Use of artificial sweeteners and fat-modified foods in weight loss maintainers and always-normal weight individuals

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Abstract

Objective:

The purpose of this study was to compare the dietary strategies, and use of fat- and sugar-modified foods and beverages in a weight loss maintainer group (WLM) and an always-normal weight group (NW).

Subjects:

WLM (*N*=172) had maintained ≥10% weight loss for 11.5 years, and had a body mass index (BMI) of 22.0 kg m^{-2}. NW (*N*=131) had a BMI of 21.3 kg m^{-2} and no history of being overweight. Three, 24-h recalls on random, non-consecutive days were used to assess dietary intake.

Results:

WLM reported consuming a diet that was lower in fat (28.7 vs 32.6%, $P<0.0001$) and used more fat-modification strategies than NW. WLM also consumed a significantly greater percentage of modified dairy (60 vs 49%; $P=0.002$) and modified dressings and sauces (55 vs 44%; $P=0.006$) than NW. WLM reported consuming three times more daily servings of artificially sweetened soft drinks (0.91 vs 0.37; $P=0.003$), significantly fewer daily servings of sugar-sweetened soft drinks (0.07 vs 0.16; $P=0.03$) and more daily servings of water (4.72 vs 3.48; $P=0.002$) than NW.

Conclusions:

These findings suggest that WLM use more dietary strategies to accomplish their weight loss maintenance, including greater restriction on fat intake, use of fat- and sugar-modified foods, reduced consumption of sugar-sweetened beverages and increased consumption of artificially sweetened beverages. Ways to promote the use of fat-modified foods and artificial sweeteners merits further research in both prevention- and treatment-controlled trials.

Keywords:

fat-modified foods, artificial sweeteners, successful weight loss, sugar-sweetened beverages

Introduction

Fat- and sugar-modified foods and beverages are at present widely available and consumed in the belief that they assist in reducing caloric intake and in achieving or maintaining a healthy body weight. However, the role of modified foods and beverages in promoting long-term weight control is still open to considerable debate. In the general population, use of fat-modified foods has been reported to be easily adopted and is a highly acceptable weight control strategy[1] that has been associated with the consumption of a more nutrient-dense diet.[2] Normal weight individuals who switch from full fat to reduced fat products have shown reductions in fat and energy intake, and use of fat-modified products has been identified as a strategy to prevent overweight and obesity in this population.[3] In obese individuals, however, most reports have shown that those who switch to reduced fat foods *do not have* significant reductions in total energy[4, 5] or sustained body weight decreases over time.[1, 6, 7] Similarly, reduced fat diets have been shown to produce only modest (approximately 2 kg) weight losses; thus, for obese individuals, the recommendation has been to consume a low fat diet in the context of a calorie restriction.[8] There is still no consensus on the usefulness of substituting artificial sweeteners for sugar to obtain better weight control.[9] Short-term laboratory-based studies have been mixed with some studies showing that artificial sweeteners have a stimulating effect on appetite[10, 11, 12] and (most) other studies finding no appetite effects.[13, 14, 15, 16, 17] Several epidemiological studies have found positive dose-response relationships between intake of artificial sweeteners and subsequent prospective weight gain in adults,[18, 19] raising concerns that use of artificial sweeteners may be fueling the obesity epidemic.[18] However, randomized intervention studies of obese individuals, both with[20] and without[21, 22, 23] energy restriction, have shown that intake of artificial sweeteners can increase adherence to a low calorie diet, and result in decreased energy intake and body weight and improved weight loss maintenance over time.[24]

Surprisingly, little is known about the use of fat- and sugar-modified foods and beverages in the two groups who are achieving long-term weight control in our current obeseogenic environment: long-term weight loss maintainers (WLM) and normal weight individuals who do not have a history of obesity (always-normal weight group (NW)). Understanding whether and how these two groups use nutrient-modified products is important to the design of future weight loss and weight gain prevention interventions. Previously we reported that WLM engaged in more physical activity than NW of equal weight, suggesting that WLM must work harder than NW to maintain normal body weight.[25] The purpose of the current study was to examine the diet and use of modified foods and beverages in these two groups. We hypothesized that, due to their previous history of obesity, WLM would report consuming a lower calorie and lower fat diet and correspondingly report higher dietary restraint. Moreover, we hypothesized that WLM would employ more low-fat dietary strategies, consume more fat-modified and sugar-modified foods, and consume more artificially sweetened beverages than NW controls.

