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Ethnic and sex differences in the distributions of body mass index and waist circumference among adults: a binationally representative study in South Korea and the United States

S. EUM[1], J.W. SON[2], C. MIN[3], W. CHO[3], S. KIM[4], H.G. WOO[5], R. KWON[3,6], K.N. LEE[7], K.-D. HAN[8], D.K. YON[3,9], S.Y. RHEE[3,10]

[1]Department of Medicine, Kyung Hee University College of Medicine, Seoul, Republic of Korea
[2]Division of Endocrinology and Metabolism, Department of Internal Medicine, Bucheon St. Mary's Hospital, The Catholic University of Korea, Bucheon, Republic of Korea
[3]Center for Digital Health, Medical Science Research Institute, Kyung Hee University Medical Center, Kyung Hee University College of Medicine, Seoul, Republic of Korea
[4]Department of Family Medicine, [5]Department of Neurology, Kyung Hee University College of Medicine, Seoul, Republic of Korea
[6]Department of Biomedical Engineering, University of Michigan, Ann Arbor, Michigan, USA
[7]Department of Biomedicine and Health Science, The Catholic University of Korea, Seoul, Republic of Korea
[8]Department of Statistics and Actuarial Science, Soongsil University, Seoul, Republic of Korea
[9]Department of Pediatrics, [10]Department of Endocrinology and Metabolism, Kyung Hee University College of Medicine, Seoul, Republic of Korea

S. Eum and J.W. Son equally contributed to this study

Abstract. – OBJECTIVE: The ethnic and sex differences in the distributions of body mass index (BMI) and waist circumference (WC) among adults are largely unknown. Therefore, we aimed to investigate the percentiles of BMI and WC in groups divided according to age, sex, and ethnicity.

PATIENTS AND METHODS: We conducted a population-based binational study of adults aged ≥20 years based on data from two sources: US National Health and Nutrition Examination Survey (2015 to 2020) and Korea National Health and Nutrition Examination Survey (2016 to 2019).

RESULTS: Weight, height, and WC were measured in 13,144 American adults and 30,191 Korean adults. Overall, BMI increased at younger ages and decreased at older ages, which indicates a reversed U-shaped relationship, and differed in terms of age, sex, and ethnicity. Women in the other Hispanic, non-Hispanic white, non-Hispanic black, and "other ethnic groups" showed a common BMI peak at ages 50-54 years. The patterns of WC distribution were similar to those of BMI distribution.

CONCLUSIONS: In this binational representative study, we found varied distributions of ethnic and sex differences in BMI and WC. Considering the differences in these distributions may help improve individual and personalized treatment strategies.

Key Words:
Obesity, Abdominal obesity, Body mass index, Waist circumference, Ethnicity, Age, Sex.

Introduction

Increasing the public awareness about obesity necessitates redefining the criteria for obesity in line with social changes and trends[1]. In addition, the risk of obesity-related diseases differs according to age, sex, and ethnicity. To reflect the factors related to obesity and show recent public health trends associated with this condition, body mass index (BMI) and waist circumference (WC) distributions have been analyzed based on age, sex, and ethnicity[2].

The criteria for obesity have been defined[3]. Obesity is believed to increase the risk of

Corresponding Authors: Dong Keon Yon, MD; e-mail: yonkkang@gmail.com
Sang Youl Rhee, MD, Ph.D; e-mail: rheesy@khu.ac.kr

weight-related diseases in persons with a BMI higher than a specific cutoff value (for adults) or percentile value (for children and adolescents)[4]. When defining obesity in children, interpreting the BMI as a percentile value specific to age and sex is a more rigorous method than comparing the calculated BMI number against a population-based cutoff value. Moreover, alerting people about the risks of having obesity is important. Therefore, we aimed to investigate the percentiles of BMI and WC in groups divided according to age, sex, and ethnicity. In addition, this study was performed to provide reference data for assessing the degree of obesity, strictly defining obesity, and formulating public health policies related to obesity.

Patients and Methods

Study Population and Data Sources

This population-based binational study was conducted based on data from the US National Health and Nutrition Examination Survey (NHANES) and the Korea NHANES (KNHANES)[5,6]. NHANES is a national surveillance system conducted by the National Center for Health Statistics, a unit of the Centers for Disease Control and Prevention (CDC). The NHANES applies a complex, multistage probability sampling design to represent the civilian non-institutionalized US population. The NHANES has been used to assess the health and nutritional status of US civilians since 1971.

The KNHANES is a nationwide population-based cross-sectional surveillance system conducted by the Korea Disease Control and Prevention Agency (KDCA) and aims to evaluate the health and nutritional status of Koreans through three-component surveys (i.e., health interviews, health examinations, and nutrition surveys)[7]. The survey collects information on socioeconomic status, health-related behaviors, quality of life, health-care utilization, anthropometric measures, biochemical and clinical profiles of non-communicable diseases, and dietary intake. It has been conducted since 1998 and implemented annually since 2007; the data obtained since 2011 are publicly available.

The NHANES and KNHANES data were anonymized, and the study was approved by Sejong University (SJU-HR-E-2020-003), the US CDC, and the KDCA.

Covariate Definitions

BMI and WC data were analyzed according to ethnicity and age. In terms of ethnicity, the participants were categorized as Mexican Americans, other Hispanics, non-Hispanic whites, non-Hispanic blacks, non-Hispanic Asians, and other ethnic groups. In terms of age, the participants were divided into the following groups: 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, and > 75 years.

Diagnostic Criteria

The existing criteria for overweight, obesity, and abdominal obesity in adults are defined according to specific values of BMI and WC[8]. However, in this study, the criteria were defined using percentiles of BMI and WC. As the distributions of BMI and WC differ according to age, sex, and ethnicity, the criteria for overweight, obesity, and abdominal obesity for adults were defined using the following percentile cutoff values: overweight, 85^{th} percentile of BMI; obesity, 95^{th} percentile of BMI; and abdominal obesity, 90^{th} percentile of WC[9].

Endpoints

The NHANES and KNHANES body measurement examinations are conducted in specific centers in compliance with standardized procedures[10,11]. Trained staff is assigned to collect high-quality body measurement data following standardized examination procedures using well-calibrated equipment. Height was measured using a stadiometer with a fixed vertical backboard and adjustable headpiece while the participant was standing unassisted without a head ornament. Weight was measured (in kilograms) using a digital weighing scale with the participant wearing a prescribed dress item. WC was measured (in centimeters) above the iliac crest. BMI was calculated as weight in kilograms divided by height in meters squared.

