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Association between carbohydrate intake and body composition: The Korean National Health and Nutrition Examination Survey

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ABSTRACT

Objective: Several studies have investigated the effects of dietary carbohydrate intake on body composition. However, the results are controversial and few studies have been conducted on an Asian population. The aim of this study was to investigate whether dietary carbohydrate intake is associated with body composition in Korean adults.
Methods: The present study used data from the Korean National Health and Nutrition Examination Survey, a cross-sectional survey of Korean civilians, conducted from 2008 to 2011. The study analyzed 9594 participants. Carbohydrate intake was defined as the proportion of energy consumed from carbohydrate. Waist circumference, body mass index, and lean and fat mass using a whole-body dual-energy x-ray absorptiometry scanner were measured as body composition parameters.
Results: After adjusting for age, household income, smoking, alcohol consumption, physical activity, history of diabetes, hypertension, dyslipidemia, and intake of energy and fiber per day, the proportion of carbohydrate intake was positively correlated with total limb lean mass in men ($\beta = 0.141$, $P = 0.046$), and in women, the proportion of carbohydrate intake was positively associated with appendicular skeletal muscle mass index ($\beta = 0804$, $P = 0.003$) but negatively associated with trunk fat percentage ($\beta = -0.075$, $P = 0.026$). Total limb lean mass and appendicular skeletal muscle mass index in women showed an increasing trend as the proportion of carbohydrate intake increased.
Conclusions: No positive association was found between the proportion of carbohydrate intake and any measure of obesity or body fat mass in either men or women. Further studies are needed to evaluate the effects of quantity and quality of carbohydrate intake on body composition.

Introduction

Body composition is important for physiological functioning and in metabolic disorders, cardiovascular disease (CVD), and mortality. Obesity, which is the accumulation of excess body fat, is an important public health problem because it is associated with an increased risk for type 2 diabetes mellitus, dyslipidemia, hypertension, and CVD, and its prevalence is increasing worldwide [1]. Body fat distribution, as well as body fat mass, is closely associated with metabolic disturbances. Abdominal obesity, presenting as an increase in visceral adiposity, plays a vital role in the development of insulin resistance and associated metabolic abnormalities [2]. In addition, trunk fat mass also is negatively related to insulin sensitivity [3], but leg fat mass has beneficial effects on glucose [4] and is associated with a low risk for diabetes [5] and CVD [6]. A reduction in muscle mass, known as sarcopenia, is associated with physical and functional impairment and negative metabolic outcomes [7]; therefore, sarcopenia is a major global health issue. In addition, muscle distribution is associated with metabolic disturbances [8].

Numerous factors influence body composition, such as age, sex, physical activity, dietary pattern, alcohol intake, and concomitant disease. Dietary intake of macronutrients, such as carbohydrate, protein, and fat, are also related to body composition; several studies have investigated the associations between macronutrients and body composition, typically in Western populations [9,10]. However, Western and Asian populations exhibit different dietary patterns [11,12] because the traditional Asian diet is characterized by a higher carbohydrate and lower fat intake than the Western diet. In particular, Korean adults consume 62.2% of total energy from dietary carbohydrate [12], whereas carbohydrate intake of total energy in U.S., U.K., and Spanish adults is 48%, 46.5%, and 40.5%, respectively [13–15].

Both authors conceived the study, analyzed and interpreted the data, and read and approved the final manuscript. Ha-Na Kim wrote the manuscript. Sang-Wook Song supervised writing of the paper and provided critical revisions. The authors have no conflicts of interest to declare.

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Dietary carbohydrate is a primary driver of insulin secretion that promotes the uptake, retention, and storage of fat in adipose tissue, suggesting that high carbohydrate intake could induce accumulation of body fat [16,17]. Therefore, several studies have investigated the effects of dietary carbohydrate on body fat and obesity, but the results are controversial [18–21]. Several studies showed a greater weight loss in individuals on low-carbohydrate diets compared with those on low-fat diets [18,19]. However, in another randomized controlled trial, more body fat was lost by individuals with an isocaloric reduction of dietary fat than in those having restricted carbohydrate intake [20], and a meta-analysis showed that low-carbohydrate diets and isoenergetic-balanced diets did not differ in terms of weight loss [21]. Furthermore, to our knowledge, few studies have examined the association between dietary carbohydrate intake and various body composition parameters, including muscle and fat mass, in an Asian population [22]. Therefore, using data from the Korean National Health and Nutrition Examination Survey (KNHANES), we investigated whether the proportion of energy intake from carbohydrate as dietary carbohydrate intake is associated with various body composition parameters in Korean adults.

