CHANGES IN THE PREVALENCE OF U.S. ADULTS DIETING AND EXERCISING FOR WEIGHT LOSS BETWEEN 1999-2016

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Abstract

This study was conducted to evaluate: 1) changes in the proportion of men and women with and without obesity engaging in different weight loss methods over time; and 2) sex and obesity differences in these weight loss methods over time. Data from the National Health and Examination Survey (NHANES Continuous 1999-2016) was used. Over time, there was no change in the prevalence of individuals using prescription weight loss pills ($p=0.70$) and a reduction in the prevalence of individuals reducing fat intake ($p<.0001$) or using diet products ($<.0001$) for weight loss. Further, there was a greater proportion of women with obesity partaking in exercise for weight loss over time ($p=0.0006$), with no changes in the prevalence of exercise for the rest of the population ($p>0.05$). Reasons for these changes in weight loss practices over time are unclear. This study can convey individuals' current weight loss practices to researchers and public health professionals.

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Chapter 1.0 General Introduction

In the United States (U.S.), the obesity rate for adults has risen from 13% in 1960[1] to 39.8% in 2016[2]. Obesity is a disease that arises from multiple factors, including genetics, the environment[3] or physical inactivity and unhealthy eating[4]. It is a risk factor for numerous diseases, such as heart disease, type 2 diabetes and hypertension[5,6], as well as infertility, obstructive sleep apnea, liver disease and many cancers[7,8]. The U.S. has one of the highest rates of obesity in the world[5]. Obesity has a significant economic impact, accounting for 5% to 7% of healthcare costs in the U.S[9].

Common weight loss practices individuals partake in are exercise, diet and the use of diet products and prescription weight loss pills[10–18]. While there is a significant amount of research into the effectiveness of these weight loss practices, it is unclear how many individuals engage in these practices and if there have been changes in the popularity of these practices between 1999-2016. Further, it is unknown whether there are sex or obesity differences in the engagement of weight loss practices over time.

Thus, the objectives of this thesis will be to investigate:

1) The changes in the prevalence of these weight loss practices over time.
2) Sex and obesity differences in participants engaging in these weight loss practices over time.

Chapter 2.0 Literature Review

2.1 Introduction

The present literature review will explore weight loss practice engagement. Specifically, the review will describe the use of various diets, physical activities, prescription weight loss pills and diet products for weight loss. Further, it will explore the popularity and promotion of these weight loss practices. The review will also examine existing trends of some weight loss practices over time. It will also investigate sex and obesity differences in individuals partaking in weight loss practices.

2.2 Exercise

Amongst individuals trying to lose weight, the prevalence of individuals engaging in exercise ranges between 53.0[16]-61.3%[15]. Individuals engage in many types of exercise for the purpose of weight loss, such as regular[25–27] and intensive walking[22], bike-riding[22], aerobics[22], jogging[22,25], Zumba dancing[28], resistance training[28–30] and cycling[22,25], among others. However, many individuals may find that exercise is boring[31,32] and that many exercise centres have inconvenient hours or locations[32]. Further, 44% of individuals stop partaking in exercise weight loss within 16 months[33]. This may be due to individuals experiencing a lack of motivation sometime after starting an exercise program[34], as individuals only lose approximately 3% of their body weight when exercising more than 150 minutes per week for weight loss[35]. Generally, since the early 2000s[36], there has been an increasingly common promotion of exercise[36] by celebrity endorsers. However, it is unknown whether there has been an increase in the prevalence of exercise weight loss over time.

2.3 Caloric, Fat and Carbohydrate Intake Reduction

Of the individuals attempting weight loss, 61.0[16]-64.7%[15] partake in weight loss diets. Common weight loss diets generally either restrict the overall calories without adjusting for macronutrient distribution or focus on restriction of one certain type of macronutrient. Most diets generally fall under the categories of low-carbohydrate[13,18,38,39,40], high-protein[13,18,38,39,40], low-fat[13,39,40], or low-caloric/portion control diets[18,39,40] (Supplementary Table 1). The low-carbohydrate and high-protein diets are often synonymous with each other, since one usually increases their protein intake when reducing their carbohydrate intake[39,40]. The Zone and Atkins diets[39,40] are a couple of examples of low-carbohydrate diets, which suggest high-protein and high-fat foods such as eggs, nuts and dairy products[41]. Conversely, low-fat diets, including the Ornish[39,40] and LEARN diets[39], contain foods with a high-carbohydrate and moderate protein foods, such as bread and pasta[42], as well as lean meats[42], fruits and vegetables[42,43]. Finally, Weight Watchers[39,40] and Nutrisystem[39,40] are a couple of examples of low-caloric or portion controls diets that contain foods low in calories[15] and/or prescribe smaller portion sizes[40]. Generally, one year after starting low-caloric, low-carbohydrate and low-fat diets, individuals usually lose approximately 2% to 5% of their body weight[39,40]. Further, adherence rates of individuals on these diets gradually decrease over time[39,40], with 42% of participants ending their diets within 1 year of starting them[40].

To date, there is limited research on trends in diet weight loss practices. However, a nationally representative study by Andreyeva et al.[20] reports that the proportion of men and women attempting weight loss was higher in 2003 than 1996. Specifically, the proportion of individuals that report engaging in a low-calorie diet for weight loss was higher in 2003 (24.9%) than 1996 (11.3%)[20], though it is unknown whether this proportion is due to promotion of the low-calorie diet by health professionals during that time frame[14,44]. However, the proportion of

individuals that report engaging in a low-fat diet for weight loss decreased during the same timeframe from 41.6% to 29.1%[20]. Since the early 2000s, many health professionals have disputed the benefits of low-fat diets on the grounds that many low-fat products contain a significant amount of added sugar and/or refined, simple carbohydrates[45,46], and thus may be unhealthy for consumption[47]. This may be why the low-carbohydrate diet became popular in the early 2000s[48]. While the popularity of the low-carbohydrate diet decreased a few years later[42,49], it has seen a resurgence more recently[49,50]. Generally, the changes in the prevalence of these diets in a nationally representative sample over time is not well described, and the reasons driving the changes in the popularity of the diets are unknown.

