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ORIGINAL RESEARCH

20-Year Trends in Metabolic Syndrome Among Korean Adults From 2001 to 2020

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ABSTRACT

BACKGROUND The number of people with metabolic syndrome (MetS) is increasing worldwide, and many socioeconomic and environmental factors contribute to this.

OBJECTIVES The authors investigated tangible trends in the prevalence of MetS using the 2001 to 2020 versions of the Korea National Health and Nutrition Examination Survey (KNHANES).

METHODS In these surveys, stratified multistage sampling designs were used to approximate the entire population. Blood pressure, waist circumference, and lifestyle variables were examined in a standardized fashion. Metabolic biomarkers were measured in a central laboratory operated by the Korean government.

RESULTS The age-adjusted prevalence of MetS increased significantly from 27.1% in 2001 to 33.2% in 2020. It was more prevalent in men (25.8%→40.0%) but did not change in women (28.2%→26.2%). Among the 5 MetS components, the proportions of high glucose level and large waist circumference increased substantially by 17.9% and 12.2% over 20 years, while high-density lipoprotein cholesterol levels increased significantly, resulting in a decrease in low high-density lipoprotein cholesterol by 20.4%. Caloric intake derived from carbohydrates decreased from 68.1% to 61.3%, while fat consumption increased from 16.7% to 23.0%. Notably, sugar-sweetened beverage consumption showed an almost 4-fold increase from 2007 to 2020, while physical activity levels decreased by 12.2% from 2014 to 2020.

CONCLUSIONS Glycemic dysregulation and abdominal obesity were key features contributing to the increased prevalence of MetS observed in Korean men during the past 20 years. Rapid economic and socioenvironmental changes in this period may be involved in this phenomenon. Understanding these changes in MetS could be valuable for other countries undergoing such socioeconomic transformation. (JACC: Asia 2023;3:491–502) © 2023 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

BP = blood pressure

HDL-C = high-density lipoprotein-cholesterol

KNHANES = Korea National Health and Nutrition Examination Survey

MetS = metabolic syndrome

SSB = sugar-sweetened beverage

T2D = type 2 diabetes

TG = triglyceride

WC = waist circumference

Metabolic syndrome (MetS) is an atherogenic and diabetogenic condition characterized by abdominal obesity, insulin resistance, hypertension, and dyslipidemia. Key lifestyle features contributing to the development of MetS are the increased consumption of energy-dense, highly processed foods and a decrease in physical activity as byproducts of economic development and the remarkable increase in electronic device use.

In the United States, the prevalence of MetS showed an increasing tendency from 32.5% in 2011 to 2012 to 36.9% in 2015 to 2016.[1] The prevalence of MetS has also been increasing in many other countries, particularly in the Asia-Pacific and Latin American regions, presenting a major challenge for public health and health care professionals, in addition to causing socioeconomic problems in those locations.[2,3] Indeed, the prevalence of MetS in the People's Republic of China increased dramatically from 3.7% in 2000 to 2001 to 21.3% in 2009.[4] MetS is rapidly increasing among Hispanic and Asian ethnic groups in the United States, which is problematic because of the substantial growth rates in these subpopulations.[1] A recent projection reported that by 2030 half of the population of the United States will have obesity, and one-quarter of them will have severe obesity.[5] The growth of metabolic disorders based on obesity has become a serious problem with a major financial burden on health-care systems in most countries.[6]

Having MetS raises the risk for the development of cardiometabolic disorders, such as type 2 diabetes (T2D), cardiovascular diseases, and many types of cancers.[7] The characteristics of MetS vary in different countries for multiple reasons. Hence, investigating the changing pattern of MetS in people living in rapidly changing socioeconomic environments could be helpful in guiding other countries facing similar situations to set up appropriate strategies to tackle this detrimental syndrome.

South Korea was a poor country after the Korean War ended in 1953.[8] However, South Korea has enjoyed strong economic growth since 1990. For example, its gross domestic product increased from US$283.47 billion in 2000 to US$1,638.26 billion in 2020.[9] It is well documented that socioeconomic status affects lifestyles; therefore, it is essential to understand how lifestyle changes affect MetS characteristics, considering that other countries are facing similar socioeconomic changes as observed in South Korea.

Here, we investigated changes in the features of MetS using the 2001 to 2020 versions of the Korea National Health and Nutrition Examination Survey (KNHANES) by applying the harmonized definition of the MetS with waist circumference (WC) defined by Korean population criteria.[10] Secular changes in lifestyle and socioeconomic factors from these nationwide surveys were also examined because they might potentially contribute to changes in MetS and its components.

METHODS

STUDY COHORT. The KNHANES is a cross-sectional national representative survey conducted annually by the Korea Disease Control and Prevention Agency since 2001 to evaluate the health and nutritional status of the noninstitutionalized South Korean population.[11] Details of the surveys performed in 2001 and 2005 have been described,[12] and the survey methods have been standardized since 2005.

In brief, a stratified multistage probability sampling design was used with a selection made from sampling units based on attributes such as geographical area, sex, and age groups using household registries. Weights were assigned to each respondent, enabling the results to represent the entire population. This weighting method guarantees unbiased point estimates of population parameters for a population and its subsets.[13]

To minimize bias resulting from dropouts, the noncompliers' important demographics and other characteristics were compared with those of the completers. There were no differences between participants and nonparticipants in all surveys. Among 124,801 people who participated in the 2001 to 2020 KNHANES, 98,489 (78.9%) respondents were ≥20 years of age and met the criteria of MetS with Korean-specific WC criteria. The numbers and characteristics of study subjects are presented in **Table 1**. All individuals in the study participated voluntarily and gave informed consent. All surveys were approved by the institutional review board of the Korea Disease Control and Prevention Agency.

MEASUREMENT OF ANTHROPOMETRY, LIFESTYLE, AND BIOCHEMICAL FACTORS. All surveys conducted anthropometric measurements in a standard manner by well-trained examiners. The nutritional survey data were collected by dietitians trained to use a 1-day 24-hour recall. Physical activity data were collected since 2014 through face-to-face interviews by trained interviewers using the Global Physical Activity Questionnaire. Detailed information about the measurement of anthropometry, lifestyle,

and biochemical parameters is provided in the Supplemental Appendix.

DEFINITION OF MetS. According to the harmonized definition for MetS,[10] an individual may be diagnosed as having this disorder if they have 3 or more of the following criteria: 1) high WC (≥90 cm for men and ≥85 cm for women) based on the International Obesity Task Force criteria for the Asia-Pacific population[14] and the Korean Society for the Study of Obesity[15]; 2) high serum triglyceride (TG) levels (≥150 mg/dL) or currently undergoing drug treatment for dyslipidemia; 3) low high-density lipoprotein cholesterol (HDL-C) levels (<40 mg/dL in men and <50 mg/dL in women) or currently undergoing drug treatment for dyslipidemia; 4) high blood pressure (BP) (≥130/85 mm Hg) or currently undergoing antihypertensive drug treatment; and 5) high glucose (≥100 mg/dL) or currently undergoing glucose-lowering drug treatment.

