Observational Study

Medicine®

OPEN

Fat-restricted low-glycemic index diet controls weight and improves blood lipid profile

A pilot study among overweight and obese adults in Southwest China

Yuping Liu, MD[a,b], Ping Sun, MD[b], Ping Shuai, PhD[a,b], Qichuan Qiao, BD[a,b], Tingxin Li, MD[a,b,*]

Abstract

Evidence from trials demonstrating the benefits and risks of low-glycemic index and fat-restricted diets in weight loss and blood lipid profile changes is unclear. This study aimed to assess the implemented and effects of a fat-restricted low-glycemic index diet on weight control and blood lipid profile changes in in overweight/obese Southwest Chinese individualst.

This prospective pilot study enrolled overweight/obese subjects at the People's Hospital of Sichuan Province between February and July 2019. The daily energy intake was reduced by 300 to 500 kcal according to the participant's weight and activity level, with low-glycemic index carbohydrate- and fat-energy ratios < 45% and 25% to 30%, respectively. Participants received guidance for 3 months by telephone follow-up, internet interaction, or WeChat. Changes in weight, body composition, and blood profile were measured.

A total of 254 patients were finally analyzed, including 101 males and 153 females. After adjusting for potential confounders, weight ($P < .001$), body mass index ($P < .001$), waist circumference ($P < .001$), waist-hip ratio ($P < .001$), body fat percentage ($P < .001$), visceral fat area ($P < .001$), basal metabolism ($P = .002$), cholesterol ($P < .001$), and triglycerides ($P < .001$) were significantly reduced after the 3-month intervention. The above indexes showed no significant differences between men and women.

Regardless of gender, fat-restricted low-glycemic index diet might be helpful for controlling weight and lowering blood cholesterol and triglycerides in overweight/obese individuals in Southwest China.

Abbreviations: BMI = body mass index, CVD = cardiovascular disease, FBG = fasting blood glucose, GI = glycemic index, HDL-C = high density lipoprotein cholesterol, LC = low-carbohydrate, LCs = low-carbohydrate diets, LDL-C = low density lipoprotein cholesterol, SMM = skeletal muscle mass, WC = waist circumference.

Keywords: blood lipids, diet control, low carbohydrate diet, obesity, weight loss

1. Introduction

Obesity has become a growing global public health problem, owing to its high prevalence and substantial morbidity and mortality. Obesity and abdominal obesity are associated with an increased risk of multiple chronic diseases, including diabetes, cardiovascular disease (CVD), hypercholesterolemia, asthma and cancer.[1,2] China has the largest number of affected people worldwide, with about 46% of adults being obese or overweight.[3] Increasingly, the Chinese society is making efforts to address the rising obesity and chronic disease epidemic.[4]

With a rapid economic development, the Chinese population tends to embrace high-glycemic index (GI) diets (e.g., refined grains, soft drinks, and other high sugar-containing foods). This change in dietary patterns is strongly related to increased obesity incidence.[5] Consequently, overweight and obesity have become common in Southwest China (25.8% and 7.9%, respectively).[6] Cardiovascular disease represents the leading cause of death.[7] Moreover, there are very high, significant positive associations of waist circumference (WC), body fat percentage (BF%), body mass index (BMI) and visceral adipose with cardiovascular indicators.[8,9] To address the growing burden of cardiovascular disease, current recommendations suggest a low-carbohydrate (LC), low-fat calorie-restricted, or Mediterranean diet to control weight.[9] The conventional dietary guidelines for weight loss (i.e., low-fat, high-carbohydrate, reduced-calorie diets)[10] have been challenged, especially by supporters of low-carbohydrate

Editor: Hasanain Faisal Ghazi.

YL and PS contributed equally to this work.

The study was approved by the Human Ethics and Research Ethics committees of Sichuan Provincial People's Hospital (Approval Number 2017–153). Written informed consent was obtained from all study participants.

The authors have no conflicts of interest to disclose.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

[a] Health Management Center, Sichuan Provincial People's Hospital, University of Electronic Science and Technology, [b] Chinese Academy of Sciences Sichuan Translational Medicine Research Hospital, Chengdu, China.

[*] Correspondence: Tingxin Li, Health Management Center, Sichuan Provincial People's Hospital, University of Electronic Science and Technology of China, Chinese Academy of Sciences Sichuan Translational Medicine Research Hospital, Chengdu, 610072, China (e-mail: xintinli@163.com).

How to cite this article: Liu Y, Sun P, Shuai P, Qiao Q, Li T. Fat-restricted low-glycemic index diet controls weight and improves blood lipid profile: a pilot study among overweight and obese adults in Southwest China. Medicine 2021;100:21 (e26107).

Received: 22 October 2020 / Received in final form: 13 March 2021 / Accepted: 31 March 2021

http://dx.doi.org/10.1097/MD.0000000000026107

diets (LCs). Emerging evidence mainly derived from Western countries clearly shows that LCs could be effective dietary strategies for weight loss. A meta-analysis revealed that LCs have greater long-term effects on weight loss compared with traditional low-fat diets; furthermore, triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and blood pressure are also more favorably altered in LCs,[11] which may have the potential to alleviate the features of metabolic disorder and reduce the risk of developing CVD. Not surprisingly, there are both positives and negatives associated with lowering carbohydrate content in the diet. LCs tend to result in reduced intake of fibers and fruits, and increased intake of proteins from animal sources, cholesterol and saturated fats, all of which are risk factors for mortality and CVD.[12] The ideal amount of carbohydrates in a healthy diet has become a controversial issue. The key questions are as followed. How low is too low? Which is more important, quality or quantity? Moreover, while consuming few carbohydrates, what potential risk will it cause if fat intake is not restricted?

Meanwhile, few studies have tested whether LCs are also useful and feasible for the large Chinese overweight/obese population[13] given that people in China and in Western countries have distinct dietary patterns and preferences.[14] Since the main source of energy for Chinese individuals is high-GI carbohydrates, it may lead to different levels of acceptance toward LCs. Furthermore, previous LC trials invariably administered diets *ad libitum* without focus on GI or no emphasis on fat restriction.[15] Undeniably, this approach is more effective and easier to implement in public practice, where researchers are unable to provide strict controls and intensive monitors of diet compared to the clinical setting. Yet, it is difficult to evaluate whether the cardiometabolic health outcomes resulting from these LCs should be attributed to changes of fat intake or the carbohydrate dietary pattern. It is necessary to evaluate how it affects weight and blood indicators. Therefore, with potential confounding factors being controlled, it is necessary to provide initial evidence regarding the effects of LCs with a low-GI and fat-restricted intake on weight and cardiovascular health in the Chinese population. We hypothesized that the low-GI/fat-restricted LCs intervention could effectively improve health and be implemented in overweight/obese Southwest Chinese individuals.

