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Low Fat vs. Low Carbohydrate Diet Strategies for Weight Reduction: A Meta-Analysis

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Abstract

Background: Overweight and obesity are a global crisis. Lifestyle interventions, including weight loss diets, are the first line treatment for this problem. In addition to energy restriction, some diets emphasize manipulation of macronutrient composition to promote weight loss. Such diets may be broadly classified into low fat and low carbohydrate diets.

Objective: This meta-analysis was designed to compare low fat to low carbohydrate diets in terms of weight loss.

Methods: Studies were included in the present meta-analysis if they were 1) well-designed randomized clinical trials comparing low fat to low carbohydrate diets; 2) included healthy overweight and obese adults; 3) had a follow-up of 12 weeks or longer; 4) measured weight loss as the a stated endpoint; 5) were published in 2010 or later.

Results: Nine studies meeting all inclusion criteria were identified. Together, these studies included 1161 subjects, 592 of whom were exposed to low carbohydrate diets and 569 to low fat diets. Two of the included studies provided meals to participants. One study included two low-carbohydrate arms, one with high glycemic index and one with low glycemic index carbohydrates. A high degree of heterogeneity between studies was identified, I2=94.8, Q=154.8, p<0.001. In a random effects model, no significant advantage to either diet strategy could be identified – standardized difference in means 0.42, 95% CI: 0.13-0.98, p=0.14. None of the metabolic endpoints examined, including lipid profile (triglycerides, total, low or high density lipoprotein cholesterol), glucose of blood pressure differed by diet exposure.

Conclusion: Both types of macronutrient-centered weight loss diets produced weight loss. Manipulation of macronutrient composition of weight loss diets does not appear to be associated with significantly different weight loss or metabolic outcomes.

Keywords: Low fat; Weight reduction; Overweight; Obesity

Introduction

Worldwide, the prevalence of overweight and obesity (body mass index (BMI)>25 kg/m^2) has increased in both children adults since 1980 [1]. In 2014, 1.9 billion adults were overweight and 600 million adults were obese, representing 39% and 13% of the global adult population, respectively [2]. This means that more than half of the adult population on the planet is fatter than necessary for optimal health. Additionally, 42 million children younger than 5 years of age were overweight or obese in 2013 [2], suggesting continued high rates of excess body weight.

Obesity prevalence is increasing in both developed and developing nations [3]. In developing countries, obesity and overweight may coexist with under-nutrition [4]. In fact, overweight prevalence is increasing fastest in low- and middle-income countries [5].

The World Health Organization (WHO) recommends that overweight and obesity should be addressed through lifestyle changes [1]. Specifically, the WHO recommends limiting energy intake from total fats and sugars; increased intake of fruit, vegetables, legumes, whole grains and nuts; and participation in regular physical activity, defined as not less than 60 minutes each day for children and at least 150 minutes each week for adults.

This common sense approach is intuitive; however, there is no evidence that increased fruit and vegetable intake reduces body weight if other dietary components are unchanged [6]. Furthermore, physical activity without dietary alterations is not consistently associated with weight loss [7,8]. And while reducing total fat and sugar intake may reduce total energy intake, these macronutrients are generally more affordable and thus often over-represented in the diets of low-income groups [9].

Alterations in macronutrient composition have emerged as a possible weight loss strategy in recent years. Proponents of low fat diets

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suggest that by replacing fat with carbohydrates, dieters can cut energy intake by more than 50% gram for gram [10]. This diet type has been endorsed and adopted by institutions such as the American Dietetic Association [11] and the American Cancer Society [12]. Reduction of non-communicable disease risk is among benefits associated with this diet style.

An alternative macronutrient alteration is reduced carbohydrate intake. Examples of this approach are the Atkins [13] and Zone [14] diets. These diets restrict carbohydrate but not energy, and note spontaneous reduction in energy intake by the dieter. Rationale for this diet includes enhanced thermogenic effect of food, improved satiety and preservation of muscle mass [15].