STATISTICAL ANALYSES. To evaluate the MetS trends representing the Korean population, we first applied sampling weights and then calculated the age-standardized prevalence according to year. All analyses were conducted after accounting for sampling weights and complex survey designs such as clustering and stratification. Direct age-adjustment of the data was performed using the age- and gender-specific structures of the estimated population based on the 2020 population projections for South Korea released by the Korean Statistical Information Service to adjust for differences in results from a change in the age structure in each year. To assess the time trends in the MetS prevalence across all years, we used the Jonckheere-Terpstra trend test. The weighted chi-square test was used to compare differences in prevalence over the intervals 2001 to 2010 and 2001 to 2020. The entire data are presented as the mean ± SE or prevalence (%). Statistical significance was set at $P < 0.05$. All statistical analyses were performed with STATA (version 17.0, StataCorp).

RESULTS

CHANGES FROM 2001 TO 2020. Over the 20 years, height increased by 3.3 cm and body weight increased by 4.7 kg, which raised the body mass index (BMI) by 0.7 kg/m^2 with a sex difference (ie, an increase of 1.5 kg/m^2 in men vs a decrease of 0.1 kg/m^2 in women) (**Table 1**). The percentage of current smokers decreased substantially in men by 24.8% over the 20 years, while it remained the same in women, which was very low (5.7%). The percentage of people exercising regularly decreased significantly from 56.1% in 2014 to 43.9% in 2020, and this decreasing pattern was similar in both sexes (**Table 1**, Supplemental Table 1). In dietary assessment, carbohydrate consumption decreased by 6.8%, while fat consumption increased by 6.3% over the same period with similar changing patterns in men and women (**Table 1**, Supplemental Table 2B). Sodium intake decreased by 40.0%, with similar decreasing trends in both sexes.

METABOLIC SYNDROME. The age-adjusted prevalence of MetS increased significantly from 27.1% in 2001 to 33.2% in 2020, which is a 6.1% absolute change over the recent 20 years with a marked difference between men and women (14.2% in men; −2.0% in women) (**Table 2**, Supplemental Table 3). Using the National Cholesterol Education Program criteria[16] for abdominal obesity, ≥102 cm in men and ≥88 cm in women, the prevalence of MetS changed from 11.4% in 2001 to 15.4% in 2020 (11.9% in men; −1.5% in women).

Among the 5 MetS components, the high glucose criterion increased the most over 20 years (a 17.9% absolute increase). High WC and hypertriglyceridemia followed, with increases of 12.2% (23.2% in men; 1.6% in women) and 3.8% (5.0% in men; 1.6% in women), respectively. In contrast, the proportions of low HDL-C and high BP criteria decreased by 20.4% and 2.5%, respectively, over the same period, with a greater decrease in women (11.7% in men and 27.8% in women for HDL-C; 0.5% in men and 5.1% in women for high BP).

In terms of the 10-year interval changes, the prevalence of MetS increased by 3.0% (0.8% absolute increase) over the 2001 to 2010 period followed by a 19.0% increase (5.3% absolute increase) in the next decade (**Table 2**, Supplemental Table 4, Supplemental Figure 1). The high glucose and high WC criteria increased by 92.3% and 47.7%, respectively, over 20 years. The low HDL-C criterion decreased by 41.6% during the same time. The proportion of people taking antihypertensive, antidiabetic, or lipid-lowering medications increased substantially from 2001 to 2020: 10.1%→18.3%, 4.2%→8.5%, and <1.0%→13.7%, respectively (Supplemental Tables 4 and 5).

The serial changing patterns by sex are shown in **Figure 1**. Since 2013, the prevalence of MetS showed an increasing trend in men with no obvious trend in women over the same period. Such a sex difference appeared to be driven by a greater increase in the high glucose levels, higher WC, and higher TG levels in men than women (Supplemental Table 6). Of note, the low HDL-C measure decreased in both sexes, but there was a significantly greater decrease in women ($P < 0.05$). The sex difference in the incidence of MetS is increasing with time. In 2001, there was a 2.4%

TABLE 1 Characteristics of the Study Population in the KNHANES 2001 to 2020

	2001 (n = 5,886)	2005 (n = 5,349)	2007 (n = 2,815)	2008 (n = 6,436)	2009 (n = 7,028)	2010 (n = 5,766)	2011 (n = 5,697)
Age, y	44.9 ± 0.2	47.1 ± 0.2	49.7 ± 0.3	48.9 ± 0.2	48.9 ± 0.2	49.2 ± 0.2	50.7 ± 0.2
Men	48.7	49.0	49.3	49.3	49.4	49.5	49.6
Height, cm	162.0 ± 0.3	162.2 ± 0.4	162.1 ± 0.5	162.8 ± 0.3	163.1 ± 0.3	163.3 ± 0.3	163.4 ± 0.3
Men	169.0 ± 0.3	168.9 ± 0.4	168.9 ± 0.5	169.5 ± 0.3	170.0 ± 0.3	170.2 ± 0.3	170.3 ± 0.4
Women	155.6 ± 0.3	156.0 ± 0.3	155.8 ± 0.4	156.4 ± 0.3	156.5 ± 0.3	156.7 ± 0.3	156.9 ± 0.3
Weight, kg	62.0 ± 0.4	62.6 ± 0.5	62.5 ± 0.6	62.8 ± 0.4	63.1 ± 0.4	63.2 ± 0.5	63.5 ± 0.5
Men	67.1 ± 0.6	68.4 ± 0.6	68.7 ± 0.8	68.9 ± 0.6	69.5 ± 0.5	69.8 ± 0.6	69.9 ± 0.7
Women	57.1 ± 0.5	57.4 ± 0.5	57.0 ± 0.6	57.1 ± 0.4	57.5 ± 0.4	57.3 ± 0.5	57.7 ± 0.5
BMI, kg/m^2	23.5 ± 0.1	23.7 ± 0.1	23.7 ± 0.2	23.6 ± 0.1	23.6 ± 0.1	23.6 ± 0.1	23.7 ± 0.1
Men	23.6 ± 0.2	23.9 ± 0.2	24.0 ± 0.2	23.9 ± 0.2	24.0 ± 0.2	24.0 ± 0.2	24.0 ± 0.2
Women	23.5 ± 0.2	23.5 ± 0.2	23.5 ± 0.2	23.3 ± 0.2	23.4 ± 0.2	23.3 ± 0.2	23.4 ± 0.2
Lifestyle							
Current smoker	31.2	24.5	23.6	26.1	25.4	25.9	25.5
Men	58.4	45.0	42.5	45.9	45.0	46.3	45.5
Women	5.7	5.0	5.3	7.0	6.4	5.9	6.1
Regular drinker	–	–	33.9	36.2	37.1	36.7	36.0
Regular exercise	–	–	–	–	–	–	–
Stress	33.7	34.0	26.5	28.0	30.4	27.7	27.1
Diet							
Total energy, calories/d	1,927.4 ± 35.1	2,019.2 ± 36.1	1,830.0 ± 43.2	1,868.5 ± 31.5	1,899.5 ± 30.1	2,068.7 ± 38.3	2,030.1 ± 37.8
CHO	68.1	66.2	69.0	68.8	68.5	67.9	67.4
Fat	16.7	18.1	16.3	16.6	17.0	17.6	18.0
Protein	15.1	15.7	14.7	14.5	14.5	14.6	14.6
SSB, g/d	–	–	121.7 ± 33.4	106.0 ± 12.7	137.3 ± 18.5	229.2 ± 44.3	228.1 ± 39.8
Soda, g/d	–	–	25.3 ± 8.1	19.4 ± 4.3	24.0 ± 3.7	36.7 ± 6.1	42.4 ± 15.2
Sugar-containing coffee, g/d	–	–	57.7 ± 24.2	46.1 ± 6.9	70.0 ± 14.6	120.4 ± 35.8	115.0 ± 20.5
Sodium, g	5.5 ± 0.1	5.7 ± 0.2	4.7 ± 0.2	4.9 ± 0.1	4.9 ± 0.1	5.1 ± 0.1	5.1 ± 0.2