Statistical Analysis

We categorized the cohort into 12 age groups, 2 sex groups (male and female), and 7 ethnic groups [Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, non-Hispanic Asian, Korean, and other ethnic groups]. We analyzed the BMI and WC data from the NHANES and KNHANES using SPSS version 25.0 (IBM Corp., Armonk, NY, USA) and SAS (version 9.4; SAS Institute Inc., Cary, NC, USA)[12,13]. Continuous variables are expressed as means with standard deviation (SDs) and were validated using a *t*-test. Categorical variables are expressed as percentages with SDs and were validated using the Chi-square test. We investigated the distributions of BMI and WC according to age, sex, and ethnicity and identified the BMI and WC values for defining obesity and abdominal obesity in each group.

Results

In this study, we analyzed 13,144 participants from the NHANES (6,389 [48.6%] men and 6,755 [51.4%] women) and 30,191 participants from the KNHANES (13,342 [44.2%] men and 16,849 [55.8%] women). The baseline characteristics of the participants are presented in Table I. In the NHANES data, 1,827 (13.9%) participants were Mexican American, 1,512 (11.5%) were other Hispanic, 4,473 (34.0%) were non-Hispanic white, 3,204 (24.4%) were non-Hispanic black, 1,569 (11.9%) were non-Hispanic Asian, and 559 (4.3%) were of other ethnic groups.

Table II, III, and **Supplementary Table I** show the distribution of BMI according to age, sex, and ethnicity in the NHANES and KNHANES. The mean BMI increased at younger ages and decreased at older ages, showing a reversed U-shaped curve according to age in men and women. In addition, BMI peaks were observed at certain age ranges. In men, BMI peaked at ages 30-34 and 40-44 years. In women, BMI peaked at ages 35-39 and 50-54 years.

Supplementary Table II shows the distribution of WC according to age, sex, and ethnicity in the NHANES and KNHANES. Similar to BMI, WC also had a tendency to initially increase and subsequently decrease. Moreover, the peak patterns of WC were similar to those of BMI.

Discussion

Main Findings

This study was based on binationally representative data of multiethnic populations. The BMI distribution differs according to ethnicity, sex, and age and may be affected by culture, molecular biochemistry, and living environment.

The proportion of persons with obesity or abdominal obesity significantly differs according to the disease criteria. The BMI cutoff values for obesity are 25 kg/m^2 in Korea and 30 kg/m^2 in the United States[14]. The WC cutoff values for abdominal obesity are 90 cm for men and 85 cm for women in Korea and 102 cm for men and 88 cm for women in the United States[14]. The results of this study reflect the importance of these standards. In addition, Table I shows that the association between obesity and metabolic syndrome differed according to ethnicity. In particular, non-Hispanic Asians showed a relatively higher prevalence of diabetes mellitus, hypertension, and hypercholesterolemia than the other ethnic groups when comparing the obesity rate[15]. This finding is in accordance with the results of previous studies that reported that the relationship between obesity and weight-related diseases may vary depending on ethinicity[15].

We first analyzed the mean BMI. The distributions of BMI and WC differed in terms of sex, age, and ethnicity and demonstrated a reversed U-shaped curve. In most cases, although non-Hispanic Asians have a larger body build than Koreans, they generally showed similar changes. In particular, non-Hispanic Asians and Koreans had the lowest weight-related measures among the seven groups. The other five groups showed mean BMI ranges of 25-34 kg/m^2 in men and 26-36 kg/m^2 in women. Non-Hispanic black people showed significant BMI changes at younger ages. All groups showed large BMI slopes between 20 and 34 kg/m^2 for men and between 20 and 44 kg/m^2 for women. In addition, men had a higher mean BMI than women in all ethnic and age groups except in Koreans whose BMI was > 60 kg/m^2. Among the groups, non-Hispanic Asians and Koreans had the smallest deviations in BMI during their life span. In contrast, the BMI of non-Hispanic black people increased sharply from 20 to 34 kg/m^2 in men and from 20 to 44 kg/m^2 in women and decreased in the later stage of life compared with that of people from other ethnic groups. Furthermore, the "other ethnic groups" group showed a relatively large deviation, which may have been caused by the small sample number. The "other ethnic groups" group included only 559 participants, whereas all other groups included > 1,500 participants. Men and women both showed a reversed U-shaped association between BMI and age. However, the mean BMI showed a sex-related difference, especially in Koreans. Male Koreans showed a higher

Table I. Baseline characteristics of the participants based on NHANES (n = 13,144) and KNHANES (n = 30,191) data.

