

Three-Year Weight Change in Successful Weight Losers Who Lost Weight on a Low-Carbohydrate Diet

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Key words: weight loss, physical activity, weight maintenance, weight control, low-carbohydrate diet

Abstract

Objective: The purpose of this study was to evaluate long-term weight loss and eating and exercise behaviors of successful weight losers who lost weight using a low-carbohydrate diet.

Research Methods and Procedures: This study examined 3-year changes in weight, diet, and physical activity in 891 subjects (96 low-carbohydrate dieters and 795 others) who enrolled in the National Weight Control Registry between 1998 and 2001 and reported ≥ 30 -lb weight loss and ≥ 1 year weight loss maintenance.

Results: Only 10.8% of participants reported losing weight after a low-carbohydrate diet. At entry into the study, low-carbohydrate diet users reported consuming more kcal/d (mean \pm SD, 1895 ± 452 vs. 1398 ± 574); fewer calories in weekly physical activity (1595 ± 2499 vs. 2542 ± 2301); more calories from fat ($64.0 \pm 7.9\%$ vs. $30.9 \pm 13.1\%$), saturated fat (23.8 ± 4.1 vs. 10.5 ± 5.2), monounsaturated fat (24.4 ± 3.7 vs. 11.0 ± 5.1), and polyunsaturated fat (8.6 ± 2.7 vs. 5.5 ± 2.9); and less dietary restraint (10.8 ± 2.9 vs. 14.9 ± 3.9) compared with other Registry members. These differences persisted over time. No differences in 3-year weight regain were observed between low-carbohydrate dieters and other Registry members in intent-to-treat analyses (7.0 ± 7.1 vs. 5.7 ± 8.7 kg).

Discussion: It is possible to achieve and maintain long-term weight loss using a low-carbohydrate diet. The long-term health effects of weight loss associated with a high-fat diet and low activity level merits further investigation.

Introduction

A large number of Americans have adopted a low-carbohydrate dietary approach to weight loss and/or weight maintenance (1), but we know little of its long-term effects or consequences. Short-term evaluations have reported significant weight losses among low-carbohydrate diet users (2,3). However, two long-term evaluations found no significant differences in weight loss between low-carbohydrate dieters and controls at 1 year (4,5); findings in both studies were limited by significant attrition.

The purpose of the present study was to evaluate the use and effectiveness of low-carbohydrate diets among a group of individuals who have been successful at long-term weight loss maintenance. Participants were members of the National Weight Control Registry (NWCR),¹ a Registry of individuals who have lost ≥ 13.6 kg (30 lb) and kept it off for ≥ 1 year. Previously, we found that only a minority of Registry participants reported consuming a low-carbohydrate diet (6). However, the prevalence of low-carbohydrate

¹ Nonstandard abbreviations: NWCR, National Weight Control Registry; EI, energy intake; BMR_{est}, estimated basal metabolic rate.

diets in the Registry has increased in recent years (7). The present study evaluated the characteristics of participants in the Registry who reported consuming a low-carbohydrate diet that resulted in their successful weight loss maintenance. In addition, low-carbohydrate dieters in the Registry were compared with other Registry members on changes in weight, eating, exercise, and dietary restraint over the course of 3 years of follow-up.

Research Methods and Procedures

Participants

Participants were members of the NWCR. Participants in the NWCR are recruited from coverage and advertisements in various media, including newspaper, magazine, radio, and television. To be eligible for enrollment in the NWCR, participants must have lost at least 13.6 kg (30 lb) and kept it off for ≥ 1 year. Registry participants complete annual questionnaire-based assessments of weight and/or behavioral factors. We limited our sample to participants who enrolled between January 1998 and 2001, at which time the Atkins' diet (8) Website encouraged members to enroll in the Registry and provided a link to the Registry's Website. Through the Registry's Website, interested participants could request to receive more information about the study. Participants enrolled in the study completed questionnaires sent through the mail. Participants in this study were limited to those who had enrolled in the Registry at least 3 years ago, had completed a Weight History Timeline (see Group Inclusion Criteria), and denied pregnancy from study entry to the Year 3 follow-up ($N = 891$).

