Impact of COVID-19 and Associated Preventive Measures on Cardiometabolic Risk Factors in South Korea

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Abstract

Background: During the COVID-19 pandemic, people have been required to follow preventive measures such as government policy including the closure of exercise facilities and movement restriction, can lead to an unhealthy lifestyle. We investigated the effect of these preventive measures on metabolic parameters in individuals with cardiometabolic disorders.

Methods: In the current retrospective observational study of patients who visited the hospital at least twice a year for the past 4 years, changes in cardiometabolic factors from the COVID-19 pandemic (2019–2020) were compared with changes in the same cohort at the same annual time points during the previous seasons of 2016–2019.

Results: A total of 1,485 individuals with a mean age of 61.8 ± 11.7 years were included in the analysis. During the COVID-19 pandemic, the number of patients whose metabolic syndrome worsened increased significantly by 21% compared with the 2018–2019 season. The body mass index increased by 0.09 ± 1.16 kg/m2 in the 2019–2020 pandemic period, whereas it decreased by −0.39 ± 3.03 kg/m2 in 2018–2019 and by −0.34 ± 2.18 kg/m2 in 2017–2018 (both $p < 0.05$). Systolic blood pressure increased by 2.6 ± 18.2 mmHg in the COVID-19 pandemic period, while it decreased in the three antecedent seasons (all $p < 0.05$). The lipid profiles worsened in the pandemic period compared with the previous years. The Framingham coronary heart disease risk score also increased significantly.

Conclusions: With preventive procedures during the contagious disease pandemic, nationwide strategies to maintain cardiometabolic health are necessary.

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection causes coronavirus disease 2019 (COVID-19). As of February 23, 2021, 111,365,509 cases and 2,466,239 deaths have been confirmed [1]. SARS-CoV-2 induces mild symptoms in the initial stage but has the potential to result in severe illness, including a systemic inflammatory response syndrome, acute respiratory distress syndrome, multiorgan involvement, and shock [2].

In South Korea, the COVID-19 pandemic broke out in February 2020 (**Fig. 1A**), and the government raised the crisis alert level to "severe," the highest (**Fig. 1B**). The infectious disease prevention and control measures included shutting down public facilities such as libraries and sports centers, and suspending school attendance. The public was requested to refrain from going outside unnecessarily, except for commuting to/from work, and to maintain at least 1–2 meters distance from others in the workplace [3]. As a result, personal movements based on mobile big data decreased by 38.1% during the early period of the COVID-19 outbreak compared with before the outbreak [4]. Thanks to these preventive measures and cooperation from the general public, the number of daily new domestic infections in South Korea fell dramatically.

In the early days following the introduction of the measures, people were cautious and made lifestyle changes, but people became less cautious over time. The infection rate dropped from 441 to 47 per day as of October 15, 2020— although it has risen to 621 per day as of February 17, 2021 [5]. The Korean government has again raised the crisis alert level, which means stricter observation of social distancing, and a ban on staying in public places and in indoor health facilities, cafés, bars, and any places where people can get together, and is also prohibiting large-scale gatherings (see http://ncov.mohw.go.kr/en).

Several groups including ours, have reported that old age, diabetes mellitus (DM), cardiovascular disease (CVD), hypertension, metabolic syndrome, and obesity are risk factors for fatal outcomes of COVID-19 [6]. People with coronary heart disease (CHD) or DM had a higher chance of being admitted to intensive care units, needing mechanical ventilation, or of dying due to SARS-CoV-2 infection [7]. Because elevated glucose levels directly promote SARS-CoV-2 replication, which essentially requires glycolysis in the host [8], patients with uncontrolled DM are expected to experience a more rapid progression of COVID-19 [6]. Moreover, metabolic syndrome induces host immune dysregulation and pro-inflammatory milieu, leading to increased severity and mortality in COVID-19 via vasculopathy, thrombosis, and coagulopathy [9].

