Gender Differences in Factors Associated with Clinically Meaningful Weight Loss among Adults Who Were Overweight or Obese: A Population-Based Cohort Study

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Keywords

Predictors · Clinically meaningful weight loss · Gender difference · Adults

Abstract

Objectives: The impact of heterogeneity on gender difference for achieving clinically meaningful weight loss (cmWL) remains unclear. Here, we explored the potential gender differences in factors associated with cmWL. **Methods:** A total of 60,668 participants with body mass index (BMI) ≥ 25 kg/m² at study entry and available BMI values at follow-up were included in this study. cmWL was defined as a weight loss of $\geq 5\%$ from the study entry to follow-up. The associations of social-demographic factors, personal history of chronic diseases, lifestyle behaviors, and history of BMI with cmWL were evaluated using logistic regression models. **Results:** During a median follow-up of 9.13 years, 26.6% of the participants had a cmWL (30.8% for females vs. 23.1% in males; $p < 0.001$). Participants with older age, obesity at study entry, being more physical activity compared to 10 years ago, being re-

lapsed smokers or consistent current smokers, having a history of chronic diseases (i.e., diabetes, osteoporosis, and stroke), cancer diagnosis during the study period, and more than 10-year follow-up were more likely to achieve cmWL in both males and females (all $p < 0.05$). The new smoking quitters and participants with less active in physical activity compared to 10 years ago were less likely to achieve cmWL in both males and females (all $p < 0.05$). Specifically, males with a history of emphysema were more likely to reach cmWL, and for females, those being overweight at 20 years old and current drinkers were more likely to reach cmWL ($p < 0.05$). Sensitivity analyses demonstrated similar results. **Conclusion:** Age, BMI status, physical activity, smoking status, family income, and health status were independent factors in males and females for weight management. However, further well-designed prospective studies are warranted to confirm our findings.

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Introduction

Excess body weight (i.e., overweight and obesity) is a prominent global health issue. Its prevalence in adults has increased from 21% in men and 24% in women to almost 40% in both genders, in the past 4 decades [1]. Excess body weight increases the risk of chronic diseases, such as cardiovascular diseases [2], diabetes mellitus [3], musculoskeletal disorders [4], and cancers [5, 6]. Clinically meaningful weight loss (cmWL), defined as more than 5% weight loss from initial body weight, has been associated with significant health benefits among adults, such as a decreased risk of chronic health conditions (e.g., diabetes, hypertension, cancers) and mortality [7–9]. Moreover, intentional weight loss could reduce obesity-related oxidative stress and promote self-well-being [10, 11]. However, successful weight loss along with its long-term maintenance is challenging. Around 63% of adults with obesity in the US expressed a strong desirability to control their body weight, while only 40% of them successfully reached cmWL [12]. In exercise-based interventional studies aiming to induce weight loss, the observed mean weight loss was modest and sometimes far less than the investigated individuals' expectations [13]. The potential benefits of weight loss on well-being highlight the necessity to investigate factors associated with the successful cmWL among the general population, and such information would be useful for designing effective intervention programs for body weight management.

A variety of potential factors were found to be associated with weight loss, such as demographic factors (e.g., older age, marital status, ethnicity), severe obesity, healthy lifestyle (e.g., reduced energy intake, moderate-to-vigorous intensity physical activity), and medical interventions (e.g., surgery, pharmacotherapy, behavioral intervention) [14–21]. Several studies have also reported that gender differences may impact weight control. A community survey among older adults with obesity from the US and UK evaluated the demographic predictors of cmWL and found that women had generally better weight control than men [16]. In contrast, a meta-analysis of 49 randomized controlled trials found that men might lose slightly more weight than women in both diet and diet plus exercise interventions [22]. This inconsistency regarding gender difference in weight control might be partially attributed to the differences of the study sites (i.e., community vs. clinical site), study duration, baseline body weight, enrolled sample size, and types of interventions. Compared with clinical studies, community-based cohort studies could reveal more epi-

demiological implications regarding body weight management for the general population.

The gender difference in weight control is definitely observed. Nevertheless, heterogeneity resource of gender difference related to weight control was still unclear. Only a few studies, some examined weight loss only in men or women and some in both genders, have reported some gender-specific predictors, such as workday sitting time and marital status for men, leisure-time physical activity and stress for women, to be associated with weight loss [23–28]. However, few studies compared 2 gender groups to explore the potential difference in predictors associated with weight loss.

In this study, using a large-scale prospective cohort from the Prostate, Lung, Colorectal and Ovarian (PLCO) program, we systematically explored the gender differences in potential predictors associated with cmWL among adults who were overweight or obese, including social-demographic factors, personal history of chronic diseases, lifestyle behaviors and their changes during the study period, and the history of body mass index (BMI).

Methods

Study Design and Participants

The participants were a sub-sample of the PLCO cancer screening trial program. The study was designed as previous reported [29]. Briefly, a total of 154,879 eligible participants, aged from 55 to 74 years from ten centers in the US, were enrolled from 1993 to 2001. Recruitment at all centers ended in 2001. Participants were annually followed up for incidence of cancers and cause-specific mortality until December 31, 2009. All participants self-completed a questionnaire at study entry, and a subsequent follow-up survey was introduced to update the baseline information in 2006. This study was a secondary analysis for the data from the PLCO program, and the trial was approved by the Institutional Review Board of the National Cancer Institute and the participating centers.

In this study, eligible participants were those with: (1) BMI ≥ 25 kg/m² at study entry; (2) no personal history of cancers before study entry; and (3) available BMI values at follow-up. Consequently, a total of 60,668 participants were included in this study.