Group Inclusion Criteria. Low-carbohydrate diet participants were identified based on self-reported use of a low-carbohydrate diet. Specifically, a Weight History Timeline was administered to assess weight changes before study enrollment. Participants were asked to develop a timeline of weight changes between their lifetime maximum weight and their study entry weight and to indicate, by completing an open-ended table, the reasons and type of weight loss regimen used to produce these changes. All timelines were then evaluated to determine the type of weight loss regimen used in the participant's most recent successful weight loss. Those who indicated low-carbohydrate regimens (e.g., the Atkins' diet; South Beach diet; "low carb" diet) were compared with all other participants who enrolled in the Registry during the same time period (i.e., after 1998). To be coded as having followed a low-carbohydrate diet, participants must have lost at least 30 lbs on the diet, and it must have been the most recent diet associated with their successful weight loss. Exclusions were not made based on medical factors or use of other concomitant methods for weight loss (e.g., exercise).

All participants provided written informed consent, and this study was approved by the Miriam Hospital Institu-

tional Review Board for the Protection of Human Subjects in Research.

Measures

Behavioral measures were administered at entry into the study and at 1- and 3-year follow-ups. Compensation for completing the questionnaires was not provided. However, to improve the 3-year response rate, individuals who did not complete the full assessment battery (of both weight and behavior) were sent \$5 and asked simply to report their weight.

Demographics. Demographic information included self-assessments of age, gender, marital status, education level, ethnicity (i.e., white, black, Asian, Hispanic, or other), and duration of weight loss from the 30-lb criterion. These data were collected and analyzed as potential moderators of outcome.

Weight. Weight was self-reported at study entry and subsequently at 1-, 2-, and 3-year follow-ups. All participants in the Registry are asked to provide either before-and-after weight-loss pictures or names of individuals who can document their current weight (e.g., physician or weight-loss counselor). For the current study, second party verification was collected but not formally analyzed; in previous research with the Registry population, the correlation between Registry participants' self-reported weight and the weight documented by their physician or weight loss counselor was 0.97 ($p = 0.0001$) (9). Other studies have similarly found that self-reported current weight is a valid measure of actual weight (10,11).

Weight History and Weight Loss Methods. At entry into the study, participants were asked to provide a detailed weight-loss history, including their highest lifetime maximum weight, the date when a 30-lb weight loss was achieved, and the duration of maintaining a minimum of a 30-lb weight loss. As discussed in Group Inclusion Criteria, participants also completed a Weight History Timeline. In addition, questions were asked about participants' diet and activity methods used to promote weight loss. Specifically, participants were asked to indicate the strategies they used to lose weight, including exercise, use of exercise classes, prescription medication or over-the-counter diet pills, surgery, a diet book/magazine, or another person. Participants were asked to indicate (on a scale where 0 = not at all and 5 = major aspect) the degree to which several strategies were part of their successful weight loss, including decreasing quantities of types of food eaten, limiting intake of certain types of foods (fat or sugars) or specific classes of food (desserts), limiting intake to only 1 or 2 types of foods, counting calories, counting fat grams, and using liquid formula.

Food Intake. Dietary factors were assessed by the Block Food Frequency questionnaire (12), which yields total grams of carbohydrate, fat, and protein consumed daily as

well as percentage of calories from these nutrients and daily caloric intake. The Block has been shown to correlate significantly with 4-day food diaries (13). Under-reporting of dietary intake has been recognized as a common problem (14) and is often addressed by computing a ratio of energy intake (EI) to estimated basal metabolic rate (BMR_{est}) (15). In this study, we estimated BMR_{est} using the Harris-Benedict equation (16) and classified participants with an EI: $BMR_{est} < 0.9$ as under-reporters (15).

Physical Activity. Physical activity was assessed using the Paffenbarger Activity Questionnaire (17). This measure yields estimates of the total energy expended in physical activity per week. The Paffenbarger Activity Questionnaire has been shown to have high test-retest reliability (18) and to be significantly correlated with measures of cardiovascular fitness (19).