To directly test whether one of these macronutrient manipulations is indeed associated with improved weight loss and/or metabolic outcomes, we conducted a meta-analysis, a method employed to integrate data from multiple primary studies addressing the same study question. The primary objective of the present study was to compare low carbohydrate to low fat diets in terms of weight loss outcomes. Secondarily, the present study compared these two diet approaches in terms of lipid profile, blood pressure and glucose homeostasis.

Methods

Literature search

The following databases were searched to identify eligible studies: PubMed, EMBASE, the Cochrane Collaboration Database of Systematic Reviews and Google Scholar. Search terms included “low carbohydrate diet,” “low fat diet,” “randomized clinical trial,” “dietary macronutrient composition” and “macronutrient manipulation.” The search was restricted to studies conducted in healthy adult human subjects, and studies were filtered so that only English language studies published between January 1, 2010 through June 30, 2015, were included.

Eligibility criteria

Included in the present meta-analysis were randomized clinical trials conducted in healthy human adults, in which macronutrient manipulation of weight loss diets was performed. Not less than three months of follow-up was required for study inclusion. In each study, subjects were randomized to a weight loss diet described as either low fat or low carbohydrate, and the diets were compared “head to head” as the primary analysis in an intention-to-treat analysis. Low carbohydrate diets were defined as providing 45% or less of total energy intake as carbohydrate, while low fat diets provided 30% or less of the total energy intake as fat. The stated primary endpoint of each included study was weight loss.

Data extraction

Data from each study were extracted using a standardized data extraction for which included fields for anthropometric, biochemical and, demographic descriptions of the subjects; dietary data; and completion rates. Two investigators independently abstracted data in duplicate (MB,OR).

Statistics

Data were summarized in Excel spreadsheet (Microsoft Inc., USA) and analyzed using Comprehensive Meta-Analysis software (Biostat Inc., USA). Calculated were summary statistics, and effect size was expressed as the standardized difference using between-group mean/pooled standard deviation of the means for each of the outcomes. Heterogeneity was assessed by calculating the Q, I and Z statistics. Since significant heterogeneity was detected, a random effects model was employed.

Results

Study selection

As shown in Figure 1, 143 studies were initially identified, but only 9 were included in the final analysis when studies were excluded for a variety of reasons, including not being a randomize clinical trial, not being conducted in the appropriate population (healthy adults), lacking adequate follow-up time (not less than three months), or focusing on the wrong primary endpoint (for example, weight maintenance rather than weight loss). Included studies [16-24] are summarized in Table 1.

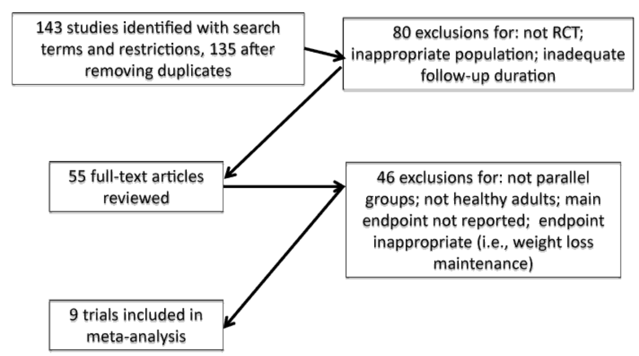

Figure 1: Study selection.

Study	Low Fat Diet Composition (F:P:C)	Low Carbohydrate Diet Composition (F:P:C)	Number of subjects enrolled (n)	Follow-up duration (weeks)	% Completed
Llanos et al. [16]	0.847917	1.271296	79	52	48
Liu et al. [17]*	1.263102	1.435185	50	12	96
Kitabachi et al. [18]*	1.261053	1.271296	32	24	75

Foster et al. [19]**	1.261053	X:X:10	307	104	62
De Luis et al. [20]	1.139502	1.518495	280	12	100
Bazzano et al. [21]**	1.261053	X:X:13	148	52	80
Ruth et al. [22]	25:15:60	2.524363	55	12	60
Dalle Grave et al. [23]	0.845868	0.85816	88	52	78
Juanola-Falgarona et al. [24]	1.263102	1.679653	122	24	85
F: %Fat; P: %Protein; C: %Carbohydrate; *Study meals provided by investigators; **X indicates that limits on fat and protein intake were permitted ad libitum					

Table 1: Diet composition, number of enrolled subjects and follow-up duration of included studies.

