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Long-Term Weight Loss Success and the Health Behaviors of United State Adults: Findings from a Nationally Representative Cross-sectional Study

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Long-Term Weight Loss Success and the Health Behaviors of United State Adults: Findings from a Nationally Representative Cross-sectional Study

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Abstract

Objective To describe the relationship between long-term weight loss (LTWL) success and lifestyle behaviors among US adults.

Design Serial cross-sectional data from NHANES cycles 2007-2014.

Setting and Participants Population based nationally representative sample. The analytic sample included 3,054 adults aged 20-64 years who tried to lose weight in the past year.

Measures: Participants were grouped into five LTWL categories (<5%, 5-9.9%, 10-14.9%, 15-19.9%, and $\geq 20\%$). Lifestyle related behaviors included: alcohol intake, physical activity, smoking, fast-food consumption, dietary quality (healthy eating index [HEI]), caloric intake, and total number of lifestyle behaviors. Multivariable regression was employed adjusting for: age, sex, race/ethnicity, marital status, education, household income and size, as well as self-reported health status.

Results: Individuals in the 15-19.9% LTWL group differed significantly from the reference group (<5% LTWL) in their physical activity and dietary quality (HEI) but not caloric intake. Specifically, they had a higher HEI score ($\beta=3.99$; 95%CI 1.56, 6.41), and were more likely to meet physical activity guidelines (OR= 1.98; 95%CI 1.12-3.50). In comparison, the $\geq 20\%$ LTWL group was significantly more likely to smoke (OR=1.70; 95%CI 1.08, 2.68) and to consume lower daily calories ($\beta = -219.10$; 95%CI -360.32, -77.87) than the reference group; however, dietary quality and physical activity did not significantly differ. When examining the combined score of multiple healthy behaviors, only the 15-19.9% LTWL group engaged in a higher number of healthier behaviors than the reference group (OR=1.72; 95% CI 1.23, 2.62).

Conclusion: Among a national sample of adults, a higher level of LTWL success does not necessarily equate to healthy weight loss behaviors. Future research should attempt to design

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3 interventions aimed at facilitating weight loss success while encouraging healthy lifestyle
4 behaviors.
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Article Summary

Strengths and Limitations

- This study includes four cycles of a nationally representative data among US adults attempting to lose weight.
- Few studies have examined (un)healthy weight loss practices among adults with varying levels of long-term weight loss success.
- The study design is cross-sectional which prohibits determining a temporal relationship and reaching causal inferences.
- Despite using validated instruments many study variables are based on participant report which could lead to over-reporting (e.g., physical activity) or under-reporting (e.g., alcohol consumption).

Introduction

Obesity, defined as excessive fat accumulation,[1] is related to increased risks for metabolic syndrome, type 2 diabetes, cardiovascular disease, some cancers, and premature mortality.[2–4] For example, González-Muniesa et al. observed that in men, obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$) and central adiposity (waist circumference $\geq 102 \text{ cm}$) were each independently related to 42% and 50% higher risks (respectively) for cardiovascular disease mortality, even after adjusting for covariates such as physical activity.[5] A meta-analysis by Flegal et al. observed that obesity increased the risk for all-cause mortality by 18% in both men and women.[6] Beyond adverse health outcomes, obesity impacts the medical care system with direct costs related to medical treatment as well as indirect costs, such as productivity loss.[2] In fact, the total medical related costs for obesity was estimated at 342.2 billion United States (US) dollars in 2013.[7]

Despite detrimental health and economic consequences, the prevalence of obesity continues to rise. Over the past two decades, the prevalence of obesity among US adults increased from 30.5% in 1999-2000 to 42.4% in 2017-2018. [2] Whereas human physiology and genes have remained constant, the environment has drastically changed to one that is conducive to overeating and physical inactivity.[8–10] More specifically, the introduction of energy saving technology (e.g., motorized transport) alongside constant environmental cues encouraging increased caloric intake of energy dense nutrient poor foods and beverages has led to positive energy balance. [8,11–13]. That is, energy intake exceeds expenditure, which leads to weight gain and often an obesity weight status [13–15].

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Once weight gain has occurred it is extremely difficult to lose weight with only 20% of the population able to successfully achieve long-term weight loss (LTWL); defined as losing 5-10% of initial body weight within 6 months and maintaining it for a year or longer. [16] Those successful have achieved LTWL by significantly changing their diet (e.g., improved diet quality and smaller portion sizes) via self-monitoring of weight, and by habitually engaging in health promoting physical activity [17,18]. In addition to eating a healthful diet (e.g., increased fruits and vegetables) and being physically active, other behaviors have been found to positively or negatively affect LTWL. For example, cigarette smoking has been shown to decrease appetite, thereby positively contributing to LTWL, [19,20] while simultaneously increasing cancer and premature mortality risk.[21,22] Thus, engaging in unhealthy behaviors such as smoking may lead to weight loss while having adverse health consequences.[23] However, it is unclear whether adults who reach higher levels of LTWL are in fact engaging in healthy weight loss practices to achieve success. Research on this topic has primarily focused on adolescents,[24] with scant research centered on adults, particularly using nationally representative samples.

Therefore, the main goal of the present study is to examine the relationship between LTWL, and associated health behaviors among adults concerned with their weight. Specifically, we seek to identify lifestyle behaviors related to LTWL success, including physical activity, smoking, alcohol consumption, fast-food consumption, overall dietary quality, and caloric intake. To this end we utilize data from the National Health and Nutrition Examination Survey (NHANES), which has extensive information pertaining to health behaviors from a nationally representative sample of US adults.

Methods

Data and Participants

Data for the study were derived from four cycles (2007-08, 2009-10, 2011-12, 2013-14) of NHANES, which is operated by the National Center for Health Statistics (NCHS). It consists of bi-annual multistage cross-sectional data collection on the health, nutritional status, and lifestyle behaviors of adults and children in the US.[25] Data are collected via interviews and questionnaires, physical examinations including biological samples (e.g., saliva).[16] All study participants provide informed consent, and NHANES has received ethics approval from the NCHS Ethics Review Board. In the present study, we focus on adult participants who were overweight or obese at one point during their life, and who aimed to lose weight.

To this end, a total of 4,380 participants meeting the following criteria were considered for inclusion: aged 20-64 years;[16] who tried to lose weight in the past year; who were not underweight ($BMI < 18.5 \text{ kg/m}^2$), had a maximum $BMI \geq 25 \text{ kg/m}^2$, not pregnant, and free of confusion and memory problems or physical/mental/emotional limitations. Adhering to a complete case analytic approach, [16] a total of 1,326 observations were omitted due to missing information on the independent or dependent variables as well as covariates. This resulted in 3,054 participants included in the analytic sample.

