Iran J Public Health, Vol. 52, No.4, Apr 2023, pp.713-721

Original Article

Relationship between a Low-Carbohydrate, High-Fat Diet and Risk of Metabolic Syndrome in Korean Women

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(Received 19 Oct 2021; accepted 21 Jan 2022)

Abstract

Background: Prevalence of metabolic syndrome with aging is higher in women than in men, and it increases after menopause. Interventions to reduce the risk of metabolic syndrome in women are important. A low-carbohydrate, high-fat diet is effective in weight loss and improvement cardiovascular risk factors including abdominal circumference, blood pressure, and blood lipid profile. We aimed to determine the relationship between a low-carbohydrate, high-fat diet and the risk of metabolic syndrome in Korean women.

Methods: This cross-sectional study was conducted using secondary data from the 2014–2018 Korean National Health and Nutrition Examination Survey. Overall, 8,222 women aged >19 yr were included. The effect of a low-carbohydrate, high-fat diet on the risk of metabolic syndrome was analyzed by multiple logistic regression analysis using a complex sampling procedure.

Results: The diet significantly reduced the likelihood of metabolic syndrome development (P=0.044). In addition, regardless of the fat type, the diet significantly reduced the likelihood of low high-density lipoprotein cholesterolemia (low-carbohydrate, high-total fat, P=0.013; low-carbohydrate, high-unsaturated fat, P=0.006; low-carbohydrate, high-saturated fat, P=0.006).

Conclusion: A low-carbohydrate, high-fat diet is an important intervention that can reduce the risk of metabolic syndrome, and the reduced consumption of carbohydrates can decrease the risk of low high-density lipoprotein cholesterolemia regardless of fat type. Therefore, it is necessary to actively explore the potential of this diet, targeting Asians, including Koreans.

Keywords: Metabolic syndrome; Diet; Carbohydrate-restricted; High-fat; Nutritional intake; Women

Introduction

Metabolic syndrome (MetS) is a cluster of cardiometabolic risk factors that include abdominal obesity, high blood pressure, high levels of fasting blood sugar, triglycerides, and low high-density lipoprotein (HDL) cholesterol (1). It is associated with an increased risk of chronic diseases such as diabetes, hypertension, cardiovascular disease, and kidney disease, and certain cancers, such as breast and colon cancer (2, 3), and is associated with increased mortality (2), so ongoing prevention and control are required. The prevalence of MetS in Korea was 32.1% in 2015 and is increasing (4, 5). The prevalence is higher in men (26.9%-35.2%) than in women (17.9%-

29.1%) (4), but the prevalence in women increases with age, especially after menopause (6). MetS is an important health problem in women because cardiovascular disease is a major cause of death (7).

The exact pathogenesis of MetS remains unclear, but overnutrition, lack of exercise, and environmental factors play a role (6, 8, 9). In Korea, the increasing prevalence is due to lifestyle factors, such as overnutrition and lack of exercise (1, 6, 8). Thus, lifestyle interventions targeting diet and exercise can delay or prevent the onset of MetS (10). Previous studies have suggested the importance of diet in MetS prevention (11, 12).

Low-carbohydrate diets limit carbohydrate intake to <130 g/day or <26% of total calorie intake (13). Low-carbohydrate, high-fat (LCHF) diets result in weight loss within a relatively short period (14), and effectively increase the HDL cholesterol level, associated with prevention of abdominal obesity (15, 16). As an LCHF diet improves blood sugar control in patients with diabetes mellitus (17), it can help to prevent MetS.

An LCHF diet may increase in the risk of cardiovascular disease due to an increase in total and low-density lipoprotein cholesterol as a result of increased fat intake (14). However, saturated fat-centered low-carbohydrate diets were associated with an increased total mortality rate, whereas unsaturated fat-based low-carbohydrate diets were associated with a reduced overall and cardiovascular mortality (18). Therefore, the effects of dietary sources of fat on MetS are important. In addition, most studies of the relationship between the consumption of an LCHF diet and MetS have been conducted among Western populations. Westerners and Koreans have different dietary habits and body composition (8); therefore, an LCHF diet may have different effects. Thus, it is important to determine the relationship between an LCHF diet and the risk of developing MetS in Koreans.