Participant characteristics

Figure 2 shows the diet exposure for the 1161 participants in the 9 studies. As can be seen, a total of 569 subjects were exposed to low fat diets, while 592 subjects were exposed to low carbohydrate diets. The difference in the macronutrient exposure by group is attributable to on study in which there were two levels of low carbohydrate exposure [24].

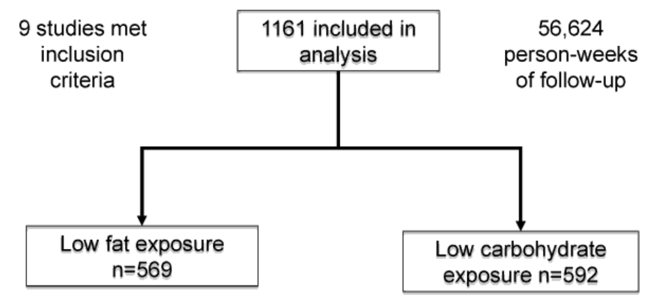

Figure 2: Total participant exposure.

Table 1 presents diet composition of each of the intervention arms by study, number of enrolled subjects and duration of follow-up. Mean diet composition of the low fat diets was 27% fat, 16% protein and 57% carbohydrate. In the low carbohydrate exposure, mean diet composition was 36% fat, 25% protein and 39% carbohydrate. It is noteworthy that participants in the Liu et al. [17] and Kitabachi et al. [18] studies received all meals from investigators throughout the follow-up period.

Baseline participant characteristics are presented by diet exposure in Table 2. Groups were similar in terms of baseline characteristics. Over-representation of females was clear in both diet exposures. Consistent with recruitment of "healthy adults," subject metabolic measures were within normal limits.

Outcomes

Table 3 summarizes weight loss outcomes for the 9 included studies. In six of the studies, no significant between-group difference in weight loss was demonstrated. In the Kitabachi et al. [18] study, resting energy expenditure was increased in the low carbohydrate diet group relative to the low fat diet group, but this was not expressed in a between-group difference in weight loss. On the other hand, significantly greater weight loss was observed in the low carbohydrate diet group in the Bazzano et al. [21] and Juanola-Falgarona et al. [24] studies.

Characteristic	Low Fat Diet	Low Carbohydrate Diet
Age (years)	42.5 ± 4.1	47.2 ± 11.3
Sex (% females)	83.6	84.6
Weight (kg)	93.3 ± 16.1	94.4 ± 17.6
Total cholesterol (mg/dl)	195.2 ± 46.9	193.9 ± 45.6
HDL (mg/dl)	51.1 ± 15.9	50.2 ± 16.4
LDL (mg/dl)	122.9 ± 41.3	123.8 ± 39.8
Triglycerides (mg/dl)	118.0 ± 47.1	126.4 ± 45.6
Glucose (mg/dl)	98.8 ± 21.3	99.0 ± 19.6
Systolic blood pressure (mmHg)	1.263102	1.679653
Diastolic blood pressure (mmHg)	80.6 ± 12.0	80.5 ± 13.9
Continuous variables are presented as mean ± standard deviation		

Table 2: Baseline characteristics of study participants.