Dependent and independent variables

The primary independent variable was LTWL success. Consistent with previous research on this topic, [11,16,26] LTWL was calculated by subtracting participants' reported current weight or weight 1 year ago (the highest of the two) from their maximum weight. This was then divided by

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3 the maximum weight and multiplied by 100 to reach weight loss percentages. LTWL percentages
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5 were then grouped into the following clinically meaningful categories: less than 5% (reference
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7 group), 5%- 9.9%, 10%-14.9%, 15%-19.9%, and $\geq 20\%$. [16,26,27]
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12 The dependent variables pertained to lifestyle behaviors. Specifically, current smoking
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14 status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.[28] Alcohol
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16 intake was based on the reported average number of drinks per day consumed in the past 12
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18 months. Participants were defined as meeting alcohol guidelines for moderate use if consuming 1
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20 alcoholic drink or less per day for women or 2 drinks or less daily for men. [29] Leisure-time
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22 physical activity was based on the reported frequency (times) per week and duration (minutes) per
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24 day within moderate and vigorous intensity categories.[30] For each intensity category, the product
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26 of the reported duration and frequency was multiplied by 4 and 8 metabolic equivalent of task
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28 (METs) for moderate and vigorous intensity, respectively, and expressed as $\text{MET} \cdot \text{min} \cdot \text{wk}^{-1}$. The
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30 intermediate scores were summed to derive a final summary estimate of leisure-time physical
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32 activity. A threshold of ≥ 500 MET minutes per week was applied to categorize participants as
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34 meeting (or not) the 2018 Physical Activity Guidelines [31] ($3.3 \text{ METs} * 150 \text{ minutes per week}$;
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36 where 3.3 METs is equivalent to walking for pleasure at approximately 3.0 miles per hour) [32].
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45 Moreover, the number of meals consumed at a fast-food or pizza place in the last 7 days,
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47 was based on self-report. [33] For analysis, responses were grouped into the following categorized
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49 based on consumption per week: 0-1, 2-3, 4-6, 7-10, >10. [34,35] In addition, participants' dietary
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51 quality was determined via the Healthy Eating Index (HEI)-2010, which assesses the degree of
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53 alignment with the Dietary Guidelines for Americans.[36] The HEI score ranges from 0 to 100
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with the maximum score indicating complete adherence to dietary recommendations.[37–39] The HEI-2010 was developed by the US Department of Agriculture (USDA) Center for Nutrition Policy and Promotion; and then the National Cancer Institute’s methodology was employed to compute the HEI scores from the first day of 24-hour dietary recall data..[38,40] Alongside dietary quality, total daily calories (kcal) intake was regarded as a separate dependent variable. Finally, to examine adherence to multiple health behaviors, a composite score (0-4) was created to indicate adherence to the following healthy behaviors: meeting physical activity guidelines (≥ 500 MET minutes a week), moderate alcohol consumption (women: ≤ 1 daily drink; men: ≤ 2 daily drinks), not currently smoking (cotinine levels < 3.8 ng/mL), and a HEI score of 60 or higher. Consistent with previous research,[41] a score of ‘0’ is indicative of not following the above mentioned health behaviors at all, whereas a score of ‘4’ refers to engaging in all the healthy behaviors.

Covariates

The following covariates were taken into account in multivariable analyses based on the literature[11,16]: age (years), sex (women/men), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanics, and others), marital status (married, widowed, divorced/separated, never married), college education (no/yes), household size (continuous), annual household income ($< \$20,000$, $\$20,000$ – $\$44,999$, $\$45,000$ – $\$74,999$, and $\geq \$75,000$),[42] and self-reported health status (poor, fair, good, very good, and excellent).

Statistical Analysis

Weighted descriptive statistics were employed to depict participants’ baseline characteristics. Multivariable logistic regression was used when the dependent variables were dichotomous (e.g.,

meeting physical activity guidelines [no/yes]), whereas ordinary least square (OLS) regression models were computed when the dependent variables were continuous (e.g., HEI). Further, when the dependent variable was the ordinal (e.g., number of healthy behaviors), ordered logistic regression was used, which should be interpreted as transitioning to a higher category in comparison to remaining in the same category.[43] Separate multivariable models were computed for each dependent variable while adjusting for covariates: age, sex, race/ethnicity, marital status, college education, annual house income and household size, and self-reported health status. In logistic regression models the point estimates were odds ratios (OR), whereas in OLS they were beta coefficients (β). The measure of precision was 95% confidence intervals (CI). STATA 15.1 (Stata-Corp LP) was used for analysis and appropriate survey weights were utilized to account for the complex sampling design of NHANES. [44]

Patients and public involvement

Neither the patients nor the public were involved in the study design, data collection, analytics or write up.

Results

Participant characteristics are presented in Table 1. Briefly, the mean (\pm SE) age of the participants was 42.4 \pm 0.3 years, of whom more than half (56.8%) were women. More than two thirds (70.0%) were non-Hispanic white, followed by Hispanics (13.4%), and non-Hispanic blacks (10.9%). Moreover, 59.4% were currently married, and 36.2% had a college degree. In addition, 21.1% were current smokers and 51.9% met moderate drinking guidelines. A total of 39.9% achieved LTWL success of 5% or higher. Almost two thirds (65.2%) met physical activity guidelines. The

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3 average daily caloric intake was 2,173.9, and the overall dietary quality, as measured by the HEI,
4 was 53.6/100.
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10 The multivariable relations between LTWL success to health behaviors (e.g., smoking,
11 physical activity, alcohol intake), dietary quality (HEI), and caloric intake are shown in Table 2.
12 In comparison to the reference group (LTWL <5%), the health behaviors of those achieving 5-
13 9.9% LTWL did not differ significantly except for fast-food intake (OR=0.79; 95% CI 0.63, 0.99).
14 Similarly, the behaviors of those achieving 10-14.9% LTWL did differ markedly from the
15 reference. In contrast, participants in 15-19.9% LTWL group significantly differed in their
16 physical activity and dietary quality, yet not caloric intake. Specifically, the 15-19.9% LTWL
17 group were almost twice (OR= 1.98; 95%CI 1.12, 3.50) as likely to meet physical activity
18 guidelines, and to have a higher HEI score (β =3.99; 95%CI 1.56, 6.41). Ordered regression
19 revealed that the 15-19.9% LTWL category was the only group that had significantly higher odds
20 (OR= 1.72; 95%CI 1.12, 2.62) of engaging in more healthy behavior versus remaining in the same
21 number of behaviors (Figure 1). Finally, individuals in the \geq 20% LTWL group were 1.7 times
22 (95%CI 1.08, 2.68) more likely to be current smokers, and consumed 219.1 fewer daily calories
23 (95%CI -360.32, -77.87) than the reference group. No significant differences were observed in
24 dietary quality and other health behaviors (Table 2).
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Discussion

Study findings show that adults in the 15-19.9% LTWL category likely achieved this success through healthy behaviors, whereas those losing more weight (LTWL of 20% or more) appear to have attained success through behaviors that were primarily detrimental to their health. More specifically, the 15-19.9% group had higher odds to eat a higher quality diet and to meet physical activity guidelines. Notably, participants who achieved LTWL of $\geq 20\%$ smoked more and consumed significantly fewer calories; however, their overall diet quality was similar to those who were not successful in LTWL. Thus, while reaching a higher degree of weight loss might lower cardiometabolic risk,[16] achieving this goal by engaging in harmful behaviors, such as smoking, could adversely impact health and longevity.[22,45] Indeed, it increases cancer risk and shortens lifespans.[21,45,46] Evidence has shown that engaging in multiple health behaviors simultaneously reduces mortality risk from all-causes, cardiovascular disease and cancer. For example, Khaw et al. found that in comparison to those adhering to four healthy behaviors (physical activity, fruit & vegetable intake, not smoking, and moderate drinking), not adhering to any healthy behaviors was associated with a 4-fold increased risk for all-cause mortality. [41]

While the current study takes a similar approach to Khaw et al. by combining four health behaviors into a cumulative score, the health behaviors differed slightly (e.g., present study: overall dietary quality versus fruit & vegetable consumption). Furthermore, the present study focuses on the health behaviors of individuals with various levels of LTWL success rather than mortality as an endpoint.[41] Present findings reveal that those achieving 15-19.9% LTWL success are significantly more likely to engage in a higher number of combined health behaviors than the <5% LTWL group. Thus, this group is likely to benefit not only from weight loss and weight