Participants and methods

Study population

We used data from the KNHANES collected between 2008 and 2011. The KNHANES is conducted by the Korean Center for Disease Control and Prevention at 3-y intervals to assess public health status and provide baseline data to develop, establish, and evaluate public health policies for the Korean population. KNHANES participants are non-institutionalized and aged ≥1 y; they are selected using a stratified, multistage cluster probability sampling design to ensure an independent, homogeneous, and nationally representative sample. Data are collected using household interviews, anthropometric and biochemical measurements, and nutritional status assessments. All protocols were approved by the Institutional Review Board of the Korean Center for Disease Control and Prevention, and all participants provided written informed consent at baseline.

The KNHANES 2008–2011 recruited 32 014 participants, of which, 26 348 completed the survey (participation rate: 82.3%). In this cross-sectional study, we originally examined 19 774 adults ≥20 y of age, from among 26 348 participants. We excluded individuals with missing data for body composition parameters (n = 697), those who reported implausible energy intakes (<500 or >5000 kcal/d; n = 2,650), were on a specific diet (n = 3934), or whose intake on the day of the 24-h dietary recall survey was not representative of their usual intake (n = 2899). Thus, the population for the current study consisted of 9594 participants (Fig. 1). The current study was approved by the Institutional Review Board of the Catholic University of Korea.

Dietary assessments

Trained interviewers estimated the dietary intake of the participants using the 24-h dietary recall method, including all foods and beverages that were consumed in the previous 24 h. The nutrition survey was conducted at the participants' homes, and additional tools, such as food models, two-dimensional food volumes, and containers were used to help participants recall their nutrient intake. Dietary intake was estimated from the food composition tables of the Rural Development Administration, in combination with the nutrient database of the Korea Health and Industry of Development Institute [23]. Carbohydrate intake was defined as a proportion of energy consumed from carbohydrate. The calculation of energy from carbohydrate intake was based on standard conversion factors used to convert gram to kcal (4 kcal/g for carbohydrates) and the proportion of energy intake from carbohydrate was calculated as energy for carbohydrate intake/total energy intake (%). The proportion of energy consumed from carbohydrate was categorized into quartiles, with quartile 1 (Q1) representing the lowest proportion of carbohydrate intake, Q2 a low-medium proportion of carbohydrate intake, Q3 a high-medium proportion of carbohydrate intake, and Q4 the highest proportion of carbohydrate intake.

Measurements of body composition factors

After an overnight fast, specially trained examiners measured each participant's height, weight, and waist circumference (WC); the WC was measured using a measuring tape in the horizontal plane around the umbilical region after the individual had exhaled. Abdominal obesity was defined as WC ≥ 90 cm for men and ≥85 cm for women [21]. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2), and obesity was defined as BMI ≥ 25 kg/m^2 [24,25]. Body composition factors, including lean and fat mass, were measured using a whole-body dual-energy x-ray absorptiometry (DXA) scanner (Discovery-W fan-beam densitometer; Hologic Inc., Waltham, MA, USA). Participants wore a