Study	Mean Difference ± Standard Deviation	Standardized Difference in the Mean	Standard Error	p-value
Llanos et al. [16]	0.20 ± 3.50	0.057	0.225	0.8
Liu et al. [17]	0.20 ± 3.33	0.06	0.283	0.83
Kitabachi et al. [18]	1.60 ± 4.24	0.377	0.359	0.29
Foster et al. [19]	-1.03 ± 2.30	-0.448	0.116	0.33
De Luis et al. [20]	-0.90 ± 3.95	-0.228	0.12	0.06
Bazzano et al. [21]	3.50 ± 1.90	1.842	0.196	<0.001
Ruth et al. [22]	1.80 ± 4.08	0.441	0.273	0.11
Dalle Grave et al. [23]	2.10 ± 12.20	0.172	0.214	0.42

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Juanola-Falgarona et al. [24]	2.34 ± 1.65	1.56	0.217	<0.001
Total (random effects)	1.09 ± 4.13	0.422	0.284	0.137

Table 3: Effect of macronutrient composition on weight loss. Standardized mean difference calculated by subtracting the change from baseline weight observed in subjects randomized to the low carbohydrate diet from the change from baseline weight observed in subjects randomized to the low fat diet.

The model can be summarized as 0.42, 95% CI: 0.13-0.98, p=0.14, Q=154.8, p<0.0001, I^2=94.8, indicating a lack of significant effect of macronutrient composition on weight loss and extremely high between-study heterogeneity (Figure 3).

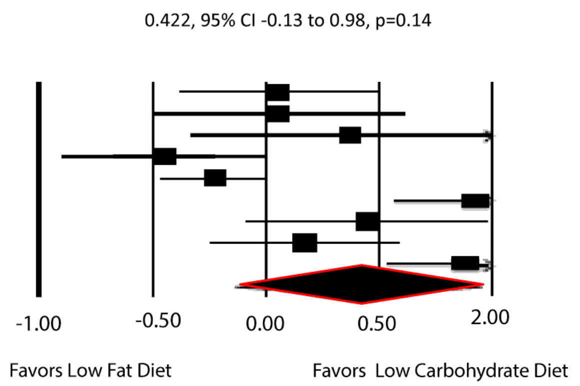

Figure 3: Macronutrient composition and weight loss.

Shown in Table 4 are the mean differences with standard deviation for each of the metabolic study outcomes, together with the standardized differences in the mean with 95% confidence intervals. As noted, total, high density lipoprotein (HDL) and low density lipoprotein (LDL) values were not reported in the Kitabachi et al. study [18], so analysis is based on the other eight included studies. Similarly, blood pressure values were not reported in the Juanola-Flagarona et al. study [24], so analysis is based on the remaining eight included studies. No significant differences in any of the metabolic outcomes were detected by diet exposure, indicating that a clear benefit for one of the macronutrient manipulations was not observed.

Discussion

Meta-analysis is used to synthesize quantitative information from related studies and produce results that summarize a whole body of research, permitting clinically meaningful. Meta-analysis increases sample size and effect size precision, enhancing generalizability of findings [25].

Selection of the appropriate model for meta-analysis is predicated on the homo- and heterogeneity of the included studies. Heterogeneity may be random and largely within-study, or it may reflect true between-study differences in treatment effect [26], necessitating use of the random effects approach as performed in the present meta-analysis. True between-study heterogeneity may arise from actual differences in study populations (such as age or other patient characteristics), interventions received (such as prescribed diet, treatment compliance), follow-up length, and other factors. Included studies in the present meta-analysis were characterized by large differences in dietary exposure, with carbohydrate intake ranging from 5-45% of total energy in the low carbohydrate arm, and fat intake ranging from 20-30% in the low fat arm. Further, two of the studies provided meals for participants, while some included physical exercise and/or psychological support. Studies were also conducted in a variety of ethnic groups including American, European and Asian populations.