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3 maintenance, but also enjoy enhanced quality of life and lower mortality risk.[47,48] In contrast,
4 the higher LTWL group (20% or more), did not consume a higher quality diet nor did they exercise
5 more than the reference (LTWL <5%), and thus might not obtain the same potential long term
6 health benefits. A previous study by Wilson,[49] examined the relationship between physical
7 activity and diet to LTWL among NHANES participants, finding that those with 10% LTWL were
8 more likely to engage in vigorous intensity physical activity and to have lower caloric intake.[49]
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10 The present study, however, differs from Wilson's study in three main ways: (1) the current
11 research utilizes four waves of NHANES versus two; (2) it examines multiple health behaviors
12 (independently and combined) rather than only physical activity and diet; and (3) it focuses
13 specifically on adult dieters who may experience specific weight control challenges,[50] while
14 employing a more nuanced approach by examining five levels of LTWL (consistent with previous
15 research on this topic),[16,26] versus a dichotomous LTWL variable.[49]
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33 The current exploration of multiple levels of LTWL revealed that those achieving the
34 highest level of success might have attained it by engaging in detrimental practices (e.g., smoking).
35 Smoking has been found in the literature to suppress appetite and prevent overeating, subsequently
36 leading to LTWL success, despite its harmful effects.[45,51,52] Phalen et al., in a population based
37 study, observed that higher odds of LTWL success were related to markedly more smoking. [52]
38 Indeed, in the current study those reaching $\geq 20\%$ LTWL were 91% more likely to be current
39 smokers than those who were not successful in weight loss (<5% LTWL). Research among
40 adolescents underscores that there is a relationship between unhealthy weight loss practices (e.g.,
41 diet pill use, fasting) and substance use behaviors, such as tobacco and marijuana smoking. [24] A
42 longitudinal study by Haynos et al. found that unhealthy weight control practices among
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3 adolescents persist into adulthood and therefore there is a need to design intervention programs to
4 decrease these practices in adolescence and young adulthood.[53] The present study was
5 conducted among adults aged 42 years (on average), showing that those best at LTWL ($\geq 20\%$)
6 likely achieved this not by being physically active and improving diet quality but via caloric
7 reduction (219 fewer daily calories) which might have been the result (at least partly) of smoking's
8 appetite suppression effects. Thus, there is a need to understand the underlying psychological
9 mechanisms explaining the unhealthy behavioral choices of individuals in the highest LTWL
10 group. This could facilitate the design and implementation of effective interventions in the future
11 research aimed at encouraging the adoption and maintenance of healthier behaviors among this
12 group with the goal of improving health outcomes.
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28 While underlying psychological variables that illuminate participants' decision making are
29 not available in the data, the psychological literature might shed light on these findings. Previous
30 research has linked high levels of self-regulation to virtuous decision making in the health,
31 education, and financial domains.[11,54–56] Specifically, high self-regulation necessitating goal
32 setting and planning to meet a-priori objectives, overcoming impediments and the ability to delay
33 immediate gratification,[57,58] has been linked to reduced obesity and cardiovascular disease risk,
34 as well as better employment prospects.[59–62] In a previous study among NHANES participants
35 of low-income, we found that participants in the highest LTWL category ($\geq 20\%$) were also 45%
36 less likely to save money.[11] Based on previous research, we hypothesized that this group used
37 significant cognitive efforts to achieve LTWL and therefore did not have enough “mental
38 resources” when it came to financial decision making. [11,50]
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The current results add to our prior findings by showing that highest LTWL category ($\geq 20\%$) might have achieved weight loss via lower caloric intake and more smoking which suppress appetite, thereby likely exerting less self-control when it came to making healthy food choices. Indeed, the dietary quality of participants in the high LTWL group resembled those of the reference group (i.e., LTWL $< 5\%$). It is unclear from the current study, whether these decisions were implicit or explicit,[63] thus future research utilizing data with robust psychological variables to examine the above-mentioned suppositions is needed. In comparison, participants in the 15-19.9% LTWL category were the most likely to engage in numerous healthy behaviors simultaneously to achieve their weight loss goal. It is plausible that these participants had a higher level of self-regulation than the $\geq 20\%$ LTWL group, yet this assumption needs to be substantiated with direct measurement. Further, based on previous health psychology research, it is possible that the 15-19.9% LTWL group might have had a mental framework of themselves (i.e., self-schema) as being healthy weight maintainers, thereby facilitating engagement multiple health behaviors.[64–66] The NHANES dataset, however, does not measure self-schemas, thus these explanations need to be empirically examined in future work.

Beyond lacking psychological variables, the present study has additional limitations that should be noted. Specifically, many of the variables used are based on participant reported responses to questionnaires which often leads to either over-reporting (e.g., physical activity) or under-reporting (e.g., alcohol intake). However, validated instruments were employed using standard protocols, thus if misclassification has occurred it is likely non-differential which leads to results being biased towards the null.[67] Hence the observed point estimates might be weaker than the true difference. In addition, the study design is cross-sectional which impedes examining

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3 a temporal relationship between the exposure and outcome and subsequently inferring any causal
4 relationships. Finally, it should be noted that participants' weight (maximum, 1 year ago, and
5 current) used to calculate LTWL, was determined at one point in time. While historical weight has
6 been found to be relatively stable,[16,68] a longitudinal approach is preferable and prevents recall
7 bias.
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17 In summary, data from a nationally representative sample of US adults who tried to lose
18 weight, shows that higher LTWL does not necessary relate to healthy weight loss practices.
19 Notably, those achieving the most LTWL ($\geq 20\%$) were more likely to smoke, and to have lower
20 caloric intake without improved diet quality. In comparison, those achieving slightly less LTWL
21 (15-19.9%) were engaged in a significantly higher number of healthy behaviors, such as meeting
22 physical activity guidelines and having a better-quality diet. Thus, higher LTWL does not
23 necessarily reflect healthier lifestyle practices, which can in turn, adversely impact future health
24 and welfare. Future research should focus on understanding mechanisms explaining healthy and
25 unhealthy weight loss practices of adults. This will enable the design and implementation of
26 interventions aimed at helping adults lose weight while improving future health outcomes.
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4

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7
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10
11

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14

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16
17

18 **Patient consent for publication:** Not required.
19
20

21 **Ethics approval:** The current study received approval from the University of Haifa Institutional
22 Review Board (IRB: 297/20), exempt status from the University of Texas Health Science Center's
23 Committee for the Protection of Human Subjects (HSC-SPH-17-0925), and exempt from the
24 Morehouse School of Medicine's IRB.
25
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27 **Data availability statement:** The current study used data from NHANES. It is publicly available
28 and can be downloaded from the Centers for Disease Control and Prevention website:
29
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31 <https://wwwn.cdc.gov/nchs/nhanes/>
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Table 1: Weighted characteristics of study sample: NHANES 2007-2014 (n=3,054)