Given the above, we designed this prospective pilot study. Our objectives were as follows:

(1) To examine the effects of 3-month low-GI/fat-restricted LCs on weight and body composition as the primary endpoint;
(2) To compare the effects on baseline metabolic level and blood lipid profile as the secondary endpoint (i.e. value of TG, TC, HDL-C etc.);
(3) To study the Southwest Chinese's compliance with this diet.

2. Materials and methods

2.1. Participants

This was a single-arm, prospective pilot study conducted at the Health Examination Center of the People's Hospital of Sichuan Province. Participants included individuals undergoing physical examination at the Medical Examination Center between February and July 2019. A representative sample of the group was obtained by the multistage stratified cluster sampling method. Overweight and obesity were defined by the body mass index (BMI). For Chinese, an individual with a BMI of 24 to 28 kg/m^2 is considered to be overweight, and an individual with a BMI≥28 kg/m^2 is considered to be obese.[16] Inclusion criteria were:

(a) BMI between 24 to 39.9 kg/m^2;
(b) age of 18 to 55 years;
(c) adoption of the LC diet and agreement to be followed up for 3 months.

Exclusion criteria were:

(1) severe obesity (BMI≥40 kg/m^2);
(2) acute coronary syndrome, cerebrovascular events, or uncontrolled hypertension (systolic blood pressure≥160 mm Hg and/or diastolic blood pressure≥100 mm Hg) in the previous 3 months;
(3) obesity due to endocrine disorders or medication;
(4) severe depression or other mental disorder;
(5) regular medication, including but not limited to medications for the following diseases: respiratory disease, diabetes/insulin therapy, hypertension, dyslipidemia or kidney disease;
(6) inflammatory bowel disease, acute or chronic infections, irritable bowel syndrome, or serious gastrointestinal diseases;
(7) malignant tumor;
(8) engagement in a dietary regimen, intake of diet pills, or surgery for weight loss within six months prior to the study; and
(9) pregnancy, breastfeeding or planning to become pregnant. All subjects had retained their respective daily energy intake levels before the intervention.

The trial was approved by the Human Ethics and Research Ethics committees of Sichuan Provincial People's Hospital (Approval Number 2017–153), which were in complete accordance with the ethical standards and regulations of human studies of the Helsinki declaration (2014). All participants provided written informed consent.

2.2. Low-GI and fat-restricted diets

All participants received the booklet "Guide to Choosing Food" (Table 1), which explains the benefits, strategies and possible adverse reactions of this diet plan, as well as the obstacles and ways to overcome it. The daily energy intake was reduced by 300 to 500 kcal according to the participant's weight and level of activity,[17] with carbohydrate- and fat-energy ratios <45% and 25% to 30%, respectively. All diets were replaced with one glass of soy milk (200 mL), one small dish of starch-free vegetables (no more than 50 g) and one/two boiled eggs for breakfast; starch-free vegetables (<200 g) and 100–150 g of low-fat meat (e.g., beef, lean pork, skinless chicken, fish, etc.) were provided for lunch and dinner.

Participants were encouraged to select low-GI and low-fat foods, avoid sugary drinks, viscera and fat, reduce cooking oil, salt and sugar, drink at least 1.8 L of water per day (three 600-ml graduated drinking cups), increase the intake of starch-free vegetables and whole-grain cereals, and maintain pre-intervention activity levels.[18] The "Guide to Choosing Food" and the priority list of recommended foods are shown in Tables 1 and 2. Alcohol and sugary drinks were prohibited throughout the study.

Five health managers in the People's Hospital of Sichuan Province were trained by dietitians in standardizing the content of health education, supervision steps during return visits, etc. Throughout the study, the trained health managers were

Table 1

Food groups recommendation for the Low-GI and fat-restricted diets.

Alternative meat groups	Alternative vegetable groups	Foods to avoid
grass carp, fish, bass, salmon, mullet, river shrimp, squid, small yellow croaker, lean mutton, quail, bone chicken, cod, rabbit meat, skinless chicken, lobster, lean beef, eel, lean pork, egg, clam, crab, and oyster.	water celery, lettuce, cabbage, kale, green cabbage, rape, kelp, wax gourd, mushroom, mung bean sprout, Chinese cabbage, lettuce head, oyster mushroom, cucumber, leek, green onion, pea tip, celery, broccoli, Portuguese cabbage, gourd, vegetables, spinach, green bamboo shoots.	viscera, cream, chicken skin, fat poultry, fat livestock, potato, rice, noodles, wine, beverages, candy, ice cream, nuts, sweet potato, fried food

1. Try to choose food groups near the top of the list.
2. Be sure not to take any other drugs (e.g., Chinese medicine, syrup, infusions, etc.).
3. Drink at least 1800 mL of water every day; no alcohol, sugure or other beverages are allowed.
4. Weigh in the morning and record waist circumference as well as the types, quantities, and weights of daily consumed foods; communicate timely with dieticians.
5. Do not change the original exercise level.

responsible for guidance, consultation, supervision, and presentation of the low-GI and fat-restricted diet, while the dietitians were responsible for intervention plans and solving individual problems such as adverse reactions and food allergies.

The whole process was completed by the participants themselves. Professional dietitians and trained health managers provided regular nutritional support. Close guidance was given during the first two weeks to help participants learn and implement this intervention plan. In the subsequent intervention, follow-up guidance was given regularly at least twice a week, to record the participant‘s performance, and to help resolve possible adverse reactions until the end of the intervention. A scaled drinking cup (600 ml) and pictures of weighted food in the plate were auxiliary tools. Participants were encouraged to buy food weighing scales voluntarily to accurately record the amount of food consumed. They could take photographs of their dinner plates and beverage situations and send to their health managers via WeChat or internet interaction, or inform by phone calls for guidance or follow-up.

Table 2

Reference GI values of food groups.

