exercise behaviors. This is dissimilar to other studies assessing the effects of stage of change on weight related behaviors. Specifically, other studies showed that most, or all, of participants were in a pre-action stage, primarily preparation [31-33]. This may suggest that Veterans receiving primary care from the Atlanta VA healthcare system are receiving increased counseling and encouragement leading to increased initiative to engage in healthy behaviors, however more research in this area is needed.

The results of the multilevel modeling showed that BMI was significantly decreasing over time among those in the action phase, when controlling for age and diabetes status. This was an unexpected result, as nationally, weight in Veterans has been shown to significantly increase over time [36]. Additionally, results did not confirm our hypothesis that a self-identified action stage would be associated with greater weight loss over time compared to other stages. The BMI of those in the action phase did decrease over time, but not at a faster rate compared to those who were not trying. That is, all participants on average had lost weight over time. For action stages, our finding may be supported by research which has shown that while diet and exercise changes may produce meaningful short term weight loss, long-term weight maintenance is difficult to achieve and regain is common [42-44]. In a meta-analysis including 29 long-term weight loss studies, Anderson, Konz, Frederich, & Wood (2001) found that individuals regain over 80% of lost weight by year five [45]. Therefore, individuals who were actively trying to make healthy behavior changes may have had little overall weight loss over the entire period.

Fat reduction was the only behavior that resulted in significant differences in the rate of change for BMI between the stages, but those who were not trying to reduce their dietary fat intake were able to lose significantly more weight than those who were actively trying, or already consistently eating a low-fat diet. Although we do not have follow-up information on participant's success with the behavior itself, this finding suggests that reducing dietary fat does not result in long-term weight loss. This is supported by previous research showing that rise of the obesity epidemic is correlated with the recommendation of a low-fat diet by the U.S. Government in the late 1970's, possibly due to the replacement of fat with sugar and highly processed foods [46 47]. Additionally, studies show that low-fat diets do not result in significant amounts of lost weight long term, compared to other diets [48 49]. However, more research on fat reduction practices linked to pre-action stages would be useful.

Overall, BMI was decreasing at a faster rate among older participants and those with diabetes. While a longitudinal decrease in BMI was unexpected, there is some evidence to support these findings for our study population which had a mean age of 55 years. Specifically, while adults generally tend to gain weight through middle age, there is evidence suggesting that weight gain begins to plateau around age 50 and decrease around age 70 [50-52]. This is supported by national weight trends in Veterans which shows a decrease in weight among older adults and an increase in weight among younger adults [36]. Additionally, a faster decrease in BMI among participants who were found to have diabetes is consistent with previous literature. The American Diabetes Association and the European Association for the Study of Diabetes recommends that initial treatment of type 2 diabetes include lifestyle interventions and metformin initiation [53]. Multiple studies have shown a weight loss benefit associated with metformin initiation [54] including the Diabetes Prevention Study which found that participants

taking metformin had significantly reduced body weight compared with the placebo group, and the magnitude of weight loss was directly correlated with adherence [55]. This may also be explained by the nature of the original Screening for Diabetes and Prediabetes in Primary Care study. Specifically, participants who had not previously been diagnosed with diabetes were provided glucose challenge test and oral glucose tolerance test results, many for the first time [38]. The review of these results could have incited a self-directed motivation to be healthier, especially among those who were newly diagnosed with diabetes.

This study exhibits multiple strengths. The primary strength is the use of longitudinal data to explore the association between stage of change and weight changes over a period time greater than 8 years for most participants, representing follow-up time up to 4 times longer than other studies examining stage of change. Previous research studying stage of change has focused on a follow-up period of 1-24 months [31-33]. Additionally, the study sample was fairly large with a total population size of 886 participants, a similar size to two other studies and significantly larger than a third. This allowed for improved estimation of sample means and reduced error. Lastly, this is the first study to assess stage of change as the primary exposure for analysis of weight changes over time. Other studies are primarily focused on assessing the effects of a specific clinical weight loss intervention, with stage of change as a secondary analysis. However, since most people do not participate in clinical weight loss interventions in their lifetime, and weight loss success relies on complex behavioral changes, examining associations between stage of change and weight trends without the implementation of an intervention may fill gaps in understanding barriers to weight loss.

Despite the strengths of this study, several limitations should be considered. First, while the original study population was collected using patients in VA waiting rooms, not all

participants were Veterans. Therefore, study results may not be generalizable to the larger Veteran population or to others across the U.S. Second, misclassification bias may have been introduced into the results due to the nature of the PACE+ questionnaire administered to participants at baseline. Specifically, the questionnaire did not assess all five stages of change, and questions may have been interpreted inconsistently by participants across different behaviors. However, we tried to reduce this bias by limiting the stages to 3 categories for the calorie reduction to minimize differences in the population. Lastly, the study was limited in the number of confounders it assessed. Research shows that weight changes, especially in older adults, have been associated with a number of factors such as the presence and amount of comorbidities, current medications, psychosocial disorders, smoking status, socioeconomic status and marital status [52 56]. Therefore, additional research is necessary to explore these associations with stage of change.

This study adds to the research on obesity control, a continuously growing issue in the United States. It supports a growing body of research showing that long term weight loss is difficult and motivation alone may not be enough to achieve meaningful results. There are many areas for future research to explore in support of this study. First, future studies should develop an improved survey that assesses stage of change more precisely, or utilize an interview style assessment, and conduct the survey periodically to determine how progression and cycling through the stages may affect weight outcomes. Additionally, future work could assess the effects of additional co-morbidities and medications, study the gender- and age-based associations more extensively, or explore the effects of administering the survey itself. Finally, the effects of changing multiple behaviors at once, compared to just one, on longitudinal weight fluctuations should be studied further.

Chapter III: Public Health Implications and Future Research

PUBLIC HEALTH IMPLICATIONS

The increasing prevalence of obesity, especially among the Veteran population, underscores the urgency in developing meaningful weight loss interventions. In this study population alone, over 60% of participants were obese and previous research has shown that, nationally, Veterans are gaining significant amounts of weight over time [36]. In order to develop interventions that are meaningful, it is important to understand the various factors contributing to weight changes. We found that age and diabetes status were significantly associated with weight change over time. Specifically, younger participants without diabetes were gaining more weight compared to their older, counterparts with diabetes. Previous research shows that annual weight gain is associated with a significant increase in risk of developing diabetes [57]. Therefore, our results suggest that younger individuals without diagnosed diabetes could be targeted for preventative interventions early on to help prevent the progression of obesity and development of diabetes.