Materials and methods

Subjects and procedures

A sample of men and women was recruited by placing advertisements in national and local publications and articles about the study in publications that target a general audience. Individuals interested in joining the study were asked to call a 1–800 number or to visit our website (www.nwcr.ws). Participants were located across the United States, but predominantly in New England, California and the Washington, D.C. area. Eligibility was confirmed via phone screen.

To be eligible for the study, weight loss maintainers had to be overweight or obese (body mass index (BMI) ≥ 25 kg m^{-2}) at some point in their life, currently normal weight (BMI 18.5–25 kg m^{-2}), and must have lost ≥10% of maximum body weight. In addition, to identify individuals who were clearly succeeding at weight loss maintenance, they were required to have kept off a loss of ≥10% for at least 5 years and be weight stable (±10 lbs) within the past 2 years. Participants in the NW group had to be normal weight (BMI between 18.5–25 kg m^{-2}) and have no history of overweight or obesity (BMI ≥25 kg m^{-2}). The criteria for participants in the NW group also required that they be weight stable

(±10 lbs) for at least 2 years before enrollment. Of the 556 subjects who responded to advertisements specifying these criteria, 386 (69%) were deemed eligible for the current study. Of these, 303 signed written informed consent forms and participated in the study assessments. Participants were paid $50 for completing the study assessments. The study was approved by the Institutional Review Board at the Miriam Hospital in Providence, Rhode Island, USA.

Measures

Weight and demographics

Weight and weight history were based on self-report. Participants provided information about marital status, ethnicity/race (Hispanic/Non-Hispanic, American Indian, Asian, Black/African-American, Native Hawaiian, White, or other) and education. These data were collected for descriptive purposes.

Dietary intake

Food intake information was obtained by 24-h telephone-based dietary recall, using the Nutrition Data System Software developed by the Nutrition Coordinating Center, University of Minnesota, Minneapolis, USA. Trained and 'blinded' dietary interviewers administered three recalls on random, non-consecutive days of the week (2 weekday and 1 weekend day). Food pictures were sent to participants and used to facilitate portion size quantification. Previous research has shown strong linear relationships (rs.>0.66) between 24-h recalled food intake and independently observed food intake[26, 27] as well as food diaries.[28] With three independent observations, within-person variation is adjusted for and distributions of nutrient intake can be estimated.[29]

Variables of interest included calories, protein, carbohydrates and fat. Beverage consumption was also calculated. Beverage groupings were based on Nutrition Data System Software categorizations that, in some cases, were combined across Nutrition Data System Software groups: (1) sweetened soft drinks; (2) other sweetened drinks (that is, sweetened fruit drinks, tea, coffee, coffee substitute and water); (3) artificially sweetened soft drinks; (4) other artificially sweetened drinks (that is, fruit drinks, tea, coffee,

coffee substitute and water); (5) unsweetened water; (6) juices (that is, citrus juice, fruit juice excluding citrus juice and vegetable juice); (7) whole milk (that is, ≥2% fat); (8) low fat and fat free milk (that is, 1% or fat free); and (9) alcohol (that is, beer and ales, cordial and liquor, distilled liquor and wine). Standard serving sizes were based on Nutrition Data System Software classifications with one serving equaling: 8 fluid ounces of soft drinks, sweetened drinks or water; 12 fluid ounces of beer; 1.5 fluid ounces of liqueurs or cordials; 5 fluid ounces of table wine; 3 fluid ounces of dessert wine; 3 fluid ounces of sake; 12 fluid ounces of wine coolers; 1 cup of milk; and, 4 fluid ounces of juice.

The frequency of use of fat-modified foods was also calculated using Nutrition Data System Software standard serving sizes (available upon request) and groupings for energy dense snacks (for example, cakes, cookies, chips, pudding, candy and dessert), unmodified dairy foods (for example, full fat cheese, yogurt and cream), unmodified dressings (for example, margarine, butter, salad dressing, gravy and sauces), modified dairy foods (for example, reduced fat/ artificially sweetened/no sugar added yogurt, cheese and cream) and modified dressings (for example, reduced fat/artificially sweetened/no sugar added salad dressings, gravy, sauces and butter).