2.4 Prescription Weight Loss Pills

Amongst individuals trying to lose weight, the proportion of individuals using prescription weight loss pills in cross-sectional studies is quite low, ranging between 2.5[16]-3.2%[15]. Some prescription weight loss pills available for use in the U.S. are phentermine, diethylpropion, phendimetrazine, benzphetamine, lorcaserin[51], orlistat[51,52] and liraglutide[52]. Generally, prescription weight loss pills are prescribed to individuals with a BMI of at least 30 kg/m^2 or a BMI of at least 27 kg/m^2 with the existence of at least one weight-related condition such as hypertension or type 2 diabetes[53]. However, individuals generally lose less than 10% of their weight using prescription weight pills alone[54]. Further, many prescription weight loss pills are expensive[3]. Many of these pills also have side effects, such as dizziness, headaches[51] and/or micronutrient deficiencies[52]. These circumstances may deter individuals from ingesting these pills. Overall, Hampp et al. report that 47–58% of individuals who use prescription weight loss pills discontinue by 30 days[55]. Generally, direct to consumer advertising exists for prescription weight loss pills[56,57], although there is no study that determines whether the prevalence of such

advertising has increased over time. However, since media exposure has increased since the early 2000s[58–61] and there is a positive association between media use and advertising[62], it is reasonable to presume that exposure to the advertising of prescription weight loss pills may have also increased over time. Nevertheless, it is unknown whether there has been an increase in the prevalence of individuals using these pills over time.

2.5 Diet Products

Of the individuals attempting weight loss, 5.8[16]-11.5%[15] use diet products. Diet products are wide-ranging and can come in the form of meal replacements, supplements, pills, shakes and teas. Meal replacements and shakes aid in caloric restriction as they are low in calories, while other diet products may include various substances, such as herbs, ephedra and/or caffeine that are promoted to induce weight loss by increasing one's energy expenditure[63,64] and suppressing one's appetite[65]. However, the use of herbs such as Camellia sinensis[66], which is used in green tea, was not associated with weight loss, as reported by Jurgens et al[67]. Further, there are warnings from the Food and Drug Administration (FDA) regarding the safety of some diet products[68–71], such as ephedra and green tea extract[68,69], which may discourage individuals from ingesting them. Generally, since the early 2000s[72–74], celebrity endorsers have been increasingly promoting diet product use[72–74]. However, it is unknown whether there has been an increase in the prevalence of diet product use over time.

2.6 Sex Differences in Weight Loss Practices

The research on sex differences in the uptake of weight loss practices over time is extremely limited. Generally, many studies report that women are more likely to attempt weight loss than men[12,15–17,30,75,76]. Further, there may be sex differences in the types of weight loss

practices that individuals engage in[12,15,16,19,21]. Generally, women are more likely than men to report engaging in diet weight loss practices[12,15,16,21,76,77] such as reducing caloric intake[16,17,21], reducing fat intake[16,20,23,77], reducing carbohydrate intake[76,77] and using prescription weight loss pills[15,17] diet products[15,22] and diet supplements[12,15–17,22] but are less likely than men to engage in physical activity for weight loss[12,15–17,22]. However, when examining sex differences in the effectiveness of weight loss practices, it has been reported that women lose less weight through exercise[33], and caloric[78] and carbohydrate intake reduction[79], but more weight through the use of the prescription weight loss pill orlistat[80], than men, while men and women lose a similar amount of weight through the reduction of fat intake[79]. Nevertheless, there is a lack of studies that examine the effectiveness of diet products and most prescription weight loss pills by sex. Generally, most of these studies do not examine diet and exercise weight loss trends over time[12,17,18,21,33,38,39,76–79]. Thus, it is unclear if and why the sex differences in weight loss practices have changed over time. One possible reason for these probable changes is increasing media exposure since the early 2000s[58–61]. Due to societal and media pressure on women to be thin[81–83], media exposure is associated with more weight dissatisfaction in women[84,85] than men. Weight dissatisfaction is also associated with diet weight loss practices, such as reducing food intake, reducing fat intake and using diet products[86]. Thus, it may not be surprising that studies report that media exposure is associated with partaking in diet weight loss practices, with more women partaking in these practices than men[85,87]. Conversely, men, are expected to attain the social ideals of being lean, fit, and muscular[88,89]. For men, media exposure is associated with internalization of the aforementioned social ideals[89–91], which is associated with self-objectification and body dissatisfaction[89–91], that in turn may lead to a higher likelihood of engaging in exercise[89,91]. Thus, there may be disproportionately more women choosing diet

weight loss practices than men, and disproportionately more men exercising for weight loss than women, now than before.

2.7 Obesity Differences in Weight Loss Practices

There are very few studies that examine obesity differences in the uptake and effectiveness of weight loss practices over time. Although the engagement of weight loss practices is more common in those with obesity, individuals without obesity also report engaging in such practices[12,19,20]. Further, research implies that individuals with obesity are less likely to successfully lose weight through caloric intake reduction than those without obesity[92]. Research suggests that there are differences in the type of diet weight loss practices individuals with and without obesity engage in[12,19,20]. In one of these studies, individuals with obesity are more likely to report reducing caloric intake[12] and using diet products[12] than individuals without obesity, while two of these studies determine that there are no differences in these weight loss practices or the reduction of fat intake between individuals with and without obesity[19,20]. However, the studies that report no obesity differences are published earlier[19,20] than the studies that report obesity differences[12]. Notably, weight discrimination has increased over time[93], and a higher BMI is associated with a higher likelihood of experiencing weight discrimination[94,95]. Weight discrimination, in turn, is associated with a higher willingness to select riskier diet weight loss practices[94], such as partaking in very low-caloric diets[96,97] or using potentially harmful diet products[94,97]. Thus, there may be disproportionately more individuals with obesity choosing these weight loss practices than individuals without obesity now than previously. Generally, while individuals with obesity may be more likely to engage in diet weight loss practices[12], a few studies report that individuals with obesity are less likely to engage in exercise for weight loss than individuals without obesity[12,19]. Obesity differences related to exercise may have also

changed over time due to weight discrimination, which is associated with a higher likelihood of individuals feeling too embarrassed to exercise[98,99]. Feelings of embarrassment in exercising are positively associated with BMI[100]. Further, those without obesity are more likely to successfully lose weight through exercise than those with obesity[92]. Thus, this situation may discourage those with obesity to attempt weight loss through exercise. Overall, there may be disproportionately fewer individuals with obesity exercising for weight loss than individuals without obesity, now than previously. Generally, with regards to prescription weight loss pills, such medications are only approved for use in individuals with obesity or individuals with a BMI of at least 27 kg/m^2 and at least one weight-related condition[53]. However, many prescription weight loss pills are entering the market illegally, giving individuals in all BMI categories the opportunity to buy them[101]. Nevertheless, 65.7% of individuals who use prescription weight loss pills have obesity[55]. Given the increasing amount of prescription weight loss pills available in the U.S.[51], there may be disproportionately more individuals with obesity using such pills than individuals without obesity now than previously. Generally, it is unclear if obesity differences for any weight loss practices have changed over time, as these studies do not examine trends in weight loss practices over time[12,17,19,20].