Characteristics	%
Women	56.77%
Age: mean (SE)	42.44 (0.29)
LTWL^a	
<5%	60.06%
5-9.99%	20.75%
10-14.99%	9.72%
15-19.99%	4.45%
≥ 20%	5.01%
Race/ethnicity	
Non-Hispanic White	70.05%
Hispanic	13.38%
Non-Hispanic Black	10.86%
Other	5.71%
Marital status	
Married	59.36%
Widowed	1.05%
Divorced/separated	13.99%
Never married	17.86%
College Educated	36.25%
Self-reported health status	
Excellent	9.21%
Very good	32.91%
Good	42.75%
Fair	13.19%
Poor	1.94%
Household Size: mean (SE)	3.10 (0.04)
Annual household income	
<\$20,000	9.06%
\$20,000–\$44,999	20.13%
\$45,000–\$74,999	25.70%
≥\$75,000	45.12%
Fast-food meals-past week	
0-1	53.83%
2-3	27.53%
4-6	11.67%
7-10	5.21%
>10	1.76%
HEI-2010^b: mean (SE)	53.59 (0.41)
Kcal^b: mean (SE)	2173.95 (18.04)
Smoking^c	20.47%
Moderate Alcohol^d	51.90%
Physical activity guidelines^e	65.19%
Num. of healthy behaviors^f	
0	5.25%
1	17.81%
2	32.56%

3	30.88%
4	13.49%

LTWL: Long term weight loss; HEI: Healthy Eating Index; Kcal: kilocalorie; SE: Standard Error; Num.: Numbers

^aLTWL was calculated by subtracting the reported weight 1 year ago or current weight (the higher of the 2), by the reported maximum weight, and then multiplying by 100 to receive a percentage.

^bcHEI-2010: Indicates adherence to Dietary Guidelines for Americans. The score ranges from 0 to 100 with the highest score indicative of complete compliance with the guidelines. Kcal- total daily calories.

^cSmoking- current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.

^dModerate Alcohol- Participants were defined as meeting moderate drinking guidelines, if consuming 1 alcoholic drink or less per day for women or 2 drinks or less daily for men.

^eMET minutes per week for leisure time physical activity. Meeting physical activity guidelines refers to ≥ 500 MET minutes per week.

^fA composite score (0-4) was created to indicate adherence to the following healthy behaviors: meeting physical activity guidelines, moderate alcohol consumption, not currently smoking, and a HEI ≥ 60 . A score of '0' is indicative of not following of the above-mentioned health behaviors, whereas a score of '4' refers to engaging in all the healthy behaviors.

Table 2: Long Term Weight Loss (LTWL) Success and Lifestyle Behaviors of Adults attempting to Lose Weight^a: Multivariable Regression^b

LTWL ^c	HEI-2010 ^d	Kcal ^d	Fast-Food ^e	Smoking ^f	Moderate Alcohol ^g	Physical Activity ^h
	β (95% CI)	β (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
5-9.9%	0.53 -0.73, 1.79	-24.47 -116.60, 67.66	0.79* 0.63, 0.99	1.05 0.80, 1.38	0.93 0.75, 1.15	1.26 0.97, 1.64
10-14.9%	2.09 -0.42, 4.60	-34.79 -155.75, 86.16	0.913 0.64, 1.30	1.41 0.97, 2.03	0.97 0.69, 1.37	1.06 0.72, 1.56
15-19.9%	3.99** 1.56, 6.41	-71.28 -255.57, 113.02	0.77 0.50, 1.19	1.38 0.84, 2.26	1.25 0.82, 1.91	1.98* 1.12, 3.50
>20%	-0.32 -2.86, 2.23	-219.10** -360.32, -77.87	0.90 0.61, 1.32	1.70* 1.08, 2.68	0.89 0.58, 1.37	1.72 0.98, 3.04

LTWL- Long Term Weight Loss; β - beta coefficient; CI- Confidence Interval, HEI- Healthy Eating Index

* p<0.05; **p<0.01,

^a NHANES data 2007-2014 (n= 3,054)

^b Separate regression models were employed for each dependent variable. Logistic and ordinal regression models were used when the variable was dichotomous (e.g., meeting physical activity guidelines: yes/no) and ordered (fast-food), respectively. Ordinary least square regression models were utilized for continuous variables (HEI, kcal). NHANES weights were employed. Models adjust for age, sex, race/ethnicity, marital status, college education, household income, household size, and self-rated health status.

^c LTWL was calculated by subtracting the reported weight 1 year ago or current weight (the higher of the 2), by the reported maximum weight, and then multiplying by 100 to receive a percentage.

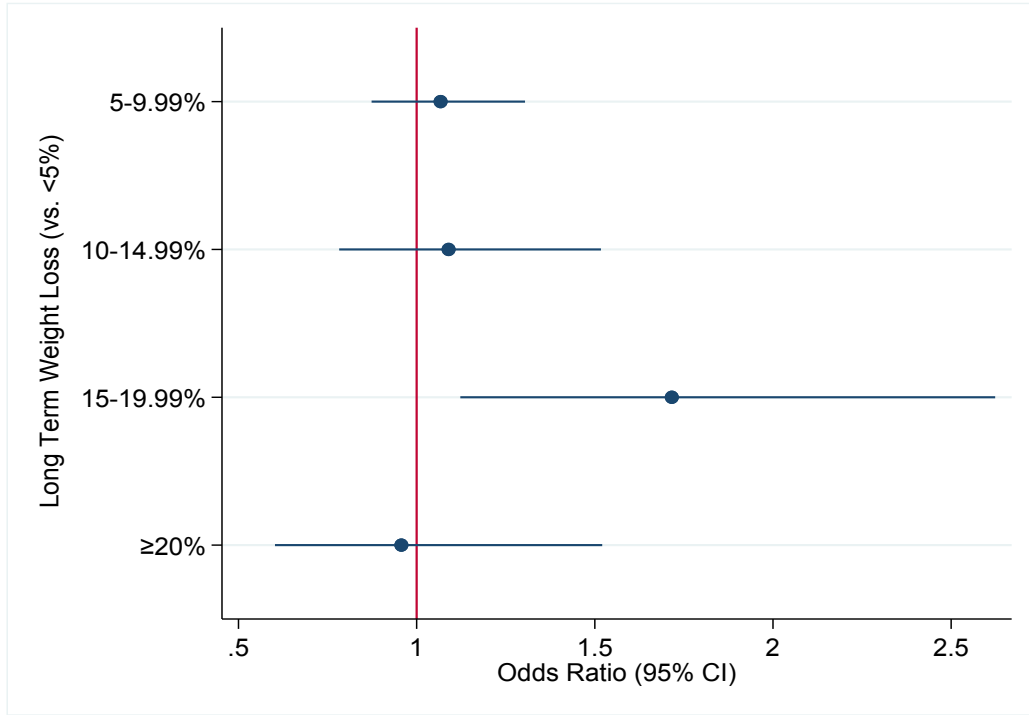
^d HEI-2010: Indicates adherence to Dietary Guidelines for Americans. The score ranges from 0 to 100 with the highest score indicative of complete compliance with the guidelines. Kcal- total daily calories.

^e Number of fast-food or pizza place meals in the past 7 days: 0-1, 2-3, 4-6, 7-10, >10.

^f Smoking- current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.

^g Alcohol- Participants were defined as meeting moderate drinking guidelines, if consuming 1 alcoholic drink or less per day for women or 2 drinks or less daily for men.

^h MET minutes per week for leisure time physical activity. Meeting physical activity guidelines refers to ≥ 500 MET minutes per week.



LTWL- Loss Term Weight Loss; CI- Confidence Interval.

The width of the horizontal line represents the 95% confidence interval of the estimate and the circle represents the odds ratio. Values are adjusted for age, sex, race/ethnicity, marital status, college education, household income and size, and self-rated health status.