Conversely, inactivity associated with social and physical distancing for COVID-19 might impair metabolic control [10]. Thus, the preventive measures initiated as a response to the COVID-19 pandemic, such as preventing people from going outdoors and shutting down exercise facilities, are likely to have a negative influence on public lifestyle and behaviors [11], which could adversely affect cardiometabolic health [12]. So far, the exact effects of COVID-19 prevention and related control measures on the impact of such chronic diseases have not yet been evaluated. Here, we hypothesized that the COVID-19 pandemic and associated unhealthy lifestyles have produced negative influences on metabolic parameters in individuals with cardiometabolic risk factors.

Methods

Study design and population

This was a single-center, retrospective, observational cohort study conducted at Seoul National University Bundang Hospital (SNUBH) in South Korea. The study was approved by our independent Ethics Committee/Institutional Review Board (SNUBH: B-2008/630-102). The study population was adults aged over 19 years with diagnosed cardiometabolic risk factors including impaired glucose metabolism, hypertension, dyslipidemia, or obesity who visited the outpatients' clinic at the Department of Endocrinology and Metabolism at SNUBH. Patients who visited from September 1, 2016 to May 31, 2020 at least twice a year, before and after February, the time of South Korea's COVID-19 outbreak, were further selected. In all, 7,094 patients were identified to have International Classification of Diseases Tenth Edition (ICD-10) diagnostic codes of E10–14 for DM, I10 and I15 for hypertension, E78 for dyslipidemia, and E66 for obesity using the hospital database, clinical data warehouse (CDW) [13].

Patients who were hospitalized for a major illness or major surgery, and who received dialysis during the study period were excluded (**Supplementary Fig. 1**). Major surgery was defined as surgery performed for neoplasms, diseases of the blood-forming organs, circulatory, or digestive systems, or injuries determined by ICD-10 codes starting with C, D, I, K, or S. The number of patients hospitalized in the endocrinology unit did not differ between years, but they were excluded from the study analysis because hospitalization for intensive glucose-lowering therapy might have hindered identifying the impact of pandemic preventive measures. The number of patients who visited the outpatients' clinic during the COVID-19 pandemic was similar to the numbers who visited the clinic during the same time frame in previous years. Thus, the loss of follow-up during the study period was unlikely to affect the study results.

Collection of clinical parameters

The Korean government reinforced the national public health emergency response by emphasizing the need to maintain social distance on February 29, 2020. Therefore, we divided the clinical data according to the date of examination: (i) from September 2019 to November 2019 ("fall"); (ii) from December 2019 to February 2020

("winter"), and (iii) from March 2020 to May ("spring"), and compared the clinical parameters in each season with those of the previous years (2016–2017, 2017–2018, and 2018–2019; Fig. 1C).

Patients' outpatient care information, admission information, clinical laboratory values, anthropometric measurements, and prescription information were retrieved from the CDW. Body weight, body mass index (BMI), systolic and diastolic blood pressure (SBP and DBP, respectively), and metabolic profiles such as the levels of fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), total cholesterol, triglyceride (TG), high-density lipoprotein-cholesterol (HDL-c), and low-density lipoprotein-cholesterol (LDL-c) in each season were analyzed as means for each individual. Data cleaning was performed for manually inputted anthropometrics into the system at the time of care. Values that were obviously inaccurate, provided in ranges, or physically impossible and considered as typographic errors were discarded, such as height >300 cm, body weight <10 kg, and DBP > SBP. For clinical values with a high standard deviation (SD) in each individual, such as SBP SD >50 or weight SD >10, the consecutive measurements were checked further to determine whether this was an error or a change of clinical status. Height was converted to a 4-year mean measure for each patient considering the measurement variation. Then, the BMI was recalculated as mass (in kilograms) divided by height (in meters) squared. The use of medications for DM, hypertension, and dyslipidemia was also investigated.

Anthropometric and biochemical parameters

Anthropometric and biochemical parameters were measured in SNUBH as reported previously [14]. Height and body weight were measured using standard methods with the subjects in light clothing. The FPG concentration was measured using the glucose oxidase method (747 Clinical Chemistry Analyzer; Hitachi, Tokyo, Japan). HbA1c levels were measured using a Bio-Rad Variant II Turbo High-Performance Liquid Chromatography Analyzer (Bio-Rad, Hercules, CA, USA) in a National Glycohemoglobin Standardization Program level II certified laboratory. Total cholesterol, TG, HDL-c, and LDL-c levels were measured using a 747 Clinical Chemistry Analyzer (Hitachi).