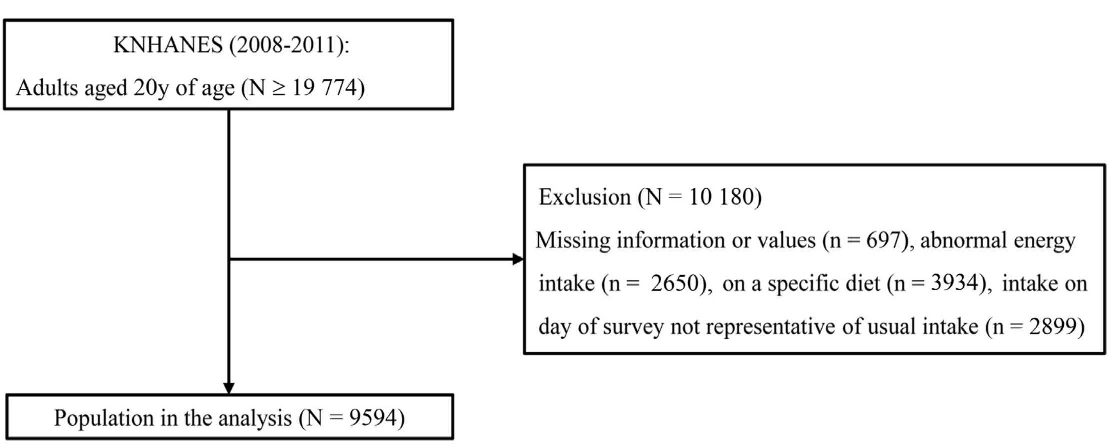

Fig. 1. Study population: Data from the 2008–2011 Korean National Health and Nutrition Examination Survey (KNHANES).

lightweight gown and were free from metal objects during the measurements. Body fat and lean mass were obtained using a whole-body DXA scan and divided into six regions: head, trunk, and upper and lower limbs on both sides. The trunk region was bordered by a horizontal line below the chin, vertical borders lateral to the ribs, and oblique lines passing through the femoral neck, and the leg region included all tissues below these oblique lines. Total fat percentage was calculated by the following equation: [total fat mass (kg)/total mass (total fat mass + total lean mass + total body mineral content, kg)] × 100; trunk fat percentage as: (trunk fat mass/trunk mass) × 100; limbs fat percentage as: (limb fat mass/limb mass) × 100; and lower limbs fat percentage as: (lower limb fat mass/lower limb mass) × 100. The appendicular skeletal muscle mass index (ASMI) was calculated using the equation: [total limb lean mass/(height)^2, kg/m^2] [7].

Other variables

Self-reported information regarding age; sex; smoking status; alcohol consumption; amount of physical activity; household income; and history of diabetes, hypertension, and dyslipidemia were obtained. Cigarette smoking was divided into three categories based on current use estimates: non-smoker, ex-smoker, and current smoker. Information on alcohol consumption included the frequency of drinking days and number of drinks consumed per drinking day during the 1 y that preceded the household interview for KNHANES. We used the Korean version of a "standard drink" (any drink that contains 10 g of pure alcohol) based on 4.5 vol% in beer, 12 vol% in wine, 6 vol% in Korean traditional makgeolli, 21 vol% in Korean soju, and 40 vol% in whisky and classified alcohol consumption into three categories: abstinence (no alcoholic drinks consumed within the previous year), moderate drinking (≤14 standard drinks consumed for men and 7 for women per week) and heavy drinking (>14 standard drinks consumed for men and 7 for women per week) [26]. Participants were asked about physical activity during the 1 wk that preceded the interview and physical activity was classified as low or not low: low physical activity was defined as ≤150 min/wk of moderate intensity or ≤75 min/wk of vigorous intensity exercise [27]. Household income was classified using monthly equivalized household income (quartiles), which were estimated as total monthly household income divided by the square root of the total number of household members.

Statistical analysis

We used the SAS PROC SURVEY (SAS Institute, Cary, NC, USA) module, which considers strata, clusters, and weights, to analyze the data according to a complex sampling design. All analyses were performed using the sample weights from KNHANES. Sex-specific characteristics of the study population were analyzed using independent *t* tests for continuous variables and the χ^2 test for dichotomous variables. The data are expressed as means ± standard error or as a percentage. The associations between the proportion of energy from carbohydrate intake as the independent variable and body composition parameters as the dependent variable were analyzed using a multiple linear regression analysis. Differences in mean values of body composition parameters by carbohydrate intake quartiles were evaluated using analysis of covariance, with age; smoking status; alcohol consumption; physical activity; household income; history of diabetes, hypertension, and dyslipidemia; and intake of energy and fiber per day as included covariates. All statistical analyses were performed using SAS software version 9.2 (SAS Institute). $P < 0.05$ was considered significant.

Results

The present study was conducted using data from 9594 participants (4125 men and 5469 women). The mean calorie intake per day was 1957.1 ± 10.6 kcal (2275.9 ± 16.4 kcal for men and 1651.5 ± 10.7 kcal for women). The proportions of carbohydrate, fat, and protein intake were 69.7% (67.9% for men and 71% for women), 16.2% (17.3% for men and 15.3% for women), and 14.2% (14.8% for men and 13.7% for women), respectively (Table 1).