Potential Predictors

Social-Demographic Factors. Participants' age, race/ethnicity, education level, annual family income, marital status, occupational status, and family history of cancer in the first relative degree were self-reported according to the standard questionnaire at study entry.

Personal History of Chronic Diseases. Information on a personal history of arthritis, diabetes, emphysema, heart attack, hypertension, osteoporosis, and stroke were self-reported using the questionnaire. Additionally, the incidence of cancer after study entry was ascertained by proper diagnostic evaluation and recorded through an annually update questionnaire, telephone calls, cancer registries, medical records, and/or death certificate [29].

Table 1. Sample characteristics of participants stratified by gender

Characteristics	Total (n = 60,668)	Males (n = 33,026)	Females (n = 27,642)
Age at randomization			
≤59 years	22,507 (37.1)	12,040 (36.5)	10,467 (37.8)
60–64 years	19,737 (32.5)	11,040 (33.4)	8,697 (31.5)
65–69 years	12,547 (20.7)	6,935 (21.0)	5,612 (20.3)
≥70 years	5,877 (9.7)	3,011 (9.1)	2,866 (10.4)
Race/ethnicity			
Non-Hispanic Whites	55,626 (91.7)	30,397 (92.0)	25,229 (91.3)
Non-Hispanic Blacks	2,233 (3.7)	848 (2.6)	1,385 (5.0)
Others	2,809 (4.6)	1,781 (5.4)	1,028 (3.7)
Educational level			
High school graduate or lower	17,649 (29.1)	8,209 (24.9)	9,440 (34.2)
Some college	21,293 (35.2)	11,032 (33.5)	10,261 (37.2)
College graduate	10,267 (17.0)	6,326 (19.2)	3,941 (14.3)
Postgraduate	11,351 (18.7)	7,395 (22.4)	3,956 (14.3)
Annual family income			
<USD 50,000	30,195 (59.6)	15,057 (53.0)	15,138 (68.2)
USD 50,000–99,000	15,666 (31.0)	9,961 (35.1)	5,705 (25.7)
≥USD 100,000	4,743 (9.4)	3,382 (11.9)	1,361 (6.1)
Marital status			
Married/cohabiting	48,162 (79.5)	28,511 (86.5)	19,651 (71.2)
Single	12,410 (20.5)	4,459 (13.5)	7,951 (28.8)
Occupational status			
Employed	26,326 (43.6)	15,943 (48.5)	10,383 (37.7)
Homeworker/unemployed/retired	31,651 (52.4)	15,673 (47.6)	15,978 (58.1)
Extended sick leave/disabled	1,124 (1.8)	596 (1.8)	528 (1.9)
Others	1,327 (2.2)	692 (2.1)	635 (2.3)
Arm			
Screening	31,328 (51.6)	17,327 (52.5)	14,001 (50.6)
Usual care	2,849 (48.4)	15,699 (47.5)	13,641 (49.4)
Years from study entry to follow-up			
<10 years	40,128 (66.1)	19,922 (60.3)	20,206 (73.1)
≥10 years	20,540 (33.9)	13,104 (39.7)	7,436 (26.9)
Family history of cancer			
No	26,601 (44.0)	15,570 (47.3)	11,031 (40.0)
Yes	33,913 (56.0)	17,382 (52.7)	16,531 (60.0)
Personal history of chronic diseases			
Arthritis	29,600 (48.8)	12,948 (43.7)	16,652 (56.3)
Diabetes	10,510 (17.3)	6,229 (59.3)	4,281 (40.7)
Emphysema	2,003 (3.3)	1,210 (60.4)	793 (39.6)
Heart attack	6,076 (10.0)	4,656 (76.6)	1,420 (23.4)
Hypertension	33,667 (55.5)	17,660 (52.5)	16,007 (47.5)
Osteoporosis	6,837 (11.3)	928 (13.6)	5,909 (86.4)
Stroke	3,409 (5.6)	2,043 (59.9)	1,366 (40.1)
Diagnosis of cancer during the study period			
No	49,709 (83.5)	25,903 (80.3)	23,806 (87.3)
Yes	9,801 (16.5)	6,340 (19.7)	3,461 (12.7)
Baseline smoking status			
Never smoker	28,285 (46.6)	12,346 (37.4)	15,939 (57.7)
Current smoker	27,851 (45.9)	18,017 (54.6)	9,834 (35.6)
Former smoker	4,523 (7.5)	2,655 (8.0)	1,868 (6.7)

Table 1 (continued)