Food groups	GI* value	Food groups	GI* value
Carbohydrates	Bean products		
Glucose	100	Soybeans (soaked, boiled)	18
Sucrose	65	Mung beans	27.2
Lactose	46	Lentils	38
Cereals/products	Vegetables		
Rice	83.2	Carrot	71
Glutinous rice	87	Pumpkin	75
Barley flour	66	Beet	64
Potato, starch, and products	Fruits and products		
Potato	62	Apple	36
Sweet potato	54	Pear	36
Lotus root starch	32.6	Grape	43
Seeds	Dairy products		
Peanut	14	Milk	27.6
Sunflower seed	13	Yoghurt (with sugar)	48
Pine nut kernel	2.2	Low-fat milk	11.9
Fast food	Beverages		
Hamburger	61	Cola	40.3
White bread	87.9	Ice-cream	61
Soda biscuit	7	Juice	57

* Glycemic index (GI), calculated using glucose as standard.

Participants who were found to be in violation of the rules would receive corrective suggestions from health managers and 3-day close follow-up; the dietary intervention would be stopped if there were still incorrect diets over three times a week.

After completing the three-month intervention, the participants were asked to return to the hospital for endpoint examinations. Changes after the 3-month intervention were assessed.

2.3. Data measurement and collection

Face-to-face comprehensive health interviews were conducted to record demographics and socioeconomic status (age, income levels, education levels, etc.), physical activity levels, and self-reported medical history: diagnosis and treatment of hypertension, hyperglycemia and hyperlipidemia, etc.

Physical measurements, including height, weight and WC, were measured by trained medical personnel. The body composition of subjects was measured by the Inbody 770 body composition detector (Biospace, Seoul, Korea). Body weight, body fat percent (%BF) and skeletal muscle mass (SMM) were measured before and after the intervention. The test subjects were required to empty their bowels and bladders as much as possible, and to remove jackets, watches, necklaces, and other metal objects after at least eight hours of fasting. On an empty stomach, the subjects stood barefoot on the footplate electrode and held the electrode part of the handle with both hands, with the detector operated by a trained health administrator. Body height was measured without shoes in light indoor clothing on the same height scale (Omron HNH-318, Kyoto, Japan) at each physical examination. The BMI (kg/m^2) was calculated by dividing each subject's weight (kg) by the square of his or her height (m^2). Blood pressure was measured twice after at least 5 min of rest in the sitting position by standardized automatic electronic sphygmomanometer (Omron HBP-9020, Kyoto, Japan).

An automatic biochemical analyzer (Olympus AU400, Olympus, Tokyo, Japan) was used to assay fasting blood glucose (FBG), serum uric acid (SUA), total cholesterol (TC), total triglyceride (TG), HDL-cholesterol (HDL-C) and LDL-cholesterol (LDL-C) amounts before and after the intervention as the the second endpoints. The coefficients of variation for intra-assay and inter-assay were all below 3%. All blood samples were assayed by standard procedures in accordance with the manufacturer‘s instructions, and were performed in the laboratory of People‘s Hospital of Sichuan Province.

Participants completed the measurements before and after the intervention. The primary outcome was weight and body

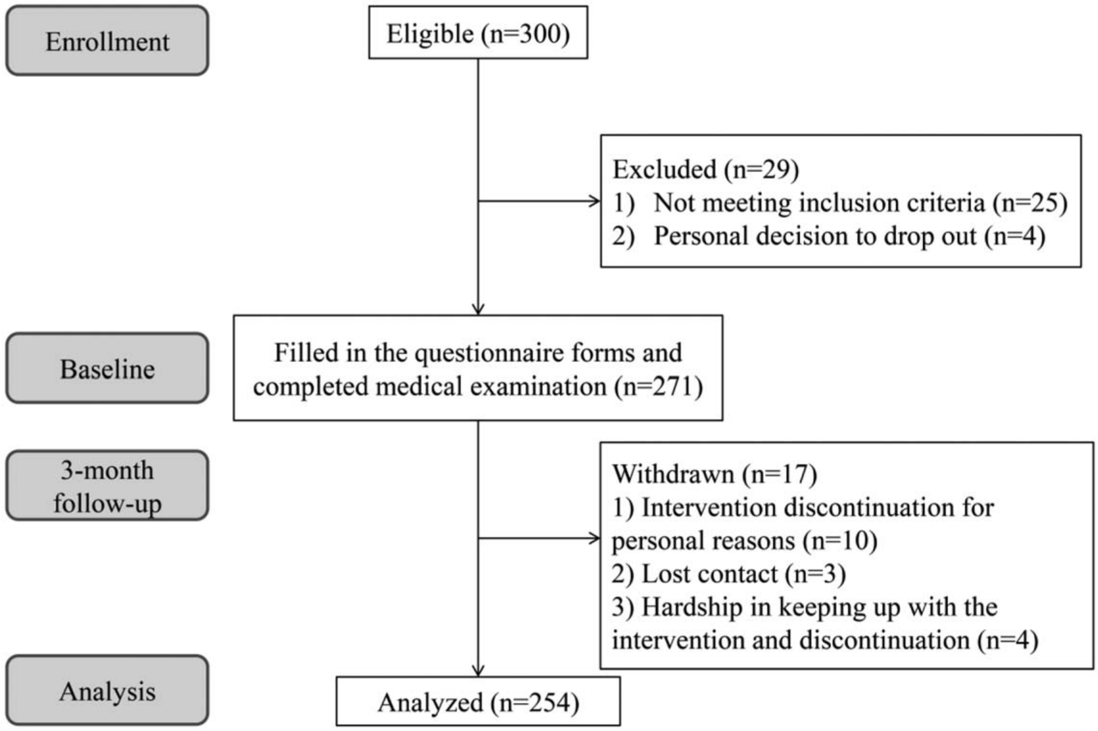

Figure 1. Study flowchart.

composition, including BMI, body fat percentage (BF%), visceral fat area, WC, waist-hip ratio and SMM. Secondary outcomes were basal metabolic level, FBG, SUA, TC, TG, HDL-C, and LDL-C.

2.4. Statistical analysis

Continuous variables were expressed as mean and standard deviation, and discrete variables as N (%). Changes in the values measured before and after the intervention were analyzed by the paired t-test. Individual analyses for significant items were conducted by the paired *t*-test and Wilcoxon signed-rank test. The significance between discrete frequencies was analyzed by the chi-square test, while differences among multiple groups were analyzed by *one-way ANOVA* and nonparametric Kruskal-Wallis tests. All results from statistical analysis were tested for significance at $P<.05$. Data were analyzed with the Statistical Package for the Social Sciences Version 17.0 (SPSS Inc.).