Eating Behavior. The Eating Inventory (20) was used to assess levels of dietary restraint, disinhibition, and hunger. Items on the Restraint subscale reflect behaviors used to control dietary intake (e.g., “consciously control my intake” and “count calories”). The Dietary Disinhibition subscale measures a person’s reported loss of control while eating. The Hunger subscale measures food intake in response to feelings and perceptions of hunger. All three scales have been found to have good test-retest reliability and internal consistency (20,21).

Statistics

Analyses were performed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 13.0 and SAS for Windows, version 9.1. Descriptive statistics are presented as either mean \pm SD for continuous measures or percentages for categorical responses. Independent t tests and χ^2 tests were used to compare differences in demographic variables between the low-carbohydrate and other Registry member groups. χ^2 tests were also used to compare differences in weight loss methods and individual restraint scale items between the low-carbohydrate and other Registry member groups. A series of 2×2 ANOVAs were conducted to evaluate group differences as a function of dropout status on demographic variables. Differences among groups in changes in weight were compared using ANCOVA with repeated measures, controlling for differences at entry into the study. We also compared groups on the distribution of weight change using the 2-sample Kolmogorov-Smirnov statistic. Completer analyses were conducted using all available data within the SAS Proc Mixed procedure. For intent-to-treat analyses, a 2.5-kg/yr weight regain was assumed in the case of missing data. This value was selected based on the weight regain of ~ 2.5 kg/yr observed in previous studies of NWCR participants (22). Moreover, this approach is more conservative than a last-observation-carried forward analysis, which would seem to overestimate weight maintenance success given the well-

documented weight regain that occurs over time (23). Changes in other study measures (food intake, physical activity, eating behavior) were also examined using ANCOVA with repeated measures, adjusting for differences at entry into the study. These analyses, however, were limited to participants who were available at the time of assessment (i.e., treatment completers). Supplemental analyses were conducted excluding participants whose EI: BMR_{est} was < 0.9 .

Results

Only 10.8% ($n = 96$) of the 891 participants reported losing weight after a low-carbohydrate diet. These participants, compared with all others, were more likely to endorse having lost weight by using a diet program obtained from a book or magazine and limiting specific types or classes of food; they were less likely to endorse using exercise, counting calories, or counting fat grams to lose weight (Table 1). Low-carbohydrate diet participants were also more likely to be male (54.2% vs. 27.0%; $p = 0.0001$) and had a shorter duration of successful weight loss maintenance (34.4 ± 45.1 vs. 73.1 ± 99.0 months; $p = 0.0001$), higher body weight at study entry (80.2 ± 16.7 vs. 73.5 ± 17.1 kg; $p = 0.0001$), and less weight loss from lifetime maximum weight before study enrollment (27.6 ± 13.5 vs. 32.1 ± 16.2 kg; $p = 0.003$) compared with the other Registry participants (Table 2). Subsequent analyses controlled for these demographic differences.

Attrition

The low-carbohydrate and other Registry member (i.e., non-low-carbohydrate diet) groups did not significantly differ in the proportions reporting weight data at 1, 2, and 3 years (77.1%, 80.1%, and 70.4%, respectively) or the proportions reporting behavioral data at 1 and 3 years (76.8% and 65.3%, respectively). Individuals who failed to return weight data at 3 years were significantly younger than those who returned data (47.4 ± 12.9 vs. 50.3 ± 12.5 years; $p = 0.002$) and were heavier at entry into the study (76.2 ± 18.5 vs. 73.4 ± 16.7 kg; $p = 0.03$). No significant differences were observed in other demographic characteristics or magnitude of weight regain before attrition.