Characteristics	Total (<i>n</i> = 60,668)	Males (<i>n</i> = 33,026)	Females (<i>n</i> = 27,642)
Pack-years			
0	28,285 (47.1)	12,346 (37.9)	15,939 (58.2)
1–10	5,816 (9.7)	3,078 (9.4)	2,738 (10.0)
11–50	18,753 (31.3)	11,902 (36.5)	6,851 (25.0)
51–100	6,091 (10.1)	4,422 (13.6)	1,669 (6.1)
≥101	1,055 (1.8)	863 (2.6)	192 (0.7)
Change in smoking status			
Consistent non-smoker	25,805 (45.5)	10,856 (35.3)	14,949 (57.5)
Consistent former smoker	25,939 (45.7)	16,947 (55.1)	8,992 (34.6)
New quitter	1,577 (2.8)	960 (3.1)	617 (2.4)
Relapsed smoker	860 (1.5)	533 (1.7)	327 (1.3)
Consistent current smoker	2,577 (4.5)	1,488 (4.8)	1,089 (4.2)
Drinking status			
Never	4,917 (8.1)	1,639 (5.0)	3,278 (11.8)
Former drinker	7,846 (12.9)	4,092 (12.4)	3,754 (13.6)
Current drinker	39,139 (64.5)	22,510 (68.1)	16,629 (60.2)
Missing	8,766 (14.5)	4,785 (14.5)	3,981 (14.4)
Activity level compared with 10 years ago			
About the same	21,550 (36.0)	12,604 (38.8)	8,964 (32.8)
Less active	33,382 (55.8)	17,339 (53.3)	16,043 (58.8)
More active	4,884 (8.2)	2,581 (7.9)	2,303 (8.4)
BMI at study entry (kg/m ²)			
Overweight (25–29.9)	39,595 (65.3)	23,013 (69.7)	16,582 (60.0)
Obesity class I (30–34.9)	15,182 (25.0)	7,954 (24.1)	7,228 (26.1)
Obesity class II/III (≥35)	5,891 (9.7)	2,059 (6.2)	3,832 (13.9)
BMI at 20 years old (kg/m ²)			
Underweight (<18.5)	2,798 (4.6)	945 (2.9)	1,853 (6.7)
Normal weight (18.5–24.9)	44,799 (74.2)	22,268 (67.7)	22,531 (81.9)
Overweight (25–29.9)	11,281 (18.7)	8,797 (26.7)	2,484 (9.0)
Obesity (≥30)	1,512 (2.5)	875 (2.7)	637 (2.3)
BMI at 50 years old (kg/m ²)			
Underweight (<18.5)	40 (0.1)	18 (0.1)	22 (0.1)
Normal weight (18.5–24.9)	15,034 (24.9)	5,406 (16.4)	9,628 (36.0)
Overweight (25–29.9)	33,441 (55.3)	21,153 (64.2)	12,288 (46.7)
Obesity (≥30)	11,963 (19.7)	6,381 (19.3)	5,582 (20.2)
Percent weight change, mean (SD)	−0.55 (8.75)	−0.13 (7.95)	−1.07 (9.59)
Clinically meaningful weight loss	16,135 (26.6)	7,624 (23.1)	8,511 (30.8)

Data are presented as *n* (%) unless otherwise stated. The numbers may not sum to the total number of participants due to missing data. BMI, body mass index; SD, standard deviation.

Lifestyle Behaviors. Information on smoking, alcohol drinking and physical activity were collected using the questionnaire. Smoking status (including non-smokers, former smokers, and current smokers) was surveyed at both study entry and follow-up. Changes in smoking status from study entry to follow-up were categorized into 5 groups: consistent non-smokers (participants who reported no smoking both at study entry and follow-up), consistent former smokers (participants who were former smokers both at study entry and follow-up), new quitters (participants who were current smokers at study entry but former smokers at follow-up), relapsed smokers (participants who were former smokers at study

entry but current smokers at follow-up), and consistent current smokers (participants who were current smokers both at study entry and follow-up). Pack-years were calculated by the number of cigarette packs smoked per day × years smoked. Alcohol drinking was categorized into never, former, and current drinkers. Physical activity level compared to 10 years ago was surveyed at follow-up, and categorized into 3 groups: about the same level compared to 10 years ago, less active compared to 10 years ago, and more active compared to 10 years ago.

BMI. Participants' body weight at 20 years old, 50 years old, study entry, and follow-up were self-reported. The self-reported

Table 2. Factors associated with clinically meaningful weight loss among all participants

Factors	Males (<i>n</i> = 33,026)		Females (<i>n</i> = 27,642)	
	<i>n</i> (%) of cmWL	ORu (95% CI)	<i>n</i> (%) of cmWL	ORu (95% CI)
<i>Social-demographic variables</i>				
Age at randomization				
≤59 years	2,170 (18.0)	1	2,661 (25.4)	1
60–64 years	2,405 (21.8)	1.27 (1.19–1.35)***	2,576 (29.6)	1.23 (1.16–1.32)***
65–69 years	1,952 (28.2)	1.78 (1.66–1.91)***	1,999 (35.6)	1.62 (1.51–1.74)***
≥70 years	1,097 (36.4)	2.61 (2.39–2.85)***	1,275 (44.9)	2.35 (2.16–2.56)***
Race/ethnicity				
Non-Hispanic Whites	6,986 (23.0)	1	7,760 (30.8)	1
Non-Hispanic Blacks	207 (24.4)	1.08 (0.92–1.27)	417 (30.1)	0.97 (0.86–1.09)
Others	431 (24.2)	1.07 (0.96–1.20)	334 (32.5)	1.08 (0.95–1.24)
Educational level				
High school graduate or lower	1,932 (23.5)	1	2,927 (31.0)	1
Some college	2,479 (22.5)	0.94 (0.88–1.01) [†]	3,218 (31.4)	1.02 (0.96–1.08)
College graduate	1,510 (23.9)	1.02 (0.94–1.10)	1,146 (29.1)	0.91 (0.84–0.99)*
Postgraduate	1,689 (22.8)	0.96 (0.89–1.04)	1,206 (30.5)	0.98 (0.90–1.06)
Annual family income				
<USD 50,000	3,681 (24.5)	1	4,817 (31.8)	1
USD 50,000–99,000	2,134 (21.4)	0.84 (0.79–0.90)***	1,584 (27.8)	0.82 (0.77–0.88)***
≥USD 100,000	659 (19.5)	0.75 (0.68–0.82)***	343 (25.2)	0.72 (0.64–0.82)***
Marital status				
Married/cohabiting	6,593 (23.1)	1	6,019 (30.6)	1
Single	1,020 (22.9)	0.99 (0.92–1.06)	2,477 (31.2)	1.03 (0.97–1.08)
Occupational status				
Employed	3,183 (20.0)	1	2,804 (27.0)	1
Homeworker/unemployed/retired	4,080 (26.0)	1.41 (1.34–1.49)***	5,276 (33.0)	1.33 (1.26–1.41)***
Extended sick leave/disabled	166 (27.9)	1.55 (1.29–1.86)***	182 (34.5)	1.42 (1.18–1.71)***
Others	156 (22.5)	1.17 (0.97–1.40) [†]	212 (33.4)	1.36 (1.14–1.61)***
Arm				
Usual care	3,615 (23.0)	1	4,094 (30.0)	1
Screening	4,009 (23.1)	1.01 (0.96–1.06)	4,417 (31.6)	1.08 (1.02–1.13)**
Years from study entry to follow-up				
<10	4,134 (20.8)	1	5,855 (29.0)	1
≥10	3,490 (26.6)	1.39 (1.32–1.46)***	2,656 (35.8)	1.36 (1.29–1.44)***
Family history of cancer				
No	3,628 (23.3)	1	3,327 (30.2)	1
Yes	3,981 (22.9)	0.98 (0.93–1.03)	5,163 (31.2)	1.05 (1.00–1.11) [†]