	NHANES							KNHANES
	Total	Mexican American	Other Hispanic	Non-Hispanic White	Non-Hispanic Black	Non-Hispanic Asian	Other ethnic groups	Korean
Number	13,144	1,827	1,512	4,473	3,204	1,569	559	30,191
Age groups, % (SD)								<.0001
20-29	15.83 (0.46)	19.27 (1.26)	15.57 (1.15)	13.4 (0.7)	16.25 (0.73)	16.53 (1.09)	20.7 (1.83)	16.5 (0.37)
30-39	16.03 (0.49)	18.2 (1.26)	16.73 (0.99)	14.57 (0.73)	14.93 (0.63)	17.91 (1.19)	20.22 (2.31)	17.66 (0.42
40-49	16.28 (0.44)	17.96 (1.05)	13.79 (1.1)	14.12 (0.5)	17.27 (0.7)	20.06 (1.21)	18.34 (1.99)	20.18 (0.36)
50-59	17.14 (0.38)	16.86 (1.2)	19.09 (1.28)	15.46 (0.66)	17.33 (0.85)	20.45 (1.05)	16.05 (1.73)	20.2 (0.32)
60-69	18.68 (0.4)	18.56 (1.27)	23.5 (1.37)	15.71 (0.74)	23.1 (0.98)	15.31 (1.1)	14.06 (1.35)	13.74 (0.29)
≥ 70	16.04 (0.72)	9.14 (1.26)	11.32 (1.01)	26.74 (1.02)	11.13 (0.63)	9.74 (1.13)	10.63 (1.47)	11.72 (0.3)
Sex, male, n (%)	48.66 (0.38)	47.8 (1.07)	46.18 (1)	50.38 (0.65)	47.44 (0.7)	47.53 (1.02)	54.27 (1.97)	49.88 (0.27)
Smoking, % (SD)								
Non-smoker	58.17 (0.94)	64.77 (1.84)	64.46 (1.52)	48.36 (1.14)	57.82 (1.49)	78.78 (1.42)	44.25 (2.37)	58.87 (0.34)
Ex-smoker	23.35 (0.6)	22.13 (1.2)	21.9 (1.41)	31.39 (0.9)	18.17 (0.81)	12.99 (0.94)	25.71 (1.64)	20.21 (0.25)
Current smoker	18.49 (0.76)	13.1 (1.35)	13.63 (1.09)	20.25 (1.02)	24.01 (1.4)	8.23 (0.9)	30.04 (2.02)	20.92 (0.34)
Regular exercise, % (SD)	62.57 (0.67)	60.23 (2.02)	60.59 (1.97)	65.8 (0.79)	61.29 (1.14)	57.97 (1.67)	69.4 (2.39)	45.62 (0.43)
BMI groups, % (SD)								
< 18.5	1.44 (0.12)	0.5 (0.19)	0.93(0.23)	1.48 (0.16)	1.75 (0.33)	2.32 (0.34)	1.12 (0.41)	3.98 (0.14)
< 23	13.74 (0.47)	6.96 (0.73)	9.11(0.73)	13.65 (0.59)	13.05 (0.77)	27 (1.07)	14.37 (1.46)	37.47 (0.35)
< 25	10.87 (0.38)	7.92 (0.91)	8.91(0.74)	11.54 (0.5)	7.96 (0.53)	20.59 (1.02)	9.54 (1.06)	22.75 (0.28)
< 30	32.01 (0.48)	34.86 (1.2)	37.57(1.45)	31.83 (0.72)	27.12 (0.88)	36.31 (1.29)	26.63 (1.66)	29.82 (0.33)
< 35	21.96 (0.47)	27.13 (0.78)	25.27(1.11)	21.58 (0.87)	23.27 (0.75)	10.3 (0.65)	25.18 (2.42)	5.01 (0.16)
≥ 35	19.99 (0.65)	22.63 (1.24)	18.2(1.25)	19.91 (0.86)	26.86 (0.69)	3.48 (0.55)	23.17 (1.92)	0.97 (0.08)
Obesity, % (SD)								
BMI ≥ 25	73.95 (0.68)	84.61 (1.27)	81.05 (0.91)	73.33 (0.95)	77.24 (0.95)	50.09 (1.31)	74.97 (1.46)	35.8 (0.36)
BMI ≥30	41.95 (0.83)	49.75 (1.32)	43.47 (1.73)	41.49 (1.1)	50.12 (1.01)	13.78 (0.95)	48.35 (1.99)	5.98 (0.18)

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Table I ***(Continued)*****.** Baseline characteristics of the participants based on NHANES (n = 13,144) and KNHANES (n = 30,191) data.

	NHANES							KNHANES
	Total	Mexican American	Other Hispanic	Non-Hispanic White	Non-Hispanic Black	Non-Hispanic Asian	Other ethnic groups	Korean
Abdominal obesity, % (SD)								
Male, WC ≥ 90 cm; female, WC ≥ 85 cm	77.92 (0.68)	86.19 (0.93)	82.05 (1.03)	81.73 (0.83)	77.42 (0.95)	55.5 (1.3)	76.86 (1.79)	31.76 (0.38)
Male, WC ≥ 102 cm; female, WC ≥ 88 cm	59.94 (0.86)	67.27 (1.25)	60.85 (1.67)	64.46 (1)	63.35 (1.02)	30.34 (1.33)	61.52 (1.5)	12.42 (0.26)
Diabetes mellitus, % (SD)	21.80 (0.68)	26.68 (1.53)	24.82 (1.94)	18.71 (1.12)	23.08 (1.08)	20.07 (1.54)	20.78 (2.39)	10.96 (0.23
Hypertension, % (SD)	41.24 (0.79)	32.17 (1.63)	38.14 (1.87)	41.81 (1.19)	51.66 (1.38)	32.43 (1.44)	35.55 (2.33)	28.28 (0.39)
Hypercholesterolemia, % (SD)	27.85 (0.48)	24.74 (1.53)	26.83 (1.11)	31.34 (0.65)	25.41 (0.94)	27.01 (1.24)	28.15 (1.7)	21.39 (0.31)
Age, years, mean ± SD	50.16 ± 0.33	46.83 ± 0.81	49.44 ± 0.60	53.74 ± 0.49	49.42 ± 0.36	47.41 ± 0.57	45.83 ± 0.80	47.91 ± 0.19
Weight, kg, mean ± SD	83 ± 0.39	82.06 ± 0.43	80.18 ± 0.67	84.95 ± 0.49	88.47 ± 0.48	67.92 ± 0.42	87.98 ± 1.05	65.67 ± 0.10
Height, cm, mean ± SD	166.61 ± 0.15	162.76 ± 0.36	163.06 ± 0.24	168.72 ± 0.16	168.69 ± 0.18	162.59 ± 0.32	169.95 ± 0.39	164.84 ± 0.08
BMI, kg/m^2, mean ± SD	29.81 ± 0.13	30.89 ± 0.21	30.07 ± 0.23	29.75 ± 0.17	31.13 ± 0.14	25.56 ± 0.14	30.35 ± 0.30	24.04 ± 0.03
Waist circumference, cm, mean ± SD	100.77 ± 0.34	102.24 ± 0.4	100.19 ± 0.5	102.81 ± 0.44	102.37 ± 0.44	89.94 ± 0.32	102.36 ± 0.75	83.16 ± 0.09
Fasting glucose, mg/dL, mean ± SD	113.21 ± 0.54	118.33 ± 1.71	116.89 ± 1.95	111.93 ± 1.00	112.22 ± 1.14	109.96 ± 1.26	112.26 ± 1.89	100.47 ± 0.18
Systolic BP, mmHg, mean ± SD	124.79 ± 0.6	124.18 ± 0.93	125.3 ± 1.16	124.27 ± 0.55	128.53 ± 0.83	120.27 ± 1.06	123.31 ± 2.43	118.04 ± 0.15
Diastolic BP, mmHg, mean ± SD	69.66 ± 0.57	68.75 ± 0.4	68.35 ± 1.27	68.89 ± 0.6	70.77 ± 1.06	72.13 ± 0.45	71.89 ± 1.1	76.00 ± 0.09
Total cholesterol, mg/dL, mean ± SD	187.28 ± 0.73	188.81 ± 1.17	188.93 ± 1.46	187.61 ± 1.18	182.33 ± 1.15	192.62 ± 1.35	188.06 ± 2.15	192.71 ± 0.28

BMI, body mass index; BP, blood pressure; KNHANES, Korea National Health and Nutrition Examination Survey; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation; WC, waist circumference. Continuous variables are expressed as mean ± SD and were validated using the *t*-test. Categorical variables are expressed as percentage (SD) and were validated using the chi-square test.