Behavioral Measures

Repeated-measures analyses of covariance with post hoc contrasts indicated that individuals in the low-carbohydrate group reported consuming significantly more calories per day at entry into the study ($F = 15.5$; $p = 0.0001$) (Table 3). At entry into the Registry and at 1- and 2-year follow-ups, low-carbohydrate dieters also reported consuming greater percentage of calories from fat ($F = 483.7$; $p = 0.0001$), including higher saturated ($F = 273.1$; $p = 0.0001$), mono-unsaturated ($F = 477.0$; $p = 0.0001$), and polyunsaturated

Table 1. Percentage of participants in each group using specific strategies to lose weight

Characteristic	Low-carbohydrate diet followers (<i>n</i> = 96)	Other Registry members (<i>n</i> = 795)	<i>p</i>
Physical activity	44.8	88.1	0.0001
Exercise classes	5.2	24.8	0.0001
Prescription or over-the-counter pills	1.0	6.7	0.03
Surgical procedure	1.0	1.5	0.71
Diet program obtained from a book, magazine, or another person	96.9	26.9	0.0001
Liquid formula	1.0	12.2	0.001
Decreasing the quantity of all types of foods eaten*	7.3	63.9	0.0001
Limiting intake of certain types of food or specific classes of food*	98.9	82.9	0.0001
Limiting intake to only 1 or 2 types of foods*	18.8	4.5	0.0001
Counting calories*	0%	34.6	0.0001
Counting fat grams*	0%	29.9	0.0001

* Percentage of participants who endorsed 4 or 5 on a scale of 0 to 5 (where 5 = major aspect and 0 = not at all).

($F = 97.2$; $p = 0.0001$) fat intake. Low-carbohydrate dieters also reported a significantly higher percentage of calories from protein ($F = 48.1$; $p = 0.0001$) and lower percentage of calories from carbohydrate ($F = 457.7$; $p = 0.0001$) at all time-points. Table 3 also shows the within-group changes,

which, although significant, were far smaller in magnitude than between-group differences.

Low-carbohydrate dieters also reported expending significantly fewer calories per week in physical activity ($F = 19.2$; $p = 0.0001$) at all time-points (Table 3). Similarly, a

Table 2. Participant characteristics at entry into the National Weight Control Registry

Characteristic	Low-carbohydrate diet followers (<i>n</i> = 96)	Other Registry members (<i>n</i> = 795)	<i>p</i>
Age (years) [mean (SD)]	49.0 (11.7)	49.5 (12.8)	0.76
BMI (kg/m ²) [mean (SD)]	26.6 (3.9)	25.7 (5.1)	0.08
Weight (kg) [mean (SD)]	80.2 (16.7)	73.5 (17.1)	0.0001
Weight loss (kg) from maximum weight [mean (SD)]	27.6 (13.5)	32.1 (16.2)	0.003
Duration (months) at 13.6-kg weight-loss criterion [mean (SD)]	34.4 (45.2)	73.1 (99.0)	0.0001
Gender (% male)	54.2	27.0	0.0001
Ethnicity (% white)	97.9	94.8	0.71
Education (% completed)			
High school	16.7	11.8	
Some college	31.3	29.4	
College	27.1	23.7	
Graduate or professional	25.0	35.1	0.27

SD, standard deviation.

Table 3. Behavioral characteristics of low carbohydrate and other Registry members