The multivariate-adjusted associations between carbohydrate intake as a proportion of total energy intake and body composition factors are shown in Table 2. After adjusting for confounding factors, such as age; household income; smoking status; alcohol consumption; physical activity; history of diabetes, hypertension, and dyslipidemia; and intake of energy and fiber per day, the proportion of carbohydrate intake was positively correlated with total limb lean mass in men ($\beta = 0.141$, $P = 0.046$). In women, the proportion of carbohydrate intake was positively associated with ASMI ($\beta = 0804$, $P = 0.003$), but negatively associated with trunk fat percentage ($\beta = -0.075$, $P = 0.026$).

The mean values of the body composition parameters, adjusted for the aforementioned covariates, according to the carbohydrate as a proportion of total energy intake quartiles are shown in Tables 3 and 4 for men and women, respectively. In men, the carbohydrate proportion in Q1, Q2, Q3, and Q4, was <58.1%, 58.1–67.4%, 67.4–74.7% and ≥74.7%, respectively. No significant differences were observed in mean body composition parameter values according to carbohydrate proportion quartile in men (Table 3).

In women, carbohydrate as a proportion of total energy intake, in Q1, Q2, Q3, and Q4, was <64.6%, 64.6% to 72.6%, 72.6% to 79.6% and ≥79.6%, respectively. Total, trunk, limb, and lower limb lean mass and ASMI values were significantly different according to quartiles of the proportion of total energy intake from carbohydrate ($P = 0.016$, 0.021, 0.020, 0.028, and 0.002, respectively). Total limb lean mass and ASMI showed an increasing trend as carbohydrate proportion increased (P_{trend}, 0.031 and < 0.001, respectively; Table 4).

Discussion

We investigated the associations between carbohydrate intake as a proportion of total energy intake and body composition parameters in Korean adults. The results of this study showed that the proportion of carbohydrate intake in men was positively associated with total limb lean mass, and in women, as the proportion of carbohydrate intake increased, total limb lean mass and ASMI increased. However, there was no association between the proportion of carbohydrate intake and any measure of obesity and body fat mass in either men or women, except trunk fat percentage in women.

The causes of obesity remain incompletely understood, and conventional calorie-restricted diets continue to be used to control weight and prevent the disease. Dietary carbohydrate is the most potent effector of insulin secretion, which plays a major role in promoting the uptake and storage of fat in adipose tissue; this underlies the hypothesis that high-carbohydrate diets induce accumulation of excess body fat and obesity [16,17]. Therefore, low-carbohydrate diets have recently become very popular for weight loss. Several studies on carbohydrate intake as a factor related to accumulation of excess body fat and obesity have been conducted, but the results remain inconsistent [18–21,28,29]. In some meta-analyses, individuals who restricted carbohydrate intake to <20 to 40 g/d lost more weight than those on a low-fat diet [18,29], and a low-carbohydrate diet (<40 g/d) was more effective for weight loss than a low-fat diet in a randomized controlled trial of 148 obese adults [28]. However, in a randomized