This study aimed to provide basic data about dietary interventions for the prevention and management of MetS in women by analyzing the effect of an LCHF diet on the prevalence of MetS using data from the Korea National Health and Nutrition Survey (KNHANES).

Materials and Methods

Research design and samples

This cross-sectional study was conducted using secondary data from the 2014–2018 KNHANES, a nationwide survey evaluating the nutrition and health status of the Korean population. It is a survey based on the National Health Promotion Act and is conducted by the Korea Disease Control and Prevention Agency (KDCA) and the Korean Ministry of Health and Welfare. Prior to the survey, the study was approved by the Institutional Review Board of the KDCA. The participants were determined through a complex, stratified, multistage, probability, cluster sampling. Among 17,577 women aged >19 yr, participants diagnosed with hypertension, diabetes mellitus, dyslipidemia, cardio-cerebrovascular disease; those using medications (n = 3,874); and pregnant or lactating participants (n=114) were excluded. In total, 8,222 participants who completed the survey were included in the final analysis.

Measurements

MetS

MetS was defined according to the diagnostic criteria of the American Heart Association and the National Heart, Lung, and Blood Institute (19), and waist circumference was measured based on the criteria of the Korean Society for the Study of Obesity (20). MetS was defined as the presence of ≥3 of the following: waist circumference ≥ 85 cm, blood pressure ≥ 130/85 mm/Hg or anti-hypertensive treatment, triglyceride level ≥ 150 mg/dl or dyslipidemia treatment, HDL cholesterol <50 mg/dl or dyslipidemia treatment, and fasting glucose level ≥ 100 mg/dl or diabetes treatment.

LCHF diet

For dietary assessment, a 24-hour recall method was used. Macronutrient intake was calculated as a percentage of total energy using standard conversion factors (4 kcal/g for carbohydrate and 9 kcal/g for fat). The scores for the LCHF diet were determined according to the study by Ha et al(21) and the percentages of carbohydrate and fat intake relative to total energy were calculated as deciles. Participants in the highest decile of fat intake were assigned 10 points, and those in the lowest decile were assigned 1 point. One point was assigned to those in the highest decile of carbohydrate intake and 10 points to those in the lowest decile. Therefore, the score for the consumption of an LCHF diet was the sum of the scores for carbohydrate and fat intake, which ranged from 2 to 20 points, indicating that the higher the scores, the higher the participant adherence to an LCHF diet. In addition, fat was divided into unsaturated and saturated fat, calculated using the same method described above, and described as unsaturated LCHF diet and saturated LCHF diet, respectively. Thus, the participants were assigned scores according to the fat type (i.e., total, unsaturated, and saturated).

Covariates

The biopsychosocial model proposed by Hoffman and Driscoll was used to investigate the covariates associated with the risk of MetS development (22). Biomedical factors (age, body mass index, family history of hypertension, dyslipidemia, type 2 diabetes, cardio-cerebrovascular disease, and menopause), biosocial factors (socioeconomic status and education level), and psychosocial factors (stress, smoking, alcohol consumption, physical activity, sedentary time, and total energy intake) were evaluated to adjust the variables related to MetS development.

Statistical analysis

Data were analyzed using the SPSS 24.0 complex sample analysis module (IBM, Armonk, NY, USA) that considered strata, clusters, and weights according to the analysis guidelines of the KNHANES. LCHF diet scores and non-dietary variables (biomedical, biosocial, and psychosocial factors) were analyzed using descriptive statistics. LCHF diet scores are presented as mean and standard deviation, and other variables are presented as frequency and percentage. The differences in LCHF diet scores and non-dietary variables according to the prevalence of MetS were analyzed by t-test and the Rao-Scott chi-square test. The differences in LCHF diet scores according to components of MetS and non-dietary variables were analyzed using t-test and analysis of variance, followed by the Bonferroni post-hoc test. Logistic regression analysis was performed to determine the effect of LCHF diet on the prevalence of MetS and its components, and statistically significant variables in the Rao-Scott chi-square test were included to adjust for covariates. *P*-values of <.05 were considered statistically significant.

Ethics approval

The KNHANES was conducted after obtaining approval from the Institutional Review Board of the KDCA, and it consisted of anonymized data from participants. In this study, data were downloaded from the KNHANES website with the approval of the KDCA. For secondary analysis, this study was approved for review exemption by the Institutional Review Board of the institution the researcher is affiliated with (approval no. 2021-03-012).