2.8 Summary of Literature

While data on the effectiveness of the weight loss practices exists, changes in the trends of these weight loss practices over time require more investigation. Further, while some studies examine sex and obesity differences in weight loss practices, these have largely been limited to cross-sectional or short-term studies. Thus, this thesis will examine the proportion of weight loss methods over time as well as sex and obesity differences in individuals partaking in these weight loss methods over time.

Chapter 3: Manuscript

Changes in the Prevalence of U.S. Adults Dieting and Exercising for Weight Loss Between 1999-2016

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3.1 Introduction

Exercise, diet and the use of diet products and prescription weight loss pills are well-known methods for weight loss[10–14,15–17]. For U.S. adults attempting weight loss, exercise and dieting are the most prominent weight loss methods, while fewer U.S. adults attempt weight loss using diet products or prescriptions weight loss pills[15,16]. As the obesity rate in the United States has increased over the past twenty years, it is prudent to determine whether the prevalences of individuals dieting, exercising and using prescription weight loss pills and diet products for weight loss have increased, decreased or stayed the same over time. Changes in the popularity of certain weight loss practices over time may occur for many reasons, including the influence of health professionals[14,44], media influencers[81–83] and celebrity endorsers[72,73,102,103], all of which may increase individuals' engagement in certain weight loss practices. These changes may occur despite the possible harm associated with some of these weight loss practices, such as the use of diet products and prescription weight loss pills. Whether there are sex and obesity differences in individuals partaking in certain weight loss strategies over time is also of particular interest. Sex and obesity differences may exist in part due to engrained discriminatory societal attitudes towards the treatment of obesity, particularly in the media[81–83] and in social interactions with individuals in one's life[94,96,97], both of which may further impact the weight loss practices individuals choose. This may be since individuals of different sexes and obesity statuses experience differences in discriminating social attitudes, particularly in the way these attitudes are conveyed and the extent to which these attitudes are expressed.

Thus, the objectives of this study are to examine the trends of these weight loss practices over time and to examine sex and obesity differences in participants partaking in these weight loss practices over time. It is hypothesized that, over time, there would be a higher proportion of

individuals who report engaging in weight loss with exercise, low-calorie and low-carbohydrate diets, prescription weight loss pills and diet products, but a lower proportion of individuals who report engaging in a low-fat diet for weight loss. Further, over time, disproportionately more women would report using diet weight loss practices than men, while disproportionately more men would report engaging in exercise for weight loss than women. Finally, over time, disproportionately more individuals with obesity would report using diet weight loss practices than those without obesity, and disproportionately less individuals with obesity would report engaging in exercise for weight loss than those without obesity.

3.2 Methods

3.2.1 National Health and Nutrition Examination Survey

The National Health and Nutrition Examination Survey (NHANES) is a series of nationally representative cross-sectional surveys of United States non-institutionalized civilians. Data for this study was obtained from the NHANES continuous surveys (1999-2000, n=9,965; 2001-2002, n=11,039; 2003-2004, n=10,122; 2005-2006, n=10,348; 2007-2008, n=10,149; 2009-2010, n=10,537; 2011-2012, n=9,756; 2013-2014, n=10,175; 2015-2016, n=9,971). Informed consent was obtained from all participants[104–106], and NHANES data was obtained from publicly released data files on the NHANES website[107–109]. This study did not require ethics approval from our institutional review board, as it is an analysis of publicly available and anonymous data.

3.2.2 Sample size.

Across all survey years, a total of 92,062 participants completed questions related to health and nutrition. Analyses were restricted to the data collected from participants aged 20 years and older (n = 49,512). Participants were also excluded if they had a BMI under <18.5 kg/m^2 (n=755), were pregnant (n=1486), were not attempting weight loss (n=25,702) or were missing measured BMI (n=3352), education (n=107), smoking (n=72). The final sample size of the population for analysis was 18,242.

3.2.3 Survey Methods.

Household questionnaires were used to assess age, sex (male/female), ethnicity (white/others), education status (< high school/ ≥ high school), smoking status (smoker/non-smoker), weight loss status (yes or no) and self-reported weight loss practices. Participants who

were asked "How have you tried to lose weight in the past 12 months?"[110] were given a list of weight loss practices: exercising, eating less food, eating low-calorie food, reducing fat intake, reducing carbohydrate intake, consuming a liquid diet, consuming diet products, using prescription pills, using non-prescription pills, skipping meals, joining a weight loss program, taking laxatives or vomiting, drinking a lot of water, following a special diet, smoking, eating more fruits and vegetables, changing eating habits, eating less sugar, eating less junk food or fast food, having weight loss surgery and other[110]. For this study, the responses "eating less food" and "eating low-calorie food" were combined into one variable and renamed as "reducing caloric intake". The responses "consumed a liquid diet", "consumed diet products" and "used non-prescription pills" were combined into one variable and renamed as "diet products". The response 'eating high-protein' was not analyzed due to its low sample (n = 54 participants across all survey years).

3.2.4 Examination Measures.

All body measures were obtained by trained health technicians at the mobile examination center (MEC). Standing height was measured to the nearest tenth of a centimeter (0.1 cm) using a stadiometer with a fixed vertical backboard and an adjustable head piece. Body weight was measured in kilograms using a digital weight scale. BMI was then calculated using weight in kilograms divided by height in meters squared (kg/m^2). Normal weight was defined as a BMI of 18.5-24.9 kg/m^2, overweight was defined as a BMI of 25.0-29.9 kg/m^2 and obesity was defined as a BMI of 30 kg/m^2 and over[111].

3.2.5 Statistical Analysis.

For the NHANES sample, the descriptive characteristics of age, ethnicity, education status, smoking status, weight loss attempt and obesity status were presented as means with standard error, or prevalence, % with standard error and stratified by sex, obesity status and weight loss attempt. Differences in descriptive characteristics and obesity status between and across survey years were evaluated using linear regression, with differences by sex, obesity status, weight loss status and survey year evaluated using the least square differences post-hoc tests[112].