Figure 1: Adjusted odds ratios for adhering to healthy behaviors (0-4) according to long-term weight loss (LTWL) categories among US adults attempting to lose weight in the past year. The healthy behaviors include meeting guidelines for physical activity, meeting guidelines for moderate alcohol consumption, not currently smoking, and a healthy eating index (HEI) ≥ 60 .

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	7
		(d) If applicable, describe analytical methods taking account of sampling strategy	10
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Explained in Methods
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	10-11 and Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(b) Report category boundaries when continuous variables were categorized	7-9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Long-Term Weight Loss Success and the Health Behaviors of Adults in the United States: Findings from a Nationally Representative Cross-sectional Study

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10 Behaviors of Adults in the United States: Findings from a
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13 Nationally Representative Cross-sectional Study
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Abstract

Objective To describe the relationship between long-term weight loss (LTWL) success and lifestyle behaviors among US adults.

Design Serial cross-sectional data from NHANES cycles 2007-2014.

Setting and Participants Population based nationally representative sample. The analytic sample included 3,040 adults aged 20-64 years who tried to lose weight in the past year.

Measures: Participants were grouped into five LTWL categories (<5%, 5-9.9%, 10-14.9%, 15-19.9%, and $\geq 20\%$). Lifestyle related behaviors included: alcohol intake, physical activity, smoking, fast-food consumption, dietary quality (healthy eating index [HEI]), and caloric intake. Multivariable regression was employed adjusting for: age, sex, race/ethnicity, marital status, education, household income and size, current BMI, and self-reported health status.

Results: Individuals in the 15-19.9% LTWL group differed significantly from the reference group (<5% LTWL) in their physical activity and dietary quality (HEI) but not caloric intake. Specifically, they had a higher HEI score ($\beta=3.19$; 95%CI 0.39, 5.99), and were more likely to meet physical activity guidelines (OR= 1.99; 95%CI 1.11-3.55). In comparison, the $\geq 20\%$ LTWL group was significantly more likely to smoke (OR=1.63; 95%CI 1.03, 2.57) and to consume lower daily calories ($\beta =-202.91$; 95%CI -345.57, -60.25) than the reference group; however, dietary quality and physical activity did not significantly differ.

Conclusion: Among a national sample of adults, a higher level of LTWL success does not necessarily equate to healthy weight loss behaviors. Future research should attempt to design interventions aimed at facilitating weight loss success while encouraging healthy lifestyle behaviors.

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For peer review only

Article Summary

Strengths and Limitations

- This study includes four cycles of a nationally representative data among US adults attempting to lose weight.
- Few studies have examined (un)healthy weight loss practices among adults with varying levels of long-term weight loss success.
- The study design is cross-sectional which prohibits determining a temporal relationship and reaching causal inferences.
- Despite using validated instruments many study variables are based on participant report which could lead to over-reporting (e.g., physical activity) or under-reporting (e.g., alcohol consumption).

Introduction

Over the past two decades, the prevalence of obesity among United States (US) adults increased from 30.5% in 1999-2000 to 42.4% in 2017-2018. [1] Whereas human physiology and genes have remained constant, the environment has drastically changed to one that is conducive to overeating and physical inactivity.[2–4] Specifically, the introduction of energy saving technology (e.g., motorized transport) alongside constant environmental cues encouraging increased caloric intake of energy dense nutrient poor foods and beverages has led to positive energy balance. [2,5–7]. That is, energy intake exceeds expenditure, which leads to weight gain and often an obesity weight status [7–9]. Obesity is related to increased risks for type 2 diabetes, cardiovascular disease, some cancers, and premature mortality.[1,10,11] Beyond adverse health outcomes, obesity impacts the medical care system with direct costs related to medical treatment as well as indirect costs, such as productivity loss.[1]

Once weight gain has occurred it is extremely difficult to lose weight with only 20% of the population able to successfully achieve long-term weight loss (LTWL); defined as losing 5-10% of initial body weight within 6 months and maintaining it for a year or longer. [12] Those successful have achieved LTWL by significantly changing their diet (e.g., improved diet quality and smaller portion sizes) via self-monitoring of weight, and by habitually engaging in health promoting physical activity [13,14]. In addition to eating a healthful diet (e.g., increased fruits and vegetables) and being physically active, other behaviors have been found to positively or negatively affect LTWL. For example, cigarette smoking has been shown to decrease appetite, thereby positively contributing to LTWL, [15,16] while simultaneously increasing cancer and premature mortality risk.[17,18] Thus, engaging in unhealthy behaviors such as smoking may lead

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3 to weight loss while having adverse health consequences.[19] However, it is unclear whether
4 adults who reach higher levels of LTWL are in fact engaging in healthy weight loss practices to
5 achieve success. Studies on this topic have primarily focused on adolescents,[20] with scant research
6 centered on adults, particularly using nationally representative samples.
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13 Therefore, the main goal of the present study is to examine the relationship between
14 LTWL, and associated health behaviors among adults concerned with their weight. Specifically,
15 we seek to identify lifestyle behaviors related to LTWL success, including physical activity,
16 smoking, alcohol consumption, fast-food consumption, overall dietary quality, and caloric intake.
17 To this end we utilize data from the National Health and Nutrition Examination Survey
18 (NHANES), which has extensive information pertaining to health behaviors from a nationally
19 representative sample of US adults.
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33 **Methods**

34 **Data and Participants**

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36 Data for the study were derived from four cycles (2007-08, 2009-10, 2011-12, 2013-14) of
37 NHANES, which is operated by the National Center for Health Statistics (NCHS). It consists of
38 bi-annual multistage cross-sectional data collection on the health and nutritional status of adults
39 and children in the US.[21] All study participants provide informed consent, and NHANES has
40 received ethics approval from the NCHS Ethics Review Board. In the present study, we focus on
41 adult participants who were overweight or obese at one point during their life, and who aimed to
42 lose weight.
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To this end, a total of 4,380 participants meeting the following criteria were considered for inclusion: aged 20-64 years; [12] who tried to lose weight in the past year; who were not underweight ($BMI < 18.5 \text{ kg/m}^2$), had a maximum $BMI \geq 25 \text{ kg/m}^2$, not pregnant, and free of confusion and memory problems or physical/mental/emotional limitations. Adhering to a complete case analytic approach, [12] a total of 1,340 observations were omitted due to missing information on the independent or dependent variables as well as covariates. This resulted in 3,040 participants included in the analytic sample. Outliers were not removed from the dataset to minimize type 1 error. [22]

Dependent and independent variables

The primary independent variable was LTWL success. Consistent with previous research on this topic, [5,12,23] LTWL was calculated by subtracting participants' reported current weight or weight 1 year ago (the highest of the two) from their maximum weight. This was then divided by the maximum weight and multiplied by 100 to reach weight loss percentages. LTWL percentages were then grouped into the following clinically meaningful categories: less than 5% (reference group), 5%- 9.9%, 10%-14.9%, 15%-19.9%, and $\geq 20\%$. [12,23,24]

The dependent variables pertained to lifestyle behaviors. Specifically, current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL. [25] Alcohol intake was based on the reported average number of drinks per day consumed in the past 12 months. Participants were defined as meeting alcohol guidelines for moderate use if consuming 1 alcoholic drink or less per day for women or 2 drinks or less daily for men. [26] Leisure-time physical activity was based on the reported frequency (times) per week and duration (minutes) per