Results

Table 1 shows the differences between the groups with and without MetS according to biomedical, biosocial, and psychosocial variables. All biomedical and biosocial variables showed differences between the two groups. Among psychosocial variables, there were differences in current binge alcohol consumption, physical activity, and total energy intake between the two groups. LCHF diet scores were significantly higher in women without MetS than in those with MetS.

Table 1: Difference in the prevalence of metabolic syndrome according to biomedical, biosocial, and psychosocial variables (N = 8,222)

Variables		*Categories*	*Total (N = 8,222)*	*With metabolic syndrome n = 1,004 (10.8%)*	*Without metabolic syndrome n = 7,218 (89.2%)*	*t/ χ^2*	*P*
			n* (%)† or M ± SD	n* (%)† or M ± SD	n* (%)† or M ± SD		
Biomedical variables							
	Age (yr)	19–39	3,236 (46.4)	181 (22.2)	3,055 (49.3)	163.668	<.001
		40–64	4,294 (48.0)	614 (61.6)	3,680 (46.4)		
		≥65	692 (5.6)	209 (16.2)	483 (4.3)		
			41.38 ± 0.20	50.09 ± 0.49	40.32 ± 0.20	-19.099	<.001
	Body mass index	Non-obesity	4,790 (60.6)	155 (15.0)	4,635 (66.1)	744.207	<.001
		Overweight or obese	3,432 (39.4)	849 (85.0)	2,583 (33.9)		
	Family history	Yes	4,951 (59.2)	642 (64.9)	4,309 (58.5)	9.449	.002
		No	3,271 (40.8)	362 (35.1)	2,909 (41.5)		
	Menopause	Yes	2,662 (26.2)	552 (47.9)	2,110 (23.6)	217.734	<.001
		No	5,560 (73.8)	452 (52.1)	5,108 (76.4)		
Biosocial variables							
	Socioeconomic status of family	High	2,813 (35.0)	234 (25.6)	2,579 (36.2)	41.342	<.001
		Middle	4,536 (55.5)	571 (56.6)	3,965 (55.3)		
		Low	873 (9.5)	199 (17.8)	674 (8.5)		
	Education level	Less than graduation of middle school	1,528 (14.7)	401 (34.2)	1,127 (12.3)	139.288	<.001
		Graduation of high school	2,969 (38.0)	341 (36.6)	2,628 (38.2)		
		Higher than college education	3,725 (47.3)	262 (29.1)	3,463 (49.5)		
Psychosocial variables							
	Stress	A little or less	5,786 (69.2)	728 (71.0)	5,058 (68.9)	1.215	.271
		Severe	2,436 (30.8)	276 (29.0)	2,160 (31.1)		
	Smoking	Current or past smoker	951 (12.6)	114 (11.7)	837 (12.7)	0.527	.468
		Never	7,271 (87.4)	890 (88.3)	6,381 (87.3)		
	Current binge alcohol consumption	Yes	1,474 (20.7)	152 (16.3)	1,322 (21.2)	8.772	.003
		No	6,748 (79.3)	852 (83.7)	5,896 (78.8)		
	Physical activity (MET-min/week)	<600	2,847 (32.7)	399 (36.8)	2,448 (32.2)	6.833	.009
		≥600	5,375 (67.3)	605 (63.2)	4,770 (67.8)		
	Sedentary time (h)	<8	3,966 (46.1)	498 (48.3)	3,468 (45.9)	1.526	.217
		≥8	4,256 (53.9)	506 (51.7)	3,750 (54.1)		
	Total energy intake (kcal/day)		1,773.76 ± 9.52	1,683.76 ± 24.99	1,784.66 ± 10.10	3.795	<.001

Note. *Unweighted; †weighted.

Comparison of LCHF diet scores by fat type for MetS and its components

Table 2 presents the comparison of LCHF diet scores by fat type for MetS and its components. The scores of LCHF diet regardless of fat type were higher in women without MetS than in those with MetS. In addition, the LCHF scores were significantly different depending on the presence of the metabolic components.