However, when developing interventions, the results of this study are important to consider as it showed that individuals who were actively trying to make healthy behavior changes were not more successful at reducing their weight long-term than their counterparts, who were not trying. For many years it was thought that the primary reason weight loss interventions fail was due to a lack of motivation, will power, or desire on behalf of obese individuals [58]. However, more recent research shows that long term weight loss is complex and not merely based on individual action. For example, there are specific physiological changes that occur in response to weight loss that favor weight regain such as decreased energy expenditure and endocrine disruptions leading to increased appetite, decreased satiety and altered

nutrient metabolism [59-61]. Additional non-biological factors such as the level of social support available to patients, the food environment, mental stability and socioeconomic factors are all important aspects to consider.

FUTURE RESEARCH

In order to develop weight loss recommendations, specifically for the Veteran population regarding the stage of change theory, there are a number of future studies that could be explored. First, we did not assess the association of combined categories, however previous research has shown that individuals engaging in multiple behavior changes simultaneously were more successful [31]. Therefore, future work could assess how longitudinal weight fluctuations among individuals who were trying to change multiple behaviors compared to those attempting to change just one or two.

Older participants in our study population, and nationally, were found to be losing weight more rapidly than younger Veterans [36]. Therefore, a second area of future research could examine why younger people, even those actively trying to make healthy behavior changes, have a difficult time losing weight and maintaining lost weight. Additionally, future studies could assess how baseline stage of change, as well as, cycling through the stages, differentially impacts short term vs. long term weight change and weight maintenance.

While the VA predicts that women comprise only 10% of the Veteran population, Tamas, Khakharia, Rothenberg, & Phillips (2018) found significant differences between the weight trends of men and women. Women without diabetes were gaining significantly more weight than men both with and without diabetes. Therefore, another area of future work could explore more closely how stage of change impacts weight changes differently in women compared to men.

Our study was limited in the number of predictors it assessed. Research shows that weight changes, especially in older adults, have been associated with a number of factors especially the presence and amount of comorbidities an individual has and the medications they use [52 56]. Therefore, additional research is necessary to explore how comorbidities could affect both a participant's baseline stage of change and its effect on weight over time.

Another important aspect to be explored is the potential effect of the administration of the survey on participant's weight. Future research could analyze weight data from a matched cohort of individuals from the VA in Atlanta who did not participate in the original Screening for Diabetes and Prediabetes in Primary Care study. Longitudinal weight changes of the matched cohort could be compared to those who were included in this study to determine if merely asking the stage of change questions had a significant impact on weight.

Lastly, methodology improvements could be made to the current study, specifically to the way stage of change was assessed. The PACE+ questionnaire used to assess stage of change could be improved to include all five stages of change in a clear and consistent manner across the various behaviors. Alternatively, an interview-style assessment could be employed, allowing a more complete understanding of the participant's readiness to change. Interviews could collect more comprehensive information about participant's current state of mind as well as past changes they may have made. This would allow future studies to accurately take into account the temporal aspect of participant's stage as well as assess how past cycling through stages may affect weight fluctuations.

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Tables

Table 1a. Comparison of Baseline Characteristics across Stages of Change for Calorie Intake Behavior

	Overall Sample n = 886		**Precontemplation** n = 66 (7.5%)		**Contemplation** n = 279 (31.5%)		**Action** n = 541 (61.1%)		p*
BMI (kg/m^2)	32.5	(4.9)	32.1	(0.6)	32.0	(0.3)	32.9	(0.2)	0.045
Weight (kg)	102.9	(17.6)	102.8	(2.2)	101.2	(1.1)	103.7	(0.8)	0.148
Age (years)	55.1	(10.4)	57.8	(1.3)	56.1	(0.6)	54.3	(0.4)	0.007
Diabetes Status									0.431
Diabetes	104	(11.7%)	7	(6.7%)	40	(38.5%)	57	(54.8%)	
Prediabetes	395	(44.5%)	32	(7.0%)	114	(28.9%)	248	(60.8%)	
Normal	388	(43.8%)	27	(8.1%)	125	(32.2%)	236	(62.9%)	
Age									0.001
< 65	745	(84.1%)	45	(6.0%)	235	(31.5%)	465	(62.4%)	
≧ 65	141	(15.9%)	21	(14.9%)	44	(31.2%)	76	(53.9%)	
BMI Category									0.330
Normal	22	(2.5%)	3	(13.6%)	9	(40.9%)	10	(45.5%)	
Overweight	272	(30.7%)	22	(8.1%)	92	(33.8%)	158	(58.1%)	
Obese	592	(66.8%)	41	(6.9%)	178	(30.1%)	373	(63.0%)	
Race									0.684
Black	639	(72.1%)	50	(7.8%)	203	(31.8%)	386	(60.4%)	
White	233	(26.3%)	14	(6.0%)	73	(21.4%)	146	(62.7%)	
Other	14	(1.6%)	2	(14.4%)	3	(31.3%)	9	(64.3%)	
Family History of Diabetes									0.246
No	452	(51.1%)	42	(9.3%)	140	(31.0%)	270	(59.7%)	
Yes	424	(47.9%)	24	(5.7%)	134	(31.6%)	266	(62.7%)	
Did not answer	9	(1.0%)	0	0	4	(44.4%)	5	(55.6%)	
Sex									0.006
Male	817	(92.2%)	66	(8.1%)	263	(32.2%)	488	(59.7%)	
Female	69	(7.8%)	0	0	16	(23.2%)	53	(76.8%)	

*p-value comparing stage of change
Data represent mean (SD) for continuous variables and n (%) for categorical variables

Table 1b. Comparison of Baseline Characteristics across Stage of Change for Fruit Intake Behavior

	Overall Sample	Precontemplation	Contemplation	Action	Maintenance	
	n = 866	n = 97 (11.0%)	n = 312 (35.2%)	n = 416 (47.0%)	n = 61 (6.9%)	p*
BMI (kg/m^2)	32.5 (4.9)	31.8 (0.5)	32.4 (0.3)	32.8 (0.2)	32.3 (0.6)	0.231
Weight (kg)	102.9 (17.6)	99.8 (1.8)	103.1 (1.0)	103.2 (0.9)	104.5 (2.3)	0.300
Age	55.1 (10.4)	57.2 (1.0)	54.0 (0.6)	55.0 (0.5)	58.9 (1.3)	0.001
Diabetes Status						0.489
Diabetes	104 (11.7%)	14 (13.5%)	31 (29.8%)	54 (51.9%)	5 (4.8%)	
Prediabetes	395 (44.5%)	48 (9.0%)	135 (37.6%)	183 (46.1%)	28 (7.1%)	
Normal	388 (43.8%)	35 (12.2%)	146 (34.3%)	179 (46.5%)	28 (7.2%)	
Age						0.0002
< 65	745 (84.1%)	74 (9.9%)	276 (37.1%)	353 (47.4%)	42 (5.6%)	
≧ 65	141 (15.9%)	23 (16.3%)	36 (25.5%)	63 (44.7%)	19 (13.5%)	
BMI Category						0.618
Normal	22 (2.5%)	3 (13.6%)	9 (40.9%)	9 (40.9%)	1 (4.6%)	
Overweight	272 (30.7%)	36 (13.2%)	95 (34.9%)	119 (43.8%)	22 (8.1%)	
Obese	592 (66.8%)	58 (9.8%)	208 (35.1%)	288 (48.7%)	38 (6.4%)	
Race						0.217
Black	639 (72.1%)	66 (10.3%)	240 (37.6%)	295 (46.2%)	38 (6.0%)	
White	233 (26.3%)	30 (12.9%)	67 (28.8%)	114 (48.9%)	22 (9.4%)	
Other	14 (1.6%)	1 (7.1%)	5 (35.7%)	7 (50.0%)	1 (7.1%)	
Family History of Diabetes						0.174
No	452 (51.1%)	56 (12.4%)	169 (37.4%)	193 (42.7%)	34 (7.5%)	
Yes	424 (47.9%)	39 (9.2%)	141 (33.3%)	218 (51.4%)	26 (6.1%)	
Did not answer	9 (1.0%)	2 (22.2%)	2 (22.2%)	4 (44.4%)	1 (11.1%)	