Values are mean ± SE or %. The age-standardized prevalence was calculated using the direct standardization method based on a 2020 population projection for South Korea. Rate of regular aerobic exercise: percentage of people who spent time corresponding to each activity; more than 2.5 hours of moderate-intensity physical activity a week or more than 1 hour and 15 minutes of high-intensity physical activity a week or mixing moderate- and high-intensity physical activity (1 minute of high intensity is equivalent to 2 minutes of moderate intensity). Rate of regular walking: percentage of people who walked for exercise, for more than 10 minutes each time, more than 30 minutes each day, 5 days or more per week, over the past 1 week.

BMI = body mass index; CHO = carbohydrate; KNHANES = Korea National Health and Nutrition Examination Survey; SSB = sugar-sweetened beverage.

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difference in MetS prevalence between men and women. It increased to 4.4% by 2010, and this sex gap further increased to 13.8% by the 2020 KNHANES survey. Age-standardized rates of MetS and its components by sex (Supplemental Table 6) further support the notion of a gap between the sexes, considering the increases in the percentages of men with high glucose and high WC criteria, which were 130.3% and 105.0%, respectively. Moreover, the percentage change among women with low HDL-C was −45.7%, whereas the same parameter for men was −32.6%. In addition, aspartate aminotransferase and alanine aminotransferase levels also increased in men while remaining stable in women (Supplemental Table 6). In all surveys, there was a tendency for men to have a relatively higher prevalence of MetS in those 20 to 59 years of age, but in subjects ≥60 years of age, women had a higher prevalence than men (**Figure 2**).

ASSOCIATION OF LIFESTYLE FACTORS WITH MetS.

There was a significant increase in sedentary time spent per day, while concomitantly there was a significant decrease in regular exercise over the past years. Fat intake and consumption of sugar-sweetened beverages (SSBs) have been increasing significantly since 2007 (**Figure 3**, Supplemental Table 7).

DISCUSSION

We performed a nationwide study to investigate the MetS trends representing the entire South Korean adult population. The age-adjusted prevalence of MetS increased from 27.1% in the 2001 KNHANES to 33.2% in the 2020 KNHANES, applying the harmonized definition using Asia-Pacific abdominal obesity criteria (**Central Illustration**). The absolute increase in MetS was 6.1% over the 20 years, 14.2% in men,

TABLE 1 Continued

2012 (n = 5,210)	2013 (n = 4,820)	2014 (n = 4,487)	2015 (n = 4,816)	2016 (n = 5,774)	2017 (n = 5,823)	2018 (n = 5,947)	2019 (n = 6,023)	2020 (n = 5,657)
51.1 ± 0.2	49.1 ± 0.2	50.8 ± 0.2	51.8 ± 0.2	51.1 ± 0.2	51.7 ± 0.2	51.7 ± 0.2	52.0 ± 0.2	52.5 ± 0.2
49.6	49.8	49.8	49.8	50.1	50.1	50.3	50.3	50.4
163.6 ± 0.4	163.6 ± 0.3	163.8 ± 0.4	164.0 ± 0.3	164.3 ± 0.3	164.6 ± 0.3	164.9 ± 0.3	165.2 ± 0.3	165.3 ± 0.3
170.6 ± 0.4	170.5 ± 0.4	170.8 ± 0.4	171 ± 0.4	170.9 ± 0.3	171.4 ± 0.3	171.8 ± 0.3	171.9 ± 0.3	172.1 ± 0.3
157.0 ± 0.3	157.3 ± 0.3	157.3 ± 0.3	157.5 ± 0.3	157.7 ± 0.3	157.9 ± 0.3	158.3 ± 0.3	158.7 ± 0.3	158.6 ± 0.3
64.0 ± 0.5	63.6 ± 0.5	63.6 ± 0.5	64.5 ± 0.5	64.9 ± 0.5	64.9 ± 0.5	65.5 ± 0.5	65.4 ± 0.5	66.7 ± 0.5
70.5 ± 0.7	70.6 ± 0.6	70.8 ± 0.7	71.7 ± 0.7	71.9 ± 0.6	72.2 ± 0.6	72.8 ± 0.6	72.9 ± 0.6	74.9 ± 0.7
58.0 ± 0.6	57.8 ± 0.5	57.3 ± 0.5	57.8 ± 0.5	58.4 ± 0.5	58.2 ± 0.5	58.5 ± 0.5	58.6 ± 0.5	59.0 ± 0.5
23.8 ± 0.2	23.7 ± 0.1	23.6 ± 0.1	23.9 ± 0.1	23.9 ± 0.1	23.9 ± 0.1	24.0 ± 0.1	23.9 ± 0.1	24.2 ± 0.2
24.1 ± 0.2	24.2 ± 0.2	24.2 ± 0.2	24.4 ± 0.2	24.5 ± 0.2	24.5 ± 0.2	24.6 ± 0.2	24.6 ± 0.2	25.1 ± 0.2
23.5 ± 0.2	23.3 ± 0.2	23.1 ± 0.2	23.3 ± 0.2	23.4 ± 0.2	23.3 ± 0.2	23.3 ± 0.2	23.3 ± 0.2	23.4 ± 0.2
Lifestyle								
24.3	22.7	22.9	21.4	22.4	21.0	21.4	20.5	19.7
42.1	40.7	42.1	38.0	38.9	36.9	36.1	35.0	33.6
7.0	5.7	4.7	5.2	6.0	5.0	6.6	6.0	5.7
35.3	34.6	34.6	35.8	36.2	36.2	36.2	36.2	36.0
—	—	56.1	50.4	47.8	46.0	44.8	45.7	43.9
25.8	23.1	24.4	29.1	27.6	29.1	27.1	28.6	29.1
Diet								
2005.8 ± 43.8	2,059.0 ± 39.0	2,075.0 ± 38.3	2,105.2 ± 41.7	2,052.7 ± 39.3	2,001.9 ± 41.1	2,001.7 ± 36.9	1,943.1 ± 36.8	1,906.1 ± 38.2
66.7	66.4	65.7	65.6	64.8	64.5	63.8	62.4	61.3
18.6	19.2	19.8	19.9	20.1	20.4	20.9	22.0	23.0
14.7	14.4	14.5	14.5	15.1	15.2	15.3	15.6	15.7
239.2 ± 27.1	290.8 ± 27.2	315.5 ± 34.3	361.6 ± 43.8	332.1 ± 35.1	317.7 ± 35.7	286.7 ± 22.2	355.3 ± 38.2	358.3 ± 37.7
38.7 ± 5.9	47.6 ± 6.6	56.5 ± 12.0	61.9 ± 8.7	63.9 ± 11.2	57.3 ± 12.4	43.4 ± 5.7	53.7 ± 7.9	57.8 ± 10.4
126.9 ± 21.6	161.1 ± 23.4	174.5 ± 22.5	202.4 ± 37.8	151.2 ± 24.1	147.9 ± 18.9	153.3 ± 17.7	199.8 ± 31.2	194.8 ± 28.1
4.8 ± 0.2	4.0 ± 0.1	3.9 ± 0.1	4.1 ± 0.1	3.5 ± 0.1	3.5 ± 0.1	3.4 ± 0.1	3.4 ± 0.1	3.4 ± 0.1

while no increase was observed in women. These data indicate that one-third of Korean adults now have multiple metabolic impairments.