Table 2 (continued)

Factors	Males (<i>n</i> = 33,026)		Females (<i>n</i> = 27,642)			
	<i>n</i> (%) of cmWL	ORu (95% CI)	ORm (95% CI)	<i>n</i> (%) of cmWL	ORu (95% CI)	ORm (95% CI)
<i>Personal history of chronic diseases</i>						
Arthritis						
No	3,606 (21.5)	1	NS	2,398 (28.4)	1	NS
Yes	3,131 (24.2)	1.16 (1.10–1.23)***		5,263 (31.6)	1.16 (1.10–1.23)***	
Diabetes						
No	5,207 (20.5)	1	1	6,431 (28.9)	1	1
Yes	2,032 (32.6)	1.88 (1.76–1.99)***	1.71 (1.57–1.86)***	1,704 (39.8)	1.63 (1.52–1.75)***	1.33 (1.21–1.43)***
Emphysema						
No	6,763 (22.5)	1	1	7,778 (30.4)	1	–
Yes	364 (30.1)	1.48 (1.31–1.68)***	1.30 (1.08–1.56)**	258 (32.5)	1.10 (0.95–1.28)	
Heart attack						
No	5,691 (22.2)	1	NS	7,359 (30.1)	1	NS
Yes	1,258 (27.0)	1.30 (1.21–1.40)***		523 (36.8)	1.36 (1.21–1.52)***	
Hypertension						
No	2,949 (22.2)	1	–	3,028 (29.7)	1	–
Yes	4,071 (23.1)	1.05 (0.99–1.11) [†]		4,939 (30.9)	1.05 (1.00–1.11) [†]	
Osteoporosis						
No	6,871 (22.6)	1	1	5,746 (29.0)	1	1
Yes	299 (32.2)	1.63 (1.42–1.88)***	1.62 (1.35–1.95)***	2,069 (35.0)	1.32 (1.24–1.40)***	1.28 (1.18–1.39)***
Stroke						
No	6,497 (22.3)	1	1	7,553 (30.1)	1	1
Yes	647 (31.7)	1.62 (1.47–1.78)***	1.34 (1.16–1.54)***	561 (41.1)	1.62 (1.45–1.81)***	1.42 (1.21–1.67)***
Diagnosis of cancer during the study period						
No	5,720 (22.1)	1	1	7,153 (30.1)	1	1
Yes	1,593 (25.1)	1.18 (1.11–1.26)***	1.14 (1.05–1.24)**	1,161 (33.6)	1.18 (1.09–1.27)***	1.15 (1.04–1.28)**
<i>Risk behaviors</i>						
Baseline smoking status						
Non-smoker	2,734 (22.1)	1	NS	5,008 (31.4)	1	NS
Current smoker	4,270 (23.7)	1.09 (1.03–1.15)**		2,964 (30.1)	0.94 (0.89–0.99)*	
Former smoker	619 (23.3)	1.07 (0.97–1.18)		538 (28.8)	0.88 (0.79–0.98)*	
Pack years						
0	2,734 (22.1)	1	NS	5,008 (31.4)	1	NS
1–10	700 (22.7)	1.04 (0.94–1.14)		815 (29.8)	0.93 (0.85–1.01) [†]	
11–50	2,706 (22.7)	1.04 (0.97–1.10)		2,048 (29.9)	0.93 (0.88–0.99)*	
51–100	1,122 (25.4)	1.20 (1.10–1.30)***		508 (30.4)	0.96 (0.86–1.07)	
≥101	244 (28.3)	1.39 (1.19–1.62)***		58 (30.2)	0.95 (0.69–1.29)	
Change in smoking status						
Consistent never smoker	2,392 (22.0)	1	1	4,665 (31.2)	1	1
Consistent former smoker	3,963 (23.4)	1.08 (1.02–1.14)*	1.02 (0.95–1.10)	2,658 (29.6)	0.93 (0.87–0.98)**	1.01 (0.94–1.10)
New quitter	163 (17.0)	0.72 (0.61–0.86)***	0.69 (0.55–0.87)***	98 (15.9)	0.42 (0.34–0.52)***	0.46 (0.35–0.61)***
Relapsed smoker	154 (28.9)	1.44 (1.19–1.74)***	1.72 (1.33–2.22)***	120 (36.7)	1.28 (1.02–1.60)*	1.77 (1.32–2.39)***
Consistent current smoker	408 (27.4)	1.34 (1.18–1.51)***	1.67 (1.42–1.96)***	397 (36.5)	1.27 (1.11–1.44)***	1.75 (1.48–2.06)***