	Study entry	Year 1	Year 3	Main effect (<i>p</i>)	Time-by-group interaction (<i>p</i>)
Total kcal per day					
L-CHO	1894 (752) ^a	1579 (641) ^b	1610 (698) ^b		
Others	1398 (574) ^a	1366 (565) ^b	1340 (582) ^b		
<i>p</i> *	0.003	0.39	0.069	0.0001	0.0001
% kcal fat					
L-CHO	64.0 (7.9) ^a	60.9 (10.5) ^b	58.8 (11.6) ^b		
Others	30.9 (13.1) ^a	31.3 (12.3) ^a	32.6 (11.2) ^a		
<i>p</i> *	0.0003	0.0003	0.0003	0.0001	0.0001
% kcal saturated fat					
L-CHO	23.8 (4.1) ^a	22.5 (5.1) ^b	21.4 (5.4) ^b		
Others	10.5 (5.2) ^a	10.6 (5.0) ^a	11.1 (4.4) ^b		
<i>p</i> *	0.0003	0.0003	0.0003	0.0001	0.0001
% kcal monounsaturated fat					
L-CHO	24.4 (3.7) ^a	23.2 (4.5) ^b	22.0 (4.8) ^c		
Others	11.0 (5.1) ^a	11.3 (4.9) ^b	11.8 (4.5) ^c		
<i>p</i> *	0.0001	0.0001	0.0001	0.0001	0.0001
% kcal polyunsaturated fat					
L-CHO	8.6 (2.7) ^a	8.4 (2.5) ^a	8.7 (3.4) ^a		
Others	5.5 (2.9) ^a	5.6 (2.7) ^a	5.8 (2.7) ^b		
<i>p</i> *	0.0001	0.0001	0.0001	0.0001	0.355
% kcal protein					
L-CHO	23.2 (4.2) ^a	22.2 (4.1) ^b	20.4 (3.8) ^c		
Others	18.9 (4.5) ^a	18.6 (4.5) ^a	18.6 (4.6) ^a		
<i>p</i> *	0.0003	0.0003	0.015	0.0001	0.0001
% kcal carbohydrate					
L-CHO	9.5 (6.9) ^a	13.9 (11.1) ^b	16.9 (12.1) ^c		
Others	48.2 (15.2) ^a	48.1 (14.5) ^a	46.6 (13.1) ^b		
<i>p</i> *	0.0003	0.0003	0.0003	0.0001	0.0001
Exercise kcal/wk					
L-CHO	1595 (2499) ^a	1434 (1597) ^a	1119 (1113) ^a		
Others	2542 (2301) ^a	2370 (2412) ^{ab}	2246 (2130) ^b		
<i>p</i> *	0.0003	0.012	0.0006	0.0001	0.91
Dietary restraint					
L-CHO	10.8 (2.9) ^a	11.1 (2.6) ^a	11.4 (3.4) ^a		
Others	14.9 (3.9) ^a	14.7 (3.9) ^a	14.4 (3.9) ^a		
<i>p</i> *	0.0003	0.0003	0.0003	0.0001	0.0001
Dietary disinhibition					
L-CHO	6.5 (3.3) ^a	7.0 (3.8) ^a	7.1 (4.2) ^a		
Others	6.6 (3.6) ^a	6.9 (3.9) ^a	6.9 (4.1) ^a		
<i>p</i> *	0.869	0.783	0.419	0.962	0.793
Hunger					
L-CHO	3.6 (3.1) ^a	3.6 (3.0) ^a	4.2 (3.2) ^a		
Others	4.4 (3.2) ^a	4.5 (3.3) ^a	4.7 (3.5) ^a		
<i>p</i> *	0.34	0.31	1.0	0.0164	0.864

L-CHO, low-carbohydrate diet. Values are mean (standard deviation). Across rows, values with difference superscript letters indicate significant differences by time within each group ($p < 0.05$), in Bonferroni-adjusted post-hoc contrasts.

* *p* value for difference between groups based on post hoc Bonferroni-corrected contrasts.

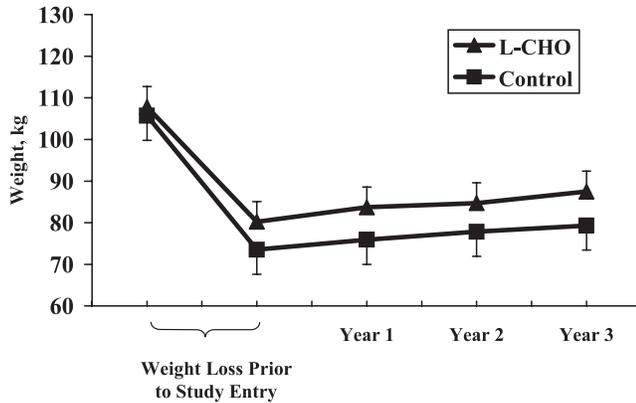


Figure 1: Changes in body weight for participants in the two groups, using intent-to-treat analysis. L-CHO, low carbohydrate diet.

smaller proportion of low-carbohydrate dieters indicated that they had modified physical activity to accomplish their successful weight loss (44.8% vs. 88.1%; $p = 0.0001$).