3. Results

3.1. Baseline features of the participants

A total of 300 participants were enrolled, and 29 were excluded for not meeting the inclusion criteria (n=25) or dropping out (n=4). Of the 271 remaining individuals, 17 were excluded from the final analysis for discontinuing the intervention (n=10), lost contact (n=3) and hardship in continuing the study (n=4). Therefore, 254 were finally analyzed, including 101 men and 153 women. Figure 1 presents the study flowchart. Mean participant age was 36.33±9.65 years, and BMI averaged 29.53±10.34 kg/m^2 before the intervention. Other features of the study subjects, including age, gender, smoking status, income status, education and exercise level, are shown in Table 3.

3.2. Effects of the intervention and subgroup analysis based on gender

As shown in Table 4, significant differences in weight, BMI, WC, waist-hip ratio, BF%, visceral fat area, basal metabolism, TC and TG were found between baseline and 3 months in total participants. SMM, LDL-C and HDL-C had no significant changes during the intervention period.

In subgroup analysis, FBG and basal metabolism in males were significantly decreased after the intervention, but no significant changes were found in females. While TC decreased significantly in females, no significant changes were seen in males. The changes in parameters after the intervention by paired *t*-test analysis showed no significant differences between genders. These data are detailed in Table 4.

3.3. Adverse reactions during the intervention

In the first 2 weeks of intervention, totally 18 participants reported varying degrees of adverse reactions such as dizziness, palpitation, fatigue, weakness, diarrhea, constipation, flatulence, etc. Two participants could not follow and gave up. After 2 to 4 weeks of persistent intervention, these symptoms almost disappeared. By the end of the intervention, 14 participants gave up and 3 had lost contact. Totally 93.7% of participants were able to adapt to this intervention. No serious adverse reactions were reported during the intervention. The adverse reactions recorded during the intervention period are shown in Figure 2.

Table 3

Characteristics of the study participants.

Variables	Population	Male	Female	F/χ^2 value	P-value
Cases (%)	254	101 (39.8)	153 (60.2)	–	–
Age (yr)	36.3±9.7	36.31±9.0	36.35±10.1	0.001	.98
Education level (%)					
Primary school or lower	52 (20.5)	19 (18.8)	33 (21.6)		
Secondary school	42 (16.9)	14 (13.9)	28 (18.3)		
High school	101 (39.8)	38 (37.6)	63 (41.2)	5.3	.26
Above high school	8 (3.1)	5 (4.9)	3 (2.0)		
No answer	51 (20.1)	25 (24.8)	26 (17.0)		
Income per month, RMB (%)					
<3000	40 (15.7)	11 (10.9)	29 (19.0)		
3000–6000	63 (24.8)	28 (27.7)	35 (22.9)		
6000–10000	50 (19.7)	13 (12.9)	37 (24.2)	14.0	.007*
>10000	49 (19.3)	19 (7.5)	30 (19.6)		
No answer	52 (20.5)	30 (29.7)	22 (14.4)		
Smoking (%)					
Never	146 (57.5)	45 (44.6)	101 (66.0)		
Former	39 (15.4)	17 (16.8)	22 (14.4)	13.2	.001*
Smoker	69 (27.2)	39 (38.6)	30 (19.6)		
Excessive alcohol consumption (%)†					
No	228 (89.8)	91 (90.1)	137 (89.5)	0.02	.5
Yes	26 (10.2)	10 (9.9)	16 (10.5)		
Exercise (%)‡					
<1 times/wk	144 (56.7)	57 (56.4)	87 (56.9)		
1–3 times/wk	80 (31.5)	31 (30.7)	49 (5.9)	0.2	.9
>3 times/wk	30 (11.8)	13 (12.9)	17 (11.2)		

* $P<.05$ indicates statistical significance.

† Excessive alcohol consumption (none vs. drinking either wine or beer vs. drinking more than 25 g/day).

‡ Continuous exercise for more than 30 minutes is considered a valid record.

4. Discussion

In this study, a low-GI and fat-restricted diet was examined. Changes in body weight, body composition, blood lipid profile, and body symptoms were assessed in healthy overweight and obese adults. Totally 93.7% of participants were able to adapt to this intervention.

LC diets for dietary intervention, including Atkins, South Beach and Zone diets, could induce a rapid weight loss.[19] An LC diet is defined as one with total energy intake from carbohydrates below 45%.[20] When carbohydrate intake is limited, the body begins to use glycogen to maintain blood glucose levels. If such limited carbohydrate intake is maintained, the majority of the

Table 4

Pre- and post-intervention data, and subgroup analysis based on gender.