Kristal eating pattern questionnaire

This 21-item questionnaire assesses 5 dimensions of low-fat dietary strategies (on a scale where 1=always; 2=usually; 3=sometimes; and, 4=never), including: (1) avoiding fat as a spread or flavoring; (2) avoiding meat; (3) modifying commonly used foods to lower their fat (for example, broiling instead of frying); (4) substituting specifically manufactured low fat foods; and, (5) replacing high fat foods with low fat food (for example, using fruit instead of ice cream for dessert).[30] Using the Kristal Eating Pattern Questionnaire during the Women's Health Trial,[31] it was shown that avoiding use of fat as a seasoning was the scale most strongly associated with decreased dietary fat intake. High scores on these scales are associated with less effort to reduce dietary fat intake.

Dietary restraint

The Eating Inventory (EI), developed by Stunkard and Messick,[32] was used to assess dietary restraint. Restraint can be defined as the degree to which a person is consciously aware of constantly monitoring their food intake.[33] Items ask participants to indicate, for example, whether they 'stop eating as a conscious means to limit intake,' and 'consciously hold back at meals.' The Eating Inventory has demonstrated adequate internal consistency (<0.80) and test-retest reliability (0.91–93).[34]

Statistics

Descriptive statistics are presented in the tables as either means±s.d. for continuous measures or percentages for categorical responses. Independent *t*-tests and χ^2 analyses were used to examine group differences in baseline demographic variables. Univariate general linear model analyses adjusting for BMI were conducted to examine group differences in macronutrient consumption, low-fat dieting strategies, beverage consumption and intake of modified food. Spearman's correlations were used to examine associations among variables.

Results

Subject characteristics are displayed in Table 1. The WLM group had reduced from 91.6±18.1 to 61.6±8.8 kg and maintained a ≥10% weight loss for over 11 years. Both groups were normal weight, but the WLM group weighed significantly more and had a higher BMI than the always normal weight group (P <0.0002).

We first compared the NW and WLM groups on dietary intake. Both groups reported consuming a low calorie diet; however, WLM reported consuming a diet that was lower in fat and higher in protein and carbohydrates than the NW group (Table 2). Consistent with these findings, WLM also employed more low-fat dieting strategies, including avoiding fat as a spread or flavoring, replacing high fat foods with low fat foods and substituting high fat foods with commercially available low fat foods. WLM also scored significantly higher on dietary restraint, suggesting a greater degree of conscious control over food intake.

We next compared WLM and NW on consumption of modified foods (that is, modified fat, sugar or both). WLM consumed a significantly greater percentage of dairy that was modified (60 vs 49%; *P*=0.002), and dressings and sauces that were modified (55 vs 44%; *P*=0.006) compared with the NW group. However, there were no significant group differences in number of daily servings and average serving sizes of these foods. Both groups reported having at least one serving per day of energy dense snacks, such as cakes, cookies, chips, pudding, candy and dessert (Table 3).

We next compared the two groups on average daily beverage consumption. As shown in Table 4, WLM reported consuming three times more daily servings of artificially sweetened soft drinks and had significantly larger average serving sizes. Also, expressed as a percentage of overall beverage intake, WLM's intake of artificially sweetened soft drinks was two times greater than that of NW individuals. Although consumption of sugar sweetened soft drinks was relatively rare in both groups, WLM consumed significantly fewer daily servings, consumed smaller serving sizes, and had a significantly smaller percentage of beverages coming from sugar-sweetened soft drinks than NW individuals (1.0 vs 2.3%, respectively; *P*=0.04). There were no significant differences between WLM and NW in juice consumption as a percentage of overall beverage intake (7.2 vs 9.8%; *P*=0.22, respectively); however, WLM consumed significantly fewer daily servings of juice and smaller average serving sizes. The two groups also differed significantly in alcohol consumption. WLM consumed fewer daily servings, had smaller serving sizes and a smaller percentage of overall beverage intake than the NW group (6.2 vs 13.3%; *P*=0.0002). In both groups, the predominant beverage consumed was unsweetened water; however, WLM consumed more daily servings of water, larger serving sizes and had a marginally greater percentage of overall beverage intake from water relative to NW individuals (58.2 vs 52.4%, respectively; *P*=0.06).