Table II. BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (Mexican American, non-Hispanic white, non-Hispanic Black).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1st	5th	10th	25th	50th	75th	90th	95th	99th	
Mexican American	Male	20-24	79	97.84	16.60	72.6	72.6	76.1	77.0	83.1	96.7	110.3	120.7	131.1	136.9	136.9
		25-29	97	101.81	15.82	76.2	76.2	78.1	81.7	90.8	99.3	111.5	120.7	131.4	154.5	154.5
		30-34	71	101.65	14.42	73.2	73.2	78.5	86.4	92.5	100.5	109.1	120.5	132.4	139.6	139.6
		35-39	88	103.13	14.12	71.8	71.8	83.8	86.7	94.6	101.7	110.0	119.3	129.8	161.3	161.3
		40-44	65	103.78	16.54	76.1	76.1	78.6	86.2	92.5	104.3	111.5	117.7	124.9	170.8	170.8
		45-49	67	102.96	12.33	74.6	74.6	83.5	89.0	94.1	101.8	109.2	121.4	127.3	134.9	134.9
		50-54	76	105.88	14.20	83.1	83.1	85.8	90.1	96.7	101.7	113.1	124.0	137.5	150.1	150.1
		55-59	59	106.01	13.85	79.6	79.6	85.8	89.8	95.0	103.7	114.4	129.7	131.4	136.3	136.3
		60-64	116	105.47	12.49	76.2	81.4	86.9	90.0	96.7	104.4	115.7	121.8	125.1	137.1	147.8
		65-69	59	107.19	11.16	83.0	83.0	86.2	93.1	100.2	106.7	113.7	123.2	126.5	136.1	136.1
		70-74	46	104.91	13.06	84.0	84.0	87.0	88.0	97.7	104.6	114.0	119.5	129.0	140.3	140.3
		over 75	44	103.80	10.04	84.4	84.4	85.7	90.4	98.2	103.1	108.6	118.5	120.2	129.1	129.1
	Female	20-24	86	94.70	17.82	64.7	64.7	70.0	73.9	82.2	92.1	104.1	118.4	134.9	143.0	143.0
		25-29	87	96.75	16.69	64.9	64.9	72.2	77.3	85.5	95.0	106.8	119.6	128.1	144.1	144.1
		30-34	76	99.44	16.16	66.6	66.6	78.4	82.7	88.5	96.8	106.9	122.2	132.5	146.7	146.7
		35-39	97	102.95	17.15	69.1	69.1	82.0	84.0	92.5	99.4	109.1	123.9	133.7	178.0	178.0
		40-44	107	99.33	14.56	72.4	74.0	79.7	81.8	89.8	99.0	104.0	115.9	129.0	143.5	149.2
		45-49	83	102.12	14.25	71.1	71.1	82.7	86.4	92.5	99.6	110.1	120.8	128.5	142.9	142.9
		50-54	85	101.50	14.96	74.6	74.6	81.4	86.7	91.4	99.7	107.6	122.4	129.1	145.2	145.2
		55-59	86	103.09	15.46	72.1	72.1	81.0	85.0	90.5	101.8	114.0	126.2	127.5	143.3	143.3
		60-64	102	104.33	14.72	79.4	79.7	83.0	88.0	95.4	102.8	113.2	121.1	126.8	152.5	164.0
		65-69	66	105.57	12.01	85.1	85.1	92.5	92.6	97.7	103.0	111.7	124.9	130.3	147.4	147.4
		70-74	41	106.07	12.77	86.3	86.3	87.4	92.3	95.4	105.6	112.5	124.7	130.3	137.2	137.2
		over 75	44	101.38	13.70	64.7	64.7	78.4	88.2	92.9	100.8	109.6	119.7	122.8	137.2	137.2

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Table II *(Continued)*. BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (Mexican American, non-Hispanic white, non-Hispanic Black).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1st	5th	10th	25th	50th	75th	90th	95th	99th	
Non-Hispanic White	Male	20-24	138	97.12	19.68	64.0	68.5	72.4	74.8	81.3	93.0	108.3	123.5	132.5	152.8	160.5
		25-29	145	96.76	17.42	67.3	67.5	75.4	77.5	83.0	92.9	109.0	122.2	129.5	144.7	146.2
		30-34	174	103.52	18.34	72.7	73.1	79.7	83.5	89.3	101.2	113.5	129.6	137.0	155.4	159.6
		35-39	153	103.92	17.56	75.0	77.6	79.6	85.0	91.5	101.0	113.0	128.7	136.5	154.5	167.1
		40-44	149	105.46	15.64	68.2	75.0	83.2	87.8	94.5	103.6	115.8	127.8	135.5	148.8	153.2
		45-49	172	106.00	16.23	74.0	77.0	81.5	86.9	96.2	104.2	112.8	126.0	137.2	159.8	162.7
		50-54	145	106.53	16.24	75.2	77.9	81.8	88.8	95.4	104.1	116.8	128.4	136.4	154.1	156.5
		55-59	200	106.73	15.83	69.5	75.7	84.4	88.8	96.2	103.5	116.3	130.9	139.3	146.2	149.5
		60-64	190	109.28	16.86	70.2	77.4	85.8	91.4	97.1	106.8	117.7	132.9	146.5	153.2	159.6
		65-69	152	108.98	14.90	74.4	74.5	88.8	91.9	97.8	107.4	118.5	130.0	136.4	143.8	155.0
		70-74	220	107.76	13.94	69.8	79.4	83.5	88.6	98.9	108.0	116.3	124.3	132.4	139.7	156.1
		over 75	418	106.43	12.56	76.9	80.2	86.3	90.8	97.7	105.5	115.0	123.6	129.2	136.5	155.7
	Female	20-24	157	89.88	18.28	63.7	65.0	67.6	70.2	73.8	86.5	101.3	118.5	125.7	143.2	145.9
		25-29	175	95.66	19.38	64.6	65.3	71.0	75.0	80.0	91.2	108.9	123.1	127.5	161.0	169.5
		30-34	163	96.56	18.62	67.1	69.7	73.5	75.3	82.4	92.3	108.2	121.4	130.4	153.3	154.9
		35-39	169	100.42	19.34	66.5	70.0	75.1	78.0	84.8	96.6	113.2	128.0	135.8	162.3	166.0
		40-44	140	101.35	18.62	65.0	66.5	74.6	78.9	88.2	98.6	114.6	127.4	134.9	148.6	159.5
		45-49	173	101.43	18.20	68.7	68.8	76.5	80.2	86.6	100.5	113.4	125.7	133.7	149.2	169.6
		50-54	151	103.43	18.20	68.7	70.5	74.5	80.5	89.4	102.2	114.6	126.7	137.2	152.9	159.2
		55-59	201	101.13	17.16	66.5	71.7	77.4	82.5	89.9	98.4	110.5	123.8	129.2	147.6	187.5
		60-64	170	103.95	17.88	69.0	70.0	76.4	80.7	90.4	102.6	116.2	129.3	132.9	148.4	149.9
		65-69	179	104.04	16.89	69.3	71.5	79.8	84.2	90.3	102.6	116.2	126.5	132.8	153.6	163.6
		70-74	159	102.99	13.89	67.4	73.8	82.2	86.4	93.3	101.4	111.5	120.5	128.4	137.1	143.1
		over 75	380	99.19	13.49	71.6	73.5	77.8	81.8	90.2	98.6	107.8	116.1	119.9	135.4	148.1