Table 1
Characteristics of the study participants*

Variables	Total	Men	Women	P-value
	9594	4125	5469	–
Age (y)	47.71 ± 0.31	46.98 ± 0.36	48.41 ± 0.35	<0.001
Current smoking (%)	26.2	46.6	6.7	<0.001
Heavy drinking (%)	17.0	24.7	7.2	<0.001
Physical activity (low, %)	12.6	12.5	12.8	0.729
Household income (low, %)	46.2	43.8	48.5	<0.001
Energy intake (kcal/d)	1957.1 ± 10.6	2275.9 ± 16.4	,651.5 ± 10.7	<0.001
Carbohydrate intake (g/d)	326 ± 1.8	362.7 ± 2.5	290.8 ± 2	<0.001
Fat intake (g/d)	36.4 ± 0.4	43.7 ± 0.7	29.4 ± 0.4	<0.001
Protein intake (g/d)	68.6 ± 0.5	80.5 ± 0.8	57.1 ± 0.5	<0.001
Energy from				
Carbohydrate (%)	69.7 ± 0.2	67.9 ± 0.2	71 ± 0.2	<0.001
Fat (%)	16.2 ± 0.1	17.3 ± 0.2	15.3 ± 0.2	<0.001
Protein (%)	14.2 ± 0.1	14.8 ± 0.1	13.7 ± 0.1	<0.001
Fiber intake (g/d)	7.5 ± 0.1	8.2 ± 0.1	6.9 ± 0.1	<0.001
Medical history (%)				
Diabetes	7	8	6.1	0.001
Hypertension	27.3	30.8	24	<0.001
Dyslipidemia	10.1	9.4	10.8	0.065
Waist circumference (cm)	80.6 ± 0.2	83.4 ± 0.2	77.9 ± 0.2	<0.001
Body mass index (kg/m^2)	23.3 ± 0.1	23.6 ± 0.1	23 ± 0.1	<0.001
Fat mass (kg)				
Total	15.75 ± 0.08	13.82 ± 0.11	17.59 ± 0.09	<0.001
Trunk	8.68 ± 0.05	8.06 ± 0.07	9.28 ± 0.06	<0.001
Limbs	7.06 ± 0.04	5.76 ± 0.05	8.31 ± 0.04	<0.001
Lower limbs	5.17 ± 0.03	4.21 ± 0.03	6.10 ± 0.03	<0.001
Fat percentage (%)				
Total	27.84 ± 0.13	21.71 ± 0.14	33.72 ± 0.12	<0.001
Trunk	28.13 ± 0.14	23.61 ± 0.06	32.46 ± 0.15	<0.001
Limbs	11.52 ± 0.06	8.28 ± 0.06	14.62 ± 0.06	<0.001
Lower limbs	8.46 ± 0.05	6.07 ± 0.04	10.76 ± 0.05	<0.001
Lean mass (kg)				
Total	40.90 ± 0.13	48.42 ± 0.14	33.70 ± 0.09	<0.001
Trunk	21.69 ± 0.06	25.04 ± 0.07	18.48 ± 0.05	<0.001
Limbs	19.22 ± 0.07	23.38 ± 0.08	15.22 ± 0.05	<0.001
Lower limbs	14.46 ± 0.05	17.33 ± 0.06	11.70 ± 0.04	<0.001
ASMI (kg/m^2)	7.13 ± 0.02	8.08 ± 0.02	6.21 ± 0.02	<0.001

ASMI, appendicular skeletal muscle mass index.
*Values are means ± standard error or %.

controlled trial, more body fat was lost by individuals who experienced an isocaloric reduction of dietary fat than in those who restricted carbohydrates [20], and a meta-analysis showed that low-carbohydrate diets (carbohydrate intake <45% of total energy) and isoenergetic-balanced diets (45–65% carbohydrate intake as a proportion of total energy) did not differ in terms of weight loss after a 2-y follow-up, indicating that weight loss could be the result of reduced total energy intake rather than to any manipulation of macronutrient proportions [21]. Consistent with the results from the previous studies, carbohydrate intake as a proportion of total energy intake was not positively associated with obesity or body fat mass in the present study. Furthermore, the present study showed that the proportion of carbohydrate intake in women was inversely associated with trunk fat percentage, implying that women with high proportion of carbohydrate intake were more likely to have low trunk fat percentage.

We hypothesized that the high proportion of carbohydrate intake would be positively associated with obesity and body fat mass or percentage. However, we found no positive association between the proportion of carbohydrate intake and obesity or body fat. The potential mechanism behind the lack of association between the proportion of carbohydrate intake and obesity or body fat can be explained by several factors. First, the characteristics of the carbohydrate intake amount in this study population may have induced null results. In previous studies of the effects of low-carbohydrate intake on body fat and weight, more severely restricted carbohydrate intake promoted a lower body weight and adiposity, but variance in carbohydrate intake around the normal recommended range was not associated with a change in weight or body fat [30]. In the present study, the proportion of total energy intake accounted for by carbohydrate in the lowest quartile, Q1, was <58.1% in men and <64.6% in women, which overlapped with the proportion of carbohydrate intake recommended for Koreans. Additional studies are warranted to clarify differences in body fat and weight according to carbohydrate intake in Korean adults having a carbohydrate intake below the recommended limit. In addition, negative effects on health as a result of severe carbohydrate restriction have not been reported consistently, but it is possible that low-carbohydrate diets are harmful because they may include a substantial amount of fat or protein from animal origin [31], and reduced fiber intake, which could lead to adverse effects on the quality of bowel movements [32] and intestinal microbiota [33]. Further studies on the negative effects of a severely restricted carbohydrate diet in the Korean population are needed. Second, the low proportion of carbohydrate intake could accompany the increased protein intake proportion, which may independently promote satiety, decrease overall energy intake, and positively influence body composition [34,35]. In this study, as the proportion of carbohydrate intake increased, the protein intake proportion showed a decreasing trend, but the detrimental effects of low protein intake proportion accompanied by the high carbohydrate intake proportion on body fat and obesity were not found. Additional studies are needed to clarify differences in body composition factors, according to macronutrient proportions in Korean adults.