Table 2: Comparison of low-carbohydrate, high-fat diet scores by fat type for metabolic syndrome and components of metabolic syndrome (*N*=8,222)

Variables	*Categories*	*Low-carbohydrate, high-total fat diet score*			*Low-carbohydrate, high-unsaturated fat diet score*			*Low-carbohydrate, high-saturated fat diet score*		
		M ± SD	t/F	*P*	M ± SD	t/F	*P*	M ± SD	t/F	*P*
Metabolic syndrome	Yes	10.74 ± 0.20	8.923	<.001	10.78 ± 0.20	8.772	<.001	10.66 ± 0.18	9.161	<.001
	No	12.54 ± 0.07			12.55 ± 0.07			12.38 ± 0.07		
Abdominal obesity	Yes	11.53 ± 0.17	5.541	<.001	11.52 ± 0.17	5.738	<.001	11.43 ± 0.16	5.445	<.001
	No	12.50 ± 0.07			12.52 ± 0.07			12.34 ± 0.07		
Elevated blood pressure	Yes	10.68 ± 0.17	10.536	<.001	10.81 ± 0.17	10.003	<.001	10.59 ± 0.17	10.598	<.001
	No	12.60 ± 0.07			12.61 ± 0.07			12.45 ± 0.07		
High triglyceride	Yes	11.29 ± 0.17	6.692	<.001	11.34 ± 0.17	6.522	<.001	11.21 ± 0.16	6.679	<.001
	No	12.51 ± 0.07			12.53 ± 0.07			12.36 ± 0.07		
Low high-density lipoprotein cholesterol	Yes	11.65 ± 0.12	6.918	<.001	11.66 ± 0.12	7.106	<.001	11.51 ± 0.12	7.214	<.001
	No	12.66 ± 0.08			12.68 ± 0.08			12.51 ± 0.08		
Impaired glucose levels	Yes	11.39 ± 0.16	6.552	<.001	11.49 ± 0.17	5.866	<.001	11.23 ± 0.15	7.096	<.001
	No	12.54 ± 0.07			12.54 ± 0.07			12.39 ± 0.07		

LCHF diet scores by fat type associated with MetS and its components

Table 3 shows the association between LCHF diet scores according to the fat type and the likelihood of developing MetS and its components. The consumption of a low-carbohydrate, high-unsaturated fat diet significantly reduced the likelihood of MetS development. In addition, regardless of the fat type, the consumption of an LCHF diet significantly reduced the likelihood of low HDL cholesterolemia.

Table 3: Adjusted odds ratios for prevalence of metabolic syndrome and metabolic components according to the low-carbohydrate, high-fat diet scores by fat type (*N*=8,222)

Variables		*Low-carbohydrate, high total-fat*		*Low-carbohydrate, high-unsaturated fat*		*Low-carbohydrate, high-saturated fat*	
		AOR† (95% CI)	*P*	AOR† (95% CI)	*P*	AOR† (95% CI)	*P*
Metabolic syndrome (Ref. No)	Yes	0.985 (0.970–1.002)	.077	0.984 (0.968–0.999)	.044	0.986 (0.970–1.003)	.099
Abdominal obesity (Ref. No)	Yes	0.994 (0.978–1.009)	.422	0.989 (0.973–1.005)	.164	0.997 (0.980–1.014)	.725
Elevated blood pressure (Ref. No)	Yes	0.989 (0.974–1.003)	.128	0.990 (0.976–1.005)	.182	0.988 (0.973–1.003)	.128
High triglyceride (Ref. No)	Yes	0.987 (0.972–1.002)	.090	0.986 (0.971–1.001)	.065	0.988 (0.973–1.004)	.137
Low high-density lipoprotein cholesterol (Ref. No)	Yes	0.985 (0.973–0.997)	.013	0.984 (0.972–0.995)	.006	0.983 (0.971–0.995)	.006
Impaired glucose levels (Ref. No)	Yes	0.997 (0.983–1.011)	.668	0.998 (0.984–1.013)	.813	0.995 (0.981–1.010)	.509

Note. †= Adjusted for age, body mass index, family history of hypertension, dyslipidemia, T2DM, or cardio-cerebrovascular disease, menopause, socioeconomic status of family, education level, current binge alcohol consumption, physical activity, total energy intake

Discussion

This study identified the effects of LCHF diets on the risk of MetS development in Korean women using data from the KNHANES between 2014 and 2018. According to the results of this study, the prevalence of MetS in Korean women was 10.8%, which is much lower than that in Korean women, reported to be 17.9%-29.1% according to a previous study (4). This is because we excluded from this study participants with chronic diseases such as hypertension, dyslipidemia, diabetes, and cardio-cerebrovascular disease.