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3 day within moderate and vigorous intensity categories.[27] For each intensity category, the product
4 of the reported duration and frequency was multiplied by 4 and 8 metabolic equivalent of task
5 (METs) for moderate and vigorous intensity, respectively, and expressed as $\text{MET} \cdot \text{min} \cdot \text{wk}^{-1}$. The
6 intermediate scores were summed to derive a final summary estimate of leisure-time physical
7 activity. A threshold of ≥ 500 MET minutes per week was applied to categorize participants as
8 meeting (or not) the 2018 Physical Activity Guidelines [28] ($3.3 \text{ METs} * 150 \text{ minutes per week}$;
9 where 3.3 METs is equivalent to walking for pleasure at approximately 3.0 miles per hour). [29]
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22 Moreover, the number of meals consumed at a fast-food or pizza place in the last 7 days,
23 was based on self-report. [30] For multivariable analysis, responses were grouped into the
24 following categorized based on consumption per week: 0-1, 2-3, 4-6, 7-10, >10. [31,32] In
25 addition, participants' dietary quality was determined via the Healthy Eating Index (HEI)-2015,
26 which assesses the degree of alignment with the 2015-2020 Dietary Guidelines for
27 Americans.[33,34] The HEI score ranges from 0 to 100 with the maximum score indicating
28 complete adherence to dietary recommendations. The HEI-2015 was developed by the US
29 Department of Agriculture (USDA) Center for Nutrition Policy and Promotion; and then the
30 National Cancer Institute's methodology was employed to compute the HEI scores from the first
31 day of 24-hour dietary recall data. [35,36] Alongside dietary quality, total daily calories (kcal)
32 intake was regarded as a separate dependent variable.
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49 Covariates

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51 The following covariates were taken into account in multivariable analyses based on the
52 literature[5,12]: age (years), sex (women/men), race/ethnicity (non-Hispanic White, non-Hispanic
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3 Black, Hispanics, and others), marital status (married/living together, widowed,
4 divorced/separated, never married), college education (no/yes), household size (continuous),
5 annual household income (<\$20,000, \$20,000-\$44,999, \$45,000-\$74,999, and \geq \$75,000),[37]
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7 current BMI (continuous), and self-reported health status (poor, fair, good, very good, and
8 excellent).
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14 15 16 17 **Statistical Analysis**

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19 Weighted descriptive statistics were employed to depict participants' baseline characteristics. The
20 weighted mean (SE) of continuous dependent variables (e.g., HEI-2015) and the prevalence of
21 categorical dependent variables (e.g., smoking) was summarized by LTWL groups, and a p-value
22 was computed to test for statistical significance across categories using the adjusted Wald test. In
23 addition, multivariable logistic regression was used when the dependent variables were
24 dichotomous (e.g., meeting physical activity guidelines [no/yes]), whereas ordinary least square
25 (OLS) regression models were computed when the dependent variables were continuous (e.g.,
26 HEI). Further, when the dependent variable was the ordinal (i.e., number of fast-food meals
27 consumed per week: 0-1, 2-3, 4-6, 7-10, >10), ordered logistic regression was used, which should
28 be interpreted as transitioning to a higher category in comparison to remaining in the same
29 category.[38] Separate multivariable models were computed for each dependent variable while
30 adjusting for covariates: age, sex, race/ethnicity, marital status, college education, annual house
31 income and household size, current BMI, and self-reported health status. In logistic regression
32 models the point estimates were odds ratios (OR), whereas in OLS they were beta coefficients (β).
33 The measure of precision was 95% confidence intervals (CI). STATA 1SE 15.1 (Stata-Corp LP)
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3 was used for analysis and appropriate survey weights were utilized to account for the complex
4 sampling design of NHANES. [39]
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8 9 **Patients and public involvement**

10 Neither the patients nor the public were involved in the study design, data collection, analytics or
11 write up.
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15 16 17 **Results**

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19 Participant characteristics are presented in Table 1. Briefly, more than half (56.7%) were women,
20 and 70.1% were non-Hispanic white, 13.3 were Hispanics, and 10.8% were non-Hispanic blacks.
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22 In addition, 21.0% were current smokers and 51.9% met moderate alcohol drinking guidelines.
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24 Almost two thirds (65.2%) met physical activity guidelines. The average daily caloric intake was
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26 2,175.4kcal, and the mean overall dietary quality, as measured by the HEI-2015, was 51.0/100.
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28 Participants' current mean BMI (kg/m²) was 31.8 and they lost 5.9 pounds, on average, from the
29
30 previous year. Moreover, a total of 39.9% achieved LTWL success of 5% or higher. Further,
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32 descriptive statistics of the dependent variables (health behaviors, dietary quality, and caloric
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34 intake) by LTWL categories are depicted in Table 2. Daily caloric intake, diet quality, and physical
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36 activity differed significantly by LTWL ($p < 0.05$ for all; see Table 2). For example, the dietary
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38 quality (HEI-2015) of those achieving 15-19.9% LTWL was higher than individuals in the $\geq 20\%$
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40 LTWL group (54.8/100 and 50.4/100, respectively).
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50 The multivariable relations of LTWL success with the dependent variables are shown in
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52 Table 3. In comparison to the reference group (LTWL <5%), the health behaviors of those
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54 achieving 5-9.9% LTWL did not differ significantly except for fast-food intake (OR=0.80; 95%
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3 CI 0.64, 1.00). Similarly, the behaviors of those achieving 10-14.9% LTWL did not differ
4 markedly from the reference. In contrast, participants in 15-19.9% LTWL group significantly
5 differed in their physical activity and dietary quality, yet not caloric intake. Specifically, the 15-
6 19.9% LTWL group were almost twice (OR= 1.99; 95%CI 1.11, 3.55) as likely to meet physical
7 activity guidelines, and to have a higher HEI score ($\beta=3.19$; 95%CI 0.39, 5.99). Finally, individuals
8 in the $\geq 20\%$ LTWL group were 1.63 times (95%CI 1.03, 2.57) more likely to be current smokers
9 and to consume 202.91 fewer daily calories (95%CI -345.57, -60.25) than the reference group. No
10 significant differences were observed in dietary quality and other health behaviors (Table 3).
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24 Discussion