Continued

Table II *(Continued)*. BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (Mexican American, non-Hispanic white, non-Hispanic Black).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1st	5th	10th	25th	50th	75th	90th	95th	99th	
Non-Hispanic Black	Male	20-24	122	85.34	16.36	62.3	63.2	68.5	70.3	74.6	80.3	90.9	107.2	113.4	148.6	153.2
		25-29	119	92.50	17.66	68.7	69.3	72.0	74.5	79.5	87.4	103.2	120.9	127.8	137.4	155.4
		30-34	105	99.78	20.71	67.2	67.2	71.3	77.9	83.4	95.6	110.4	131.4	139.5	161.5	161.6
		35-39	94	99.08	19.06	69.5	69.5	72.6	75.7	85.6	96.8	108.0	124.6	136.6	153.5	153.5
		40-44	131	104.52	15.63	69.0	74.8	77.1	84.1	93.8	104.1	114.7	124.2	134.4	143.1	144.6
		45-49	130	105.22	18.58	71.1	74.9	77.4	82.5	90.5	102.8	118.0	130.8	141.0	145.4	147.7
		50-54	132	103.68	16.92	69.5	70.1	73.0	80.3	94.3	103.2	114.3	124.5	136.3	145.4	154.4
		55-59	120	104.04	16.21	70.2	72.0	77.0	86.0	92.6	102.0	115.3	125.7	136.3	145.8	148.4
		60-64	229	102.21	16.50	65.9	69.6	77.5	82.0	91.4	101.6	111.7	121.9	132.5	147.4	169.6
		65-69	158	105.70	16.86	72.2	74.6	78.8	82.2	95.3	103.8	114.6	127.5	133.1	157.4	158.5
		70-74	76	103.79	16.31	72.3	72.3	78.0	85.0	92.6	103.1	112.5	125.2	132.3	155.7	155.7
		over 75	103	99.64	13.89	67.6	71.6	78.5	82.6	88.8	99.2	110.3	118.1	121.5	125.7	137.0
	Female	20-24	124	91.51	18.80	58.7	62.1	67.5	69.1	75.7	89.5	104.3	116.2	121.8	133.2	171.6
		25-29	162	97.21	19.74	64.0	65.0	69.5	72.5	80.5	95.6	113.0	123.0	132.5	143.5	147.8
		30-34	156	101.44	19.94	63.2	64.5	72.0	76.5	86.8	97.7	115.0	129.6	137.5	152.0	152.7
		35-39	127	104.60	19.42	69.6	70.0	76.1	79.2	91.9	103.0	116.5	129.3	137.0	165.0	173.1
		40-44	155	108.10	19.34	73.3	73.8	79.0	84.3	92.4	106.4	120.8	135.0	141.0	160.0	164.9
		45-49	147	107.32	18.84	75.2	77.2	79.8	83.0	92.0	105.8	120.0	136.4	140.0	157.3	163.7
		50-54	139	109.55	19.61	64.9	72.2	80.8	85.8	97.0	107.2	121.7	142.1	149.0	156.3	158.1
		55-59	164	106.54	18.27	57.9	68.0	78.3	84.5	94.0	106.4	118.7	131.2	138.0	151.0	157.4
		60-64	201	104.28	15.70	66.2	72.0	79.2	84.0	93.0	103.0	113.9	124.2	130.5	141.8	151.2
		65-69	133	105.87	15.48	68.7	71.9	77.0	83.5	97.2	105.0	116.8	125.4	128.8	142.4	143.5
		70-74	68	104.13	13.72	75.9	75.9	86.2	89.0	94.5	103.7	111.5	121.6	128.0	143.6	143.6
		over 75	109	101.73	15.16	71.6	73.8	76.9	81.4	93.2	100.7	111.4	121.3	129.9	139.9	142.0

BMI, body mass index; KNHANES, Korea National Health and Nutrition Examination Survey; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation.