Study	**Mean Difference ± Standard Deviation**	**Standardized Difference in the Mean**	**95% Confidence Interval for Standardized Difference in the Mean**	**p-value**
Total cholesterol	-4.07 ± 9.71	1.19	-2.21	0.08
HDL cholesterol	-3.41 ± 5.22	0.73	-1.83	0.11
LDL cholesterol	-3.48 ± 12.53	0.29	-1.5	0.17
Triglycerides	15.36 ± 29.21	0.49	-1.81	0.28
Glucose	2.22 ± 6.46	0.09	-1.55	0.81
Systolic blood pressure	2.12 ± 7.97	0.58	-1.16	0.12
Diastolic blood pressure	1.78 ± 4.32	0.37	-1.3	0.27
HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; Total cholesterol, HDL and LDL values not reported in Kitabachi et al. study; Systolic and diastolic blood pressure values are not reported in Juanola-Falgarona et al. study				

Table 4: Random effects meta-analysis of metabolic endpoints from 9 studies. Shown are standardized means with 95% confidence intervals.

The present meta-analysis of nine clinical trials in more than 1000 healthy adult subjects failed to detect a treatment benefit in terms of weight loss or metabolic outcomes for either of the macronutrient manipulations. Weight loss was significantly greater in the low carbohydrate arm in two of the nine studies [21,24]. Both of these studies enrolled more than 100 participants and reported good completion rates. The low fat arm of both studies provided 30% total fat and >50% calories as carbohydrates. The low carbohydrate arm provided only 13% calories as carbohydrates in the Bazzano et al. study [21], lower than most of the other included reports. The Juanola-Falgarona et al. study [24] actually included two low carbohydrate arms, analyzed in the present meta-analysis as a single exposure. Both low carbohydrate arms provided 42% of calories as carbohydrates, similar to most of the other studies; however, one arm included high glycemic index carbohydrates, while the other included low glycemic index carbohydrates. Improved weight loss was observed in the low glycemic index low carbohydrate group compared to the low fat diet, while weight loss in the high glycemic index low carbohydrate diet group did not differ from either of the other two groups. It is possible, then, that the quality of dietary carbohydrates and not simply their quantitative contribution to total energy intake, may influence weight loss.

Other factors that may impact treatment effect might include lack of dietary compliance, which, if non-differential, would bias between-group differences towards the null. Compliance was not reported in most of the studies, but Llanos et al. used diet records to estimate compliance to be 22% in the low fat and 29% in the low carbohydrate diet [16]. It is not possible to determine the extent to which this is generalizable to other studies. Actual intake was reported in five of the studies. Kitabachi et al. [18] reported intake of 61% carbohydrate, 14.7% protein and 24.3% fat in the low fat group and 57% carbohydrate, 15.1%protein and 27.8% fat in the low carbohydrate diet, based on participant diet records. Lack of between group differences in macronutrient intake would certainly explain the overall lack of treatment effect. On the other hand, both Bazzano et al. [21] and Ruth et al. [22] reported actual macronutrient intake much closer to study recommendations so that in the low fat groups, carbohydrate intake neared 55%, protein intake 18.6-22% and fat intake <30%. In the low carbohydrate group, Bazzano et al. reported 34% carbohydrate, 23.6% protein and 40.7% fat, while Ruth et al. reported only 9.6% carbohydrate, 33.5% protein and 56% fat.

Short term studies have suggested that increasing dietary protein (reducing dietary carbohydrate intake) is associated with appetite suppression, spontaneously reduced energy intake and enhanced weight loss [26]. These findings were supported in meta-analyses concluding that a between-group difference of 5% or more protein intake is associated with improved weight loss, but only in studies in which macronutrient intake complied with study recommendations [27,28]. However, to understand the behavior of an intervention in a population, intention-to-treat analysis is essential, since interventions are frequently associated with compliance issues. For this reason, compliance was not included in study eligibility criteria in the present meta-analysis, in which we focused on high quality weight loss studies published in the last 5 years, conducted in otherwise healthy overweight/obese adults. A more inclusive meta-analysis of the effects of macronutrient manipulation on weight loss identified a small (0.4 kg) but significant advantage to reducing carbohydrate intake. With the exception of triglycerides, serum lipids were not reduced by reducing carbohydrate intake [29]. In another meta-analysis, a low carbohydrate reduction diet was not superior to a low fat diet in terms to weight loss or waist circumference; however, compared to the low fat diet, the low carbohydrate diet was associated with significant reductions in serum triglycerides, total and LDL cholesterol coupled with a significant increase in HDL cholesterol [30]. The low carbohydrate vs. low fat diet produced similar effect sizes for weight loss and metabolic endpoints reported in previous meta-analyses, this time including the most recent studies in healthy adults. Significance of the small effect size in prior studies is likely a function of very large study populations.