Correlational analyses

In correlational analyses collapsing across groups, reduced calorie intake was significantly correlated with lower intake of sugar sweetened beverages (*r*=0.22; *P*=0.0002) and less alcohol (*r*=0.15; *P*=0.01) and milk (*r*=0.16; *P*=0.004), but was not related to lower fat intake or percentage of modified foods consumed. Lower fat intake was significantly related to greater use of low-fat dietary strategies on the Kristal questionnaire (*r*s between 0.12 and 0.46; *P*≤0.04) and greater intake of modified dairy products (*r*= -0.30; *P*=0.0001) and modified sauces and dressings (*r*= -0.38 *P*=0.0001). Higher dietary restraint was significantly associated with lower intake of sugar sweetened beverages (-0.26; *P*=0.0001) and alcohol (*r*=-0.17; *P*=0.004), and greater intake of artificially sweetened beverages (*r*=0.36; *P*=0.0001) and use of all the low-fat dietary strategies (*r*s between -0.17 and -0.49; *P*<0.003). Similar findings were observed in separate analyses conducted within each group (data not shown).

Discussion

Both NW and WLM reported consuming a low calorie, low fat diet, but WLM reported consuming less fat, more fat-modified foods, and using more low-fat dietary strategies than the always normal weight. These findings are consistent with a large body of research suggesting that consumption of a low-calorie low-fat diet is consistent with long-term weight control. Reasons for greater fat restriction and use of fat-modified foods between WLM and NW are unknown. Greater fat restriction may reflect a strategy adopted by WLM to reduce intake in the context of less sensitive internal cues.[35] Alternatively, fat restriction among WLM could reflect their history of dieting and, thus, greater knowledge of low fat dieting as compared with NW individuals.

WLM also scored significantly higher on dietary restraint than NW, and dietary restraint was significantly correlated with lower fat and calorie intakes, and higher intake of artificially sweetened beverages. High dietary restraint appears to be characteristic among successful weight losers.[36, 37] A restrained eating style may distinguish WLM from NW and enable WLM to consume a low calorie, low fat diet in the context of biological, environmental and/or other obesity-promoting cues.

We found that both groups consumed artificially sweetened beverages, but WLM consumed significantly more than normal weight. Although WLM consumed the equivalent of more than one serving (>8 fl oz) per day, normal weight controls consumed less than half a serving per day, which is an amount consistent with the general population.[38] Some have argued that the intake of artificial sweeteners may lead to overcompensation,[18] taste distortion and increased appetite for intensely sweet highly caloric foods,[18, 39] and could be fueling the obesity epidemic.[18, 40] However, several intervention studies[20, 21, 22, 23, 24] and a meta-analysis of weight change data from nine randomized clinical trials in obese individuals[24] have shown significantly greater weight loss among users of artificial sweeteners than non-users. Our findings are more consistent with these latter data and suggest that the use of artificially sweetened beverages may be an important weight control strategy among WLM. Use of artificially sweetened beverages may assist WLM in maintaining a reduced calorie diet in the context of biological, metabolic and cognitive factors[41] promoting over-consumption of energy from liquids.

Both groups consumed very little in the way of sugar-sweetened beverages. Although national data indicate that Americans consume the equivalent of about two 8 fl oz servings of sugar-sweetened beverages each day,[38, 42, 43] both groups in our study consumed the equivalent of a few daily sips (<0.16 serving per day). Evidence is mixed on the role of sugar-sweetened beverages in the promotion of weight gain and obesity; seven reviews on the topic have reached differing conclusions, with three concluding a positive effect,[44, 45, 46] and four suggesting inconclusive evidence.[47, 48, 49, 50] Our study adds to the existing literature by suggesting that individuals maintaining a healthy body weight consume little in the way of sugar-sweetened beverages. Moreover, WLM appeared to follow a general strategy of choosing lower calorie beverages, such as artificially sweetened drinks and water, and limiting the consumption of higher calorie drinks, such as sugar-sweetened beverages, juice and alcohol. Monitoring calories from beverages may be another key strategy in maintaining a long-term weight control.