Table III. BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (other Hispanic, non-Hispanic Asian, and Korean).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1st	5th	10th	25th	50th	75th	90th	95th	99th	
Other Hispanic	Male	20-24	63	94.53	17.38	69.5	69.5	70.5	73.5	80.7	93.1	100.8	117.1	127.0	145.5	145.5
		25-29	43	96.23	14.16	66.4	66.4	77.2	80.8	87.5	94.2	102.7	117.5	120.0	137.0	137.0
		30-34	61	101.38	15.39	73.4	73.4	80.1	84.3	89.5	101.0	111.5	120.7	123.9	153.1	153.1
		35-39	60	98.40	13.35	69.6	69.6	84.6	85.4	89.3	96.1	103.2	115.5	122.4	147.5	147.5
		40-44	58	105.55	14.35	87.7	87.7	88.8	90.6	93.6	101.5	115.0	123.9	134.1	156.4	156.4
		45-49	41	101.75	15.25	70.1	70.1	86.4	88.8	92.2	99.3	107.2	118.4	132.3	153.6	153.6
		50-54	69	105.38	13.12	74.4	74.4	87.4	91.1	98.2	103.7	112.4	120.2	127.7	149.0	149.0
		55-59	53	106.44	14.90	75.4	75.4	89.1	94.4	97.3	102.1	117.2	128.5	132.6	153.5	153.5
		60-64	102	106.94	14.70	73.2	76.6	87.5	91.0	97.9	105.4	114.0	125.5	135.0	149.4	153.5
		65-69	72	105.88	11.85	83.3	83.3	90.0	91.5	97.3	103.7	115.9	122.4	123.9	142.2	142.2
		70-74	43	105.91	14.62	73.0	73.0	85.9	92.9	96.6	104.6	110.2	121.1	138.7	148.7	148.7
		over 75	27	103.40	11.89	79.0	79.0	83.7	86.5	94.8	102.1	113.5	119.3	119.8	125.9	125.9
	Female	20-24	70	91.64	17.94	64.2	64.2	69.4	71.1	78.1	86.9	103.7	115.8	127.4	150.6	150.6
		25-29	58	94.47	16.18	69.2	69.2	71.4	74.4	81.2	91.2	107.5	115.4	127.0	141.0	141.0
		30-34	64	95.90	16.31	66.4	66.4	73.3	75.4	83.3	94.2	107.7	116.0	125.0	133.7	133.7
		35-39	68	94.44	16.30	65.5	65.5	69.7	75.9	85.6	91.5	103.0	116.5	132.6	151.3	151.3
		40-44	64	95.28	13.88	69.8	69.8	73.3	75.0	84.1	96.3	104.4	110.7	113.8	136.5	136.5
		45-49	48	101.46	13.02	72.4	72.4	81.0	86.2	90.2	102.3	110.2	116.2	123.4	132.4	132.4
		50-54	91	97.88	16.13	69.1	69.1	76.4	80.2	85.7	95.0	108.7	115.8	123.0	149.3	149.3
		55-59	73	101.70	12.36	73.8	73.8	81.5	84.6	93.1	103.3	108.9	117.7	122.6	128.0	128.0
		60-64	103	100.96	14.12	68.2	69.0	79.6	83.5	92.4	100.1	108.0	118.9	130.9	135.5	136.4
		65-69	80	101.89	14.68	71.1	71.1	79.4	83.2	93.1	101.2	110.0	120.0	123.0	151.0	151.0
		70-74	55	101.02	12.83	75.8	75.8	82.8	87.5	91.7	98.4	109.7	118.9	124.0	144.2	144.2
		over 75	46	97.88	9.05	79.0	79.0	85.0	86.4	89.7	98.0	105.8	109.6	113.3	114.8	114.8

Continued

Table III ***(Continued).*** BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (other Hispanic, non-Hispanic Asian, and Korean).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1st	5th	10th	25th	50th	75th	90th	95th	99th	
Non-Hispanic Asian	Male	20-24	57	87.77	12.02	70.7	70.7	71.5	73.1	80.7	85.0	95.4	101.4	118.8	126.6	126.6
		25-29	82	88.31	11.27	65.3	65.3	70.3	72.8	81.2	87.3	95.3	100.4	106.9	121.1	121.1
		30-34	76	95.84	14.29	70.5	70.5	76.7	79.8	88.0	94.9	102.2	108.4	126.5	152.2	152.2
		35-39	54	95.46	10.52	76.5	76.5	81.2	84.5	88.4	93.6	100.0	110.1	115.8	129.1	129.1
		40-44	77	93.49	10.25	73.6	73.6	76.5	80.9	86.1	93.3	100.0	109.1	112.5	117.5	117.5
		45-49	79	93.45	10.91	68.2	68.2	75.4	81.0	86.2	92.5	102.0	107.1	116.1	120.4	120.4
		50-54	82	93.97	10.21	71.3	71.3	80.0	81.7	87.6	94.7	99.0	104.9	110.4	132.8	132.8
		55-59	70	94.41	12.92	76.4	76.4	79.7	82.2	86.4	91.4	99.0	106.6	123.7	148.0	148.0
		60-64	69	94.03	10.84	66.0	66.0	76.4	78.7	87.5	94.4	99.7	108.8	111.0	130.1	130.1
		65-69	39	94.13	7.67	77.3	77.3	84.6	85.0	87.7	93.9	99.3	107.2	108.5	108.6	108.6
		70-74	27	92.32	9.14	69.2	69.2	81.9	83.6	88.2	90.7	97.9	102.2	113.0	116.2	116.2
		over 75	41	94.10	10.02	73.3	73.3	79.5	82.1	87.3	94.0	100.4	103.4	108.5	119.5	119.5
	Female	20-24	48	80.58	11.58	65.6	65.6	66.5	67.3	72.5	77.2	86.3	99.0	105.2	111.6	111.6
		25-29	82	85.57	13.41	64.5	64.5	70.5	71.8	74.3	82.9	93.3	108.4	113.5	120.0	120.0
		30-34	87	83.27	10.68	66.3	66.3	68.4	69.8	74.1	81.0	93.5	97.9	101.0	106.5	106.5
		35-39	69	83.80	10.05	63.4	63.4	69.2	72.5	75.2	83.5	90.1	98.9	102.4	105.8	105.8
		40-44	78	84.71	11.67	62.7	62.7	71.4	72.7	77.1	83.3	88.6	98.1	106.7	140.4	140.4
		45-49	84	88.07	11.60	70.8	70.8	74.5	75.9	78.4	85.2	95.8	103.2	111.5	118.1	118.1
		50-54	93	88.24	8.77	73.6	73.6	74.8	77.9	81.7	86.8	93.5	101.2	103.7	112.0	112.0
		55-59	67	88.01	10.88	65.0	65.0	71.4	73.4	77.8	89.0	97.5	101.9	103.2	111.5	111.5
		60-64	73	89.13	12.67	67.0	67.0	70.6	75.0	80.9	87.0	96.4	109.3	116.2	123.1	123.1
		65-69	52	91.00	10.73	74.8	74.8	76.2	79.0	83.6	89.7	95.7	105.0	113.3	128.0	128.0
		70-74	40	91.38	10.65	74.1	74.1	75.9	80.9	82.6	90.2	98.7	106.6	114.1	116.3	116.3
		over 75	43	88.10	9.63	64.0	64.0	75.7	77.5	79.8	87.9	95.3	100.6	101.3	111.2	111.2

Continued

Table III *(Continued)*. BMI distribution according to age, sex, and ethnicity based on NHANES and KNHANES data (other Hispanic, non-Hispanic Asian, and Korean).