Predicted least square means were computed to estimate differences in weight loss practices between and across survey years using linear regression, with main effects and interactions between sex, obesity status and survey year evaluated while adjusting for age, ethnicity, education status and smoking status. The first survey year 1999-2000 was used as the reference category[112].

All analyses were weighted to be nationally representative of the United States population using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). Statistical significance was defined as p-value <0.05.

3.3 Results

Changes in weight loss attempt over time

Descriptive characteristics and obesity status for each survey year are shown in **Table 1** for men and women by obesity status and weight loss status. From 1999 to 2016, the proportion of individuals with obesity attempting weight loss increased in men from 46.6% to 55.2% ($p<0.05$) and in women from 45.0% to 52.7% ($p<.0001$) (**Table 1**).

Changes in weight loss practices over time

Weight loss practices for each survey year are shown in **Figure 1** for men and women trying to lose weight by obesity status, while adjusting for age, ethnicity, education status and smoking status.

From 1999 to 2016, more women with obesity self-reported engaging in exercise for weight loss (from 37.8% to 49.5%, $p=0.0006$) (**Figure 1A,** time*sex*obesity interaction, $p=0.09$), while there were no significant changes in the prevalence of exercise for women without obesity or men with or without ($p>0.05$ for all groups). Across time, individuals with obesity had a lower prevalence of exercise than those without obesity ($p<.0001$), while men had a higher prevalence of exercise than women ($p=0.008$).

For all sex and obesity groups, fewer individuals reported attempting caloric intake reduction for weight loss over time (from 78.6% to 73.1%, $p=0.0001$), with no differences by obesity status (**Figure 1B**, $p=0.07$). However, across time, women had a higher prevalence of reducing caloric intake than men ($p=0.002$).

Similarly, fewer men and women with and without obesity attempted fat intake reduction for weight loss over time (from 40.6% to 28.4%, **Figure 1C,** p<.0001). Across time, while there were no differences by obesity status in men (p=0.3) or women (p=0.05), women with obesity had a higher proportion of reducing fat intake than men with obesity (p=0.004), with no sex differences for individuals without obesity (p=0.8) (sex*obesity interaction, p=0.05).

For all sex and obesity groups, the proportion of individuals reporting reducing carbohydrate intake for weight loss reduced from 2005-2010 (time; p<.0001), and then increased from 2010-2016 (time; p<.0001, **Figure 1D**). Across time, women had a higher prevalence of reducing carbohydrate intake than men (from 2005-2010; p=0.03; from 2010-2016; p=0.002). From 2005-2010, individuals with obesity had a higher prevalence of reducing carbohydrate intake than individuals without obesity (p=0.01), while there were no obesity differences from 2010-2016 (p=0.70).

For all sex and obesity groups, there were no changes in the proportion of prescription weight loss pill use over time (time; p=0.70, **Figure 1E**). Across time, men and women with obesity had a higher prevalence of prescription weight loss pill use than those without obesity (p<.0001 for both). For a given obesity group, women had a higher prevalence of prescription weight loss pill use than men (p<.0001 for both).

For all sex and obesity groups, less individuals used diet products from 1999-2012 (p<.0001), while the prevalence increased from 2012-2016 (**Figure 1F,** p=0.0003). From 1999-2012, men and women with obesity had a higher prevalence of diet product use than those without obesity (p<.0001 for both). For a given obesity group, women had a higher prevalence of diet product use than men (p<.0001 for both).

Table 1. Descriptive characteristics of men and women with and without obesity by NHANES survey years.