The LCHF diet score was significantly lower in participants with components of MetS, regardless of the type of fat consumed. In a previous meta-analysis, the LCHF diet significantly lowered weight, triglyceride level, insulin level, waist circumference, plasma C-reactive protein level, and blood pressure (23). Furthermore, the reduction in carbohydrate energy intake in LCHF diet improved the levels of blood lipids, blood pressure, and fasting blood sugar in the body (17, 23, 24). The LCHF diet is effective in reducing the prevalence of non-alcoholic fatty liver disease, diabetes, and cardiovascular disease in Koreans consuming 65% of energy as carbohydrates (24). However, the intervention period for these studies was within 6 months (17, 23), and some studies suggested that improvement in blood lipid level was associated with a decrease in total energy intake (24). Therefore, intervention studies of >6 months are needed, and differential studies are needed to determine whether the improvement in blood lipid level is the effect of LCHF alone or the effect of reducing total energy intake.

LCHF diets can reduce the incidence of MetS because they decrease insulin resistance and hormone resistance to leptin, considered the causes of MetS (18). Consuming an LCHF diet reduces the amount of glucose absorbed into the blood, resulting in decreased levels of glycogen stored in the liver and muscles and lower insulin levels as a result of decreased blood sugar levels (16). Lower insulin levels increase fat oxidation and lipolysis (25), increasing the amount of fatty acids available for fuel and decreasing the activity of key enzymes in de novo lipogenesis, altering lipoprotein metabolism and cardiometabolic profile (16, 26). In addition, the contribution of carbohydrates in the diet to the inflammatory process is more than that of fats (27). A low-carbohydrate diet improves biomarkers of inflammation, such as pro-inflammatory cytokines (e.g., tumor necrosis factor-α, interleukin-8, ICAM-1, and E-selectin), by regulating antioxidant pathways that limit reactive oxygen species generation (26, 27). Pro-inflammatory cytokines are associated with an increased risk of endothelial dysfunction and thrombosis, and reducing carbohydrate intake has a greater effect on reducing pro-inflammatory cytokine levels than on reducing saturated fat intake (27). Moreover, a low-carbohydrate diet decreases insulin and triiodothyronine levels and increases levels of growth hormone, catecholamine, cortisol, and glucagon (25). Insulin acts as a potent inhibitor of lipolysis, and growth hormone, catecholamine, cortisol, and glucagon are expected to help prevent MetS by stimulating lipolysis (25). Therefore, an LCHF diet may reduce the risk of MetS, as shown in this study.

After adjusting for the covariates in this study, the LCHF diet composed of saturated fats did not reduce the risk of MetS, whereas the LCHF diet composed of unsaturated fats decreased the risk of MetS. This suggest that fat type is also important for lowering the risk of MetS development. Unsaturated fat intake increases insulin sensitivity (16), which yields cardiometabolic benefits. However, saturated fat has a negative effect on LDL cholesterol levels, and overeating saturated fat increases LDL particle aggregation and insulin resistance (28-30). In addition, a high saturated fat diet induced endothelial fibrinolytic dysfunction, resulting in decreased flow-mediated dilatation and an increased concentration of endothelial microparticles, an indicator of endothelial injury, suggesting that a high saturated fat diet has a negative effect on endothelial function (31). Moreover, a high-saturated fat diet is highly preferred and has a low effect on satiety, potentially leading to overconsumption and obesity (32). Therefore, even reducing carbohydrate consumption seems to counteract the effect of reducing the risk of MetS due to the effect of saturated fat on MetS. Thus, unsaturated fatty foods should be recommended when considering LCHF diets to reduce the risk of MetS.

In this study, LCHF diets had a significant effect on the prevention of HDL reduction, regardless of the type of fat consumed by the study participants. LCHF diets directly improve the lipid profile of patients with cardiovascular diseases, resulting in an increase in HDL cholesterol level (29). Low-carbohydrate diets are more effective than low-fat diets in increasing HDL cholesterol level, regardless of the fat type (12). In fact, HDL cholesterol levels can increase with an increased intake of saturated fat, and low-carbohydrate diets have the greatest effect on HDL growth (29). The intake of carbohydrates has more effect on HDL cholesterol level than the intake of fat.