Ethnicity	Sex	Age (years)	N	Mean	SD	Percentile										Max
						Min	1^{th}	5^{th}	10^{st}	25^{th}	50^{th}	75^{th}	90^{th}	95^{th}	99^{th}	
Korean	Male	20-24	815	82.29	11.25	57.60	63.7	68.0	70.2	74.9	80.3	87.7	97.6	103.2	118.3	147.5
		25-29	841	86.38	10.89	61.70	67.2	71.5	73.8	79.0	84.8	92.2	101.1	105.8	117.7	135.9
		30-34	860	87.74	10.02	62.00	68.2	73.0	75.9	80.9	86.6	93.7	100.8	104.8	116.1	124.9
		35-39	1,188	87.75	9.36	60.00	68.6	72.8	75.9	81.4	87.4	93.7	99.3	102.7	114.3	132.8
		40-44	1,177	87.69	9.37	61.40	67.3	72.4	75.5	81.5	87.6	93.2	99.7	103.3	112.7	128.3
		45-49	1,219	87.63	8.63	58.10	67.8	73.5	77.2	82.0	87.6	92.8	98.4	101.9	110.3	126.4
		50-54	1,152	87.75	8.39	62.40	68.7	74.4	77.6	82.2	87.3	93.0	98.4	101.7	109.6	123.7
		55-59	1,322	87.41	8.20	62.50	68.4	74.3	77.5	82.2	87.1	92.2	97.7	101.1	108.8	129.8
		60-64	1,288	88.00	8.27	60.50	68.1	74.2	77.7	82.9	87.8	93.2	98.5	102.0	108.5	118.6
		65-69	1,111	87.82	8.54	57.80	67.1	73.2	76.4	82.5	88.1	93.1	98.7	100.8	108.2	121.5
		70-74	993	88.23	8.89	54.50	66.0	73.4	77.0	82.8	88.3	94.1	99.6	102.7	109.4	116.4
		over 75	1,376	87.25	9.21	58.60	65.7	71.1	75.0	81.4	87.7	92.8	99.2	102.2	109.3	117.7
	Female	20-24	888	72.05	9.34	54.50	58.0	60.9	62.5	65.8	70.0	76.2	84.4	91.7	104.3	115.9
		25-29	888	73.54	9.96	54.80	58.8	61.7	63.5	66.7	71.3	78.2	86.4	92.5	109.6	139.2
		30-34	1,020	76.08	10.19	24.50	60.2	63.4	65.2	68.9	74.2	81.4	90.4	96.6	104.5	127.3
		35-39	1,505	77.12	9.89	55.70	61.4	64.2	66.0	70.0	75.5	82.6	90.5	96.1	106.4	127.6
		40-44	1,475	77.39	9.70	52.50	61.0	64.3	66.6	70.3	75.8	82.7	90.5	95.3	107.5	119.2
		45-49	1,605	78.74	9.22	58.30	62.7	65.8	67.8	72.2	77.6	84.0	91.0	95.6	105.6	118.0
		50-54	1,548	79.67	8.97	56.00	61.3	67.2	69.5	73.4	78.7	84.8	91.5	96.2	104.6	121.0
		55-59	1,727	80.93	9.04	54.00	62.8	67.3	70.2	74.7	80.1	86.6	92.2	96.3	107.4	120.2
		60-64	1,641	83.03	8.72	52.30	64.5	69.4	72.4	77.0	82.6	88.3	94.5	98.3	105.8	120.9
		65-69	1,407	84.65	8.91	57.20	63.2	71.0	73.7	79.0	84.4	89.9	95.6	99.6	107.6	130.0
		70-74	1,228	85.11	8.93	58.00	64.5	70.5	73.8	79.1	85.3	90.7	96.8	100.3	106.3	113.6
		over 75	1,917	84.74	9.51	50.50	61.8	68.5	72.6	78.4	85.0	91.0	96.4	100.0	107.2	117.0

BMI, body mass index; KNHANES, Korea National Health and Nutrition Examination Survey; NHANES, National Health and Nutrition Examination Survey; SD, standard deviation.

mean BMI at age 30-34 years. Conversely, female Koreans showed a higher mean BMI at age 65-69 years. This finding indicates that the mean BMI of Koreans had a right-sided bias in women compared with men.

The mean WC increased at younger ages and decreased at older ages. Compared with the mean BMI, the decreasing slope of mean WC was less steep than the increasing slope. Koreans and non-Hispanic Asians had the lowest mean WC in most age ranges, whereas non-Hispanic black Asians showed the steepest slope among the seven ethnic groups.

Plausible Mechanism

BMI and WC showed a reversed U-shaped curve according to age: increasing in the early stages and decreasing in the late stages of life. Exercise, enzymatic activity, fat accumulation, eating habits, and culture strongly affect BMI and WC. Physical activity is the most important factor affecting weight. Physical activity varies depending on age, ethnicity, sex, life span, socioeconomic status, and area of residence[16]. Weight-related enzymatic activities lead to fluctuations in metabolism and affect the accumulation of fat[17]. In addition, the changes in food intake with age affect fat accumulation and weight gain.

When BMI and WC were compared, a difference was observed in the age at which the highest values were obtained. In particular, WC showed a right-sided bias compared with BMI. As people age, fat accumulates in the abdomen, leading to abdominal obesity, which is strongly related to obesity-related diseases[18]. This means that molecular biology changes occur throughout the life span and differ according to ethnicity, leading to a gap in BMI and WC across ethicity and age groups. In addition, these changes can be affected by lifestyle and eating habits, which may vary depending on the area of residence, ethnicity, and income quintiles.