Metabolic syndrome was defined using modified Adult Treatment Panel III criteria [15]. Because the waist circumference data were limited, the World Health Organization Asia-Pacific criteria for BMI were used [16]; metabolic syndrome was diagnosed as the existence of at least three abnormal components of: (i) FPG ³ 100 mg/dL and/or taking antidiabetic agents; (ii) SBP ³ 130 mmHg, DBP ³ 85 mmHg, and/or taking antihypertensive agents; (iii) TG ³ 150 mg/dL and/or taking lipid-lowering agents; (iv) HDL-c £ 40 mg/dL in men and HDL-c ≤ 50 mg/dL in women, and (v) BMI ³ 23 kg/m^2 and/or taking anti-obesity agents. Patients with HbA1c ³ 6.5% and/or taking antidiabetic agents were classified according to the state of DM treatment.

The 10-year CHD risk was calculated using the Framingham risk score (FRS) [17]. The correlation of calculated CHD risk with actual 10-year CHD was shown to be stronger when using total cholesterol levels than when using LDL-c scoring in Korean subjects [18]. Therefore, the FRS with total cholesterol scoring was used here.

Statistics

All data were obtained for the same subject in all 4 periods/seasons. Continuous variables are summarized as the mean ± SD and categorical variables are shown as the numbers and percentages of subjects. Normality of data distribution was evaluated using the Shapiro−Wilk test and by histograms, which showed all variables to be normally distributed with bell-shaped symmetric graphs. Student's t tests for continuous variables and chi-squared tests for

categorical variables were used for comparisons. The changes in values from winter 2019 to spring 2020 for the 2019–2020 season and those from the same time frame from 2016 to 2019 for 2016–2017, 2017–2018, and 2018–2019 seasons were obtained. The values in the 2019–2020 season were compared with those of each previous season using paired Student's t tests, with Holm–Bonferroni correction. Because the patient follow-up period was up to 6 months, not all the patients had complete seasonal data. To reduce the bias of visiting patient's characteristics, the dataset was imputed using multiple imputation by chained equations for the missing values from patients who did not have complete test results [19]. The imputed data were used to analyze changes in values. Relative risk (RR) was calculated as the number of patients who showed worse metabolic syndrome components in the 2019–2020 season than those in the 2018–2019 season, expressed as RR with a 95% confidence interval (CI). Subgroup comparisons of risk estimates by age and sex were made with test of interaction [20]. Statistical significance was considered at a two-sided p value < 0.05. All analyses were performed using R software version 4.0.2 (R Development Core Team, Vienna, Austria) and RStudio version 1.3.1056 (RStudio, Inc., Boston, MA, USA).

Results

Patient characteristics

A total of 1,485 patients were included in this study, with a mean age of 61.8 ± 11.7 years in September 2016. The proportions of men and women were almost equal among the study participants (Male: n = 757, 51.0%). All of them had at least one chronic cardiometabolic impairment such as DM, hypertension, dyslipidemia, or obesity at baseline (**Table 1**). The number of comorbid diseases tended to increase with time. The total use of antidiabetic agents increased in 2019 compared with 2016. The total use of antiobesity agents increased in 2019–2020 compared with the previous 3 years. The usage of recently approved antidiabetic drugs, sodium–glucose co-transporter 2 (SGLT-2) inhibitors and glucagon-like peptide-1 receptor agonists (GLP-1 RAs), increased in 2019–2020 (**Table 1**).