The prevalence of MetS in the 2020 KNHANES study was 33.2%, similar to the result of the 1999 to 2012 U.S. NHANES (at 34.2%).[17] However, it should be noted that a lower cutoff for high WC was used in our analysis. A recent analysis using the 2015 to 2016 U.S. NHANES data showed that among 17,048 participants the overall prevalence of MetS was 34.7%; not differing between men and women (35.1% vs 34.3%, $P = 0.47$).[1] Of note, there was a significant increase in prevalence in the participants who indicated themselves as either "other" for race/ethnicity features or as "Hispanic" for Hispanic/non-Hispanic attributes.

The most worrying finding is the dramatic increase in the high glucose criterion: from 19.4% in 2001 to 37.3% in 2020. Considering the decrease in carbohydrate consumption in meals by Korean subjects, an important contributing factor is probably the increased consumption of sugar and SSBs observed over the last 20 years (**Table 1**). Decreasing trends in physical activity might have contributed to this. Indeed, consumption of SSBs, mainly soda and sugar-containing coffee, has increased by almost 200% from 2007 to 2020. In a large study involving Americans and Europeans, a higher consumption of SSBs was associated with a greater incidence of T2D, by 13% per 1 serving per day even after adjustment for adiposity.[18] A similar association between high SSB consumption and increased T2D risk after adjusting for BMI was found in Asian populations.[19] In middle-income countries, these trends of consuming processed foods have been even more marked than in South Korea.[20] It is noteworthy that the consumption of SSBs, soda, and sugar-containing coffee has increased substantially with a greater increase in men than women (Supplemental Table 2B). Overconsumption of SSBs contributes to the development of metabolic impairments in many ways.[21] Glucose/fructose molecules from SSBs are not only absorbed rapidly, but also might play some role in activation of the dopaminergic reward system in the brain induced by hyperinsulinemia, resulting in the accumulation of visceral fat and increased cardiometabolic risk.[21] Moreover, excess fructose input more than the

TABLE 2 Age-Standardized Rates of Metabolic Syndrome and Absolute Values of its Individual Components

	2001	2005	2007	2008	2009	2010	2011	2012	2013
Prevalence of MetS									
MetS	27.1	29.0	27.0	28.0	28.3	27.9	27.9	26.8	26.8
High WC	25.6	27.4	29.4	27.9	25.8	25.1	27.9	24.7	22.2
High BP	41.4	40.3	32.8	34.6	37.0	37.1	39.1	38.7	36.4
High glucose	19.4	23.3	23.6	29.2	28.7	27.4	27.3	29.4	33.2
High TG	35.4	29.8	33.4	31.7	32.0	33.4	32.7	33.9	34.2
Low HDL-C	49.0	54.6	44.4	43.0	44.3	42.6	36.0	34.9	33.5
Absolute value									
WC, cm	81.9 ± 0.3	81.6 ± 0.4	82.6 ± 0.6	81.8 ± 0.4	81.4 ± 0.4	81.3 ± 0.4	81.7 ± 0.4	81.4 ± 0.4	80.8 ± 0.4
SBP, mm Hg	125 ± 1	120 ± 1	118 ± 1	116 ± 1	118 ± 1	118 ± 1	119 ± 1	119 ± 1	117 ± 1
DBP, mm Hg	78 ± 1	78 ± 1	77 ± 1	75 ± 0	76 ± 0	75 ± 0	76 ± 0	76 ± 0	75 ± 0
FPG, mg/dL	97.8 ± 0.7	95.5 ± 0.9	95.2 ± 1.3	98.5 ± 0.8	97.6 ± 0.7	97.4 ± 0.9	97.5 ± 0.9	98.1 ± 0.8	99.4 ± 0.8
HbA_{1c}, %	–	–	–	–	–	–	5.73 ± 0.03	5.73 ± 0.03	5.89 ± 0.03
TG, mg/dL	141 ± 3	138 ± 5	134 ± 5	137 ± 4	138 ± 4	136 ± 5	136 ± 4	136 ± 5	138 ± 5
HDL-C, mg/dL	46 ± 0	45 ± 0	48 ± 1	48 ± 0	48 ± 0	48 ± 0	50 ± 1	50 ± 1	51 ± 1

Values are % or mean ± SE. The age-standardized prevalence was calculated using the direct standardization method based on a 2020 population projection. There was a significant difference between 2001 KNHANES data and 2020 KNHANES data. *P* for trend obtained using the Jonckheere-Terpstra test for time trends across all years. [a]$P < 0.05$.

BP = blood pressure; DBP = diastolic blood pressure; FPG = fasting plasma glucose; HbA_{1c} = glycosylated hemoglobin; HDL-C = high-density lipoprotein cholesterol; KNHANES = Korea National Health and Nutrition Examination Survey; LDL-C = low-density lipoprotein cholesterol; MetS = metabolic syndrome; SBP = systolic blood pressure; TG = triglyceride; WC = waist circumference.

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capacity for glucose metabolism in the liver might contribute to increases in endogenous glucose production and lead to prediabetes and fatty liver disease.[22] Thus, consuming SSBs raises the risk of developing noncommunicable chronic diseases and increases mortality.[23]

In 2015, the World Health Organization recommended that added sugar should account for <10% of total daily energy intake[24] and the consumption of it should be discouraged particularly in adolescents and young adults.[25] In addition, several countries have initiated a policy for improving tax design, suggesting that administrative bodies could play a greater role in supporting taxation of SSBs.[26]

Based on the current serial data from the KNHANES surveys, another concern is the increase in WC. The BMI of men and women also increased: 2 out of 5 men and one out of 4 women in 2020 were categorized as having obesity, defined by a BMI ≥25 kg/m^2, the obesity cutoff suggested by World Health Organization for Asians and adopted by the Korean Society for Study of Obesity (Supplemental Table 8).[15,27] The rapid increase in obesity in Korea, which was more prominent in men than women, seems to result from the shift to unfavorable dietary habits and decreased physical activity associated with advances in sedentary modes of transportation.[15] Notably, dietary fat consumption has increased from 16.7% to 23.0% over the recent 20 years, even though total energy intake has not changed significantly (Supplemental Table 2A). In addition, regular physical activity has decreased substantially from 56.1% in 2014 to 43.9% in 2020. Men showed a greater reduction in regular aerobic exercise than women during 2014 to 2020 (Supplemental Table 1). The dramatic increase in the accessibility and use of the Internet and personal electronic devices is also likely to have contributed to sedentary lifestyles.[28]

High WC is an indicator of an increased accumulation of visceral adipose tissue that serves as an active endocrine organ releasing various bioactive mediators that deteriorate glucose regulation and lipid metabolism and aggravate insulin resistance and chronic inflammation, all contributing to increased cardiovascular risk.[29] Therefore, to reduce the obesity prevalence—particularly abdominal visceral adiposity—it will be important to facilitate national education programs and government policies to encourage people to improve the overall quality of their diet and increase their physical activity levels.