In contrast, the LCHF diet had no effect on waist circumference, blood pressure, triglyceride level, or blood sugar level, regardless of the fat type. These findings are thought to be because of the lack of calorie restriction, unlike previous studies that showed benefits such as blood pressure level decrease and weight loss, by limiting calorie intake. In this study, the total energy consumed by the groups with MetS was 1,684 and 1,785 kcal/day for groups without MetS, indicating that weight loss caused by reduction in energy intake could be an important factor in reducing cardiometabolic risk (16).

This study has some limitations. First, this study used a cross-sectional design, and care should be taken in interpreting the causal relationship between LCHF diet and the risk of MetS. Second, LCHF diet data were evaluated using a self-administered questionnaire with 24-h food recall. Therefore, this may not represent the participants' usual dietary intake. Nevertheless, this study represents the population of adult women in Korea and provides relevant information to improve the eating habits of patients with MetS. Therefore, we propose a large-scale longitudinal study in the future to clarify the relationship between LCHF diets and MetS.

Based on the results of this study, long-term future research to investigate the effects of the LCHF diet is required, lasting for >6 months while ensuring participant safety. A differential study on the effect of total energy intake should also be conducted. It is also suggested to include interventions for binge alcohol consumption and physical activity when developing an intervention program to reduce a risk of MetS.

Conclusion

This study analyzed the effect of LCHF diets on the prevalence of MetS in Korean women by analyzing data from the KNHANES. The prevalence of MetS decreased with the intake of LCHF diets, especially with an LCHF diet composed of unsaturated fats. In addition, the intake of an LCHF diet reduced the risk of low HDL, a component of MetS, regardless of the fat type. Therefore, LCHF diets composed of unsaturated fats may offer potential benefits in reducing the risk of MetS.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This research received no external funding.

Conflict of interest

The authors declare that there is no conflict of interest.

References

1. Ra JS, Kim HS (2021). Combined effects of unhealthy lifestyle behaviors on metabolic syndrome among postmenopausal women. *Healthcare (Basel)*, 9(7):848.
2. Isomaa BO, Almgren P, Tuomi T, et al (2001). Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care*, 24(4):683–689.
3. Kelli HM, Kassas I, Lattouf OM (2015). Cardio metabolic syndrome: A global epidemic. *J Diabetes Metab*, 6(3):1–14.
4. Kim YH (2020). Caution in the use of prevalence data of metabolic syndrome. *Korean J Fam Pract*, 10(1):1–2.
5. Korean Society of Lipidology and Atherosclerosis Dyslipidemia. Dyslipidemia fact sheet in Korea 2015 [Internet]. Seoul: Korean Society of Lipidology and Atherosclerosis Dyslipidemia; 2015. Available from: https://www.lipid.or.kr/
6. Ra JS, Kim HS, Jeong YH (2019). Associated factors of ischemic heart disease identified among post-menopausal women. *Osong Public Health Res Perspect,*10(2):56–63.
7. Korean Statistical Information Service. 2017 Statistics of Cause of Death [Internet]. 2018 Sept 19 [cited 2021 April 2]. http://kostat.go.kr/assist/ synap/preview/skin/doc.html?fn=synapview370710_2&rs=/assist/synap/preview
8. Ra JS, Kim HS (2017). Sex-based association between depression and metabolic syndrome in Korean middle-aged and older adults. *Osong Public Health Res Perspect*, 8(2):130–7.
9. Gaillard TR (2018). The metabolic syndrome and its components in African-American women: Emerging trends and implications. *Front Endocrinol (Lausanne)*, 8:383.
10. Tran BT, Jeong BY, Oh JK (2017). The prevalence trend of metabolic syndrome and its components and risk factors in Korean adults: Results from the Korean National Health and Nutrition Examination Survey 2008-2013. *BMC Public Health*, 17:71.
11. Na DW, Jeong E, Noh EK, et al (2010). Dietary factors and metabolic syndrome in middle-aged men. *J Agr Med Community Health,* 35(4):383–94.
12. Volek JS, Phinney SD, Forsythe CE, et al (2009). Carbohydrate restriction has a more favorable impact on the metabolic syndrome than a low fat diet. *Lipids*, 44(4):297–309.
13. Feinman RD, Pogozelski WK, Astrup A, et al (2015). Dietary carbohydrate restriction as the first approach in diabetes management: Critical review and evidence base. *Nutrition*, 31(1):1–13.
14. Kim J (2016). Effects of a low-carbohydrate, high-fat diet. *Korean J Obes*, 25(4):176–83.