Changes in cardiometabolic risk factors during the COVID-19 pandemic

The raw values of cardiometabolic risk components before and during the COVID-19 pandemic and preventive measures are shown in **Fig. 2**. The body weight, BMI, SBP, and DBP values were higher in the spring of 2020 compared with the springs of other years. The increase in HbA1c levels was most prominent in the final seasons, from 7.27 ± 1.24% in the winter of 2019 to 7.33 ± 1.25% in the spring of 2020 (2019–2020 season) compared with other seasons. Differences in the levels of other factors—FPG, triglycerides, and HDL-c—were similar across all four years. The differences in cardiometabolic risk factors are shown in **Table 2**. The SBP and total cholesterol measures increased significantly during the COVID-19 pandemic when compared with the past three years. Increases in body weight and BMI were statistically significant in the 2019–2020 season when compared with those in the 2017–2018 and 2018–2019 seasons.

Risk of developing metabolic syndrome during the COVID-19 pandemic

During the COVID-19 pandemic, the number of patients who worsened in terms of metabolic syndrome increased: 375 (25.3%) in 2019–2020 vs 309 (20.8%) in 2018–2019; RR 1.21, 95% CI 1.06–1.39) (**Fig. 3A**). Blood pressure and HbA1c levels increased significantly in the 2019–2020 COVID-19 season compared with the previous 2018–2019

season. In the comparison by the age of 65 years, patients aged under 65 years developed metabolic syndrome more during the COVID-19 pandemic season than the previous year (RR 1.24, 95% CI 1.02–1.52), compared with those < 65 years (RR 1.18, 95% CI 0.98–1.40). Among the metabolic syndrome components, the low HDL-c component increased most prominently in this elderly group (RR 1.25, 95% CI 1.01–1.54) (**Fig. 3B**). In the comparison by gender, male subjects displayed a higher RR for the development of metabolic syndrome during the COVID-19 pandemic than female subject, but there was no significant difference between them (p = 0.059). Among the metabolic syndrome components, blood pressure and low HDL-cholesterol components, and the HbA1c level increased significantly in males, while no component increased significantly in females during the COVID-19 pandemic (**Fig. 3C**).

Changes in coronary heart disease risk during the COVID-19 pandemic

The changes in 10-year CHD risk by FRS are shown in **Fig. 4**. The 10-year CHD risk increased in the 2019–2020 season, but not in the other three seasons: 1.0 ± 6.2% in 2019–2020 vs −0.7 ± 6.0% in 2018–2019, −0.2 ± 5.3% in 2017–2018, and −0.2 ± 5.4% in 2016–2017, p < 0.05. During the COVID-19 pandemic, the number of patients with a 10-year CHD risk of low to intermediate significantly increased, compared with those in the three preceding seasons (176 in 2019–2020 vs 141 in 2016–2017, 86 in 2017–2018, and 113 in 2018–2019, all p < 0.05). The number of patients in 2017–2018 (86) was significantly lower than the number in 2016–2017 and in 2018–2019.

Discussion

Here, we found that cardiometabolic risk factors deteriorated significantly in subjects with metabolic impairment in South Korea during the COVID-19 pandemic and its preventive measures. In this critical 2019–2020 season, the proportion of subjects with metabolic syndrome increased significantly by 21% compared with the 2018–2019 season. The 10-year CHD risk also increased compared with the previous three years. We also found that not only the body weight or BMI but also blood pressures, lipid profiles, and HbA1c changed in an unfavorable direction during the COVID-19 pandemic and its preventive measures.

The preventive measures against the COVID-19 outbreak implemented in South Korea include recommending social distancing of 1–2 meters, telecommuting, remote classes, and closure of exercise facilities, such as community health centers, private fitness centers, swimming pools, and parks (described in Korean at http://ncov.mohw.go.kr/socdisBoardView.do?brdId=6&brdGubun=1). These measures might contribute to an aggravation of cardiometabolic risk factors in patients who have underlying metabolic dysregulation. According to mobile big data [4], because of the social distancing policy, personal movement of the general public in South Korea decreased by 38.1% in the 4th week of the COVID-19 outbreak (February 24–March 1, 2020), compared with the period before a confirmed COVID-19 case was identified (January 9–22, 2020). Like many countries, trips to all major destinations except to personal residences in South Korea dropped significantly by 50 to 80% in early March 2020 when COVID-19 was declared a pandemic (https://kojects.com/2020/06/01/mobility-korea-covid-19/). A recent self-reporting survey showed that people spent more time at home and actually gained weight during the COVID-19 pandemic [21]. It was reported that acutely reduced physical activities during the COVID-19 pandemic might contribute to aggravating insulin resistance and gaining body weight [22].