Among the 5 MetS components, the prevalence of high TG also increased by 3.8%. Carbohydrate consumption decreased in this period by 6.8% but remains high by international guidelines.[30] Indeed, fat consumption increased from 16.7% to 23.0% over the same period. These undesirable lifestyle changes toward a high-fat diet with reduced physical activity are common in many less developed or developing countries.[31] Clearly, because South Koreans have had a higher carbohydrate intake than recommended, a decrease in carbohydrate intake and an increase in fat intake may, at first glance, appear as desirable

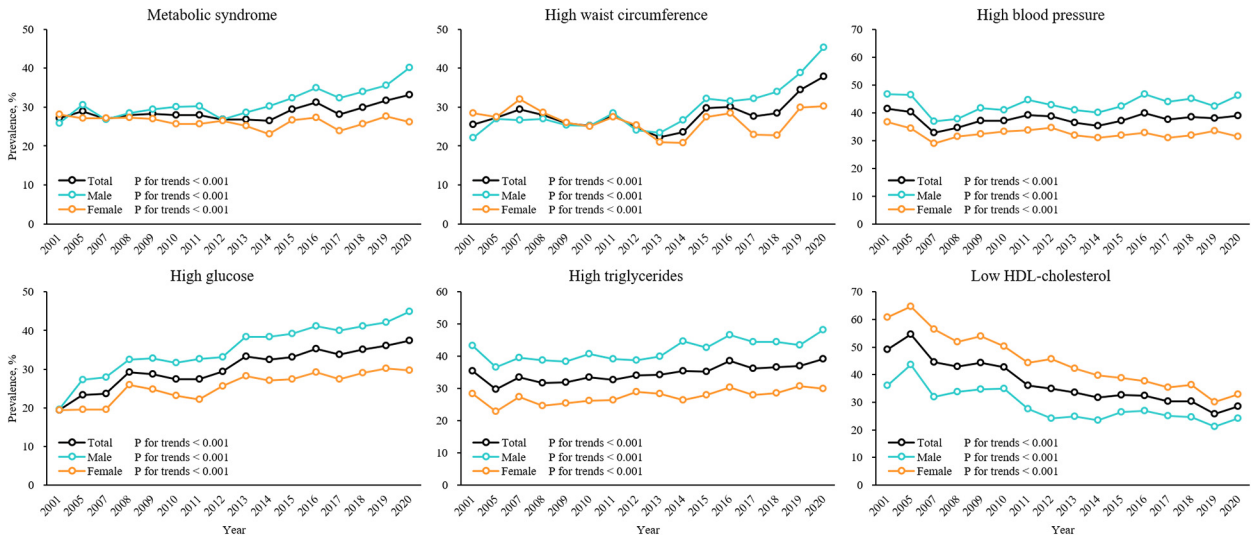
TABLE 2 Continued

2014	2015	2016	2017	2018	2019	2020	Percent Change	*P* for Trend
Prevalence of MetS								
26.4	29.3	31.2	28.1	29.9	31.6	33.2	22.5[a]	<0.001
23.6	29.8	30.1	27.5	28.4	34.4	37.8	47.7[a]	<0.001
35.4	37.0	39.7	37.5	38.5	38.0	38.9	−6.0[a]	<0.001
32.5	33.1	35.2	33.7	35.1	36.1	37.3	92.3[a]	<0.001
35.3	35.2	38.5	36.2	36.6	37.1	39.2	10.7[a]	<0.001
31.7	32.7	32.3	30.3	30.4	25.7	28.6	−41.6[a]	<0.001
Absolute value								
81.2 ± 0.4	82.8 ± 0.4	83.0 ± 0.4	81.9 ± 0.4	82.3 ± 0.4	83.9 ± 0.4	84.7 ± 0.4	3.4[a]	<0.001
117 ± 1	118 ± 1	118 ± 1	118 ± 1	118 ± 1	118 ± 1	118 ± 1	−5.4[a]	<0.001
75 ± 0	75 ± 0	76 ± 0	76 ± 0	76 ± 0	76 ± 0	76 ± 0	−2.3	0.021
99.4 ± 0.9	99.9 ± 1.0	100.3 ± 1.0	99.8 ± 0.9	100.3 ± 0.8	100.3 ± 0.8	100.7 ± 0.8	2.2[a]	<0.001
5.74 ± 0.03	5.65 ± 0.03	5.66 ± 0.03	5.64 ± 0.03	5.66 ± 0.03	5.75 ± 0.03	5.76 ± 0.03	0.5	<0.001
137 ± 5	139 ± 5	145 ± 6	136 ± 4	137 ± 4	132 ± 4	137 ± 5	−2.6	0.668
51 ± 1	51 ± 1	51 ± 1	51 ± 1	51 ± 1	53 ± 1	52 ± 1	12.7[a]	<0.001

changes in terms of a balanced diet. However, increased fat consumption from animal sources[32] and the replacement with saturated fatty acids, rather than with unsaturated fatty acids, might be harmful, ultimately requiring attention regarding cardiometabolic diseases.[33]