	1999-2000		2001-2002		2003-2004		2005-2006		2007-2008		2009-2010		2011-2012		2013-2014		2015-2016		P-value	
Planning weight loss																				
Total sample size	1161		1673		1728		1892		2270		2372		2174		2443		2529		18242	
Men																				
Sample size	430		701		704		774		923		961		911		974		1038		7416	
Obesity (%)	YES (212)	NO (218)	YES (319)	NO (382)	YES (333)	NO (371)	YES (412)	NO (362)	YES (495)	NO (428)	YES (543)	NO (418)	YES (482)	NO (429)	YES (528)	NO (446)	YES (582)	NO (456)	YES (3906)	NO (3510)
	46.6 (3.1)^	53.4 (3.1)^	44.6 (2.9)^	55.4 (2.9)^	45.7 (2.0)^	54.3 (2.0)^	52.9 (2.7)^	47.1 (2.7)^	49.0 (2.5)^	51.0 (2.5)^	54.2 (1.9)*^	45.8 (1.9)*^	51.4 (2.3)^	48.6 (2.3)^	52.3 (1.2)^	47.7 (1.2)^	55.2 (2.9)*^	44.8 (2.9)*^	0.001	0.001
Age (years)	47.5 (1.7)	44.8 (0.9)	46.2 (1.0)	45.0 (0.9)	47.0 (0.8)	46.0 (1.0)	47.1 (0.8)	45.7 (1.0)	47.3 (0.7)†	45.3 (0.8)	46.2 (0.7)	44.7 (1.2)	45.9 (1.1)^	43.8 (1.2)^	46.7 (1.1)^	45.7 (0.7)	48.1 (0.9)	47.4 (1.1)	0.70	0.30
Ethnicity (% white)	76.5 (4.0)	79.1 (2.5)^	76.7 (1.8)	78.1 (3.9)^	75.5 (4.4)	76.3 (3.0)^	73.8 (3.7)	75.0 (3.6)	70.1 (5.0)	74.2 (3.0)^	68.1 (4.2)	71.6 (3.0)^	64.7 (4.3)*†	72.3 (3.3)^	65.0 (4.2)*	66.8 (3.0)*	64.2 (4.1)*	69.2 (3.9)*^	0.0005	0.003
Education (% HS or more)	77.6 (3.1)†	87.8 (2.7)^	84.2 (1.9)†	90.5 (1.7)^	87.0 (2.0)*^	88.6 (1.6)^	83.0 (2.2)†	88.0 (2.1)^	82.5 (3.2)^	86.5 (2.6)^	87.0 (1.8)*^	89.0 (2.0)^	85.5 (1.8)*^†	89.5 (2.2)^	89.3 (1.9)*^	88.7 (1.7)^	88.6 (1.8)*	87.6 (2.3)^	0.001	0.70
Smoking status (% smoker)	12.7 (3.1)^	16.3 (3.2)^	23.5 (3.1)*	20.8 (1.7)^	22.0 (2.5)*	23.0 (1.9)^	20.7 (2.8)	19.8 (2.3)^	18.4 (2.0)	19.0 (2.1)^	12.5 (1.7)^	19.2 (2.6)^	20.3 (2.2)*†	12.0 (2.0)^	16.7 (1.6)	13.1 (1.5)^	15.2 (1.3)^	15.0 (2.5)^	0.04	0.0008
Women																				
Sample size	731		972		1024		1118		1347		1411		1263		1469		1491		10826	
Obesity (%)	YES (372)	NO (359)	YES (458)	NO (514)	YES (501)	NO (523)	YES (564)	NO (554)	YES (697)	NO (650)	YES (730)	NO (681)	YES (682)	NO (581)	YES (797)	NO (672)	YES (873)	NO (618)	YES (5674)	NO (5152)
	45.0 (2.6)^	55.0 (2.6)^	43.6 (1.8)^	56.4 (1.8)^	43.9 (2.4)^	56.1 (2.4)^	45.4 (2.1)‡^	54.6 (2.1)‡^	44.8 (1.7)^	55.2 (1.7)^	46.5 (1.5)‡^	53.5 (1.5)‡^	47.4 (2.3)^	52.6 (2.3)^	50.8 (1.7)*^	49.2 (1.7)*^	52.7 (1.6)*^	47.3 (1.6)*^	<.0001	<.0001
Age (years)	47.2 (1.0)†^	42.7 (0.7)‡^	46.9 (0.8)†	43.7 (0.9)^	46.8 (0.9)†^	44.5 (0.8)^	47.2 (1.0)†^	44.8 (0.9)^	46.5 (0.7)^	44.8 (0.8)*^	48.2 (0.7)^†‡	43.8 (0.5)^	47.8 (1.0)^	45.7 (1.2)*^	47.6 (0.7)†^	44.7 (0.7)^	48.5 (0.7)†^	46.0 (0.9)*^	0.08	0.02
Ethnicity (% white)	62.4 (3.9)†‡	71.8 (3.8)‡	70.7 (2.8)‡	76.4 (2.4)	68.9 (4.4)†‡	77.7 (3.6)	68.7 (3.2)†	76.8 (3.7)^	64.7 (5.5)†	76.0 (2.8)	63.9 (3.5)†	73.2 (3.9)^	61.4 (5.6)†	75.2 (3.0)^	62.5 (4.2)†	69.8 (4.1)	58.5 (5.2)†	68.6 (3.8)	0.05	0.07
Education (% HS or more)	73.8 (3.3)†	86.6 (1.6)^	79.2 (2.4)†	86.2 (2.2)^	82.1 (2.1)*^†‡	89.3 (1.9)^	85.5 (1.5)*^†	89.7 (1.8)^	80.5 (2.3)^†	89.7 (1.6)^	82.4 (1.5)*^‡	86.1 (1.3)^	84.8 (2.0)*^†	92.8 (1.4)*^‡	85.7 (1.9)*^†	91.1 (1.5)*^‡	88.1 (1.4)*^†	92.8 (1.2)*^‡	<.0001	0.001
Smoking status (% smoker)	14.1 (1.9)^	18.8 (3.1)	20.2 (2.8)	20.6 (2.2)	20.5 (2.0)*	19.8 (2.6)	15.5 (1.7)^	19.1 (1.8)^	16.6 (2.1)	17.9 (2.2)^	16.7 (1.3)‡	18.5 (2.2)	12.9 (1.4)‡^	12.8 (1.8)^	17.2 (1.7)^	15.0 (2.2)^	15.9 (1.4)	13.1 (1.7)^	0.20	0.001
Not planning weight loss																				
Total sample size	2873		2653		2628		2382		3181		3450		2895		2917		2723		25702	
Men																				
Sample size	1577		1488		1494		1431		1790		1895		1630		1622		1510		14437	
Obesity (%)	YES (334)	NO (1243)	YES (267)	NO (1221)	YES (325)	NO (1169)	YES (296)	NO (1135)	YES (420)	NO (1370)	YES (477)	NO (1418)	YES (339)	NO (1291)	YES (343)	NO (1279)	YES (345)	NO (1165)	YES (3146)	NO (11291)
	21.1 (1.4)	78.9 (1.4)	18.5 (1.1)	81.5 (1.1)	23.4 (1.9)*	76.6 (1.9)	21.5 (2.0)	78.5 (2.0)	22.6 (1.4)	77.4 (1.4)	25.4 (2.2)	74.6 (2.2)	22.9 (1.6)	77.1 (1.6)	24.1 (1.1)	75.9 (1.1)	25.5 (2.0)	74.5 (2.0)	0.003	0.003
Age (years)	46.1 (1.1)	44.4 (0.4)	46.8 (0.9)†	44.4 (0.6)	44.8 (1.4)	45.1 (0.5)	47.1 (0.8)	45.7 (1.0)	48.1 (0.9)†	44.9 (0.7)	48.0 (1.2)	46.2 (0.8)*	49.4 (0.9)*	47.2 (1.3)*	49.9 (0.9)*†	46.5 (0.7)*	47.6 (0.7)	46.8 (0.8)*	0.001	0.0002
Ethnicity (% white)	69.9 (3.1)	69.1 (2.6)	79.2 (2.5)*†	70.7 (2.7)	73.6 (3.7)	70.9 (4.0)	71.4 (4.1)	71.6 (2.3)	68.8 (4.8)	66.9 (4.0)	71.5 (3.8)†	66.1 (3.3)	67.6 (5.4)	66.5 (3.9)	68.9 (4.8)	65.6 (3.4)	66.5 (5.2)	61.7 (4.6)	0.10	0.04
Education status (% HS or more)	71.9 (2.2)	72.9 (2.6)	83.1 (2.0)*†	77.0 (1.7)	79.9 (2.7)*	77.9 (2.1)	80.0 (2.5)*	78.9 (2.2)	74.7 (2.6)	76.1 (2.0)	78.0 (2.2)	78.0 (1.4)	77.1 (3.2)	79.7 (2.4)	76.2 (3.2)†	82.4 (2.1)*	82.7 (4.5)*	80.1 (2.6)	0.40	0.01
Smoking status (% smoker)	22.9 (2.9)†	33.5 (2.3)	21.2 (3.2)‡	31.7 (1.7)	29.0 (4.3)	33.5 (2.1)	23.0 (3.3)†	34.0 (2.1)	25.0 (3.3)	31.9 (2.8)	21.8 (2.2)	26.8 (1.7)*	23.5 (2.7)†	30.0 (2.2)	17.2 (2.1)†	26.8 (1.7)*	25.4 (2.9)	25.8 (2.0)*	0.50	0.0003
Women																				
Sample size	1296		1165		1134		951		1391		1555		1265		1295		1213		11265	
Obesity (%)	YES (408)	NO (888)	YES (293)	NO (872)	YES (292)	NO (842)	YES (258)	NO (693)	YES (414)	NO (977)	YES (501)	NO (1054)	YES (349)	NO (916)	YES (390)	NO (905)	YES (355)	NO (858)	YES (3260)	NO (8005)
	27.9 (2.0)‡	72.1 (2.0)‡	23.9 (1.6)‡	76.1 (1.6)‡	22.6 (1.7)	77.4 (1.7)*	23.8 (1.5)	76.2 (1.5)	26.7 (1.5)‡	73.3 (1.5)‡	27.8 (1.2)	72.2 (1.2)	25.8 (1.7)‡	74.2 (1.7)‡	28.9 (2.0)‡	71.1 (2.0)‡	28.2 (2.3)	71.8 (2.3)	0.10	0.10
Age (years)	50.4 (0.8)‡	49.3 (0.8)‡	49.0 (1.2)‡	49.0 (0.7)‡	50.9 (0.9)‡	50.1 (1.0)‡	47.2 (1.0)‡	44.8 (0.9)‡	50.3 (1.2)‡	50.6 (0.8)‡	52.9 (0.9)*†‡	49.4 (0.9)‡	52.5 (1.1)	49.8 (1.2)‡	52.5 (1.1)‡	51.0 (1.0)‡	53.6 (1.2)*†‡	50.9 (1.4)‡	0.001	0.2
Ethnicity (% white)	64.7 (5.1)	72.3 (3.4)	69.2 (3.9)‡	73.3 (3.3)	64.7 (5.9)†‡	74.3 (3.6)	64.8 (5.5)	70.9 (2.9)	67.2 (5.7)	70.6 (3.7)‡	60.6 (5.1)†‡	68.7 (3.8)	60.5 (5.9)‡	64.0 (4.5)	63.9 (4.0)	66.7 (3.2)	62.8 (4.9)	64.8 (4.0)	0.40	0.01
Education status (% HS or more)	70.1 (3.3)	72.6 (2.3)	74.7 (2.0)†‡	80.7 (1.6)*	70.0 (3.4)†‡	78.8 (2.6)	72.3 (3.5)†	79.5 (1.2)*	67.8 (2.5)†‡	77.8 (1.6)	70.4 (3.1)†‡	79.7 (1.6)*	76.4 (3.4)	79.6 (2.5)*	78.0 (3.0)	82.7 (1.8)*	77.2 (2.7)†	84.5 (1.9)*‡	0.03	0.001
Smoking status (% smoker)	24.5 (3.3)	23.2 (1.6)‡	21.8 (2.1)	23.7 (2.0)‡	25.7 (2.3)	24.0 (1.9)‡	25.4 (3.7)	25.0 (1.9)‡	20.3 (2.0)	22.9 (1.8)‡	18.2 (2.9)	19.1 (1.2)*‡	21.1 (3.3)	18.5 (2.4)‡	23.5 (1.7)‡	21.1 (2.8)	18.5 (2.1)	17.5 (1.7)*‡	0.10	0.002