	Male (n=101), Mean±SD				Female (n=153), Mean±SD				Total (n=254), Mean±SD				
Characteristics	Baseline	Three months	Difference	P^a	Baseline	Three months	Difference	P^b	Baseline	Three months	Difference	P^c	P^d
Weight (kg)	87.1±15.9	81.4±14.5	5.7±3.3	<0.001*	68.7±11.7	63.6±10.9	5.1±3.1	<.001*	76.0±16.3	70.7±15.2	5.4±3.2	<.001*	.14
BMI (kg/m²)	31.7±12.9	28.0±5.0	3.7±12.3	0.003*	28.1±7.9	24.9±4.3	3.2±8.0	<.001*	29.5±10.3	26.1±4.8	3.4±9.9	<.001*	.72
WC (cm)	99.7±12.0	95.2±11.2	4.5±2.7	<0.001*	91.3±11.8	86.0±12.8	5.3±7.0	<.001*	94.6±12.5	89.7±12.9	5.0±5.7	<.001*	.29
WHR	0.94±0.06	0.91±0.05	0.04±0.03	<0.001*	0.90±0.06	0.87±0.05	0.03±0.04	<.001*	0.92±0.06	0.88±0.06	0.03±0.03	<.001*	.15
Body fat (%)	31.8±5.3	28.0±5.0	3.2±2.7	<0.001*	34.9±5.2	31.8±4.9	3.0±3.7	<.001*	33.7±5.4	30.6±5.3	3.1±3.3	<.001*	.65
VFA (cm²)	105.7±28.3	90.0±26.2	15.7±9.5	<0.001*	97.2±22.9	84.7±19.9	12.5±10.2	<.001*	100.6±25.5	86.8±22.7	13.8±10.1	<.001*	.15
Basal metabolism (kcal)	1623.0±222.4	1596.4±221.8	26.6±123.1	0.04*	1334.3±214.0	1321.4±224.2	12.8±105.7	.14	1453.3±262.5	1430.7±260.4	22.3±113.3	.02*	.10
SMM (g)	30.0±6.1	30.2±6.0	-0.2±1.4	0.08	25.5±6.4	25.4±6.5	0.04±1.4	.09	27.3±6.7	27.3±6.7	-0.007±1.4	.94	.05
TC (mmol/L)	4.9±1.0	4.7±1.2	0.2±0.7	0.06	4.7±1.2	4.2±1.0	0.4±0.8	<.001*	4.8±1.1	4.5±1.1	0.3±0.8	<.001*	.08
TG (mmol/L)	2.3±1.5	1.8±1.2	0.5±1.2	0.01*	2.2±2.2	1.8±1.8	0.4±0.8	<.001*	2.2±1.9	1.8±1.6	0.4±1.0	<.001*	.80
LDL-C (mmol/L)	3.01±0.91	2.98±0.99	0.03±0.7	0.77	2.7±0.9	2.6±0.8	0.1±0.7	.10	2.9±1.0	2.8±0.9	0.09±0.7	.17	.27
HDL-C (mmol/L)	1.34±0.71	1.32±0.68	0.01±0.3	0.77	1.3±0.4	1.3±0.3	-0.04±0.3	.35	1.32±0.6	1.33±0.6	-0.01±0.3	.61	.39
FBG (mmol/L)	5.1±0.7	4.9±0.6	0.3±0.5	0.01*	5.0±0.7	4.9±0.6	0.01±0.8	.76	5.0±0.7	4.9±0.6	0.1±0.7	.05	.05
BUA (μmol/L)	419.0±102.0	413.1±89.9	5.9±78.7	0.59	322.7±82.6	327.5±89.9	-4.9±55.7	.52	367.7±103.6	367.5±99.0	0.2±67.3	.97	.42

Difference: value of baseline minus those after 3-month intervention.

P^a value of baseline vs 3-month intervention in males.

P^b value of baseline vs 3-month intervention in females.

P^c value of baseline vs 3-month intervention in total participants.

P^d value of difference in males *vs.*difference in females.

$P<.05$ indicates statistical significance.

BMI = body mass index, BUA = blood uric acid, FBG = fasting blood glucose, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol, SD = standard deviation, SMM = skeletal muscle mass, TC = total cholesterol, TG = triglycerides, VFA = visceral fat area, WC = waist circumference, WHR = waist-hip ratio.

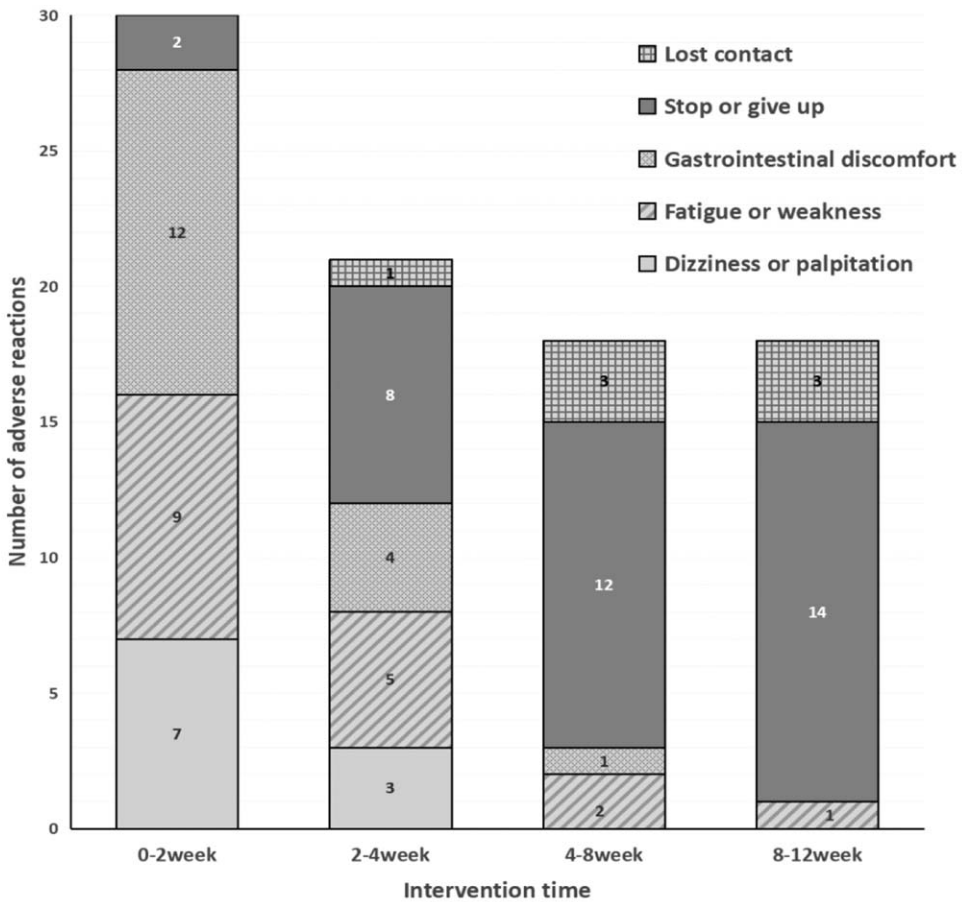

Figure 2. Adverse reactions.