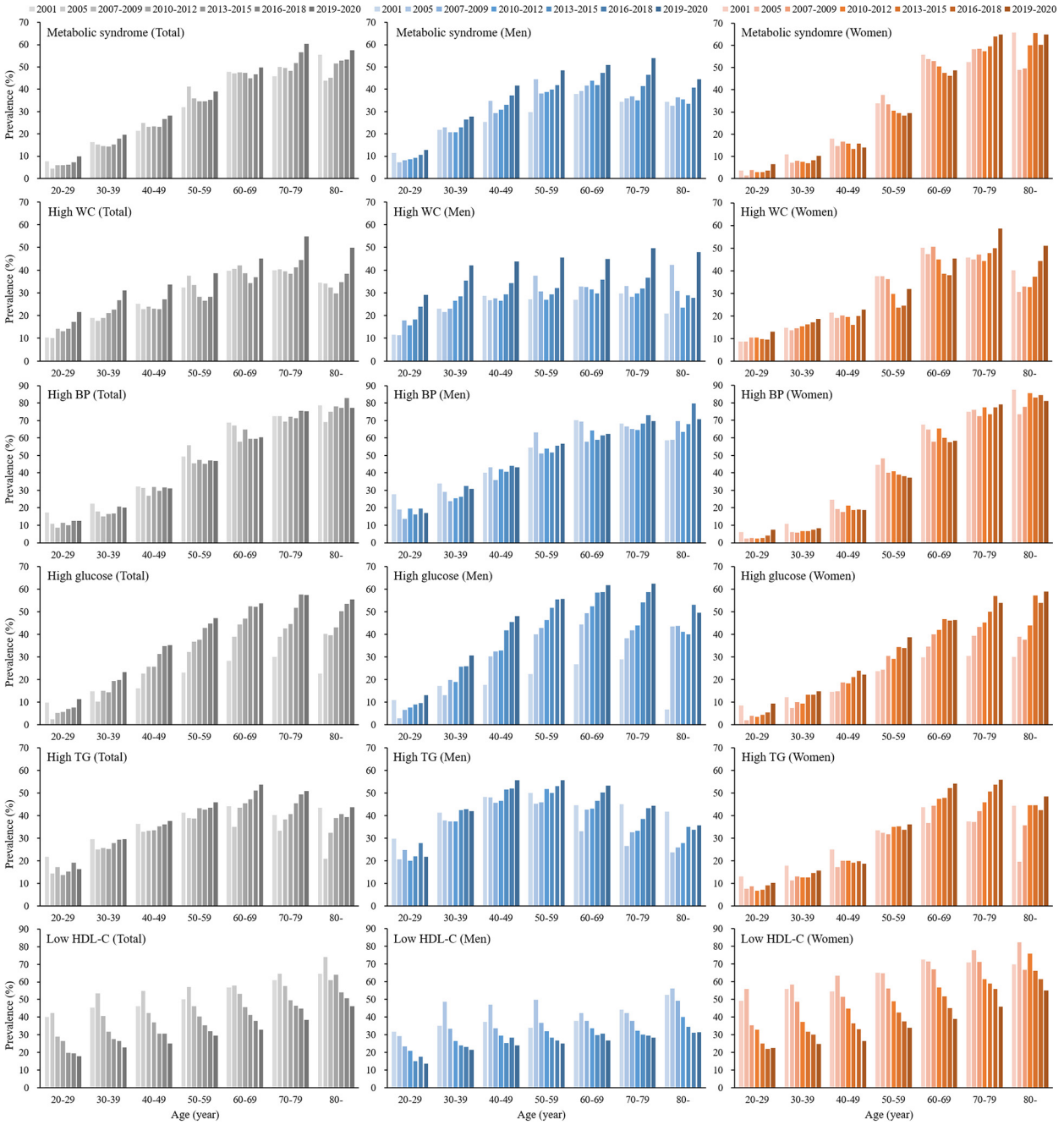
Notably, the prevalence of the low HDL-C criterion decreased from 49.0% in 2001 to 28.6% in 2020. Both a reduction in carbohydrate intake and an increase in unsaturated fat intake might have contributed to the increase in HDL-C levels.[34] More specifically, the consumption of food containing unsaturated fat, such

FIGURE 1 Serial Trends in Metabolic Syndrome and Its Components in Korea



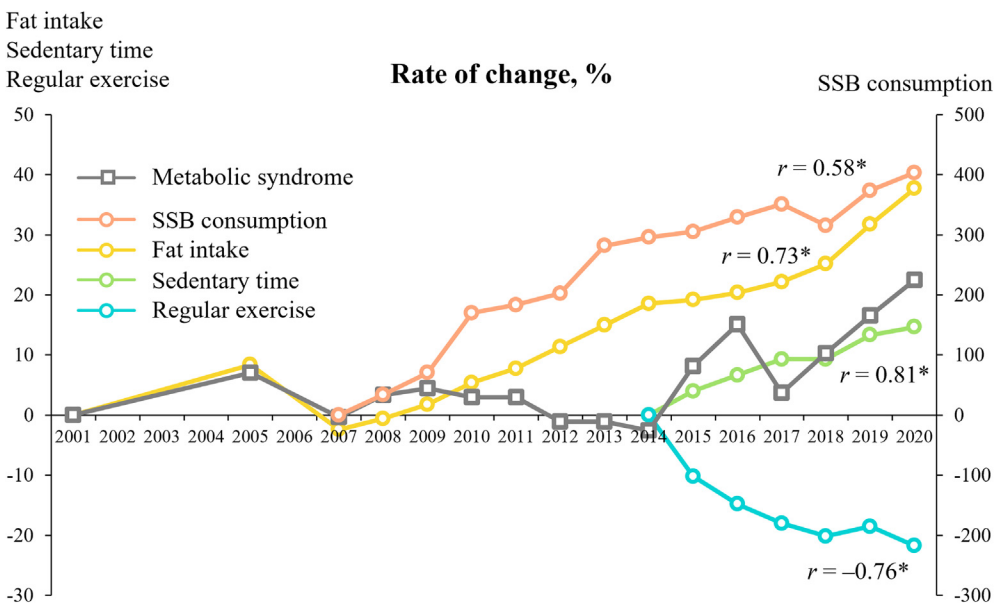
The age-adjusted prevalence of metabolic syndrome increased significantly from 27.1% in 2001 to 33.2% in 2020, which is a 6.1% absolute change over the recent 20 years, with a marked difference between men and women (14.2% in men; −2.0% in women). Among the 5 metabolic syndrome components, high glucose increased the most over 20 years (a 17.9% absolute increase). High waist circumference and hypertriglyceridemia followed, with increases of 12.2% (23.2% in men; 1.6% in women) and 3.8% (5.0% in men; 1.6% in women), respectively. By contrast, the proportions of low high-density lipoprotein (HDL) cholesterol and high blood pressure criteria decreased by 20.4% and 2.5%, respectively, over the same period with a greater decrease in women (11.7% in men and 27.8% in women for HDL cholesterol; 0.5% in men and 5.1% in women for high blood pressure).

FIGURE 2 Prevalence of Metabolic Syndrome by Sex and Age in Korea



In all surveys, there was a tendency for men aged 20 to 59 years to have a relatively higher prevalence of metabolic syndrome, but in subjects ≥60 years of age, women had a higher prevalence than men. This was prominent in high waist circumference (WC) and hypertriglyceridemia. Low high-density lipoprotein cholesterol (HDL-C) was more common in women than men in all age groups. BP = blood pressure; TG = triglyceride.

FIGURE 3 **Correlation Analyses Between Metabolic Syndrome and Lifestyle Factors**



In these correlation analyses, the prevalence of metabolic syndrome had a negative association with regular exercise and positive associations with fat intake and sugar-sweetened beverage (SSB) consumption and sedentary time (*$P < 0.05$). SSB consumption was investigated from 2007 Korea National Health and Nutrition Examination Survey, and sedentary time and regular exercise were assessed from 2014 Korea National Health and Nutrition Examination Survey.