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26 The current study significantly contributes to the literature by exploring the health behaviors of
27 adults attempting to lose weight from a national sample of Americans using 4 waves of NHANES
28 data. Few studies to date have examined whether various levels of weight loss success are achieved
29 through healthy weight loss practices in adults. Present findings show that higher levels of LTWL
30 do not necessary equate to healthier behaviors. More specifically, our analysis reveals that adults
31 in the 15-19.9% LTWL category likely achieved this success through healthy behaviors, whereas
32 those losing more weight (LTWL of 20% or more) appear to have attained success through some
33 behaviors that were likely detrimental to their health. More specifically, the 15-19.9% LTWL
34 group had higher odds to eat a higher quality diet and to meet physical activity guidelines. Notably,
35 participants who achieved LTWL of $\geq 20\%$ smoked more and consumed significantly fewer
36 calories. Thus, while reaching a higher degree of weight loss might lower cardiometabolic risk,[12]
37 achieving this goal by engaging in harmful behaviors, such as smoking, could adversely impact
38 health and longevity.[18,40] Indeed, it increases cancer risk and shortens lifespans.[17,40,41]
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6 Evidence has shown that engaging in multiple health behaviors simultaneously reduces
7 mortality risk from all-causes, cardiovascular disease and cancer. For example, Khaw et al. found
8 that in comparison to those adhering to four healthy behaviors (physical activity, fruit & vegetable
9 intake, not smoking, and moderate drinking), not adhering to any healthy behaviors was associated
10 with a 4-fold increased risk for all-cause mortality. [42] Unlike the study by Khaw, the present
11 study focuses on the health behaviors of individuals with various levels of LTWL success rather
12 than mortality as an endpoint.[42] A previous study by Wilson,[43] examined the relationship
13 between physical activity and diet to LTWL among NHANES participants, finding that those with
14 10% LTWL were more likely to engage in vigorous intensity physical activity and to have lower
15 caloric intake.[43] The present study, however, differs from Wilson's study in two main ways: (1)
16 the current research utilizes four waves of NHANES versus two; and (2) it focuses specifically on
17 adult dieters who may experience specific weight control challenges,[44] while employing a more
18 nuanced approach by examining five levels of LTWL (consistent with previous research on this
19 topic),[12,23] versus a dichotomous LTWL variable.[43]
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45 The current exploration of multiple levels of LTWL revealed that those achieving the
46 highest level of success might have attained it by engaging in detrimental practices (e.g., smoking).
47 Smoking has been found in the literature to suppress appetite and prevent overeating, subsequently
48 leading to LTWL success, despite its harmful effects.[40,45,46] Phalen et al., in a population based
49 study, observed that higher odds of LTWL success were related to markedly more smoking. [46]
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3 Indeed, in the current study those reaching $\geq 20\%$ LTWL were 63% more likely to be current
4 smokers than those who were not successful in weight loss ($< 5\%$ LTWL). Research among
5 adolescents underscores that there is a relationship between unhealthy weight loss practices (e.g.,
6 diet pill use, fasting) and substance use behaviors, such as tobacco and marijuana smoking. [20] A
7 longitudinal study by Haynos et al. found that unhealthy weight control practices among
8 adolescents persist into adulthood and therefore there is a need to design intervention programs to
9 decrease these practices in adolescence and young adulthood. [47] The present study was
10 conducted among adults aged 42 years (on average), showing that those best at LTWL ($\geq 20\%$)
11 likely achieved this not by being physically active and improving diet quality but via caloric
12 reduction (202.9 fewer daily calories), which might have been the result (at least partly) of
13 smoking's appetite suppression effects. This explanation, however, should be regarded as a
14 supposition since variables needed to explain behavioral choices were not available in the dataset.
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33 While psychological variables that illuminate participants' decision making are not
34 available in the data, the psychological literature might shed light on these findings. Previous
35 research has linked high levels of self-regulation to virtuous decision making in the health,
36 education, and financial domains.[5,48–50] Specifically, high self-regulation necessitating goal
37 setting and planning to meet a-priori objectives, overcoming impediments and the ability to delay
38 immediate gratification,[51,52] has been linked to reduced obesity and cardiovascular disease risk,
39 as well as better employment prospects.[53–56] In a previous study among NHANES participants
40 of low-income, we found that participants in the highest LTWL category ($\geq 20\%$) were also 45%
41 less likely to save money.[5] Based on previous research, we hypothesized that this group used
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3 significant cognitive efforts to achieve LTWL and therefore did not have enough “mental
4 resources” when it came to financial decision making. [5,44]
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10 The current results add to our prior findings by showing that highest LTWL category
11 ($\geq 20\%$) might have achieved weight loss via lower caloric intake and more smoking which
12 suppress appetite, thereby likely exerting less self-control when it came to making healthy food
13 choices. Indeed, the dietary quality of participants in the high LTWL group resembled those of the
14 reference group (i.e., LTWL $< 5\%$). It is unclear from the current study, whether these decisions
15 were implicit or explicit,[57] thus future research utilizing data with robust psychological variables
16 to examine the above-mentioned suppositions is needed. In comparison, participants in the 15-
17 19.9% LTWL category appear to be more likely to engage in healthy behaviors to achieve their
18 weight loss goal. It is plausible that these participants had a higher level of self-regulation than the
19 $\geq 20\%$ LTWL group, yet this assumption needs to be substantiated with direct measurement.
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21 Further, based on previous health psychology research, it is possible that the 15-19.9% LTWL
22 group might have had a mental framework of themselves (i.e., self-schema) as being healthy
23 weight maintainers, thereby facilitating healthy behaviors.[58–60] The NHANES dataset,
24 however, does not measure self-schemas, thus these explanations need to be empirically examined
25 in future work.
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47 Beyond lacking psychological variables, the present study has additional limitations that
48 should be noted. Specifically, many of the variables used are based on participant reported
49 responses to questionnaires which often leads to either over-reporting (e.g., physical activity) or
50 under-reporting (e.g., alcohol intake). However, validated instruments were employed using
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3 standard protocols, thus if misclassification has occurred it is likely non-differential which leads
4 to results being biased towards the null.[61] Hence the observed point estimates might be weaker
5 than the true difference. In addition, the study design is cross-sectional which impedes examining
6 a temporal relationship between the exposure and outcome and subsequently inferring any causal
7 relationships. Moreover, it should be noted that participants' weight (maximum, 1 year ago, and
8 current) used to calculate LTWL, was determined at one point in time. While historical weight has
9 been found to be relatively stable,[12,62] a longitudinal approach is preferable and prevents recall
10 bias. Additionally, while participants' self-reported health status was adjusted for in multivariable
11 analysis, as with other similar NHANES studies, [23,43] medical conditions (e.g., diabetes,
12 coronary heart disease) and subsequent prescribed medication, which could influence LTWL and
13 health behaviors, were not accounted for in this study. Finally, since a complete case analytic
14 approach was taken, [12] the analytic sample did not include participants with missing information
15 on the independent and dependent variables as well as covariates.
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35 In summary, data from a nationally representative sample of US adults who tried to lose
36 weight, shows that higher LTWL does not necessary relate to healthy weight loss practices.
37 Notably, those achieving the most LTWL ($\geq 20\%$) were more likely to smoke, and to have lower
38 caloric intake without improved diet quality. In comparison, those achieving slightly less LTWL
39 (15-19.9%) were engaged in healthy behaviors, such as meeting physical activity guidelines and
40 having a better-quality diet. Thus, higher LTWL does not necessarily reflect healthier lifestyle
41 practices, which might in turn, adversely impact future health and welfare. Future research should
42 focus on understanding mechanisms explaining healthy and unhealthy weight loss practices of
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3 adults. This will enable the design and implementation of interventions aimed at helping adults
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5 lose weight while improving future health outcomes.
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For peer review only

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7
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27 **Data availability statement:** The current study used data from NHANES. It is publicly available
28 and can be downloaded from the Centers for Disease Control and Prevention website:
29
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31 <https://wwwn.cdc.gov/nchs/nhanes/>
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Table 1: Weighted characteristics of study sample: NHANES 2007-2014 (n=3,040)

Characteristics	%*
Women	56.7%
Age: mean (SE)	42.4 (0.3)
Weight Change- 1 year (lbs)^a:	
mean (SE)	-5.9 (0.4)
Current BMI (kg/m²): mean (SE)	31.8 (0.2)
LTWL^b	
<5%	60.1%
5-9.99%	20.8%
10-14.99%	9.7%
15-19.99%	4.4%
≥ 20%	5.0%
Race/ethnicity	
Non-Hispanic White	70.1%
Hispanic	13.3%
Non-Hispanic Black	10.8%
Other	5.7%
Marital status	
Married/living together	67.1%
Widowed	1.0%
Divorced/separated	14.0%
Never married	17.9%
College Educated	36.3%
Self-reported health status	
Excellent	9.2%
Very good	33.0%
Good	42.7%
Fair	13.1%
Poor	1.9%
Household Size: mean (SE)	3.1 (0.0)
Annual household income	
<\$20,000	8.9%
\$20,000–\$44,999	20.1%
\$45,000–\$74,999	25.7%
≥\$75,000	45.2%
Fast-food meals-past week	
0-1	53.8%
2-3	27.5%
4-6	11.7%
7-10	5.2%
>10	1.8%
HEI-2015^c: mean (SE)	51.0 (0.4)
Kcal: mean (SE)	2175.4 (18.1)
Smoking^d	21.0%
Moderate Alcohol^e	51.9%
Physical activity guidelines^f	65.2%

LTWL- Long term weight loss; HEI- Healthy Eating Index; Kcal- kilocalorie; SE- Standard Error; Num.-Numbers; Lbs- pounds; BMI- body mass index

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3 * If percentages due not reach 100% that is due to rounding.