glycogen is depleted, and lipolysis increases; sometimes, ketone bodies begin to be generated for energy production. LC therapy has been reported to reduce body fat and maintain fat-free mass, which is partially a response to the decrease in plasma insulin.[21] However, there are both positives and negatives associated with lowering carbohydrates in the diet. LCs always have reduced intake of fruits and increased intake of proteins from animals, with cholesterol and saturated fat. This might affect the metabolism of blood lipids or cause cardiovascular risk.[22] Just restricting the amounts of carbohydrates without specifying the type of ingested carbohydrates seems to be insufficient. Recent studies have shown that focusing on the quality of carbohydrates is more important than focusing on quantity.[23] More researchers are beginning to regulate the quality of carbohydrates. The "glycemic index" (GI), a feature of carbohydrate-containing foods, measures the blood glucose-raising potential of a given carbohydrate (50g of carbohydrate versus 50g of glucose) over 2 hours. GI is an important index for evaluating carbohydrate quality. A prospective controlled trial showed that the beneficial effects of a GI-restricted diet could be improved by changing the type of carbohydrates ingested.[24] With the same amount of carbohydrates ingested, the health effects of raw and refined types may be different. In this intervention study, we not only paid attention to the choice of carbohydrates in the diet, but also strictly controlled the energy supply ratio of fat. We recommend low-GI food selection, as well as low-fat and high-protein food selection, in order to control the intake of fat and cholesterol at low level. We hoped to reduce the fat metabolism load brought by LCs and explore a healthier weight-loss diet. A previous cohort study in adults showed that low-GI score is inversely associated with HDL-C level.[25] However, other researchers reported different results.[26] A meta-analysis of 28 trials found that low-GI does not affect HDL-C or TG levels, while decreasing LDL-C levels only with increasing fiber intake.[27] In this study, along with weight loss and favorable changes in body composition, TC and TG were significantly reduced, consistent with previous clinical trials.[28,29] However, HDL-C and LDL-C levels did not change significantly. This was an exploratory pilot intervention, and there was no randomized control. As a result, it is unknown whether this change was caused by the low-GI/fat controlled diet or the particularity of the study population. Randomized controlled trials are needed for further verification.

A previous analysis indicated that approximately 60% to 70% of dietary effects on CVD risk factors cannot be explained by differences in weight loss but could be due to different macronutrient concentrations in the diet.[26] This indicates that obese adults who lose weight on an LC diet could improve their cardiovascular status and blood lipid levels to similar or higher levels versus those on a low-fat diet. The recommended LC diet is composed of carbohydrates with low GI values, while the amounts of carbohydrates remain uncertain. It is worth considering that GI is just one of the many attributes of carbohydrate-containing foods. Further, nutrients often cluster, and the effects of GI, if any, might result from other nutrients such as fibers, potassium, and polyphenols, which favorably affect health.[30] Even though consumption of low-GI foods is advocated, the independent benefits of the GI are uncertain, especially when an individual has already adopted a healthy diet rich in whole grains, vegetables, and fruits. In a recent 25-year prospective cohort study exploring the association between carbohydrate consumption and mortality, diets composed of 50% to 55% carbohydrates, regardless of source (plants or animals), were shown to be associated with lowest risk of mortality.[31] In LC diets, higher mortality rates were associated with animal-based proteins and fats compared with plant-based products. The advantages of increased plant-based food consumption should therefore be emphasized. The optimal macronutrient composition and C/F ratio in patients with obesity remain unclear. Therefore, while considering the GI, attention should be paid to the dietary pattern, especially fat, fiber, and phytonutrient amounts in the diet.

Although a large number of studies have investigated the effects of diet on weight loss, the effect of diet on basal metabolism is poorly understood. Following short-term and sustained weight loss, adaptive thermogenesis occurs, where total energy expenditure, non-resting energy expenditure and resting energy expenditure are all significantly reduced compared with pre-weight-loss measures.[32] Thus, the decline in overall energy expenditure favors regain of the lost weight, and this metabolic compensation persists well beyond the period of active weight loss.[33] Exercise-associated thermogenesis, basal metabolism thermogenesis, and the thermic effect of food constitute the three components of the changeable components of metabolism, and are known collectively as energy expenditure. Basal metabolism thermogenesis is the largest component of the changeable aspects of metabolism.[34] If the basal metabolism decreases too much during weight loss, the weight would rebound quickly and even get higher, similar to a yo-yo ball. In this study, participants were instructed to maintain their original exercise level, that is, to neither reduce their activity due to diet changes, nor deliberately increase their exercise level. This could rule out the influence of exercise changes on weight and body composition. It was reported that LCs would fight against the decline of basal metabolism and maintain weight better than low-fat diet.[35] Some scholars suggested that LCs could combat muscle loss to a certain extent due to increased protein intake.[36] However, this study found that even if protein intake was increased, reducing total energy intake still led to a decline in basal metabolism, which was more significant in males; this might due to the decrease in body weight and muscle mass.[37] Therefore, we believe that appropriate increase in exercise is a necessary measure to combat the decline of basal metabolism. Further research is needed for confirmation.

A controlled trial with an intervention period of 6 weeks found significant beneficial effects of a low-fat diet on serum cardiovascular risk factors.[38] Lower incidence rates of stroke and coronary heart disease were found among individuals consuming low glycemic index or low glycemic load diets.[39,40] Intervention dietary studies were mostly short-term trials (2–4W). We believe that changes in diet metabolism require longer observation. Based on a previous report and operability,[23] we selected a 3-month (12W) time period for intervention, suggesting that this time period is sufficient to allow detectable changes in various outcomes. In this study, low-GI and fat-restricted dietary intervention was significantly more beneficial in terms of FBG to males compared with females. Women generally lose weight more slowly and display differences in postprandial glucose and fat oxidation that might influence the rate of weight loss.[41,42] Different hormone levels and dietary preferences in men and women may be responsible for weight control effects of low-GI and fat-restricted dietary intervention. At the end of the intervention, TC and TG were significantly reduced, and there were no statistically significant changes in LDL-C and HDL-C. Longer intervention studies are required to verify these results.

A previous study reported that implementation of a low-GI diet in overweight children is feasible based on a 12-week nutritional intervention by giving brief instructions on categorized foods.[43] Replacing starches with low-GI foods in daily meals was relatively difficult to implement in the early stage but well-accepted by nearly all subjects. By learning to select foods with lower GI values and slightly changing the eating habits, individuals could improve their diet quality and keep the improved dietary style for a long time. Switching to the low-GI fat-restricted diet resulted in reversible effects as shown in Figure 2. Although the participants were explicitly told about the possible adverse events in the informed consent form before enrolment, some individuals that could not tolerate the symptoms withdrew from the study in the first few weeks. People are reticent to changing their usual eating habits without specific personal and environmental support. Therefore, emphasis should be placed on the long-term health advantages of sustaining a good diet, and educational programs on food choices for health maintenance might be helpful. In addition, timely diet counseling and feedback monitoring could significantly increase interaction and persistence. At the end of this study, 93.7% of all participants were able to adapt to this intervention. The above findings have important public health implications considering the high prevalence of excessive consumption of refined carbohydrates as well as the high global obesity and CVD rates.