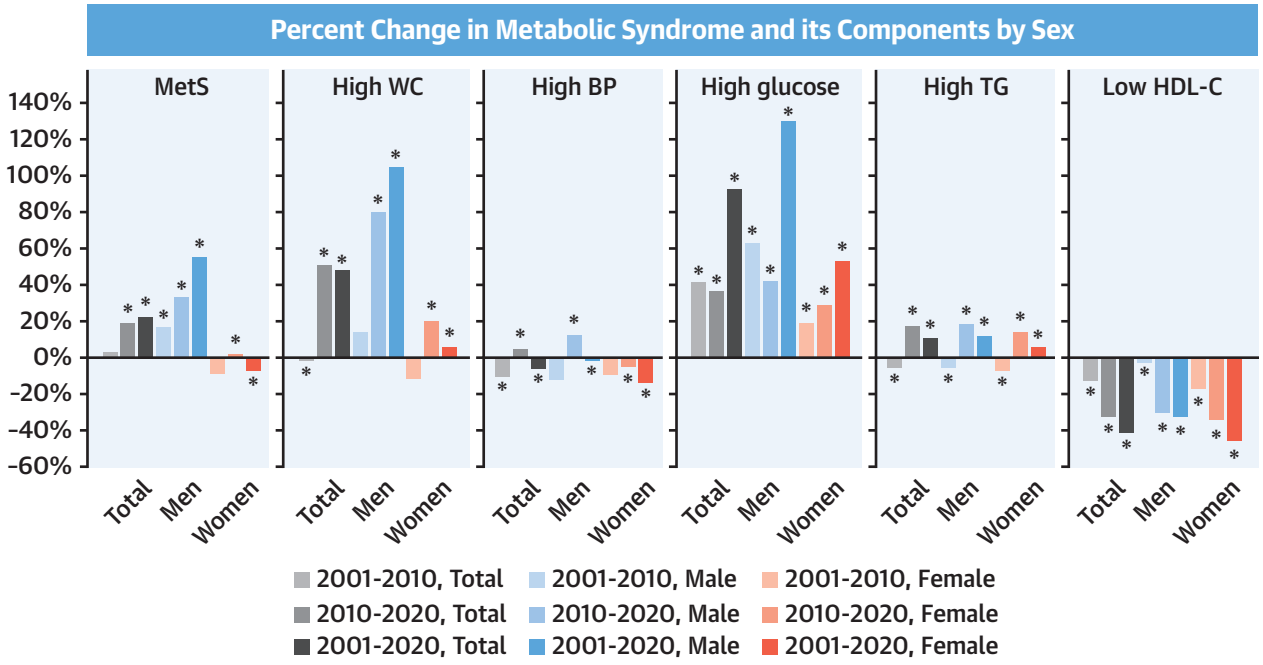
as fish and olive oil, has been increasing in South Korea.[35] In particular, the prevalence of low HDL-C decreased dramatically in women. Although sex differences in HDL-C are generally expected,[36] studies of the South Korean population reported that fat intake affects HDL-C to a greater extent in women than in men.[37] In fact, total daily energy intake decreased by 7.0% in women but increased by 3.7% in men over the same time frame, while the increase in energy intake from fat was greater in women than in men (46.0% vs 30.2%, P <0.05). On the one hand, sociocultural changes in South Korea favoring gender equality and the increase in women's employment might have contributed to a rise in HDL-C in women via their increased financial independence.[38,39]

There were dramatic changes in physical activity and dietary patterns over 20 years. Sedentary time spent per day increased significantly while regular exercise decreased significantly. It is noteworthy that consumption of SSBs, mainly soda and sugar-containing coffee, has increased almost 4-fold from 2007 to 2020 (**Figure 3**). In the correlation analyses, MetS and its several components had negative associations with regular exercise and positive associations with fat intake and SSB consumption and sedentary time. These findings suggest that increasing SSB and fat consumption and decreasing physical activity have contributed to the increasing trend of MetS over the last 20 years.

On the other hand, people with a high BP significantly decreased by 6.0%. Traditionally, Koreans were used to eating a high-salt diet; however, over the recent 20 years, daily salt consumption has decreased significantly (5.5 g in 2001 to 3.4 g in 2020) due to the national campaign encouraging the DASH (Dietary Approaches to Stop Hypertension) diet.[40] The increasing use of refrigerators and freezers has reduced the consumption of salted food.

STUDY STRENGTHS. A strength of this study is the important significance of presenting nationwide trends of MetS for 20 years using large-scale nationally representative data. Another strength is the consistency of the data observed, confirming its trend applicability for other populations. Understanding changes in the prevalence of MetS and its components in South Korea—a country that has undergone rapid economic and socioenvironmental changes

CENTRAL ILLUSTRATION **Important Sex Differences in MetS Trends in Korea**



Park D, et al. JACC: Asia. 2023;3(3):491–502.

The age-adjusted prevalence of metabolic syndrome (MetS) increased significantly from 27.1% in 2001 to 33.2% in 2020 with a marked difference between men (14.2%) and women (−2.0%). Such a sex difference appeared to be driven by a greater increase in the high glucose levels, higher waist circumference (WC), and higher triglyceride (TG) levels in men than in women. In all surveys, there was a tendency for men 20 to 59 years of age to have a relatively higher prevalence of MetS than women, but in subjects ≥60 years of age, women had a higher prevalence than men. BP = blood pressure; HDL-C = high-density lipoprotein cholesterol.

during this period—could be valuable for other countries undergoing such socioeconomic transformation, in helping to develop effective strategies against the development of atherogenic and diabetogenic dysmetabolic profiles.

STUDY LIMITATIONS. This is an analysis of cross-sectional surveys; secular changes of MetS at the individual level cannot be determined. Second, these data could not confirm the causal relationship between changes in lifestyle and MetS due to the limitations of the survey design. However, it can be inferred that the increased consumption of sugar and SSBs and decreasing trends in physical activity over the last 20 years might have contributed to the increasing trend of MetS, particularly the high glucose, high TG, and high WC components, because the secular data about diet and physical activity were obtained from the same KNHANES determining MetS components. Third, single-day 24-hour recall was used for the assessment of dietary intake, which was not able to capture within-individual variation. Fourth, there might be socioenvironmental events that we could not recognize, and these may act as potential confounding factors. Despite these limitations, this study has the important significance of presenting nationwide trends of MetS for 20 years using nationally representative data.

CONCLUSIONS

The prevalence of MetS in South Korea has increased significantly during the past 20 years. Unfavorable lifestyle changes such as a rapid increase in consumption of SSBs and energy-dense foods and physical inactivity might be key mediating factors for the evolving features of MetS. The consumption of processed foods and SSBs is increasing worldwide at an alarming rate. The problematic use of electronic devices induced by the rapid dissemination of smartphones is leading to dramatically decreased physical activity globally. Thus, concerted efforts among

policymakers, health care professionals, and public health educators should be made to induce favorable behavioral changes that can lead to improved metabolic health.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: The prevalence of MetS in South Korea has increased significantly during the past 20 years. Glycemic dysregulation and abdominal obesity are key features contributing to this increase in men. Unfavorable lifestyle changes such as a rapid increase in consumption of processed foods such as SSBs and a dramatic decrease in physical activity induced by problematic use of smartphones and electronic devices seem to be key mediating factors for the evolving features of MetS in South Korea.

TRANSLATIONAL OUTLOOK: Concerted efforts among policymakers, health care professionals, and public health educators should be made to induce favorable behavioral changes that can lead to improved metabolic health of citizens of middle-income countries undergoing a similar socioeconomic transformation.

REFERENCES

1. Hirode G, Wong RJ. Trends in the prevalence of metabolic syndrome in the United States, 2011-2016. *JAMA*. 2020;323:2526–2528.