Table 2
Associations between proportion of total energy intake from carbohydrate and body composition factors*

Model	Body composition factors	Men		Women	
		β	*P*-value	β	*P*-value
Unadjusted	Waist circumference (cm)	−0.015	0.615	0.193	<0.001
	Body mass index (kg/m^2)	−0.252	0.003	0.331	<0.001
	Fat mass (kg)				
	Total	−0.139	0.006	−0.011	0.766
	Trunk	−0.172	0.033	0.166	0.003
	Limbs	−0.429	<0.001	−0.458	<0.001
	Lower limbs	−0.590	<0.001	−0.873	<0.001
	Fat percentage (%)				
	Total	0.001	0.978	0.056	0.071
	Trunk	0.001	0.988	0.131	<0.001
	Limbs	−0.113	0.318	−0.540	<0.001
	Lower limbs	−0.174	0.230	−0.901	<0.001
	Lean mass (kg)				
	Total	−0.311	<0.001	−0.167	<0.001
	Trunk	−0.543	<0.001	−0.231	0.003
	Limbs	−0.615	<0.001	−0.400	<0.001
	Lower limbs	−0.791	<0.001	−0.686	<0.001
	SMI (kg/m^2)	−0.214	0.010	−0.235	<0.001
Adjusted	Waist circumference (cm)	−0.004	0.874	−0.024	0.181
	Body mass index (kg/m^2)	−0.016	0.829	−0.056	0.238
	Fat mass (kg)				
	Total	−0.037	0.411	−0.030	0.483
	Trunk	−0.067	0.358	−0.093	0.178
	Limbs	−0.068	0.545	0.041	0.669
	Lower limbs	−0.056	0.715	0.019	0.888
	Fat percentage (%)				
	Total	−0.073	0.073	−0.076	0.056
	Trunk	−0.060	0.090	−0.075	0.026
	Limbs	−0.143	0.170	−0.015	0.866
	Lower limbs	−0.137	0.323	−0.063	0.575
	Lean mass (kg)				
	Total	0.056	0.128	0.056	0.209
	Trunk	0.069	0.336	0.054	0.518
	Limbs	0.141	0.046	0.166	0.065
	Lower limbs	0.158	0.090	0.138	0.232
	ASMI (kg/m^2)	0.429	0.085	0.804	0.003

ASMI, appendicular skeletal muscle mass index; SMI, skeletal muscle mass index.
*Adjusted for age; smoking status; alcohol consumption; physical activity; household income; history of diabetes, hypertension, and dyslipidemia; and intake of energy and fiber per day.

Asian populations consume more carbohydrates than Western populations, mainly owing to a high intake of rice. The recommended percentages of calories from carbohydrate are 55% to 65% in Korea and 45% to 65% in the United States [36,37]; 57% of Korean adults and only 8% of U.S. adults exceed the upper recommended limit of carbohydrate intake [38]. Furthermore, the relative frequencies of metabolic syndrome components differ between U.S. and Korean populations: The most prevalent metabolic risk factors were elevated fasting glucose and WC in U.S. adults, whereas increased triacylglycerides (TGs) and decreased high-density lipoprotein cholesterol (HDL-C) are more frequently observed in Korean adults [38]. In addition, Asians are more prone to metabolic-related comorbidities at lower BMI and WC values than are Western populations [24]. In several studies of Korean adults, the high proportion of carbohydrate intake was associated with reduced HDL-C and elevated TGs [38,39]. Thus, the high carbohydrate intake of Korean adults might be CVD risk factors other than obesity and excess body fat. Further studies are needed to confirm whether ethnic differences in carbohydrate intake and metabolism are associated with an accumulation of body fat and elevated metabolic risk.