15. Bazzano LA, Hu T, Reynolds K, et al (2014). Effects of low-carbohydrate and low-fat diets: A randomized trial. *Ann Intern Med*, 161(5):309–18.
16. Brouns F (2018). Overweight and diabetes prevention: Is a low-carbohydrate–high-fat diet recommendable? *Eur J Nutr*, 57(4):1301–12.
17. Nordmann AJ, Nordmann A, Briel M, et al (2006). Effects of low-carbohydrate vs low-fat diets on weight loss and cardiovascular risk factors: A meta-analysis of randomized controlled trials. *Arch Intern Med*, 166(3):285–93.
18. Fung TT, van Dam RM, Hankinson SE, et al (2010). Low-carbohydrate diets and all-cause and cause-specific mortality: Two cohort studies. *Ann Intern Med*, 153(5):289–98.
19. Alberti KGMM, Eckel RH, Grundy SM, et al (2009). Harmonizing the metabolic syndrome: A joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. *Circulation*, 120(16):1640–5.
20. Kim MK, Lee WY, Kang JH, et al (2014). Clinical practice guidelines for overweight and obesity in Korea. *Endocrinol Metab (Seoul)*, 29(4):405–9.
21. Ha K, Joung H, Song Y (2018). Low-carbohydrate diet and the risk of metabolic syndrome in Korean adults. *Nutr Metab Cardiovasc Dis*, 28(11):1122–32.
22. Hoffman MA, Driscoll JM. Health promotion and disease prevention: A concentric biopsychosocial model of health status. In: Brown SD, Lent RW, eds. *Handbook of Counseling Psychology*. 3rd ed. New York: John Wiley & Sons, Inc; 2000:532–567.
23. Santos FL, Esteves SS, da Costa Pereira A, et al (2012). Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. *Obes Rev*, 13(11):1048–66.
24. Oh H, Ahn J, Jun DW (2017). Association between a high-fat low-carbohydrate diet and non-alcoholic fatty liver disease: Truth or myth? *Korean J Med*, 92(2):112–7.
25. Volek JS, Sharman MJ, Love DM, et al (2002). Body composition and hormonal responses to a carbohydrate-restricted diet. *Metabolism*, 51(7):864–70.
26. Forsythe CE, Phinney SD, Feinman RD, et al (2010). Limited effect of dietary saturated fat on plasma saturated fat in the context of a low carbohydrate diet. *Lipids*, 45(10):947–62.
27. O'Neill BJ (2020). Effect of low-carbohydrate diets on cardiometabolic risk, insulin resistance, and metabolic syndrome. *Curr Opin Endocrinol Diabetes Obes*, 27(5):301–7.
28. Muzio F, Mondazzi L, Harris WS, et al (2007). Effects of moderate variations in the macronutrient content of the diet on cardiovascular disease risk factors in obese patients with the metabolic syndrome. *Am J Clin Nutr*, 86(4):946–51.
29. Picklo MJ, Murphy EJ (2016). A high-fat, high-oleic diet, but not a high-fat, saturated diet, reduces hepatic α-linolenic acid and eicosapentaenoic acid content in mice. *Lipids*, 51(5):537–47.
30. Ruuth M, Lahelma M, Luukkonen PK, et al (2021). Overfeeding saturated fat increases LDL (low-density lipoprotein) aggregation susceptibility while overfeeding unsaturated fat decreases proteoglycan-binding of lipoproteins. *Arterioscler Thromb Vasc Biol*, 41(11):2823–36.
31. Lambert EA, Phillips S, Belski R, et al (2017). Endothelial function in healthy young individuals is associated with dietary consumption of saturated fat. *Front Physiol*, 8:876.
32. Shan Z, Guo Y, Hu FB, et al (2020). Association of low-carbohydrate and low-fat diets with mortality among US adults. *JAMA Intern Med*, 180(4):513–23.