It appears that reducing carbohydrate intake is at least not inferior to reducing fat as a weight loss strategy. The quality of the carbohydrate may be clinically important, perhaps more important than the quantity of carbohydrate consumed. Further study of low glycemic index carbohydrates and their impact on weight loss in addition to macronutrient manipulation appears warranted.

References

1. Morgen CS, Sørensen TI (2014) Obesity: global trends in the prevalence of overweight and obesity. Nat Rev Endocrinol 10: 513-514.
2. World Health Organization. Fact Sheet #31, Obesity and Overweight, updated January, 2015.
3. Prentice AM (2006) The emerging epidemic of obesity in developing countries. Int J Epidemiol 35: 93-99.
4. Mendez MA, Monteiro CA, Popkin BM (2005) Overweight exceeds underweight among women in most developing countries. Am J Clin Nutr 81: 714-721.
5. Global status report on non-communicable diseases 2010. Geneva, World Health Organization, 2012.
6. Rolls BJ, Ello-Martin JA, Tohill BC (2004) What can intervention studies tell us about the relationship between fruit and vegetable consumption and weight management? Nutr Rev 62: 1-17.
7. Luke A, Cooper RS (2013) Physical activity does not influence obesity risk: time to clarify the public health message. Int J Epidemiol 42: 1831-1836.
8. Dugas LR, Harders R, Merrill S, Ebersole K, Shoham DA, et al. (2011) Energy expenditure in adults living in developing compared with industrialized countries: a meta-analysis of doubly labeled water studies. Am J Clin Nutr 93: 427-441.
9. Drewnowski A, Specter SE (2004) Poverty and obesity: the role of energy density and energy costs. Am J Clin Nutr 79: 6-16.
10. Walker TB, Parker MJ (2014) Lessons from the war on dietary fat. J Am Coll Nutr 33: 347-351.
11. Kris-Etherton PM, Innis S, American Dietetic Assocition, Dietitians of Canada (2007) Position of the American Dietetic Association and Dietitians of Canada: dietary fatty acids J Am Diet Assoc 107: 1599-1611.
12. Kushi LH, Doyle C, McCullough M, Rock CL, Demark-Wahnefried W, et al. (2012) American Cancer Society Guidelines on nutrition and physical activity for cancer prevention: reducing the risk of cancer with healthy food choices and physical activity. CA Cancer J Clin 62: 30-37.
13. Gudzune KA, Doshi RS, Mehta AK, Chaudhry ZW, Jacobs DK, et al. (2015) Efficacy of commercial weight-loss programs: an updated systematic review. Ann Intern Med 162: 501-512.
14. Atallah R, Filion KB, Wakil SM, Genest J, Joseph L, et al. (2014) Long-term effects of 4 popular diets on weight loss and cardiovascular risk factors: a systematic review of randomized controlled trials. Circ Cardiovasc Qual Outcomes 7: 815-27.
15. Arora SK, McFarlane SI (2005) The case for low carbohydrate diets in diabetes management. Nutr Metab (Lond) 2: 16.
16. Llanos AAM, Krok JL, Peng J, Pennell ML, Olivo-Marston S, et al. (2014) Favorable effects of low-fat and low-carbohydrate dietary patterns on serum leptin, but not adiponectin, among overweight and obese premenopausal women: a randomized trial. SpringerPlus 3: 175-185.
17. Liu X, Zhang G, Ye X, Li H, Chen X, et al. (2013) Effects of a low-carbohydrate diet on weight loss and cardiometabolic profile in Chinese women: a randomised controlled feeding trial. Br J Nutr 110: 1444-1453.
18. Kitabachi AE, McDaniel KA, Wan JY, Tylavsky FA, Jacovino CA, et al. Effects of high-protein versus high carbohydrate diets on markers of B-cell function, oxidative stress, lipid peroxidation, proinflammatory cytokines, and adipokines in obese, premenopausal women without diabetes. A randomized controlled trial. Diabetes Care 36: 1919-1925.
19. Foster GD, Wyatt HR, Hill JO, Makris AP, Rosenbaum DL, et al. (2010) Weight and metabolic outcomes after 2 years on a low-carbohydrate versus low-fat diet: a randomized trial. Ann Intern Med 153: 147-157.
20. De Luis DA, Aller R, Izaola O, de la Fuente B, Primo D, et al. (2013) Evaluation of weight loss and adipocytokine levels after two hypocaloric diets with different macronutrient distribution in obese subjects with rs6923761 gene variant of glucagon-like peptide 1 receptor. Ann Nutr Metab 63: 277-82.
21. Bazzano LA, Hu T, Reynolds K, Yao L, Bunol C, et al. (2014) Effects of low-carbohydrate and low-fat diets: a randomized trial. Ann Intern Med 161: 309-318.
22. Ruth MR, Port AM, Shah M, Bourland AC, Istfan NW, et al. (2013) Consuming a hypocaloric high fat low carbohydrate diet for 12 weeks lowers C-reactive protein, and raises serum adiponectin and high density lipoprotein-cholesterol in obese subjects. Metabolism 62: 1779-1787.
23. Dalle Grave R, Calugi S, Gavasso I, El Ghoch M, Marchesini G (2013) A randomized trial of energy-restricted high-protein versus high-carbohydrate, low-fat diet in morbid obesity. Obesity (Silver Spring) 21: 1774-1781.
24. Juanola-Falgarona M, Salas-Salvado J, Ibarrola-Jurado N, Rabassa-Soler A, Diaz-Lopez A, et al. (2014) Effect of the glycemic index of the diet on