Table 2 (continued)

Factors	Males (<i>n</i> = 33,026)		Females (<i>n</i> = 27,642)		
	<i>n</i> (%) of cmWL	ORu (95% CI)	ORm (95% CI)	<i>n</i> (%) of cmWL	ORu (95% CI)
Drinking status					
Never	385 (23.5)	1	-	1,133 (34.6)	1
Former drinker	1,047 (25.6)	1.12 (0.98–1.28) [†]		1,264 (33.7)	0.96 (0.87–1.06)
Current drinker	5,014 (22.3)	0.93 (0.83–1.05)		4,803 (28.9)	0.77 (0.71–0.83)***
Missing	1,178 (24.6)	1.06 (0.93–1.21)		1,311 (32.9)	0.93 (0.84–1.03)
Activity level compared with 10 years ago					
About the same	2,804 (22.3)	1	1	2,823 (31.6)	1
Less active	3,772 (21.8)	0.97 (0.92–1.03)	0.77 (0.71–0.83)***	4,520 (28.2)	0.85 (0.80–0.90)***
More active	902 (35.0)	1.88 (1.71–2.06)***	2.17 (1.93–2.45)***	1,021 (44.3)	1.73 (1.57–1.90)***
<i>BMI history</i>					
BMI at study entry (kg/m ²)					
Overweight (25–29.9)	4,730 (20.6)	1	1	4,308 (26.0)	1
Obesity class I (30–34.9)	2,168 (27.3)	1.45 (1.37–1.54)***	1.56 (1.44–1.69)***	2,525 (34.9)	1.64 (1.51–1.78)***
Obesity class II/III (≥35)	726 (35.3)	2.11 (1.91–2.32)***	2.32 (2.03–2.65)***	1,678 (43.8)	2.44 (2.19–2.71)***
BMI at 20 years old (kg/m ²)					
Under or normal weight (<25)	5,188 (22.2)	1	NS	7,296 (29.8)	1
Overweight (25–29.9)	2,155 (24.5)	1.14 (1.07–1.20)***		949 (38.2)	1.46 (1.34–1.59)***
Obesity (≥30)	281 (32.1)	1.66 (1.43–1.92)***		266 (41.8)	1.69 (1.44–1.99)***
BMI at 50 years old (kg/m ²)					
Under or normal weight (<25)	1,211 (22.1)	1	NS	2,718 (27.8)	NS
Overweight (25–29.9)	4,614 (21.8)	0.99 (0.92–1.06)		3,732 (30.4)	1.13 (1.07–1.20)***
Obesity (≥30)	1,799 (28.2)	1.39 (1.28–1.51)***		2,061 (36.9)	1.52 (1.42–1.63)***

[†] $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. –, not involved in the multivariable logistic regression models; NS, not statistically significant in the multivariable logistic regression models; BMI, body mass index; cmWL, clinically meaningful weight loss; ORu, univariate odds ratios calculated using univariate logistic regression models; ORm, multivariate odds ratios calculated using multivariable logistic regression models using the stepwise method; 95% CI, 95% confidence interval.

height at study entry was used for BMI calculation. BMI was calculated as weight (kg) divided by the squared of the height (m). Underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), obesity class I (30–34.9 kg/m²), and obesity class II combined with class III (35 kg/m² or greater) were defined based on the World Health Organization guideline.

Statistical Analyses

The cmWL (1 = yes, 0 = no) was defined as a weight loss of ≥5% from the date of study entry until follow-up. Differences in potential factors related to cmWL were compared using the Student *t* test for continuous variables or χ^2 tests for categorical variables. Univariate odds ratios along with 95% confidence intervals (95% CIs) of potential factors associated with cmWL were firstly derived. Predictors associated with cmWL in univariate analyses at *p* < 0.05 level were included in multivariable logistic regression models for risk factors selection using the stepwise method. Sensitivity analyses were then conducted among the participants who had no history of chronic diseases, including arthritis, diabetes, emphysema, heart attack, hypertension, osteoporosis, stroke, and cancer.

All analyses were performed using the SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA). All *p* values were based on two-sided tests and were considered statistically significant at *p* < 0.05.

Results

Participants' Characteristics

Among the 60,668 participants, majority of the participants were non-Hispanic whites (91.7%) and were married/cohabiting (79.5%). Around 45.9% of the participants were current smokers at study entry, and 2.8% of the current smokers at study entry had quit smoking at follow-up. More than 8% of the participants had more physical activity compared to 10 years ago, and 55.8% reported less physical activity compared to 10 years ago (Table 1). The differences in all sample characteristics between males and females were statistically significant.

During a median follow-up of 9.13 years, 26.6% of the participants achieved cmWL, and the prevalence of cmWL among females was significantly higher than that among males (30.8% in females vs. 23.1% in males, *p* < 0.001; Table 1).