Low-carbohydrate dieters reported significantly less hunger than other Registry members ($F = 5.79$; $p = 0.02$); however, after Bonferroni adjustment, none of the post hoc contrasts was significant (Table 3). No significant differences in dietary disinhibition were observed. Low-carbohydrate dieters reported significantly less dietary restraint ($F = 60.3$; $p = 0.0001$). Low carbohydrate dieters were less likely to endorse taking small helpings as means of controlling their weight (18.7% vs. 68.9%; $p = 0.0001$), consciously holding back at meals in order not to gain weight (15.4% vs. 61.6%; $p = 0.0001$), and counting calories as a conscious means of controlling their weight (6.6% vs. 49.4%; $p = 0.0001$). Participants' scores on all of the individual dietary restraint scale items at entry into the study are displayed in Appendix A (available online at the *Obesity* website, www.obesityresearch.org).

Analyses conducted excluding individuals classified as extreme under-reporters (i.e., EI/BMR < 0.9) yielded the same statistical conclusions.

Weight Changes

In completer analyses, the low-carbohydrate group did not significantly differ from other Registry members on magnitude of weight regain at the 1-year (3.8 ± 8.9 vs. 2.3 ± 5.4 kg), 2-year (4.5 ± 8.0 vs. 4.0 ± 8.0), or 3-year (6.5 ± 8.5 vs. 4.7 ± 9.1 kg) follow-ups. Intent-to-treat analyses also revealed no significant differences between the low-carbohydrate diet group and other Registry members at 1 year (3.4 ± 7.5 vs. 2.3 ± 4.7 kg), 2 years (4.5 ± 6.9 vs. 4.3 ± 7.4 kg), and 3 years (7.0 ± 7.1 vs. 5.7 ± 8.7 kg) ($F = 2.0$; $p = 0.16$) (Figure 1). Analyses examining the distribution of weight changes between groups also found no significant group differences.

Discussion

This study was the first to examine long-term weight changes and behavioral patterns among a group of individuals who had successfully lost weight using a low-carbohydrate diet and had maintained their weight loss for at least 1 year. We limited our sample to participants who enrolled in the Registry between 1998 and 2001 when low-carbohydrate diets were rising in popularity and the Atkins' diet (8) Website specifically included a link to the NWCR. Even during this period of popularity for low-carbohydrate diets, only a minority (10.8%) of successful weight losers in the Registry reported losing weight using a low-carbohydrate diet approach. Nonetheless, for this subgroup of individuals, it was possible to lose and maintain long-term weight loss using a low-carbohydrate diet.

Comparing those individuals in the Registry who lost weight using a low-carbohydrate diet ($n = 96$) vs. those who used other dietary strategies ($n = 795$), we found no significant differences in magnitude of 3-year weight regain. Foster et al. (4) observed greater weight regain among low-carbohydrate dieters compared with controls 6 to 12 months after initiating a diet program. However, the current study differs markedly from Foster et al. (4) in that it is not a randomized clinical trial, and subjects were already successful at weight loss before enrolling in the study. In the current study, those individuals who reported losing weight using a low-carbohydrate diet had no greater risk of weight regain than individuals following other diets. These findings suggest that successful weight loss may be possible using a variety of different dietary approaches.

Comparisons of low-carbohydrate dieters and other Registry members revealed that fat intakes were significantly higher in the low-carbohydrate group. Indeed, 64% of daily calories of the low-carbohydrate subjects were derived from fat compared with 30% in other Registry members. Although fat intake decreased over time, low-carbohydrate participants were still consuming 59% of their calories from fat at the 3-year follow-up. This amount of fat intake is 18% higher than that reported previously among low-carbohydrate dieters participating in a 6-month randomized control trial by Samaha et al. (24). The higher fat intake among long-term successful weight losers in the current study may reflect more "extreme" adherence to the diet regimen required to maintain weight loss in the long-term.