4 ^a Weight change from previous year to the current year.

5 ^b LTWL was calculated by subtracting the reported weight 1 year ago or current weight (the higher of the 2), by the reported maximum weight,
6 and then multiplying by 100 to receive a percentage.

7 ^c HEI-2015: Indicates adherence to Dietary Guidelines for Americans. The score ranges from 0 to 100 with the highest score indicative of
8 complete compliance with the guidelines. Kcal- total daily calories.

9 ^d Smoking- current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.

10 ^e Moderate Alcohol- Participants were defined as meeting moderate drinking guidelines, if consuming 1 alcoholic drink or less per day for women
11 or 2 drinks or less daily for men.

12 ^f MET minutes per week for leisure time physical activity. Meeting physical activity guidelines refers to ≥ 500 MET minutes per week.
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Table 2: Long Term Weight Loss (LTWL) Success and Lifestyle Behaviors of Adults attempting to Lose Weight^a: Bivariate Analysis^b

LTWL ^c	HEI-2015 ^d	Kcal ^d	Fast-Food ^e	Smoking ^f	Moderate Alcohol ^g	Physical Activity ^h
	Mean (SE)	Mean (SE)	Percent ⁱ	Percent ⁱ	Percent ⁱ	Percent ⁱ
0-4.9%	50.44 (0.43)	2202.18 (23.49)	47.9%	19.9%	52.2%	62.8%
5-9.9%	50.86 (0.69)	2192.77 (39.11)	43.8%	21.5%	50.4%	68.8%
10-14.9%	52.93 (1.21)	2128.84 (63.22)	44.0%	22.9%	51.7%	64.9%
15-19.9%	54.81 (1.42)	2132.19 (102.71)	41.1%	21.1%	58.7%	77.5%
>20%	50.45 (1.22)	1911.68 (68.50)	44.3%	29.5%	48.6%	73.5%
p-value^j	0.02	0.00	0.48	0.28	0.68	0.01

LTWL- Long Term Weight Loss; β - beta coefficient; CI- Confidence Interval; HEI- Healthy Eating Index; Kcal- kilocalorie; SE- Standard Error

^a NHANES data 2007-2014 (n= 3,040)

^b Weighted descriptive statistics were employed to describe the mean (SE) for continuous variables and percentage for categorical variables by LTWL categories.

^c LTWL was calculated by subtracting the reported weight 1 year ago or current weight (the higher of the 2), by the reported maximum weight, and then multiplying by 100 to receive a percentage.

^d HEI-2015: Indicates adherence to Dietary Guidelines for Americans. The score ranges from 0 to 100 with the highest score indicative of complete compliance with the guidelines. Kcal- total daily calories.

^e Number of fast-food or pizza place was dichotomized into ≥2 (yes/no) meals in the past 7 days in bivariate analysis to ease interpretation.

^f Smoking- current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.

^g Alcohol- Participants were defined as meeting moderate drinking guidelines, if consuming 1 alcoholic drink or less per day for women or 2 drinks or less daily for men.

^h MET minutes per week for leisure time physical activity. Meeting physical activity guidelines refers to ≥ 500 MET minutes per week.

ⁱ Row percentage. That is, the percent of each categorical dependent variable (e.g., smoking) in each LTWL group. For example, 19.9% of participants in the 0-4.9% LTWL group were current smokers.

^j Adjusted p-value computed using the Wald test.

Table 3: Long Term Weight Loss (LTWL) Success and Lifestyle Behaviors of Adults attempting to Lose Weight^a: Multivariable Regression^b

LTWL ^c (Ref. 0-4.9%)	HEI-2015 ^d β (95% CI)	Kcal ^d β (95% CI)	Fast-Food ^e OR (95% CI)	Smoking ^f OR (95% CI)	Moderate Alcohol ^g OR (95% CI)	Physical Activity ^h OR (95% CI)
5-9.9%	0.25 -1.12, 1.61	-15.54 -109.38, 78.30	0.80* 0.64, 1.00	1.03 0.79, 1.35	0.94 0.76, 1.16	1.25 0.96, 1.62
10-14.9%	1.59 -0.92, 4.10	-17.22 -140.93, 106.49	0.94 0.66, 1.33	1.35 0.92, 1.96	1.01 0.71, 1.25	1.04 0.70, 1.53
15-19.9%	3.19** 0.39, 5.99	-47.66 -229.90, 134.59	0.78 0.50, 1.22	1.33 0.81, 2.19	1.30 0.85, 1.99	1.99* 1.11, 3.55
>20%	-0.27 -2.74, 2.19	-202.91** -345.57, -60.25	0.92 0.62, 1.36	1.63* 1.03, 2.57	0.92 0.60, 1.42	1.70 0.95, 3.01

LTWL- Long Term Weight Loss; β - beta coefficient; OR- Odds Ratio; CI- Confidence Interval, HEI- Healthy Eating Index; Ref.-reference category

* $p < 0.05$; ** $p < 0.01$,

^a NHANES data 2007-2014 (n= 3,040)

^b Separate regression models were employed for each dependent variable. Logistic and ordinal regression models were used when the variable was dichotomous (e.g., meeting physical activity guidelines: yes/no) and ordered (fast-food), respectively. Ordinary least square regression models were utilized for continuous variables (HEI, kcal). NHANES weights were employed. Models adjust for age, sex, race/ethnicity, marital status, college education, household income, household size, current BMI, and self-rated health status.

^c LTWL was calculated by subtracting the reported weight 1 year ago or current weight (the higher of the 2), by the reported maximum weight, and then multiplying by 100 to receive a percentage.

^d HEI-2015: Indicates adherence to Dietary Guidelines for Americans. The score ranges from 0 to 100 with the highest score indicative of complete compliance with the guidelines. Kcal- total daily calories.

^e Number of fast-food or pizza place meals in the past 7 days: 0-1, 2-3, 4-6, 7-10, >10.

^f Smoking- current smoking status was based on blood cotinine levels using an established cutoff of 3.08 ng/mL.

^g Alcohol- Participants were defined as meeting moderate drinking guidelines, if consuming 1 alcoholic drink or less per day for women or 2 drinks or less daily for men.

^h MET minutes per week for leisure time physical activity. Meeting physical activity guidelines refers to ≥ 500 MET minutes per week.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-9
Bias	9	Describe any efforts to address potential sources of bias	10
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	9-10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	7
		(d) If applicable, describe analytical methods taking account of sampling strategy	10
		(e) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Explained in Methods
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	10-11 and Table 2
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11
		(b) Report category boundaries when continuous variables were categorized	7-9
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not relevant
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.