Factors Associated with cmWL among All Participants

Multivariable logistic regression models showed that participants who were older age (ORM [multivariable odds ratio] range 1.26–2.87 for males; 1.19–2.49 for females), had an obese status at study entry (ORM range 1.56–2.32 for males; 1.64–2.44 for females), were more physically active compared to 10 years ago (ORM: 2.17 for males, 1.87 for females), were relapsed smokers (ORM: 1.72 for males; 1.77 for females) or consistent current

smokers (ORM: 1.67 for males; 1.75 for females), had a personal history of diabetes (ORM: 1.71 for males, 1.33 for females), osteoporosis (ORM: 1.62 for male, 1.28 for females), and stroke (ORM: 1.34 for males; 1.42 for females), had a cancer diagnosis during the study period (ORM: 1.14 for male; 1.15 for female), and were followed for more than 10 years (ORM: 1.23 for males; 1.31 for females) were more likely to achieve cmWL, in both males and females (Table 2). Moreover, new smoking quitters (ORM: 0.69 for males; 0.46 for females) and participants who had less physical activity compared to 10 years ago (ORM: 0.77 for males; 0.65 for females) were less likely to achieve cmWL in both males and females.

Specifically, for males, those with a personal history of emphysema were more likely to achieve cmWL (ORM: 1.30, 95% CI 1.08–1.56; *p* < 0.01). For females, those who were overweight at 20 years old (ORM: 1.20, 95% CI 1.06–1.35; *p* < 0.01), and were in the cancer screening arm (ORM: 1.08, 95% CI 1.01–1.16; *p* < 0.05) were more likely to achieve cmWL. However, current female drinkers were less likely to achieve cmWL (ORM: 0.83, 95% CI 0.74–0.92; *p* < 0.001; Table 2).

Factors Associated with cmWL among Participants without Chronic Diseases

Sensitivity analyses were conducted among the participants who had no history of chronic diseases, including arthritis, diabetes, emphysema, heart attack, hypertension, osteoporosis, stroke, and cancer. Our findings showed that participants who achieved cmWL were more likely to be older (ORM: 2.49–3.20 for males; 1.63–2.75 for females), more physically active compared to 10 years ago (ORM: 1.99 for males; 1.36 for females), and had an obese status at study entry (obesity class I: ORM = 1.91 for males and 1.56 for females; obesity class II/III: ORM = 3.41 for males and 2.86 for females), in both males and females. New smoking quitters (ORM: 0.23 for males, 0.20 for females) and those who were less physically active compared to 10 years ago (ORM: 0.81 for males; 0.53 for females) had a lower probability of achieving cmWL (Table 3).

For male participants, the probability of cmWL was significantly higher among those who were relapsed smokers (ORM: 3.13, 95% CI 1.77–5.53), consistent current smokers (ORM: 1.70, 95% CI 1.18–2.46), those on extended sick leave or disabled (ORM: 3.90, 95% CI 1.38–11.01), but lower in those who reported higher annual family income (ORM: 0.81, 95% CI 0.66–0.99 for USD 50,000–99,000; ORM: 0.68, 95% CI 0.51–0.90 for ≥USD 100,000). However, there were no female-specific factors that were associated with cmWL (Table 3).

Table 3. Factors associated with clinically meaningful weight loss among participants who had no history of chronic diseases

Factors	Men (<i>n</i> = 4,404)		Women (<i>n</i> = 2,351)	
	<i>n</i> (%) of cmWL	ORu (95% CI)	ORm (95% CI)	ORu (95% CI)
<i>Social-demographic variables</i>				
Age at randomization				
≤59 years	343 (14.8)	1	1	1
60–64 years	228 (17.1)	1.18 (0.99–1.42) [†]	1.25 (1.00–1.56) [†]	1.19 (0.96–1.47)
65–69 years	140 (24.6)	1.87 (1.50–2.34)***	2.49 (1.87–3.31)***	1.54 (1.16–2.04)**
≥70 years	53 (28.5)	2.29 (1.63–3.21)***	3.20 (2.08–4.92)***	2.45 (1.64–3.68)***
Race/ethnicity				
Non-Hispanic Whites	705 (17.2)	1	–	–
Non-Hispanic Blacks	7 (14.0)	0.79 (0.35–1.75)		0.48 (0.23–0.98)
Others	52 (21.1)	1.29 (0.94–1.77)		1.33 (0.84–2.09)
Educational level				
High school graduate or lower	137 (16.3)	1	–	–
Some college	253 (18.7)	1.19 (0.94–1.49)		0.95 (0.76–1.20)
College graduate	159 (16.8)	1.04 (0.81–1.33)		0.96 (0.73–1.26)
Postgraduate	214 (17.1)	1.06 (0.84–1.34)		0.84 (0.64–1.10)
Annual family income				
<USD 50,000	315 (19.3)	1	1	1
USD 50,000–99,000	249 (15.6)	0.78 (0.65–0.93)**	0.81 (0.66–0.99)*	0.98 (0.78–1.22)
≥USD 100,000	82 (12.9)	0.62 (0.48–0.80)***	0.68 (0.51–0.90)**	0.88 (0.62–1.24)
Marital status				
Married/cohabiting	656 (17.0)	1	–	–
Single	107 (19.6)	1.19 (0.95–1.49)		0.93 (0.75–1.15)
Occupational status				
Employed	449 (16.5)	1	1	1
Homeworker/unemployed/retired	293 (18.6)	1.16 (0.98–1.36) [†]	0.84 (0.67–1.05)	1.31 (1.09–1.57)
Extended sick leave/disabled	7 (36.8)	2.95 (1.16–7.53)*	3.90 (1.38–11.01)*	0.28 (0.04–2.17)
Others	14 (17.3)	1.06 (0.59–1.90)	1.01 (0.51–2.01)	0.83 (0.41–1.68)
Arm				
Usual care	360 (17.3)	1	–	–
Screening	404 (17.0)	1.01 (0.86–1.18)		0.93 (0.77–1.11)
Years from study entry to follow-up				
<10 years	509 (16.4)	1	NS	1
≥10 years	255 (19.8)	1.26 (1.07–1.49)**		1.08 (0.86–1.36)
Family history of cancer				
No	379 (17.9)	1	–	–
Yes	384 (16.9)	0.94 (0.80–1.10)		1.09 (0.90–1.31)
<i>Risk behaviors</i>				
Baseline smoking status				
Never smoker	328 (16.2)	1	–	–
Current smoker	375 (18.2)	1.15 (0.98–1.36)		1.04 (0.86–1.27)
Former smoker	61 (18.8)	1.20 (0.89–1.62)		0.90 (0.62–1.30)