Sex											0.0001
Male	817	(92.2%)	95	(11.6%)	300	(36.7%)	369	(45.2%)	53	(6.5%)	
Female	69	(7.8%)	2	(2.9%)	12	(17.4%)	47	(68.1%)	8	(11.6%)	

*p-value comparing stage of change

Data represent mean (SD) for continuous variables and n (%) for categorical variables

Table 1c. Comparison of Baseline Characteristics across Stage of Change for Fat Reduction Behavior

	Overall Sample		**Precontemplation**		**Contemplation**		**Action**		**Maintenance**		
	n = 866		n = 101 (11.4%)		n = 265 (29.9%)		n = 453 (51.1%)		n = 67 (7.6%)		p*
BMI (kg/m^2)	32.5	(4.9)	31.1	(0.5)	32.5	(0.3)	33.0	(0.2)	32.1	(0.6)	0.006
Weight (kg)	102.9	(17.6)	98.3	(1.8)	102.9	(1.1)	104.3	(0.8)	99.8	(2.1)	0.008
Age	55.1	(10.4)	57.6	(1.0)	53.2	(0.6)	55.5	(0.5)	56.6	(1.3)	0.001
Diabetes Status											0.187
Diabetes	104	(11.7%)	9	(8.7%)	31	(29.8%)	58	(55.8%)	6	(5.8%)	
Prediabetes	395	(44.5%)	47	(11.9%)	120	(30.5%)	206	(52.3%)	21	(5.3%)	
Normal	388	(43.8%)	45	(11.6%)	114	(29.4%)	189	(48.7%)	40	(10.3%)	
Age											0.017
< 65	745	(84.1%)	83	(11.1%)	238	(32.0%)	372	(49.9%)	52	(7.0%)	
≧ 65	141	(15.9%)	18	(12.8%)	27	(19.2%)	81	(57.5%)	15	(10.6%)	
BMI Category											0.068
Normal	22	(2.5%)	4	(18.2%)	9	(40.9%)	7	(31.8%)	2	(9.1%)	
Overweight	272	(30.7%)	41	(15.1%)	83	(30.5%)	125	(46.0%)	23	(8.5%)	
Obese	592	(66.8%)	56	(9.5%)	173	(29.2%)	321	(54.2%)	42	(7.1%)	
Race											0.073
Black	639	(72.1%)	69	(10.8%)	208	(32.6%)	316	(49.5%)	46	(7.2%)	
White	233	(26.3%)	31	(13.3%)	54	(23.2%)	130	(55.8%)	18	(7.7%)	

Other	14	(1.6%)	1	(7.1%)	3	(21.4%)	7	(50.0%)	3	(21.4%)	
Family History of Diabetes											0.981
No	452	(51.1%)	53	(11.7%)	136	(30.1%)	226	(50.0%)	37	(8.2%)	
Yes	424	(47.9%)	47	(11.1%)	126	(29.7%)	222	(52.4%)	29	(6.8%)	
Did not answer	9	(1.0%)	1	(11.1%)	3	(33.3%)	4	(44.4%)	1	(11.1%)	
Sex											0.012
Male	817	(92.2%)	99	(12.1%)	248	(30.4%)	413	(50.6%)	57	(7.0%)	
Female	69	(7.8%)	2	(2.9%)	17	(24.6%)	40	(58.0%)	10	(14.5%)	

*p-value comparing stage of change

Data represent mean (SD) for continuous variables and n (%) for categorical variables

Table 1d. Comparison of Baseline Characteristics across Stage of Change for Exercise Behavior

	Overall Sample		**Precontemplation**		**Contemplation**		**Action**		**Maintenance**		
	n = 866		n = 77 (8.7%)		n = 229 (25.9%)		n = 503 (56.8%)		n = 77 (8.7%)		p*
BMI (kg/m^2)	32.5	(4.9)	32.1	(0.6)	32.7	(0.3)	32.7	(0.2)	31.4	(0.6)	0.121
Weight (kg)	102.9	(17.6)	101.2	(2.0)	103.8	(1.2)	103.2	(0.8)	99.6	(2.0)	0.247
Age	55.1	(10.4)	57.4	(1.2)	54.7	(0.7)	54.4	(0.5)	58.8	(1.2)	0.001
Diabetes Status											0.136
Diabetes	104	(11.7%)	11	(10.6%)	35	(33.7%)	51	(49.0%)	7	(6.7%)	
Prediabetes	395	(44.5%)	31	(7.9%)	111	(28.2%)	218	(55.3%)	34	(8.6%)	
Normal	388	(43.8%)	35	(9.0%)	83	(21.4%)	234	(60.3%)	36	(9.3%)	
Age											0.006
< 65	745	(84.1%)	61	(8.2%)	203	(27.3%)	425	(57.1%)	56	(7.5%)	
≧ 65	141	(15.9%)	16	(11.4%)	26	(18.4%)	78	(55.3%)	21	(14.9%)	
BMI Category											0.162
Normal	22	(2.5%)	2	(9.1%)	6	(27.3%)	14	(63.6%)	0	0	
Overweight	272	(30.7%)	24	(8.8%)	71	(26.1%)	143	(52.6%)	34	(12.5%)	
Obese	592	(66.8%)	51	(8.6%)	152	(25.7%)	346	(58.5%)	43	(7.3%)	