Studies assessing the association between carbohydrate intake and body muscle mass are rare, and the results remain controversial. Although de Souza et al. [40] reported no differences in body composition based on the amounts of various macronutrients consumed, other studies have found that a low -carbohydrate, high-protein diet and a reduced ratio of dietary carbohydrate to protein preserved lean mass [41,42]. In the present study, the proportion of carbohydrate intake in men and women was positively correlated with total limb lean mass and ASMI, respectively, but no significant trend toward increased total limb lean mass according to the carbohydrate intake quartile was seen in men, whereas total limb lean mass and ASMI in women showed an increasing trend as carbohydrate proportion increased. The variation in the proportion of protein intake accompanied by differences in the proportion of carbohydrate intake might affect body muscle mass; therefore, further investigations are warranted to clarify the difference in body muscle mass according to the composition of macronutrient intakes in Korean adults.

Table 3
Body composition parameters according to the proportion of total energy intake from carbohydrate in men*

	Q1	Q2	Q3	Q4	*P*-value	*P* for trend
Energy from						
Carbohydrate (%)	56.5 ± 0.4	64.7 ± 0.2	71.3 ± 0.1	79.5 ± 0.2	<0.001	<0.001
Fat (%)	18.2 ± 0.2	15.4 ± 0.1	13.9 ± 0.1	11.6 ± 0.1	<0.001	<0.001
Protein (%)	25.3 ± 0.4	19.9 ± 0.2	14.8 ± 0.1	8.9 ± 0.1	<0.001	<0.001
Waist circumference (cm)	86.76 ± 0.53	86.51 ± 0.51	86.86 ± 0.59	86.76 ± 0.60	0.902	0.837
Body mass index (kg/m^2)	24.76 ± 0.20	24.66 ± 0.20	24.77 ± 0.21	24.74 ± 0.22	0.893	0.958
Fat mass (kg)						
Total	15.37 ± 0.31	15.36 ± 0.32	15.27 ± 0.33	15.04 ± 0.36	0.714	0.310
Trunk	9.37 ± 0.19	9.32 ± 0.20	9.29 ± 0.21	9.13 ± 0.23	0.690	0.271
Limbs	5.99 ± 0.12	6.03 ± 0.12	5.97 ± 0.12	5.90 ± 0.14	0.770	0.432
Lower limbs	4.29 ± 0.09	4.31 ± 0.09	4.27 ± 0.09	4.24 ± 0.10	0.924	0.615
Fat percentage (%)						
Total	23.25 ± 0.33	23.16 ± 0.34	22.94 ± 0.36	22.62 ± 0.37	0.324	0.070
Trunk	25.94 ± 0.37	25.80 ± 0.39	25.58 ± 0.41	25.22 ± 0.42	0.355	0.080
Limbs	8.30 ± 0.13	8.34 ± 0.14	8.24 ± 0.13	8.13 ± 0.14	0.458	0.161
Lower limbs	5.94 ± 0.10	5.97 ± 0.10	5.90 ± 0.10	5.86 ± 0.11	0.726	0.323
Lean mass (kg)						
Total	49.84 ± 0.42	49.83 ± 0.42	50.16 ± 0.41	50.27 ± 0.43	0.530	0.183
Trunk	26.06 ± 0.23	25.97 ± 0.22	26.20 ± 0.22	26.22 ± 0.23	0.497	0.266
Limbs	23.78 ± 0.20	23.86 ± 0.21	23.96 ± 0.20	24.05 ± 0.22	0.519	0.141
Lower limbs	17.59 ± 0.16	17.64 ± 0.17	17.69 ± 0.16	17.76 ± 0.17	0.684	0.242
ASMI (kg/m^2)	8.24 ± 0.06	8.24 ± 0.06	8.29 ± 0.06	8.32 ± 0.06	0.326	0.104

ASMI, appendicular skeletal muscle mass index.
*Values are means ± standard error. Adjusted for age, smoking, alcohol consumption, physical activity, household income, history of diabetes, hypertension and dyslipidemia, and intake of energy and fiber per day. The proportion of carbohydrate intake was categorized into quartiles: Q1, lowest proportion of carbohydrate intake; Q2, low-medium proportion; Q3, high-medium proportion; and Q4, highest proportion.