weight loss, modulation of satiety, inflammation, and other metabolic risk factors: a randomized controlled trial. Am J Clin Nutr 100: 27-35.

25. Walker E, Hernandez AV, Kattan MW (2008) Meta-analysis: Its strengths and limitations. Cleve Clin J Med 75: 431-439.

26. Weigle DS, Breen PA, Matthys CC, Callahan HS, Meeuws KE, et al. (2005) A high-protein diet induces sustained reductions in appetite, ad libitum caloric intake, and body weight despite compensatory changes in diurnal plasma leptin and ghrelin concentrations. Am J Clin Nutr 82: 41-48.

27. Santesso N, Akl EA, Bianchi M, Mente A, Mustafa R, et al. (2012) Effects of higher- versus lower-protein diets on health outcomes: a systematic review and meta-analysis. Eur J Clin Nutr 66: 780-788.

28. Bosse JD, Dixon BM (2012) Dietary protein in weight management: a review proposing protein spread and change theories. Nutr Metab (Lond) 9: 81.

29. Clifton PM, Condo D, Keogh JB (2014) Long term weight maintenance after advice to consume low carbohydrate, higher protein diets--a systematic review and meta analysis. Nutr Metab Cardiovasc Dis 24: 224-235.

30. Hu T, Mills KT, Yao L, Demanelis K, Eloustaz M, et al. (2012) Effects of low-carbohydrate diets versus low-fat diets on metabolic risk factors: a meta-analysis of randomized controlled clinical trials. Am J Epidemiol 176 Suppl 7: S44-54.