Race											0.080
Black	639	(72.1%)	48	(7.5%)	165	(25.8%)	382	(59.8%)	44	(6.9%)	
White	233	(26.3%)	28	(12.0%)	60	(25.8%)	115	(49.4%)	30	(12.9%)	
Other	14	(1.6%)	1	(7.1%)	4	(28.6%)	6	(42.9%)	3	(21.4%)	
Family History of Diabetes											0.326
No	452	(51.1%)	45	(10.0%)	115	(25.4%)	256	(56.6%)	36	(8.0%)	
Yes	424	(47.9%)	32	(7.6%)	109	(25.7%)	243	(57.3%)	40	(9.4%)	
Did not answer	9	(1.0%)	0	0	5	(55.6%)	4	(44.4%)	0	0	
Sex											0.062
Male	817	(92.2%)	76	(9.3%)	214	(26.2%)	455	(55.7%)	72	(8.8%)	
Female	69	(7.8%)	1	(1.5%)	15	(21.7%)	48	(69.6%)	5	(7.3%)	

*p-value comparing stage of change

Data represent mean (SD) for continuous variables and n (%) for categorical variables

Table 2. Parameter Estimates for Mixed Modeling Assessing Stage of Calorie Intake Change as Primary Exposure Models

	Model 1		**Model 2a**		**Model 3a**		**Model 4a**		**Model 5a**	
Variable	β	SE	β	SE	β	SE	β	SE	β	SE
Years	-0.053**	(0.02)	-0.017	(0.02)	-0.168***	(0.05)	-0.101	(0.05)	-0.126*	(0.05)
Years*Precontemplation			-0.096	(0.07)	-0.065	(0.07)	-0.065	(0.07)	-0.066	(0.07)
Years*Contemplation			-0.092*	(0.04)	-0.089*	(0.04)	-0.077	(0.04)	-0.075	(0.04)
Years*Action (referent)										
Years*Age < 65					0.175***	(0.05)	0.162**	(0.05)	0.165**	(0.05)
Years*Age ≧ 65 (referent)										
Years*Baseline Diabetes							-0.343***	(0.06)		
Years*Baseline Pre-Diabetes							-0.043	(0.04)		
Years*Baseline Diabetes Normal (referent)										
Years*Baseline Diabetes									-0.321***	(0.06)
Years*Baseline Diabetes Normal (referent)										

Table 2. Continued

	Model 6a		Model 7a		Model 8a		Model 9a	
Variable	β	SE	β	SE	β	SE	β	SE
Years	-0.063	(0.13)	-0.122*	(0.05)	-0.104	(0.06)	-0.132*	(0.05)
Years*Precontemplation	-0.067	(0.07)	-0.069	(0.07)	-0.063	(0.07)	-0.058	(0.07)
Years*Contemplation	-0.075	(0.04)	-0.068	(0.04)	-0.074	(0.04)	-0.072	(0.04)
Years*Action (referent)								
Years*Age < 65	0.159**	(0.05)	0.179**	(0.05)	0.161**	(0.05)	0.163**	(0.05)
Years*Age ≧ 65 (referent)								
Years*Baseline Diabetes	-0.321***	(0.06)	-0.323***	(0.06)	-0.326***	(0.06)	-0.322***	(0.06)
Years*Baseline Diabetes Normal (referent)								
Years*BMI Category Obese	-0.047	(0.12)						
Years*BMI Category Overweight	-0.087	(0.12)						
Years*BMI Category Normal (referent)								
Years*Race Black			-0.037	(0.04)				
Years*Race Other			0.643***	(0.16)				
Years*Race White (referent)								
Years*HxDiabetes No					-0.034	(0.04)		
Years*HxDiabetes Yes (referent)								
Years*Female							0.090	(0.07)
Years*Male (referent)								

*** *p* < .05; ** *p* < .01; *** *p* < .001**

Each model incudes the individual variables in addition to their interaction with time. For the stepwise model building, only significant variables whose interaction with time was significant were included in forward models. Model 5 was selected as the final model.

Table 3. Parameter Estimates for Mixed Modeling Assessing Fruit and Vegetable Intake SOC as Primary Exposure

	Model 1		Model 2b		Model 3b		Model 4b		Model 5b	
Variable	β	SE	β	SE	β	SE	β	SE	β	SE
Years	-0.053**	(0.02)	-0.052	(0.03)	-0.206***	(0.05)	-0.132*	(0.06)	-0.155**	(0.05)
Years*Precontemplation			-0.050	(0.06)	-0.034	(0.06)	-0.028	(0.06)	-0.030	(0.06)
Years*Contemplation			0.008	(0.04)	0.0020	(0.04)	-0.010	(0.04)	-0.009	(0.04)
Years*Maintenance			0.018	(0.08)	0.045	(0.08)	0.027	(0.07)	0.028	(0.07)
Years*Action (referent)										
Years*Age < 65					0.182***	(0.05)	0.169***	(0.05)	0.172***	(0.05)
Years*Age ≧ 65 (referent)										
Years*Baseline Diabetes							-0.346***	(0.06)		
Years*Baseline Pre-Diabetes							-0.040	(0.04)		
Years*Baseline Diabetes Normal (referent)										
Years*Baseline Diabetes									-0.326***	(0.06)
Years*Baseline Diabetes Normal (referent)										

Table 3. Continued

	Model 6b		Model 7b		Model 8b		Model 9b	
Variable	β	SE	β	SE	β	SE	β	SE
Years	-0.102	(0.13)	-0.148**	(0.06)	-0.135*	(0.06)	-0.162**	(0.06)
Years*Precontemplation	-0.029	(0.06)	-0.027	(0.06)	-0.02	(0.06)	-0.022	(0.06)
Years*Contemplation	-0.008	(0.04)	-0.007	(0.04)	-0.006	(0.04)	-0.001	(0.04)
Years*Maintenance	0.029	(0.07)	0.025	(0.07)	0.037	(0.08)	0.025	(0.07)
Years*Action (referent)								
Years*Age < 65	0.166**	(0.05)	0.186***	(0.05)	0.167**	(0.05)	0.167**	(0.05)
Years*Age ≧ 65 (referent)								
Years*Baseline Diabetes	-0.327***	(0.06)	-0.327***	(0.06)	-0.330***	(0.06)	-0.327***	(0.06)
Years*Baseline Diabetes Normal (referent)								
Years*BMI Category Obese	-0.036	(0.12)						

Years*BMI Category Overweight	-0.079	(0.12)								
Years*BMI Category Normal (referent)										
Years*Race Black			-0.039	(0.04)						
Years*Race Other			0.648***	(0.16)						
Years*Race White (referent)										
Years*HxDiabetes No					-0.035	(0.04)				
Years*HxDiabetes Yes (referent)										
Years*Female							-0.096	(0.07)		
Years*Male (referent)										

~ *p* < .10; * *p* < .05; ** *p* < .01; * *p* < .001**

Each model incudes the individual variables in addition to their interaction with time. For the stepwise model building, only significant variables whose interaction with time was significant were included in forward models. Model 5 was selected as the final model.