2. Ranasinghe P, Mathangasinghe Y, Jayawardena R, Hills AP, Misra A. Prevalence and trends of metabolic syndrome among adults in the Asia-Pacific region: a systematic review. *BMC Public Health*. 2017;17:101.

3. Cuevas A, Alvarez V, Carrasco F. Epidemic of metabolic syndrome in Latin America. *Curr Opin Endocrinol Diabetes Obes*. 2011;18:134–138.

4. Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. *Lancet*. 2005;365:1398–1405.

5. Ward ZJ, Bleich SN, Cradock AL, et al. Projected U.S. state-level prevalence of adult obesity and severe obesity. *NEnglJMed*. 2019;381:2440–2450.

6. Misra A, Khurana L. Obesity and the metabolic syndrome in developing countries. *J Clin Endocrinol Metab*. 2008;93:S9–S30.

7. Isomaa B, Almgren P, Tuomi T, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care*. 2001;24:683–689.

8. Pranav S, Katiyar A. Transformation of South Korea from a third world agrarian economy to a technologically advanced first world country. *Int J Adv Res Dev*. 2018;3:166–170.

9. Statista. South Korea: gross domestic product (GDP) in current prices from 1987 to 2027. Accessed July 29, 2022. https://www.statista.com/statistics/263579/gross-domestic-product-gdp-in-south-korea/

10. Alberti KG, Eckel RH, Grundy SM, et al. 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*. 2009;120:1640–1645.

11. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol*. 2014;43:69–77.

12. Koh DH, Kim HR, Han SS. The relationship between chronic rhinosinusitis and occupation: the 1998, 2001, and 2005 Korea National Health and Nutrition Examination Survey (KNHANES). *Am J Ind Med*. 2009;52:179–184.

13. Brogan D. Software for sample survey data, misuse of standard packages. In: Armitage P, Colton T, eds. *Encyclopedia of Biostatistics*. 2nd ed. Wiley; 2005:4167–4174.

14. World Health Organization Regional Office of the Western Pacific. *The Asia-Pacific Perspective: Redefining Obesity and Its Treatment*. Health Communications Australia; 2000.

15. Kim BY, Kang SM, Kang JH, et al. 2020 Korean Society for the Study of Obesity Guidelines for the Management of Obesity in Korea. *J Obes Metab Syndr*. 2021;30:81–92.

16. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation*. 2005;112:2735–2752.

17. Mozumdar A, Liguori G. Persistent increase of prevalence of metabolic syndrome among U.S. adults: NHANES III to NHANES 1999-2006. *Diabetes Care*. 2011;34:216–219.

18. Imamura F, O'Connor L, Ye Z, et al. Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ*. 2015;351:h3576.

19. Neelakantan N, Park SH, Chen GC, van Dam RM. Sugar-sweetened beverage consumption, weight gain, and risk of type 2 diabetes and cardiovascular diseases in Asia: a systematic review. *Nutr Rev*. 2021;80:50–67.

20. Li M, Shi Z. Ultra-processed food consumption associated with overweight/obesity among Chinese adults-results from China Health and Nutrition Survey 1997-2011. *Nutrients*. 2021;13:2796.

21. Malik VS, Hu FB. The role of sugar-sweetened beverages in the global epidemics of obesity and chronic diseases. *Nat Rev Endocrinol*. 2022;18:205–218.

22. Lim S, Kim JW, Targher G. Links between metabolic syndrome and metabolic dysfunction-associated fatty liver disease. *Trends Endocrinol Metab*. 2021;32:500–514.

23. Malik VS, Li Y, Pan A, et al. Long-term consumption of sugar-sweetened and artificially sweetened beverages and risk of mortality in US adults. *Circulation*. 2019;139:2113–2125.

24. Guideline: Sugars Intake for Adults and Children. World Health Organization; 2015. Accessed July 29, 2022. https://www.who.int/publications/i/item/9789241549028

25. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev*. 2013;14:606–619.

26. Thow AM, Rippin HL, Mulcahy G, Duffey K, Wickramasinghe K. Sugar-sweetened beverage taxes in Europe: learning for the future. *Eur J Public Health*. 2022;32:273–280.

27. Nam GE, Kim YH, Han K, et al. Obesity fact sheet in Korea, 2020: prevalence of obesity by

obesity class from 2009 to 2018. *J Obes Metab Syndr*. 2021;30:141–148.

28. Organization for Economic Co-operation Development. OECD.Stat. ICT access and usage by households and individuals. 2022. Accessed July 29, 2022. https://stats.oecd.org/Index.aspx?DataSetCode=ICT_HH2

29. Stefan N. Causes, consequences, and treatment of metabolically unhealthy fat distribution. *Lancet Diabetes Endocrinol*. 2020;8:616–627.

30. Trumbo P, Schlicker S, Yates AA, Poos M. Food and Nutrition Board of the Institute of Medicine, The National Academies. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc*. 2002;102:1621–1630.

31. Mente A, Dehghan M, Rangarajan S, et al. Association of dietary nutrients with blood lipids and blood pressure in 18 countries: a cross-sectional analysis from the PURE study. *Lancet Diabetes Endocrinol*. 2017;5:774–787.

32. Song S, Shim JE. Food behaviors accounting for the recent trends in dietary fatty acid profiles among Korean adults. *Nutr Res Pract*. 2022;16:405–417.

33. Lee KW, Cho Y, Jo G, Park YK, Shin MJ. Association of dietary intakes of total and subtypes of fat substituted for carbohydrate with metabolic syndrome in Koreans. *Endocr J*. 2016;63:991–999.

34. Lee HS, Duffey KJ, Popkin BM. South Korea's entry to the global food economy: shifts in consumption of food between 1998 and 2009. *Asia Pac J Clin Nutr*. 2012;21:618–629.

35. Ahn J, Kim NS, Lee BK, Park Kim S. Trends in the intake of fatty acids and their food source according to obese status among Korean adult population using KNHANES 2007-2017. *Food Nutr Bull*. 2020;41:77–88.

36. Davis CE, Williams DH, Oganov RG, et al. Sex difference in high density lipoprotein cholesterol in six countries. *Am J Epidemiol*. 1996;143:1100–1106.

37. Kim HJ, Park HA, Cho YG, et al. Gender difference in the level of HDL cholesterol in Korean adults. *Korean J Fam Med*. 2011;32:173–181.

38. Cooke FL. Women's participation in employment in Asia: a comparative analysis of China, India, Japan and South Korea. *Int J Hum Resour Manage*. 2010;21:2249–2270.

39. Grant BF, Chou SP, Saha TD, et al. Prevalence of 12-month alcohol use, high-risk drinking, and DSM-IV alcohol use disorder in the United States, 2001-2002 to 2012-2013: results from the National Epidemiologic Survey on Alcohol and Related Conditions. *JAMA Psychiatry*. 2017;74:911–923.

40. *National Nutrition Survey Report 1995*. Republic of Korea: Ministry of Health and Welfare; 1997.

KEY WORDS diet, epidemiology, lifestyle, metabolic syndrome, sex difference

APPENDIX For supplemental Methods, tables, and a figure, please see the online version of this paper.