All the continuous values are presented as means (SE) and categorical values as prevalence (SE). HS= high school; BMI = body mass index; SE= standard error. The sample size is unweighted. The analyses are unadjusted and weighted to represent the U.S population.

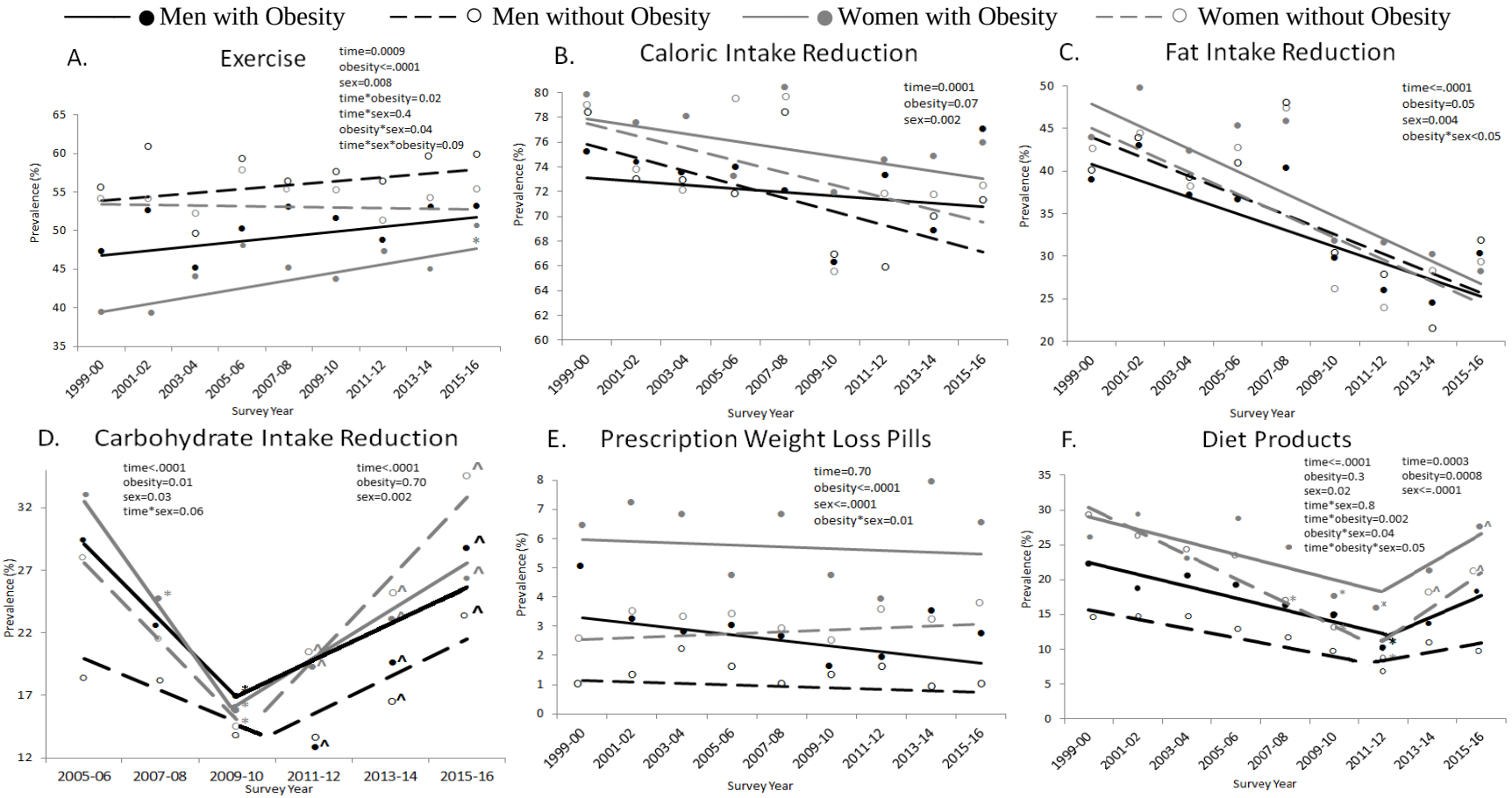
*=significantly different from 1999-2000 (p<0.05)