Table 4. Parameter Estimates for Mixed Modeling Assessing Fat Reduction SOC as Primary Exposure

	Model 1		**Model 2c**		**Model 3c**		**Model 4c**		**Model 5c**	
Variable	β	SE	β	SE	β	SE	β	SE	β	SE
Years	-0.053**	(0.02)	-0.012	(0.03)	-0.172***	(0.05)	-0.098~	(0.05)	-0.121*	(0.05)
Years*Precontemplation			-0.105~	(0.06)	-0.105~	(0.06)	-0.119*	(0.06)	-0.118*	(0.06)
Years*Contemplation			-0.101*	(0.04)	-0.116**	(0.04)	-0.119**	(0.04)	-0.119**	(0.04)
Years*Maintenance			0.010	(0.07)	0.019	(0.07)	0.0002	(0.07)	0.006	(0.07)
Years*Action (referent)										
Years*Age < 65					0.195***	(0.05)	0.181***	(0.05)	0.185***	(0.05)
Years*Age ≧ 65 (referent)										
Years*Baseline Diabetes							-0.351***	(0.06)		
Years*Baseline Pre-Diabetes							-0.040	(0.04)		
Years*Baseline Diabetes Normal (referent)										
Years*Baseline Diabetes									-0.330***	(0.06)
Years*Baseline Diabetes Normal (referent)										

Table 4. Continued

	Model 6c		Model 7c		Model 8c		Model 9c	
Variable	β	SE	β	SE	β	SE	β	SE
Years	-0.053	(0.13)	-0.116*	(0.05)	-0.010	(0.06)	-0.125*	(0.05)
Years*Precontemplation	-0.115	(0.06)	-0.116*	(0.06)	-0.112	(0.06)	-0.112	(0.06)
Years*Contemplation	-0.118**	(0.04)	-0.113**	(0.04)	-0.117**	(0.04)	-0.116**	(0.04)
Years*Maintenance	0.007	(0.07)	-0.004	(0.07)	0.014	(0.07)	0.001	(0.07)
Years*Action (referent)								
Years*Age < 65	0.179***	(0.05)	0.197***	(0.05)	0.179***	(0.05)	0.181**	(0.05)
Years*Age ≧ 65 (referent)								
Years*Baseline Diabetes	-0.330***	(0.06)	-0.332***	(0.06)	-0.335***	(0.06)	-0.332***	(0.06)
Years*Baseline Diabetes Normal (referent)								
Years*BMI Category Obese	-0.055	(0.12)						
Years*BMI Category Overweight	-0.089	(0.12)						
Years*BMI Category Normal (referent)								
Years*Race Black			-0.035	(0.04)				
Years*Race Other			0.638***	(0.16)				
Years*Race White (referent)								
Years*HxDiabetes No					-0.034	(0.04)		
Years*HxDiabetes Yes (referent)								
Years*Female							-0.081	(0.07)
Years*Male (referent)								

*** *p* < .05; ** *p* < .01; *** *p* < .001**

Each model incudes the individual variables in addition to their interaction with time. For the stepwise model building, only significant variables whose interaction with time was significant were included in forward models. Model 5 was selected as the final model.

Table 5. Parameter Estimates for Mixed Modeling Assessing Exercise SOC as Primary Exposure

	Model 1		Model 2d		Model 3d		Model 4d		Model 5d	
Variable	β	SE	β	SE	β	SE	β	SE	β	SE
Years	-0.053**	(0.02)	-0.060*	(0.02)	-0.215***	(0.05)	-0.148**	(0.05)	-0.172***	(0.05)
Years*Precontemplation			-0.081	(0.07)	-0.072	(0.07)	-0.059	(0.07)	-0.058	(0.07)
Years*Contemplation			0.030	(0.04)	0.023	(0.04)	0.044	(0.04)	0.040	(0.04)
Years*Maintenance			0.071	(0.07)	0.092	(0.07)	0.087	(0.07)	0.088	(0.07)
Years*Action (referent)										
Years*Age < 65					0.183***	(0.05)	0.168***	(0.05)	0.172***	(0.05)
Years*Age ≧ 65 (referent)										
Years*Baseline Diabetes							-0.349***	(0.06)		
Years*Baseline Pre-Diabetes							-0.044	(0.04)		
Years*Baseline Diabetes Normal (referent)										
Years*Baseline Diabetes									-0.327***	(0.06)
Years*Baseline Diabetes Normal (referent)										

Table 5. Continued

	Model 6d		Model 7d		Model 8d		Model 9d	
Variable	β	SE	β	SE	β	SE	β	SE
Years	-0.113	(0.13)	-0.159**	(0.05)	-0.151**	(0.06)	-0.178**	(0.05)
Years*Precontemplation	-0.058	(0.07)	-0.065	(0.07)	-0.055	(0.07)	-0.050	(0.07)
Years*Contemplation	0.041	(0.04)	0.036	(0.04)	0.046	(0.04)	0.043	(0.04)
Years*Maintenance	0.095	(0.07)	0.063	(0.07)	0.087	(0.07)	0.090	(0.07)
Years*Action (referent)								
Years*Age < 65	0.165**	(0.05)	0.185***	(0.05)	0.167**	(0.05)	0.168**	(0.05)
Years*Age ≧ 65 (referent)								
Years*Baseline Diabetes	-0.328***	(0.06)	-0.329***	(0.06)	-0.332***	(0.06)	-0.329***	(0.06)
Years*Baseline Diabetes Normal (referent)								
Years*BMI Category Obese	-0.040	(0.12)						

Years*BMI Category Overweight	-0.088	(0.12)						
Years*BMI Category Normal (referent)								
Years*Race Black			-0.040	(0.04)				
Years*Race Other			0.639***	(0.16)				
Years*Race White (referent)								
Years*HxDiabetes No					-0.032	(0.04)		
Years*HxDiabetes Yes (referent)								
Years*Female							-0.099	(0.07)
Years*Male (referent)								

*** *p* < .05; ** *p* < .01; *** *p* < .001**

Each model incudes the individual variables in addition to their interaction with time. For the stepwise model building, only significant variables whose interaction with time was significant were included in forward models. Model 5 was selected as the final model.