Comparison with Previous Studies

In previous studies, BMI and WC were defined using specific criteria for general and abdominal obesity in adults. The criteria for children and adolescents were defined using age-specific percentiles. The criteria for adults were determined based on the following cutoff values: underweight, BMI < 18.5 kg/m^2; normal weight, BMI 18.5-24.9 kg/m^2; overweight, BMI 25.0-29.9 kg/m^2; obesity (class I), BMI 30.0-34.9 kg/m^2; obesity (class II), BMI 35.0-39.9 kg/m^2; and extreme obesity (class III), BMI >40.0 kg/m^2. However, the distributions of BMI and WC differ according to sex and ethnicity[19]. Moreover, the symptoms, processes, and fatality rate of obesity-related diseases differ according to ethnicity and age.

On the basis of the above results, Asians have lower BMI and WC than other ethnic groups. However, Asians have a higher risk of developing weight-related diseases than Caucasians with the same BMI and WC. Asians have higher total body fat than Europeans[20]. In particular, South Asians have high levels of body fat and are prone to developing abdominal obesity. Therefore, they are at a higher risk of developing type 2 diabetes and cardiovascular disease[21]. Meanwhile, black people have a lower body fat and higher lean muscle mass than white people with the same BMI or WC. Consequently, black people have a lower risk of developing obesity-related diseases[22]. In addition, the occurrence of weight-related diseases differs according to sex and age even within the same BMI or WC category[23].

Overweight and obesity are defined according to the World Health Organization (WHO) growth curves, as follows: overweight as an age- and sex-specific BMI in the 85th-95th percentile and obesity as an age- and sex-specific BMI in the ≥ 95th percentile. Abdominal obesity is defined as WC values in the ≥ 75th percentile (moderate) and ≥ 90th percentile (high) according to sex and age[19]. Considering the results of previous studies, it is not reasonable to define overweight and obesity, which are indicators of the risk of weight-related diseases, based on certain standards for BMI and WC without considering age or ethnicity. The cutoff value for obesity should be set as a percentile of BMI or WC according to age and ethnicity, based on the WHO criteria for obesity in children and adolescents. General obesity should be defined as the top 5 percentiles of BMI and abdominal obesity as the top 10 percentiles of WC in each group according to age and ethnicity.

Although some studies have addressed the BMI distribution trends and other factors, their results had some differences from those of our study. We subdivided the participants into groups according to age and ethnicity. Wang et al[24] reported the BMI distribution trends in Chinese adults aged 20-45 years from 1989 to 2000. Flegal and Troiano[25] compared the BMI distribution from 1976 to 1980 with that from 1988 to 1994. Rundle et al[26] categorized ethnicty as non-black and black, and the sample size was approximately 250 participants. Flegal and Troiano[25] categorized ethnicity into four groups: non-Hispanic white, non-Hispanic black, Mexican American, and all Hispanic. In contrast, we examined the BMI and WC distributions in a wide range of age and ethnic groups. In addition, the number of recent samples included in our study was higher than that in other studies.

Strengths and Limitations

BMI and WC were analyzed based on ethnicity, age, and sex. Some previous studies[27,28] have focused on annual BMI and WC changes, and only a few studies have examined these changes according to ethnicity, age, and sex. The existing criteria for obesity, overweight, and abdominal obesity tend to be collectively determined using specific BMI and WC values. However, the risk of obesity-related diseases differs according to ethnicity and age. Hence, we recommend establishing new BMI criteria for obesity and abdominal obesity for each age range, sex, and ethnicity. This differentiates our study from others.

Despite these strengths and although the CDC would have attempted to collect data without bias, some statistical deviation may exist owing to the small sample size. The total number of the NHANES participants was 13,144; however, the average number of participants in each group according to age and ethnicity was relatively small. In contrast, the KNHANES data from South Korea contained information of 30,191 participants in total. To enhance the reliability of the results, a follow-up study using global data from various countries should be conducted.

Moreover, general and abdominal obesity were defined using percentiles in each group. However, these data do not accurately reflect the risk of obesity-related diseases[29]. The same BMI number and percentile value do not necessarily mean the same risk of developing weight-related diseases. To define obesity in relation to weight-related diseases, the definition should include the risk of conditions, such as heart disease, hypertension, diabetes, cancer, gallbladder disease, osteoarthritis, gout, and kidney disease[30]. If a certain score based on height, weight, and WC can predict the occurrence and severity of weight-related diseases, it could be a reasonable criterion for obesity. Hence, future studies should establish a new scoring system for assessing obesity according to age, sex, and ethnicity using weight-related factors. This would reduce unnecessary social expenditure and redistribution of medical resources.

Conclusions

This study showed the recent distributions of BMI and WC in groups subdivided according to age, sex, and ethnicity. Our data can serve as a good reference for future studies that aim to statistically analyze public health issues related to weight. Any study that is to be conducted in Korea or the United States or future studies aiming to compare these countries with other regions could utilize our data. We have also suggested new standards for evaluating general and abdominal obesity that are more rigorous than the existing criteria. In addition, our data may be useful for individuals who wish to identify their risk of developing obesity-related diseases and accordingly decide whether to visit a medical institution. Most important, we recommend establishing a scoring system that can redefine obesity in a rigorous manner.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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Ethics Approval

The NHANES and KNHANES data were anonymized, and the study was approved by Sejong University (SJU-HR-E-2020-003), the US CDC, and the KDCA.

Informed Consent

The KDCA and the US CDC obtained consent from the participants.

Availability of Data and Material

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request (Dong Keon Yon; yonkkang@gmail.com).

Authors' Contribution

Drs. Dong Keon Yon and Sang Youl Rhee had full access to all study data and were responsible for ensuring the integrity of the data and the accuracy of the data analysis. All authors approved the final version of the manuscript before submission. Study concept and design: Dong Keon Yon and Sang Youl Rhee; acquisition, analysis, or interpretation of the data: Dong Keon Yon and Sang Youl Rhee; drafting of the manuscript: Seounghyun Eum and Jang Won Son; critical revision of the manuscript for important intellectual content: Seounghyun Eum, Jang Won Son, Chanyang Min, Wonyoung Cho, Sunyoung Kim, Ho Geol Woo, Rosie Kwon, Kyu Na Lee, Kyung-Do Han, Dong Keon Yon, and Sang Youl Rhee; statistical analysis: Dong Keon Yon and Sang Youl Rhee; and study supervision: Dong Keon Yon and Sang Youl Rhee. Dong Keon Yon and Sang Youl Rhee were the study guarantors. The corresponding authors attest that all listed authors meet the authorship criteria and that no other individuals meeting the criteria have been omitted.

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