Table 4
Body composition parameters according to the proportion of total energy intake from carbohydrate in women*

	Q1	Q2	Q3	Q4	*P*-value	P_{trend}
Energy from						
Carbohydrate (%)	57.7 ± 0.3	68.4 ± 0.1	75.1 ± 0.1	82.7 ± 0.1	<0.001	<0.001
Fat (%)	16.9 ± 0.2	14.5 ± 0.1	12.8 ± 0.1	10.5 ± 0.1	<0.001	<0.001
Protein (%)	25.3 ± 0.3	17.1 ± 0.1	12.1 ± 0.1	6.8 ± 0.1	<0.001	<0.001
Waist circumference (cm)	84.59 ± 0.77	84.59 ± 0.73	85.33 ± 0.80	84.41 ± 0.82	0.306	0.830
Body mass index (kg/m^2)	25.05 ± 0.29	25.11 ± 0.28	25.37 ± 0.29	25.06 ± 0.28	0.408	0.668
Fat mass (kg)						
Total	20.49 ± 0.44	20.51 ± 0.46	20.82 ± 0.48	20.27 ± 0.46	0.358	0.908
Trunk	11.76 ± 0.29	11.73 ± 0.30	11.91 ± 0.30	11.53 ± 0.31	0.254	0.604
Limbs	8.73 ± 0.18	8.77 ± 0.18	8.91 ± 0.19	8.74 ± 0.18	0.600	0.613
Lower limbs	6.17 ± 0.13	6.18 ± 0.14	6.26 ± 0.15	6.14 ± 0.14	0.697	0.900
Fat percentage (%)						
Total	35.97 ± 0.45	35.55 ± 0.50	35.62 ± 0.48	35.29 ± 0.52	0.306	0.111
Trunk	36.47 ± 0.52	36.01 ± 0.57	36.11 ± 0.55	35.58 ± 0.61	0.252	0.095
Limbs	14.13 ± 0.19	13.99 ± 0.21	14.01 ± 0.21	14.01 ± 0.21	0.799	0.462
Lower limbs	10.02 ± 0.16	9.87 ± 0.17	9.86 ± 0.17	9.86 ± 0.18	0.523	0.219
Lean mass (kg)						
Total	35.68 ± 0.38	36.22 ± 0.40	36.60 ± 0.42	36.06 ± 0.41	0.016	0.052
Trunk	19.82 ± 0.22	20.08 ± 0.22	20.29 ± 0.23	19.97 ± 0.23	0.021	0.104
Limbs	15.86 ± 0.18	16.13 ± 0.19	16.31 ± 0.21	16.09 ± 0.19	0.020	0.031
Lower limbs	12.18 ± 0.14	12.37 ± 0.15	12.51 ± 0.17	12.28 ± 0.15	0.028	0.123
ASMI (kg/m^2)	6.43 ± 0.07	6.53 ± 0.07	6.61 ± 0.07	6.58 ± 0.07	0.002	<0.001

ASMI, appendicular skeletal muscle mass index.
*Values are means ± standard error. Adjusted for age; smoking status; alcohol consumption; physical activity; household income; history of diabetes, hypertension, and dyslipidemia; and intake of energy and fiber per day. The proportion of carbohydrate intake was categorized into quartiles: Q1, lowest proportion of carbohydrate intake; Q2, low-medium proportion; Q3, high-medium proportion; and Q4, highest proportion.

The strength of this study on the South Korean population was that the data were collected through a representative nationwide survey. In addition, to our knowledge, this was the first study of Korean adults to investigate the associations between the proportion of carbohydrate in the diet and various body composition parameters. However, this study had certain limitations. First, it used a cross-sectional design. Second, dietary intake was estimated using the 24-h dietary recall method, which can fluctuate on a day-to-day basis. Therefore, to reduce error we excluded participants whose intake on the day of the 24-h dietary recall survey was not representative of their usual intake. Third, despite adjustment for fiber intake, the quality (i.e., type) of dietary carbohydrate, such as low or high glycemic load, and sugar consumption were not included as covariates because this information was not captured by the KNHANES. Finally, we did not measure other body composition parameters on magnetic resonance imaging [43] or computed tomography [44], which are the gold standards for measuring regional body fat and lean mass, because such tools were not available in the KNHANES. However, DXA is characterized by low radiation exposure, low cost, high accuracy, and strong correlations with other measurement tools [45,46].

Conclusion

Results of the present study found no positive association between obesity, body fat, and the proportion of carbohydrate intake in Korean adults, whereas limb lean mass in men, and ASMI in women were positively associated with the proportion of carbohydrate intake. Further studies are needed to evaluate the effects of carbohydrate intake on body composition, considering the diversity in quantity and quality of carbohydrates consumed.

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