Table 6. Longitudinal Change in BMI Assessing Calorie Intake SOC as Primary Exposure

	Calorie Intake		Fruit/Veg Intake		Fat Reduction		Exercise	
Variable	β	SE	β	SE	β	SE	β	SE
Years	-0.126*	(0.05)	-0.155**	(0.05)	-0.121*	(0.05)	-0.172***	(0.05)
Years*Precontemplation	-0.066	(0.07)	-0.030	(0.06)	-0.118*	(0.06)	-0.058	(0.07)
Years*Contemplation	-0.075	(0.04)	-0.009	(0.04)	-0.119**	(0.04)	0.040	(0.04)
Years*Maintenance	-	-	0.028	(0.07)	0.006	(0.07)	0.088	(0.07)
Years*Action (referent)								
Years*Age < 65	0.165**	(0.05)	0.172***	(0.05)	0.185***	(0.05)	0.172***	(0.05)
Years*Age ≧ 65 (referent)								
Years*Baseline Diabetes	-0.321***	(0.06)	-0.326***	(0.06)	-0.330***	(0.06)	-0.327***	(0.06)
Years*Baseline Diabetes Normal (referent)								

*** *p* < .05; ** *p* < .01; *** *p* < .001**

The final models from the model building exercise where each model incudes the individual variables in addition to their interaction with time.

Figures

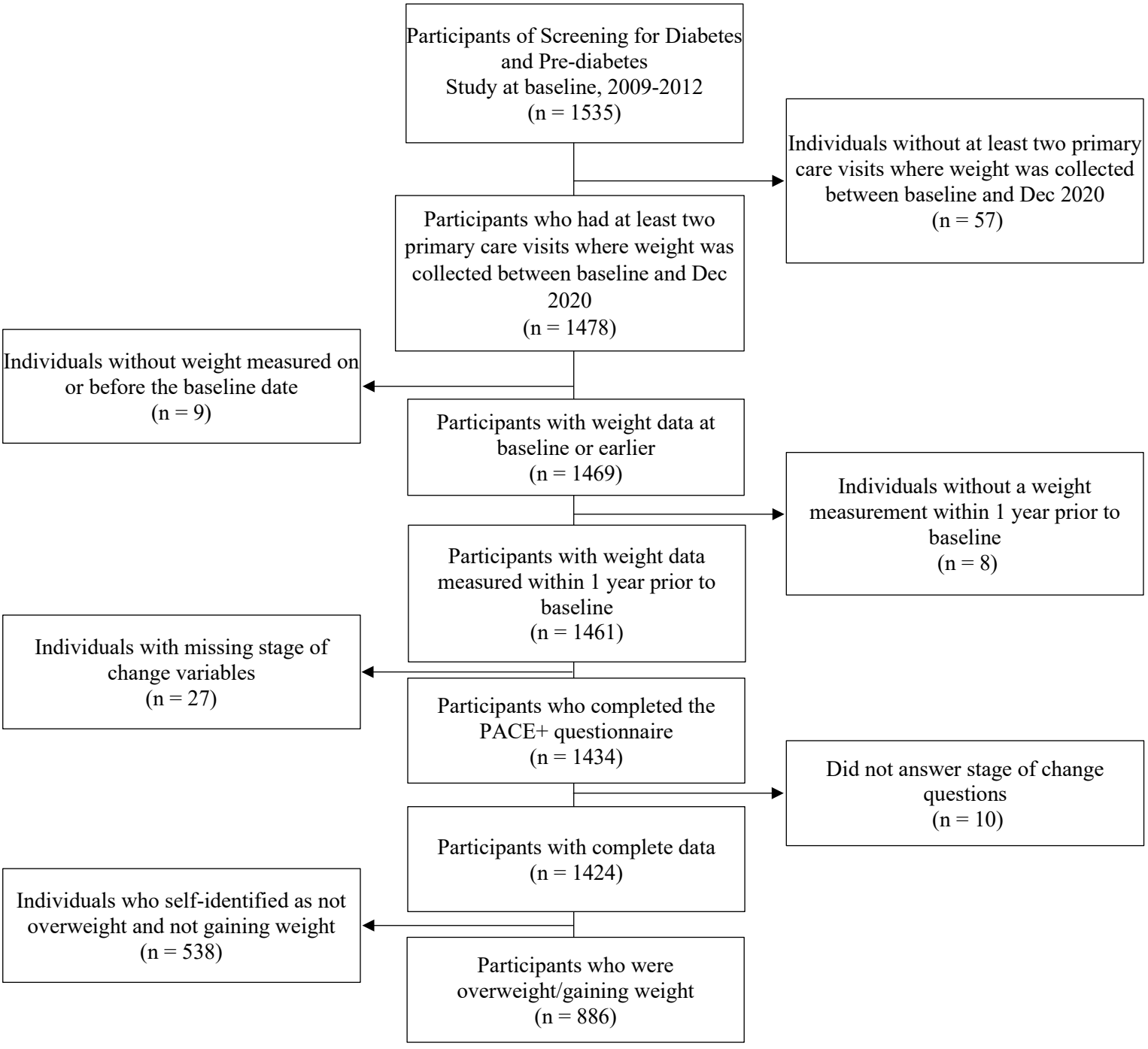


Figure 1. Flowchart of Exclusion Criteria

Please check one number that best describes your current dietary status:	**1**	I am gaining weight or am already overweight and I don't intend to reduce my calorie intake consistently in the next 6 months	Precontemplation
	2	I am gaining weight or am already overweight and I have been thinking about consistently reducing my calorie intake in the next 6 months	Contemplation
	3	I am gaining weight or am already overweight and I am trying to make a serious effort to reduce my calorie intake but I don't do it consistently	Action
	4	I am not overweight and have not been gaining weight	Excluded
	99	did not answer	Excluded
Fruit and Vegetable Intake	**1**	I eat fewer than 5 servings per day of fruits and vegetables and don't intend to start eating more fruits and vegetables in the next 6 months	Precontemplation
	2	I eat fewer than 5 servings per day of fruits and vegetables and have been thinking about starting to eat more in the next 6 months	Contemplation
	3	I am trying to eat 5 servings of fruits and vegetables each day but don't do it consistently	Action
	4	I consistently eat 5 or more servings per day of fruits and vegetables	Maintenance
	99	did not answer	Excluded
Dietary Fat Intake	**1**	I do not eat a low-fat diet and I don't intend to start eating a consistently low-fat diet in the next 6 months	Precontemplation
	2	I do not eat a low-fat diet but I have been thinking about starting to eat a consistently low-fat diet in the next 6 months	Contemplation
	3	I am trying to eat a low-fat diet but I don't do it consistently	Action
	4	I consistently eat a low-fat diet	Maintenance
	99	did not answer	Excluded
Please check one number that best describes your current exercise status:	**1**	I don't do regular vigorous or moderate exercise now and I don't intend to start in the next 6 months	Precontemplation
	2	I don't do regular vigorous or moderate exercise now but I have been thinking of starting in the next 6 months	Contemplation
	3	I'm trying to start doing vigorous or moderate exercise but I don't do it regularly	Action
	4	I'm doing vigorous exercise less than 3 times per week (or) moderate exercise less than 5 times per week	Action

	5	I've been doing 30 minutes a day of moderate exercise 5 or more days per week for the last 1-5 months	Action
	6	I've been doing 30 minutes a day of moderate exercise 5 or more days per week for the last 6 months or more	Maintenance
	7	I've been doing vigorous exercise 3 or more days per week for the last 1-5 months	Action
	8	I've been doing vigorous exercise 3 or more days per week for the last 6 months or more	Maintenance
	99	did not answer	Excluded

Figure 2. PACE+ Questionnaire and Stage of Change Assignments
Participants were issued these questions at baseline to assess their readiness to make behavior changes.