In a previous report, we found that the WLM in this sample engaged in significantly more physical activity (as assessed by accelerometry) than the always normal weight.[25] In this study, both groups had similar calorie intakes, but WLM reported higher dietary restraint, greater fat restriction and greater practice of low-fat dietary strategies. Taken together, these data suggest that the WLM may have to engage in more intensive weight control behaviors to maintain their body weight, perhaps to counteract a more efficient metabolism. Alternatively, WLM may be more likely to underreport their dietary intake.[51] Future research with more objective measures of diet (doubly labeled water) is needed to adequately address energy balance differences between these groups.

This study is one of the first to conduct a detailed comparison of the dietary intake and use of fat- and sugar-modified products in a population of WLM and individuals without a history of obesity. The study population, nonetheless, was limited to a self-selected sample of predominantly Caucasian females. Future research is needed to determine the generalizability of the current study's findings to representative samples of WLM and NM. Moreover, the groups in this study were assessed at one time point only, which limits more powerful prospective analyses.

Understanding the behaviors of individuals who are achieving long-term weight control in our current obeseogenic environment is critical to informing the development of effective weight loss and weight gain prevention programs. The current study suggests that WLM use more dietary strategies to accomplish their WLM, including greater restriction of fat intake, use of fat- and sugar-modified foods, reduced consumption of caloric beverages and increased consumption of artificially sweetened beverages. Ways to promote the use of fat-modified foods and artificial sweeteners merits further research in both prevention- and treatment-controlled trials.

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Tables

Table 1. Participant characteristics

	*Weight loss maintainer group (*N*=172)*	*Always-normal weight group (*N*=131)*	P-*value*
Age	49.9±13.2	48.2±11.6	NS
Current weight (kg)	61.6±8.8	57.8±7.3	<0.0001
Body mass index	21.99±1.67	21.29±1.45	0.0002
% Female	84.90%	90.10%	NS
% Caucasian	93%	92%	NS
% Married	67.40%	68.70%	NS
% College educated or more	76.70%	83.20%	NS
Lifetime maximum weight (kg)	91.6±18.1	—	
Duration of maintaining ≥10% weight loss, years	11.49±8.88	—	

Note: *P*-values are based on independent *t*-tests for continuous variables and χ^2 tests for dichotomous variables.

Table 2. Dietary intake and low-fat dietary strategies among weight loss maintainers and always-normal weight individuals

	Weight loss maintainer (N=*169)*	*Always normal weight* (N=*125)*	P-*value* [a]
Calories, total	1718±487	1792±539	0.1013
Fat, %	28.7±8.4	32.6±7.1	<0.0001
Protein, %	18.4±4.7	17.0±3.8	0.0102
Carbohydrate, %	55.2±10.6	48.9±8.8	<0.0001
Dietary restraint	14.8±4.2	9.8±4.8	<0.0001
Low fat dietary strategies [b]			
Summary score (reflects overall use of low fat dietary strategies)	1.96±0.40	2.25±0.38	<0.0001
Substituting specifically manufactured low fat foods	1.84±0.81	2.54±0.90	<0.0001
Modifying foods to lower fat (e.g., broiling instead of frying)	1.71±0.79	1.82±0.74	0.2462
Avoiding meat	1.19±0.36	1.25±0.32	0.0339
Replacing high fat with low fat foods	2.76±0.55	3.02±0.50	<0.0001
Avoiding fat as spread or flavoring	2.32±0.65	2.60±0.55	<0.0001

[a] *P*-values are obtained from the general linear models with adjustment for body mass index.

[b] Scores are from the Kristal Eating Pattern questionnaire;[30] higher scores indicate less frequent use of the strategy (on a scale where 1=always; 2=usually; 3=sometimes; and 4=never).