Examining types of fat, low-carbohydrate dieters were consuming 24% of daily calories from saturated fat, 24% from monounsaturated fat, and 8.6% from polyunsaturated fat. The greater intake of saturated fat in low-carbohydrate dieters is of potential concern given the association between saturated fat intake and increased plasma concentrations of lipids (25), insulin resistance (26), and coronary artery disease (27). On the other hand, the low-carbohydrate diet participants were also consuming diets higher in monounsaturated and polyunsaturated fats. Higher intakes of mono-

unsaturated and polyunsaturated fats have been associated with a decreased risk of coronary artery disease (27). In the current study, intake of monounsaturated fat in low-carbohydrate dieters was higher (24% vs. 16%) than that reported previously in a 6-month trial that showed no deleterious effects of a very low-carbohydrate diet on cardiovascular disease risk factors (28). Other research has shown high fat diets to lower cardiac risk factors over 6 months (5). Similarly, in the Nurses Health Study, Halton et al. (29) found that low-carbohydrate diets were not associated with increased risk of coronary heart disease in women during 20 years of follow-up; and in the Women's Health Initiative, low-fat diets did not to reduce cardiovascular disease outcomes over 8 years (30). It is possible that the greater intake of monounsaturated and polyunsaturated fats among the low-carbohydrate dieters in the current study could mitigate potential adverse effects of higher saturated fat intake. Further research is needed to determine the health risks associated with long-term consumption of a diet that is both high in saturated and monounsaturated and polyunsaturated fats.

The low-carbohydrate group also consumed a higher protein diet and reported less hunger, which could also be a factor in their success given prior research suggesting that higher protein consumption is related to improved satiety and less weight regain (31,32). Similarly, other research has shown that a low-carbohydrate diet can decrease food intake without negatively affecting hunger (33).

Interestingly, low-carbohydrate dieters maintained a similar weight loss as other Registry members despite reporting less dietary restraint and physical activity at all time-points (as well as greater caloric intake at entry into the study). The fact that low-carbohydrate diets de-emphasize exercise and restriction of amount of food may make these approaches appealing to consumers. However, as noted earlier, the implications of sustaining a high-fat diet over time remain unclear. Moreover, the finding that the low-carbohydrate group also reported far less physical activity is of potential concern given the importance of physical activity in successful weight loss maintenance (34), and the cardiovascular benefits of physical activity, independent of its association with successful weight loss maintenance (35).

The successful weight losers in this study who reported following a low-carbohydrate diet to achieve weight loss were more likely to be male and had a shorter duration of successful weight loss maintenance compared with general Registry members. The shorter duration may be due to the relatively recent popularity of low-carbohydrate diets. However, the prevalence and characteristics of people in the general population who initiate and succeed at long-term weight loss with a low-carbohydrate diet cannot be determined in the present study. Although our previous work has found that the characteristics of Registry members do not seem to differ significantly from successful weight losers in the general population (36), findings from the current study

are based on self-selected participants who were predominantly white and well educated and, thus, may not generalize to the population at large.

An additional limitation in the current study is that assessments were based on self-report and may be biased by under-reporting and social desirability. The potential for inaccuracy and bias in self-report measures of food intake is universally recognized and widespread (14). Unfortunately, with the exception of doubly labeled water, all available assessment methods are subject to bias and no "gold standard" exists. In the current study, excluding individuals classified as extreme under-reporters did not seem to significantly alter the study's main conclusions. This study did not include objective measures of diet or physical activity before weight loss, and information about concomitant illness at the time of weight loss was not collected. Strengths of the study include the long-term weight loss success of participants in the NWCR and the fact that this sample has been followed prospectively for several years.

In summary, 10% of the NWCR population lost their weight with a low-carbohydrate diet. There were no significant differences in weight regain between these individuals and other Registry members, suggesting that it is possible to be successful at long-term weight loss with a variety of different dietary approaches. Future studies should determine whether the health benefits achieved by those who lose significant amounts of weight with a low-carbohydrate regimen are comparable to the benefits achieved by other successful weight loss maintainers.

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