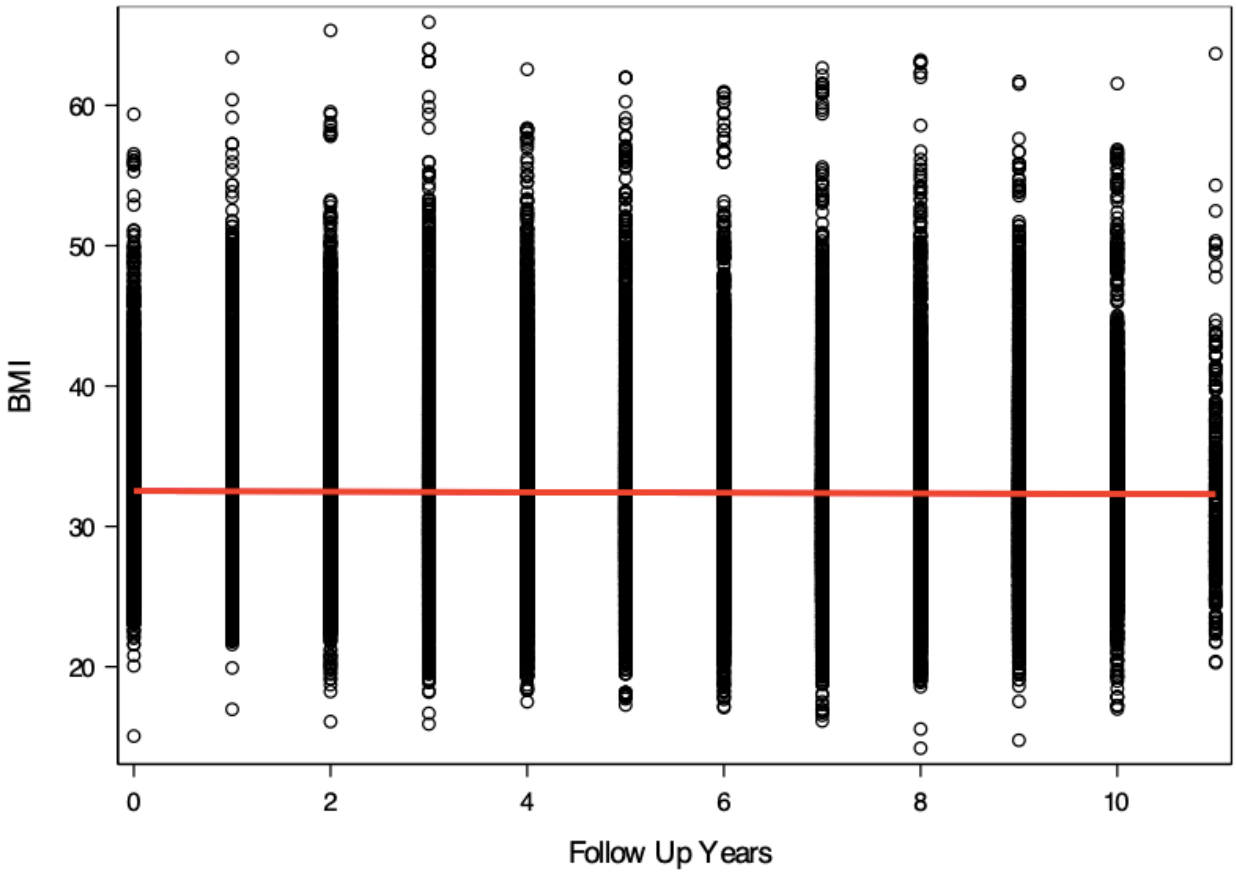
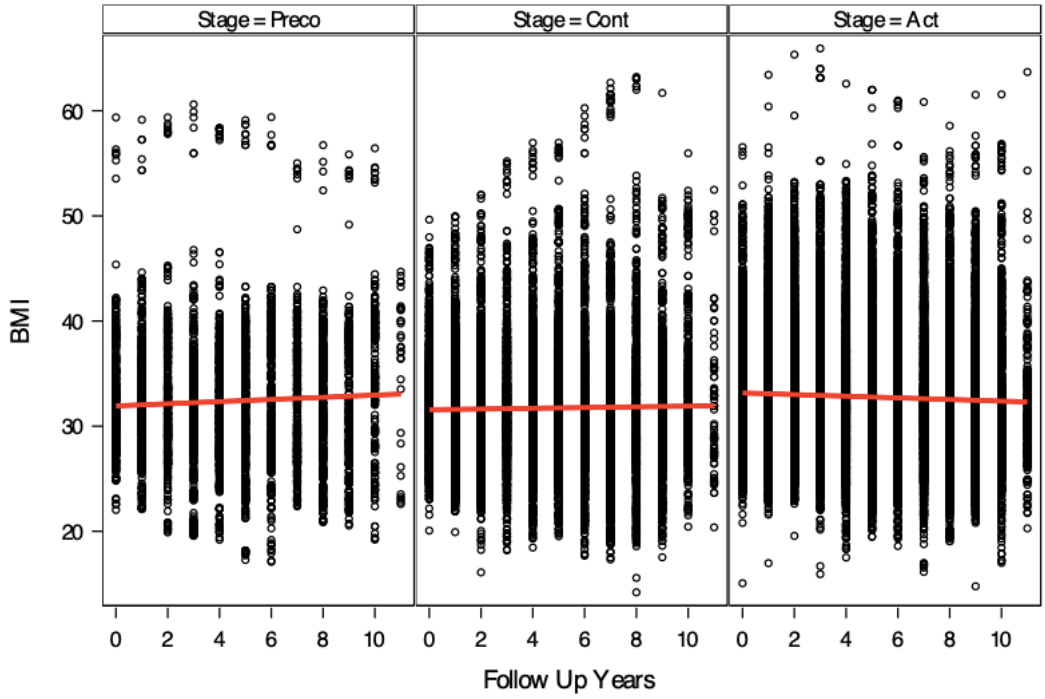
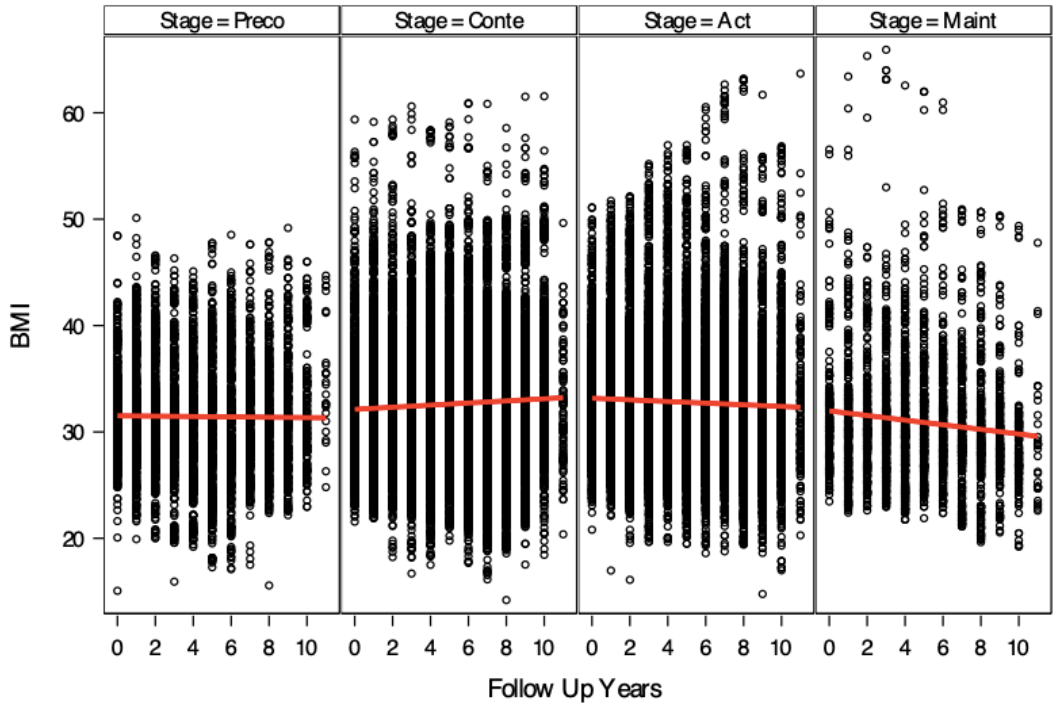