Table 3 (continued)

Factors	Men (<i>n</i> = 4,404)		Women (<i>n</i> = 2,351)		
	<i>n</i> (%) of cmWL	ORu (95% CI)	ORM (95% CI)	<i>n</i> (%) of cmWL	ORu (95% CI) ORm (95% CI)
Pack years					
0	328 (16.2)	1	-	374 (26.8)	1 -
1–10	81 (17.8)	1.12 (0.85–1.46)		70 (24.3)	0.88 (0.65–1.18)
11–50	259 (17.9)	1.12 (0.94–1.34)		141 (26.8)	1.00 (0.80–1.26)
51–100	75 (19.6)	1.26 (0.96–1.67)		35 (32.1)	1.29 (0.85–1.97)
≥101	11 (23.4)	1.58 (0.80–3.14)		3 (33.3)	1.37 (0.34–5.49)
Change in smoking status					
Consistent non-smoker	289 (15.9)	1	1	356 (26.9)	1 1
Consistent former smoker	341 (17.5)	1.12 (0.94–1.33)	1.06 (0.87–1.28)	196 (27.4)	1.03 (0.84–1.26)
New quitter	4 (5.0)	0.28 (0.10–0.77)*	0.23 (0.07–0.74)*	3 (6.4)	0.19 (0.06–0.60)**
Relapsed smoker	21 (31.8)	2.46 (1.44–4.19)***	3.13 (1.77–5.53)***	11 (40.7)	1.87 (0.86–4.08)
Consistent current smoker	54 (24.0)	1.67 (1.20–2.32)**	1.70 (1.18–2.46)**	35 (32.1)	1.29 (0.85–1.96)
Drinking status					
Never	40 (5.2)	1	-	82 (13.0)	1 -
Former drinker	95 (12.4)	1.40 (0.93–2.11)		69 (10.9)	0.78 (0.53–1.14)
Current drinker	510 (66.8)	0.97 (0.69–1.39)		393 (62.1)	0.69 (0.52–0.92)
Missing	119 (15.6)	1.33 (0.90–1.98)		89 (14.1)	0.79 (0.55–1.14)
Activity level compared with 10 years ago					
About the same	375 (17.2)	1	1	353 (30.3)	1 1
Less active	260 (14.9)	0.84 (0.71–0.99)*	0.81 (0.66–0.98)*	187 (20.1)	0.58 (0.47–0.71)***
More active	122 (27.1)	1.78 (1.41–2.25)***	1.99 (1.51–2.63)***	108 (35.8)	1.28 (0.98–1.67) [†]
BMI history					
BMI at study entry (kg/m ²)					
Overweight (25–29.9)	553 (15.5)	1	1	419 (24.4)	1 1
Obesity class I (30–34.9)	179 (24.1)	1.73 (1.43–2.10)***	1.91 (1.53–2.38)***	161 (31.6)	1.43 (1.16–1.78)**
Obesity class II/III (≥35)	32 (34.0)	2.81 (1.82–4.35)***	3.41 (2.09–5.57)***	53 (42.7)	2.32 (1.60–3.36)***
BMI at 20 years old (kg/m ²)					
Under or normal weight (<25)	547 (16.8)	1	NS	568 (26.0)	1 NS
Overweight (25–29.9)	198 (18.3)	1.11 (0.93–1.32)		57 (37.5)	1.70 (1.21–2.40)**
Obesity (≥30)	19 (29.7)	2.09 (2.21–3.60)**		8 (44.4)	2.27 (0.89–5.79) [†]
BMI at 50 years old (kg/m ²)					
Under or normal weight (<25)	131 (15.7)	1	NS	250 (25.3)	1 NS
Overweight (25–29.9)	513 (16.7)	1.07 (0.87–1.32)		297 (26.9)	1.09 (0.90–1.32)
Obesity (≥30)	120 (24.5)	1.75 (1.32–2.31)***		86 (33.6)	1.50 (1.13–2.01)**

[†] $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. –, not involved in the multivariable logistic regression models; NS, not statistically significant in multivariable logistic regression models; BMI, body mass index; cmWL, clinically meaningful weight loss; ORu, univariate odds ratios calculated using univariate logistic regression models; ORM, multivariable odds ratios calculated using multivariable logistic regression models using the stepwise method; 95%CI, 95% confidence interval.

Discussion

Using the data from the PLCO study, we systematically evaluated the potential factors associated with cmWL in males and females, separately. Our findings showed that older age, more physical activity, and obese status at study entry were positive factors of achieving cmWL, while quitting smoking was a negative factor of cmWL in both males and females. Consistent current smoking, relapsed smoking, and extended period of sick leave/being disabled were male-specific positive factors of cmWL, but high annual family income was a male-specific negative factor of cmWL.