†=significantly different from individuals without obesity, with the same gender, with the same weight loss status, within each year (p<0.05)

‡=significantly different from men, with the same obesity status, with the same weight loss status, within each year (p<0.05)

^=significantly different from individuals not planning weight loss, with the same obesity status, with the same gender, within each year (p<0.05)

Figure 1 – Trends in exercise (A), caloric intake reduction (B), fat intake reduction (C), carbohydrate intake reduction (D), prescription weight loss pill use (E) and diet product use (F) in men and women with and without obesity.



*=significantly different from the first survey year, within each group ($p<0.05$)

^=significantly different from the lowest point in the curve, within each group ($p<0.05$)

For these symbols, black=men and grey=women

●= data point. For this symbol, black=men and grey=women; filled in=with obesity and not filled in=without obesity

Mean percentages and p-values are weighted and adjusted for age, ethnicity, education status and smoking status.

If the three-way interaction between sex, obesity and time was at or over 0.1, that and any other interactions at or over 0.1 are not included in the figure.

3.4 Discussion

3.4.1 Key Findings

The aim of this study was to evaluate trends in exercise and different dieting practices in men and women trying to lose weight by obesity status over an 18-year period. Over time, there were more individuals with obesity trying to lose weight. Amongst individuals trying to lose weight, we observed that, over time, there was no change in the proportion of individuals using prescription weight loss pills and a smaller proportion of individuals using diet products or reducing fat intake. Over time, amongst individuals trying to lose weight, there was an increase in the proportion of women with obesity partaking in exercise, while there was no change in the prevalence of exercise for weight loss for the rest of the population. Thus, we observed different trends for different weight loss practices. Future research is necessary to explore reasons driving these changes in weight loss practices over time. This study can help researchers and public health professionals understand the changing trends in weight loss practice engagement.

3.4.2 Exercise

The prevalence of exercise for weight loss did not change for women without obesity or for men with or without obesity in this study from 1999-2016. This is in contrast with data from the Behavioral Risk Factor Surveillance System (BRFSS), which observed an increasing proportion of adults engaging in exercise between 2001 and 2007[113], though this study did not specifically examine exercise for the purposes of weight loss. Despite observing a high amount of physical activity promotion over time[114–116], individuals may face certain barriers that may make it more difficult for them to engage in exercise, such as living in an unsafe neighbourhood[31,117], lack of transportation to exercise facilities[31,118], lack of money[31,117,119] and lack of time[31,117,120]. Women are more likely to experience unsuccessful weight loss attempts

through exercise than men[33], while individuals with obesity are also more likely to lose less weight than those without obesity[92]. Thus, it may be determined that women with obesity are the most likely to experience unsuccessful weight loss attempts through exercise. Thus, they may have less motivation to engage in exercise weight loss than the rest of the population[120]. First, their having the lowest likelihood of losing weight may be due to their having a lower maximal oxygen consumption rate during exercise than leaner women[121,122]. When one has a higher maximum oxygen consumption rate, one can consume more oxygen[123,124] and burn more calories[123,124] during exercise[124]. Further, men with obesity have a higher maximal oxygen consumption rate than women with obesity[125]. Thus, they can have a higher energy expenditure during exercise than women with obesity[33]. However, even though women with obesity may be the least likely to lose weight through exercise, we observed that there was an increasing proportion of these individuals engaging in exercise over time. One potential explanation may be the increasing acceptance towards women's bodies[126], which may improve body image, and thus the likelihood of engaging in exercise, as body image and exercise are positively correlated[100,127]. However, despite the increase in exercise prevalence, women with obesity are still the least likely to engage in exercise for weight loss. Given the health benefits of exercise beyond weight loss, changes are needed to reduce the many barriers preventing all individuals from engaging in exercise, but particularly women with obesity.

3.4.3 Caloric, Fat and Carbohydrate Intake Reduction

The proportion of individuals trying to lose weight through caloric intake reduction decreased between 1999-2016 but remained high, as caloric intake reduction is still the most popular method for weight loss. This observation is noteworthy, given that the obesity rate has increased over time[1], and one diet many health professionals promote for weight loss is the low-

caloric diet[14,52,128,129]. Generally, amongst individuals trying to lose weight, there were no obesity differences, as caloric restriction is a weight loss practice these individuals are most likely to partake in, regardless of BMI. However, as noted by another study[24], amongst the whole population, individuals with obesity had a higher prevalence in caloric intake reduction than those without obesity, as those with obesity are the most likely to attempt weight loss[20]. Also similar to what other studies have observed[16,17], women were more likely to engage in caloric restriction than men over time. While the prevalence of caloric restriction slightly decreased, there were also fewer individuals trying to lose weight through fat reduction. Conversely, while the prevalence of individuals trying to lose weight through carbohydrate intake reduction initially decreased from 2005-2010, it increased again from 2010-2016. This is consistent with prior research that reports a similar pattern[42,49]. Though it is clear that there are variations in the popularity of certain diets over time[42,49], it is unclear why we see these differences in trends. Nevertheless, there is no one-size-fits-all dieting approach[52], as all diets can produce similar weight loss[10,11,129] and have similarly low adherence rates[40], in part due to their restrictiveness in food intake[42,39].