Previous epidemiological data have demonstrated that saturated fatty acids and trans-fatty acids are associated with increased CVD risk, which is reduced by polyunsaturated and monounsaturated fats.[44] In this study, we only focused on total fat amounts during the intervention. Although foods with high saturated fat contents (e.g., cream, chicken skin, fat poultry, and fat livestock) were restricted, we did not distinguish among saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids, which might have affected the current results.

The strengths of this study should be mentioned. This was the first study in Southwest China investigating the effects a low-GI and fat-restriction diet on overweight/obesity and blood lipid profile changes. This study encouraged specific food consumption by providing both dietary advice and supervision. It was also performed in the context of GI and fat-restricted dietary approaches. Through online instant feedback, this study had high completion and diet adherence rates. Uniform guidelines were used in all consultations, and nutritionists were involved in the intervention process. Diet feedback during the trial was observed intermittently for consistency by independent registered dietitian consultants not involved in the study.

However, this study also had limitations. First, we did not distinguish among saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids, which deserves further investigation. Secondly, the participants were mostly healthy at baseline, which might have prevented from observing changes in blood index factors. There was no control group not applying the regimen or using other dietary regimens (e.g. on a diet) for weight control. Finally, the sample size was relatively small, and the results of this single-center trial are not generalizable to the general population of Southwest China. Therefore, well-designed randomized controlled trials comparing low-fat and LC diets without confounding effects from the behavioral aspects of eating are lacking. In addition, further investigation of the effects of low-GI diets on weight loss and blood lipid profile changes is warranted.

5. Conclusions

Overall, the current findings suggest that fat-restricted low-glycemic index diet might be helpful for controlling weight and lowering blood cholesterol and triglycerides in overweight/obese individuals in Southwest China, regardless of gender. Further randomized controlled studies are warranted to comprehensively evaluate the effects of this diet.

Acknowledgments

The authors are grateful to all study participants for active cooperation. They acknowledged the contributions of survey team members, interviewers, leaders, and volunteers. They are grateful to the funding supportted by the Health Department of Sichuan Province (Grant No. 2018–228 and 18PJ585) and the National Key R & D Program of China (2017YFC0113901). The research funding provided the necessary expenses for printing promotional materials, producing a dietary guide, and following up the participants.

Author contributions

Liu Yuping (Liu YP) designed the research. Sun Ping (Sun P) conducted the research. Shuai Ping (Shuai P) analyzed the data and performed statistical analysis. Qiao Qichuan (Qiao QC) performed follow-up and data collection. Li Tingxin (Li TX) performed the entire process of intervention, wrote this manuscript and had primary responsibility for final content. All authors provided critical revisions and approved the final version of the manuscript.

Conceptualization: Yuping Liu.
Data curation: Ping Sun, Qichuan Qiao, Tingxin Li.
Formal analysis: Yuping Liu, Ping Shuai.
Investigation: Ping Sun.
Methodology: Tingxin Li.
Resources: Ping Sun.
Supervision: Ping Shuai, Qichuan Qiao.
Writing – original draft: Yuping Liu.
Writing – review & editing: Tingxin Li.

References

[1] Yang L, Yan J, Tang X, Xu X, Yu W, Wu H. Prevalence, awareness, treatment, control and risk factors associated with hypertension among adults in Southern China, 2013. PLoS One 2016;11:e146181.
[2] Wang K, Wang D, Pan L, et al. Prevalence of Obesity and Related Factors among Bouyei and Han Peoples in Guizhou Province, Southwest China. PLoS One 2015;10:e129230.
[3] Wang Y, Wang L, Qu W. New national data show alarming increase in obesity and noncommunicable chronic diseases in China. Eur J Clin Nutr 2017;71:149.
[4] Wang Y, Sun M, Yang Y, et al. China blue paper on obesity prevention and control. Zhonghua Yu Fang Yi Xue Za Zhi 2019;53:875–84.
[5] Robertson TM, Alzaabi AZ, Robertson MD, Fielding BA. Starchy carbohydrates in a healthy diet: the role of the humble potato. Nutrients 2018;10:1764.
[6] Hu L, Huang X, You C, et al. Prevalence of overweight, obesity, abdominal obesity and obesity-related risk factors in southern China. PloS one 2017;12:e0183934.
[7] Benjamin EJ, Virani SS, Callaway CW, et al. Heart Disease and Stroke Statistics-2018 Update: a report from the American Heart Association. Circulation 2018;137:e67–492.
[8] Lee J, Chen B, Kohl HW, et al. The Association of Self-Reported Muscle-Strengthening Activities with carotid intima-media thickness in older adults: cooper center longitudinal study. J Aging Phys Act 2019;1–6.
[9] Jessri M, Lou WY, L'Abbé MR. The 2015 Dietary Guidelines for Americans is associated with a more nutrient-dense diet and a lower risk of obesity. Am J Clin Nutr 2016;104:1378–92.
[10] Seagle HM, Strain GW, Makris A, Reeves RS; American Dietetic Association. Position of the American Dietetic Association: weight management. J Am Diet Assoc. 2009;109:330–46.
[11] Bueno NB, de Melo ISV, de Oliveira SL, da Rocha Ataide T. Very-low-carbohydrate ketogenic diet vs. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. Br J Nutr 2013; 110:1178–87.
[12] Tay J, Thompson CH, Luscombe-Marsh ND, et al. Effects of an energy-restricted low-carbohydrate, high unsaturated fat/low saturated fat diet versus a high-carbohydrate, low-fat diet in type 2 diabetes: a 2-year randomized clinical trial. Diabetes Obes Metab 2018;20:858–71.
[13] Sun J, Xu N, Lin N, Zhang H, Tong TK, Nie J. 317-LB: optimal weight loss effect of short-term low carbohydrate diet with calorie restriction on overweight/obese subjects in South China—a multicenter randomized controlled trial. Diabetes 2019;68.
[14] Zhai F, Wang H, Du S, et al. Prospective study on nutrition transition in China. Nutr Rev 2009;67:S56–61.
[15] Urbain P, Strom L, Morawski L, et al. Impact of a 6-week non-energy-restricted ketogenic diet on physical fitness, body composition and biochemical parameters in healthy adults. Nutr Metab (Lond) 2017;14:17.
[16] Joint committee for guideline revision. 2016 Chinese guidelines for the management of dyslipidemia in adults. J Geriatr Cardiol 2018;15:1–29.
[17] Wang SS, Lay S, Yu HN, Shen Sr. Dietary Guidelines for Chinese Residents (2016): comments and comparisons. J Zhejiang Univ Sci B 2016;17:649–56.
[18] Anand SS, Hawkes C, de Souza RJ, et al. Food consumption and its impact on cardiovascular disease: importance of solutions focused on the globalized food system: a report from the workshop convened by the World Heart Federation. J Am Coll Cardiol 2015;66:1590–614.
[19] Chen JH, Ouyang C, Ding Q, Song J, Cao W, Mao L. A moderate low-carbohydrate low-calorie diet improves lipid profile, insulin sensitivity and adiponectin expression in rats. Nutrients 2015;7:4724–38.
[20] Wolever TM, Jenkins DJ, Jenkins AL, Josse RG. The glycemic index: methodology and clinical implications. Am J Clin Nutr 1991;54:846–54.
[21] Kim JW. Effects of a low-carbohydrate, high-fat diet. Korean J Obes 2016;25:176–83.
[22] Reynolds A, Mann J, Cummings J, Winter N, Mete E. Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. Lancet 2019;393:434–45.
[23] Seid H, Rosenbaum M. Low carbohydrate and low-fat diets: what we don't know and why we should know it. Nutrients 2019;11:2749.
[24] Liu AG, Most MM, Brashear MM, Johnson WD, Cefalu WT, Greenway FL. Reducing the glycemic index or carbohydrate content of mixed meals reduces postprandial glycemia and insulinemia over the entire day but does not affect satiety. Diabetes Care 2012;35:1633–7.
[25] Hosseinpour-Niazi S, Sohrab G, Asghari G, Mirmiran P, Moslehi N, Azizi F. Dietary glycemic index, glycemic load, and cardiovascular disease risk factors: Tehran Lipid and Glucose Study. Arch Iran Med 2013;16:401–7.
[26] Jafari-Maram S, Daneshzad E, Brett NR, Bellissimo N, Azadbakht L. Association of low-carbohydrate diet score with overweight, obesity and cardiovascular disease risk factors: a cross-sectional study in Iranian women. J Cardiovasc Thorac Res 2019;11:216–23.
[27] Goff LM, Cowland DE, Hooper L, Frost GS. Low glycaemic index diets and blood lipids: a systematic review and meta-analysis of randomised controlled trials. Nutr Metab Cardiovasc Dis 2013;23:1–10.