Figure 3. Mean BMI over Time. BMI, Body Mass Index (kg/m^2). Mean BMI was calculated per person per year of follow up and graphed over time. Red regression line represents the predicted trend in mean BMI over time.

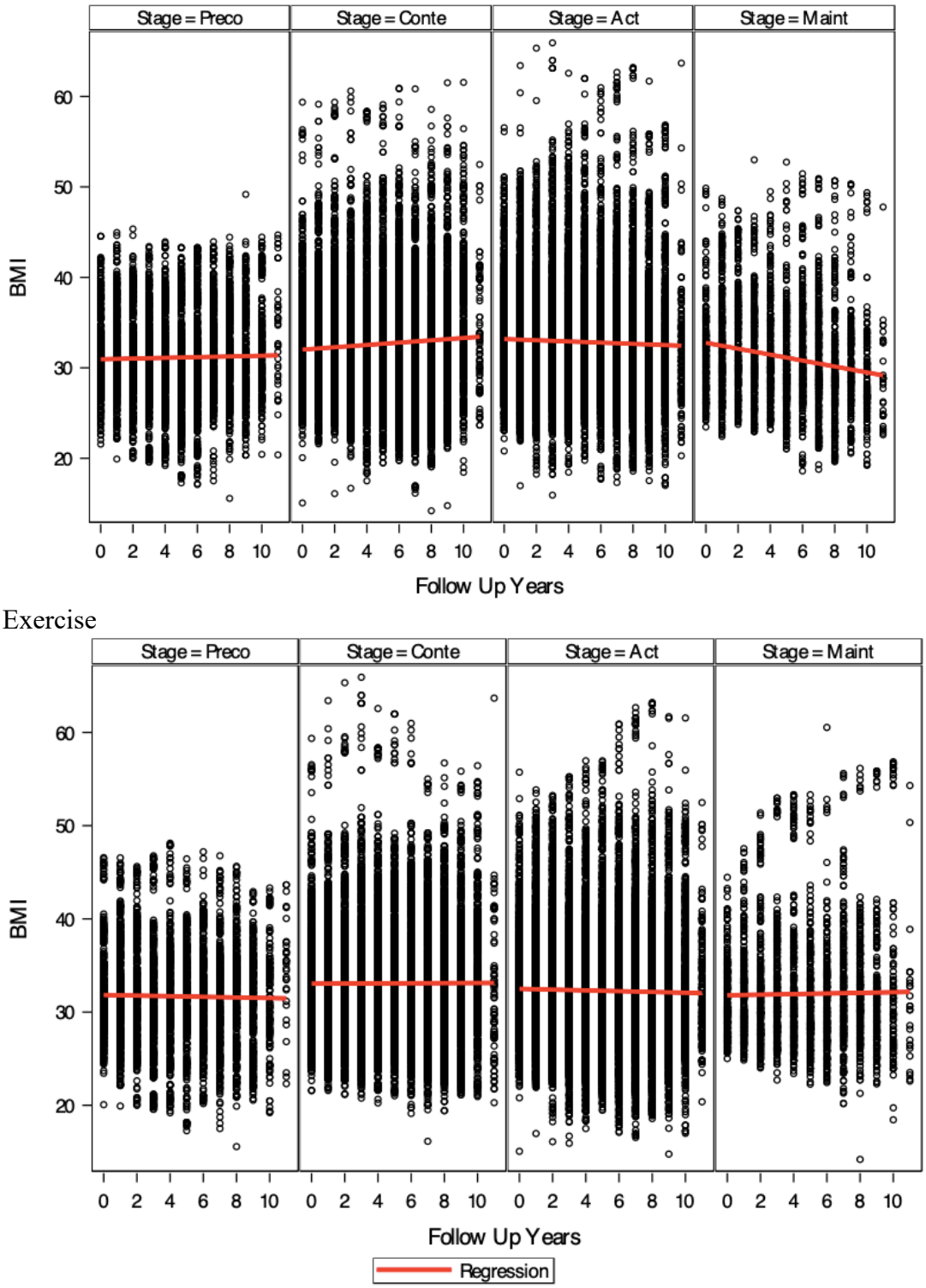
Calorie Intake



Fruit and Vegetable Intake



Fat Reduction



Exercise

Figure 4. Mean BMI over Time by Stage of Change. Regression line represents the predicted trend in BMI over time. Mean BMI was calculated per person per year of follow up and graphed over time. BMI, Body Mass Index (kg/m^2). Preco, Precontemplation. Conte, Contemplation. Act, Action. Maint, Maintenance.