3.4.4 Prescription Weight Loss Pills

For all individuals trying to lose weight, the trend of prescription weight loss pill use did not change over time. While there have been newly developed prescription weight loss medications[51], individuals may be reluctant to take them, as prescription weight loss medications have adverse effects[51], such as dizziness, headaches, insomnia[51] and micronutrient deficiencies[52]. Many prescription weight loss medications are also paid out-of-pocket, as insurance often do not cover these medications, making them less affordable[130]. There are also accessibility issues when trying to obtain these medications[131], such as a lack of access to healthcare professionals

who can prescribe these medications[132]. Thus, it may not be surprising that there was no change in the prevalence of individuals using prescription weight loss medications over time. Changes by pharmaceutical scientists, insurance companies and healthcare systems may be needed to reduce these barriers, such as producing prescription weight loss medications with fewer side effects, adding these medications to insurance plans and improving access to healthcare professionals.

3.4.5 Diet Products

There were fewer individuals trying to lose weight by using diet products from 1999-2012. Unfortunately, some individuals that have ingested diet products, such as dietary supplements and pills such as green tea extract, garcinia cambogia and OxyELITE Pro, have acquired liver injury as a result[68,133]. Thus, many individuals may be deterred from using them. Furthermore, other diet products, such as ephedra and ephedrine-containing supplements, pose safety concerns[69]. Generally, there is a shortage of evidence on the safety of diet products used for weight loss[69], especially for dietary supplements[68–71]. However, despite these issues, the proportion of individuals trying to lose weight by using diet products slightly increased from 2013-2016. This prevalence may be due to diet products being advertised as an inexpensive obesity remedy, as there is a lack of evidence-based lifestyle options in successfully treating obesity over a long period of time. More research is needed to determine whether this trend continues to increase.

3.5 Strengths and Limitations

There are several strengths and limitations worth mentioning. By using data from

NHANES, we were able to capture trends of different weight loss practices over an extensive amount of time and within a large, nationally representative sample of the U.S. population[134]. Personal interviews and questionnaires, data collections methods that have been demonstrated to decrease nonresponse bias when used together[135], were used to collect weight loss practices and weight loss status data. However, this study is cross-sectional, so causality cannot be implied. Further, it is unknown how long individuals attempted weight loss for. This is important to know, as successful weight management is a life-long process. Moreover, the intensity and the amount of time spent engaging in exercise for weight loss were not examined, since the self-reported physical activity questions refer to the intensity and the amount of time spent engaging in exercise in the past month, as opposed to the physical activities individuals partook in for the purposes of weight loss. As such, the time in which individuals self-reported the intensity and the amount of time spent engaging in exercise may not be the same period of time in which they partook in exercise for weight loss. Thus, more research may be needed to investigate whether individuals who report engaging in exercise are following the physical activity guidelines established for weight loss, which include recommendations of approximately 250-300 minutes of moderate-intensity physical activity per week[35].

3.6 Conclusion

In summary, this study observed different trends for different weight loss practices over time. Further research is needed to explore the reasons for these trends. The study's findings may be used to inform researchers and public health professionals of the types of weight loss practices individuals attempting weight loss currently engage in.

Chapter 4.0 General Conclusion

Obesity is a leading epidemic around the world, thus causing a global public health issue[136]. Worldwide, it is estimated that one billion adults will have obesity by 2025[137]. Thus, there is a need to prevent and treat this disease.

There are many weight loss practices individuals can engage in. Diet weight loss methods can improve one's blood lipid levels and reduce the effects of cardiovascular disease[52]. Common dietary approaches are reported to have similar weight loss efficacy[10,11,129]. Further, as different individuals have different dietary needs and preferences, more than one dietary approach should be incorporated into obesity management dietary guidelines. Additionally, exercise is associated with better weight management[138], despite being associated with modest weight loss. Further, physical activity is associated with diminished effects of other diseases related to obesity, such as high blood pressure and dislipidemia[138]. Thus, public health agencies should further promote physical activity and find different ways of diminishing the barriers related to exercise. As diet in conjunction with exercise can lead to a higher amount of weight loss than either of the weight loss practices alone[28,30], weight loss programs generally include both diet and exercise. However, along with diet and exercise, some individuals also use diet products and/or prescription weight loss pills. Generally, the use of diet products is not recommended for obesity treatment and weight loss, as there is a lack of evidence on their safety and efficacy. However, weight loss associated with the use of prescription weight loss pills is associated with many health benefits, such as lowered blood sugar and triglyceride levels[54]. Given the poor long-term effectiveness of lifestyle medication, in part due to known physiological adaptations that combat against long-term weight loss, pharmacotherapy is an integral part of clinically recommended obesity management. Despite its effectiveness, its

uptake has remained low. Thus, public health agencies should promote the use of these pills and dispel myths and barriers to their use. While some healthcare professionals recommend the use of prescription weight loss pills in conjunction with diet and exercise for individuals with obesity[139], others may be reluctant to prescribe these medications[140]. This may be due to their only viewing obesity as a behavioural issue that can be solved through diet and exercise[140], as opposed to also viewing obesity as a biological issue[132]. Healthcare professionals need to change this viewpoint[141], so they can treat individuals with obesity in ways that convey sensitivity towards them[132]. Further, when considering the use of prescription weight loss pills, some individuals may consider it an easy weight loss method[142]. However, given the side effects and the high cost of prescription weight loss pills, this may not be the case. Overall, there are many advantages and disadvantages in weight loss practice engagement to consider. Further, despite an existing variety of diets, physical activities, prescription weight loss pills and diet products, individuals may have different preferences for the types of weight loss practices they engage in. Thus, it is important to determine the reasons behind these preferences. Overall, in addition to conducting further research into the trends in weight loss practice engagement, researchers and public health professionals need to look beyond such engagement by also examining the genetic and environmental factors of obesity to effectively address the global obesity epidemic.

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Supplementary Tables

Supplementary Table 1. Characterization of diets

Type of Diet	Dietary intake
Low-Carbohydrate	A maximum of 150 grams[143].
Low-Fat	Less than or equal to 20% of calories from fat[11,19,144].
Low-Caloric, Portion Control	55-60% of calories from carbohydrates, 20-30% of calories from fat, 15-20% of calories from protein[18,19].
High-Protein	At least 25% calories from protein[13]. Carbohydrate intake restricted[19].