[28] Sitko S, Cirer-Sastre R, López Laval I. Effects of a low-carbohydrate diet on performance and body composition in trained cyclists. Nutr Hosp 2019;36:1384–8.
[29] Feinman RD, Pogozelski WK, Astrup A, et al. Corrigendum to "Dietary carbohydrate restriction as the first approach in diabetes management: Critical review and evidence base". Nutrition 2019;62:213.
[30] Sacks FM, Carey VJ, Anderson CA, et al. Effects of high vs low glycemic index of dietary carbohydrate on cardiovascular disease risk factors and insulin sensitivity: the OmniCarb randomized clinical trial. Jama 2014;312:2531–41.
[31] Hamdy O, Tasabehji MW, Elseaidy T, Tomah S, Ashrafzadeh S, Mottalib A. Fat versus carbohydrate-based energy-restricted diets for weight loss in patients with type 2 diabetes. Curr Diab Rep 2018;18:128.
[32] Rosenbaum M, Hirsch J, Gallagher DA, Leibel RL. Long-term persistence of adaptive thermogenesis in subjects who have maintained a reduced body weight. Am J Clin Nutr 2008;88:906–12.
[33] Washburn RA, Szabo AN, Lambourne K, et al. Does the method of weight loss effect long-term changes in weight, body composition or chronic disease risk factors in overweight or obese adults? A systematic review. PLoS One 2014;9:e109849.
[34] Trexler ET, Smith-Ryan AE, Norton LE. Metabolic adaptation to weight loss: implications for the athlete. J Int Soc Sports Nutr 2014;11:7.
[35] Greene DA, Varley BJ, Hartwig TB, Chapman P, Rigney M. A low-carbohydrate ketogenic diet reduces body mass without compromising performance in powerlifting and olympic weightlifting athletes. J Strength Cond Res 2018;32:3373–82.
[36] Cava E, Yeat NC, Mittendorfer B. Preserving healthy muscle during weight loss. Adv Nutr 2017;8:511–9.
[37] Wilkinson DJ, Piasecki M, Atherton PJ. The age-related loss of skeletal muscle mass and function: measurement and physiology of muscle fibre atrophy and muscle fibre loss in humans. Ageing Res Rev 2018;47:123–32.
[38] Phillips SA, Jurva JW, Syed AQ, et al. Benefit of low-fat over low-carbohydrate diet on endothelial health in obesity. Hypertension 2008;51:376.
[39] Cai X, Wang C, Wang S, et al. Carbohydrate intake, glycemic index, glycemic load, and stroke: a meta-analysis of prospective cohort studies. Asia Pac J Public Health 2015;27:486–96.
[40] Rossi M, Turati F, Lagiou P, Trichopoulos D, Trichopoulou A. Relation of dietary glycemic load with ischemic and hemorrhagic stroke: a cohort study in Greece and a meta-analysis. Eur J Nutr 2015;54:215–22.
[41] Clamp LD, Hume DJ, Lambert EV, Kroff J. Successful and unsuccessful weight-loss maintainers: strategies to counteract metabolic compensation following weight loss. J Nutr Sci 2018;7:e20.
[42] Blaak EE, Antoine JM, Benton D, et al. Impact of postprandial glycaemia on health and prevention of disease. Obes Rev 2012;13:923–84.
[43] Young PC, West SA, Ortiz K, Carlson J. A pilot study to determine the feasibility of the low glycemic index diet as a treatment for overweight children in primary care practice. Ambul Pediatr 2004;4:28–33.
[44] Wang DD, Hu FB. Dietary Fat and Risk of Cardiovascular Disease: Recent Controversies and Advances. Annu Rev Nutr 2017;37:423–46.