We observed that females had a higher prevalence of cmWL than males, which was consistent with a previous study [16]. Women were more likely to perceive themselves as overweight or obese status than men [30–33]. This disparity might be partially attributable to different attitudes and perceptions of body weight between males and females due to social pressure. Women generally internalize a thin ideal and usually felt unsatisfied when comparing themselves to slender female images. In contrast, the ideal and widely acceptable male body type was to be muscular rather than skinny [34], but men did not hold a strong value of shaping themselves into an ideal body size as compared to women [35]. Overall, the misperception of males in body weight was associated with their less attempts for weight control and lower level of physical activity, which consequently resulted in a lower prevalence of critical weight loss [33].

Consistent with previous studies, participants who were older, obese and more physically active had a higher probability of achieving cmWL [14, 16, 36]. Besides, relapsed smokers or consistent current smokers were more likely to reach cmWL, whereas new smoking quitters were less likely to reach cmWL [37]. Participants with a history of chronic diseases (i.e., diabetes, osteoporosis, stroke, and newly diagnosed cancers) had a higher prevalence of cmWL [38–40]. Sensitivity analyses showed that participants who were older, more physically active, and with an obese status at study entry were more likely to achieve cmWL in both genders. New smoking quitters had a lower rate of cmWL among both males and females. However, we found that only males who were relapsed smokers or consistent current smokers were more likely to reach cmWL. The association between smoking behavior and weight loss seems to be complicated. A previous study reported that smoking was positively associated with weight loss, while smoking cessation was related to weight gain [37], which was similar to our findings that

new smoking quitters were less likely to achieve cmWL. Another study reported that the number of cigarettes per day was associated with long-term weight gain following smoking cessation [41]. However, a recent study reported no difference in long-term weight loss between never smokers, former smokers, and current smokers [42]. It was intriguing to find that females in the cancer screening arm had a higher probability of achieving cmWL than those in the usual care arm. The results indicated that adults who were involved in the screening arm may intentionally control their body weight as a way to reduce the risk of morbidity and mortality. This indicates that cancer screening could serve as a potential “teachable moment” for obesity intervention [43], as the cancer screening sites could be easily applied to conduct body weight reduction intervention. However, the extent to which screening results could alarm individuals to amend their risk behaviors/factors in order to control body weight is still unknown and needs future research.

The present study investigated the predictors of cmWL among midlife to older adults and their gender differences using a large-scale prospective cohort study. The study design and data quality were reliable considering that the data in the present study was from a randomized trial. Our findings have implications for future interventional research aiming at the maintenance of long-term weight loss, given that an increase in initial weight loss was associated with larger long-term weight loss [44]. However, several limitations might exist in the present study. First, there might be recall bias due to self-reported body weight, and there may have been exaggeration of weight loss due to social desirability. Second, other potentially important factors associated with weight loss (e.g., history of medical interventions, eating behaviors and other lifestyle modification, dietary intake, psychological history, social environments) were not analyzed in this study due to the restriction of information collected in the PLCO study. Third, measurements of body weight were performed only twice, and could not accurately represent the long-term weight status. Fourth, the duration of being overweight/obese may be an important factor influencing weight control, and the intention to control weight among adults with a long-term duration of overweight/obesity is obviously different from those with a short-term duration of overweight/obesity. Fifth, there might exist unintentional weight loss in our sample which might bias our findings, although our sensitivity analyses by excluding participants with chronic diseases demonstrated similar results. Sixth, there might be third variables which mediate/moderate (e.g., attitude toward weight control) the association between predictors in our study and

cmWL across genders. Moreover, due to the nature of secondary analysis, it is less likely to make any causal inferences regarding the association between analyzed factors and cmWL.

Conclusions

Our findings suggested that consistent current smoking, relapsed smoking, and extended duration of sick leave/being disabled were male-specific positive factors associated with cmWL, while high annual family income was a male-specific negative factor associated with cmWL. Additionally, older age, more physical activity, and obese status at study entry were positive factors of cmWL, while quitting smoking was a negative factor of cmWL, in both males and females. Therefore, to facilitate long-term cmWL, factors including age, physical activity, obesity status, family income, smoking status need to be separately considered in males and females. Moreover, further well-designed prospective studies are warranted to evaluate the gender differences in other potential factors associated with weight loss, such as a history of medication use, duration of overweight/obesity, eating behavior, and diet status. Also, well-designed randomized controlled trials involving different weight loss strategies are warranted to confirm our findings.

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Statement of Ethics

This study is a secondary analysis for the data from the PLCO program sponsored by National Cancer Institute, and the clinical trial numbers were NCT00002540 (Prostate), NCT01696968 (Lung), NCT01696981 (Colorectal), NCT01696994 (Ovarian). The PLCO study was reviewed and approved by the Institutional Review Board of the National Cancer Institute (NCI) and the ten centers, and all participants provided written informed consent. The IRB protocol number of the PLCO program is OH97-C-N041. The present study (approved No. by NCI: PLCO-295) was approved by National Cancer Institute in 2017, and the data extracts were de-identified prior to their release to authors. This study was conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Conflict of Interest Statement

The authors declare that they have no competing interests.

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Author Contributions

J.-B.L., J.-D.L., and X.Z. conceived and designed this study; J.-B.L. and X.Z. did the statistical analyses. J.-B.L., Z.-Y.Q., and X.Z. drafted the manuscript. J.-B.L., Z.-Y.Q., Z.L., Q.Z., L.-F.F., J.-D.L., and X.Z. revised and critically reviewed the manuscript. All authors read and approved the final version of the manuscript.

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