Table 3. Average number of servings per day and average serving sizes of energy dense and modified foods

	Weight loss maintainer group (N=172)	***Always–normal weight group (N=131)***	**P-*value*** [a]
	Energy-dense snacks		
No. of servings per day	1.41±1.77	1.23±1.03	0.2816
Average serving size	0.67±0.66	0.59±0.50	0.4641
Dairy foods			
Unmodified			
No. of servings/day	0.51±1.64	0.57±0.62	0.5008
Average serving size	0.29±0.46	0.33±0.30	0.2285
% of all dairy	40±34% (*N*=161)	51±33% (*N*=122)	0.0020
Modified			
No. of servings per day	0.66±0.71	0.57±0.67	0.2484
Average serving size	0.41±0.38	0.35±0.33	0.1275
% of all dairy	60±34% (*N*=161)	49±33% (*N*=122)	0.0020
Dressings and sauces			
Unmodified			
No. of servings per day	0.96±1.16	1.23±1.12	0.0541
Average serving size	0.60±0.75	0.69±0.58	0.3713
% of all dressing	45±35% (*N*=165)	56±32% (*N*=125)	0.0062
Modified			
No. of servings per day	1.54±3.98	1.08±1.18	0.1395
Average serving size	0.84±1.49	0.65±0.62	0.1048
% of all dressing	55±35% (*N*=165)	44±32% (*N*=125)	0.0062

[a] *P*-values are obtained from the general linear models with adjustment for body mass index.

Table 4. Beverage consumption among weight loss maintainers and always-normal weight individuals

	Weight loss maintainer (N=172)	*Always-normal weight (N=131)*	P-*value* [a]
Artificially sweetened soft drinks			
No. of servings per day	0.91±1.59	0.37±0.93	0.0026
Average serving size	0.61±0.90	0.28±0.60	0.0008
% of all beverages	13.5±21.5% (*N*=169)	6.4±14.5% (*N*=128)	0.0043
Other artificially sweetened drinks			
No. of servings per day	0.21±0.75	0.08±0.31	0.0654
Average serving size	0.16±0.52	0.07±0.25	0.0666
% of all beverages	3.3±11.4% (*N*=169)	2.3±9.5% (*N*=128)	0.3899
Sweetened soft drinks			
No. of serv/day	0.07±0.30	0.16±0.46	0.0272
Avg serv size	0.05±0.23	0.12±0.31	0.0125
% of all beverages	1.0±5.2% (*N*=169)	2.3±5.8% (*N*=128)	0.0407
Other sweetened drinks			
No. of servings per day	0.10±0.49	0.15±0.34	0.4662
Average serving size	0.09±0.38	0.13±0.27	0.3673
% of all beverages	1.2±4.8% (*N*=169)	3.5±10.9% (*N*=128)	0.0166
Juices			
No. of servings per day	0.39±0.75	0.64±1.00	0.0289
Average serving size	0.32±0.61	0.51±0.76	0.0335
% of all beverages	7.2±14.9% (*N*=169)	9.8±15.0% (*N*=128)	0.2194
Water (unsweetened)			
No. of servings per day	4.72±4.08	3.48±2.84	0.0026
Average serving size	2.03±1.81	1.35±1.00	0.0001
% of all beverages	58.2%±31.5% (*N*=169)	52.4%±28.9% (*N*=128)	0.0630

	*Weight loss maintainer (*N=*172)*	*Always-normal weight (*N=*131)*	P-*value* [a]
Milk			
Whole			
No. of servings per day	0.03±0.13	0.05±0.18	0.4890
Average serving size	0.03±0.12	0.04±0.12	0.8425
% of all beverages	0.7%±3.0% (*N*=169)	1.0%±4.7% (*N*=128)	0.4209
Reduced fat			
No. of servings per day	0.51±0.74	0.39±0.54	0.2151
Average serving size	0.35±0.44	0.26±0.32	0.0888
% of all beverages	8.6±14.2% (*N*=169)	9.0±16.4% (*N*=128)	0.6258
% of all milk	90±27% (*N*=120)	87±30% (*N*=82)	0.4222
Alcohol			
No. of servings per day	0.35±0.66	0.70±0.92	0.0001
Average serving size	0.28±0.48	0.55±0.69	<0.0001
% of all beverages	6.2±13.5% (*N*=169)	13.3±18.5% (*N*=128)	0.0002

[a] *P*-values are obtained from the general linear models with adjustment for body mass index.