In addition, various public health interventions including staying at home, refraining from nonessential social activities, and school closures limit access to healthy food options [10]. Based on the data derived from the leading

food delivery apps in Korea (Baemin [https://www.baemin.com] and Yogiyo [www.yogiyo.co.kr]), the number of food deliveries increased by 11% during February 1–16, compared with January 6–21, after the virus had spread across the country (https://pulse news.co.kr/view.php?sc=30800 022&year=2020&no=176494). Popular delivered foods were fast foods such as pizza, fried chicken, French fries, and sugar-containing drinks [23]. These foods are reported to be more obesogenic than homemade foods [24]. More specifically, Korean-style fast foods are popular in South Korea because they are less expensive and easier to order regardless of household income levels and residential location [25]. Of particular concern, Korean-style fast foods contain high-carbohydrate ingredients such as white flour, white rice, and cornstarch. The increased consumption of these foods is associated with increased energy density and high glycemic load [26]. Some previous studies have shown that increased consumption of fast food and sugar-containing drinks is associated with an increased risk of obesity, metabolic syndrome, and DM [26, 27].

From a sociological context, the COVID-19 pandemic has produced economic disruption and many households are suffering financial distress, limiting their access to healthy foods. In addition, a decrease in outdoor activities and an increase in time spent using the Internet and social network services, playing online games, and watching TV may have also contributed to a harmful impact on their diet [28]. Thus, preventive measures against the COVID-19 outbreak may have contributed to a sedentary lifestyle and unhealthy nutrition among the general public.

We found that the 10-year CHD risk of patients has increased during the COVID-19 pandemic in South Korea. Patients aged ³ 65 years displayed an increasing trend in their 10-year CHD risk score (1.2 ± 7.1%, p = 0.08) during the 2019–2020 season compared with the previous 2018–2019 season, which may have contributed to the increased mortality rate in the elderly during the COVID-19 pandemic.

In the current analysis, body weight, blood pressure, and lipid levels decreased in spring except for the 2019–2020 COVID-19 pandemic season. This is a similar finding to the results reported in previous studies [29-31]. In contrast, the cardiometabolic risk parameters in our cohort increased significantly during the COVID-19 pandemic and its preventive measures. This opposite trend suggests that the unfavorable impact of the pandemic and its preventive procedures on cardiometabolic risk parameters.

Other mechanisms have been suggested to explain the association of the COVID-19 pandemic and related procedures, and the aggravation of metabolic profiles and increased cardiovascular risk. It is clear that the COVID-19 pandemic is having a negative influence on mental health [32]. Many people are psychologically distressed due to a fear of infection or dying, which might lead to systemic inflammation [33]. Limited access to exercise facilities and disruption of human relationships also increase psychological stress levels, which is likely to contribute to elevations in blood pressure and dysregulation of glucose homeostasis by releasing stress hormones such as cortisol and catecholamines via the hypothalamic–pituitary–adrenal axis [34]. In fact, the sympathetic system is activated with increased levels of catecholamines after catastrophic events, which influences the heart and blood vessels negatively [35]. In metabolic dysregulated status, the renin–angiotensin system is activated inappropriately, which also leads to increased production of angiotensinogen (up to 30% of circulating angiotensinogen) and to elevated plasma renin activity, which in turn contributes to increasing blood pressure and deteriorating glucose metabolism [36]. Although the effects of this pandemic may not be seen in the short term, its long-term impacts on cardiometabolic risk cannot be ignored given the stressful socioeconomic conditions [12].

In this study, both males and patients under 65 years displayed a significantly increased risk of metabolic syndrome and low HDL-c component during the COVID-19 pandemic compared with previous seasons in each population. In general, middle-aged men are more involved in economic activity than women or elderly populations [37]. Based on

this, current preventive measures might have a greater impact on cardiometabolic profiles in male and patients under 65 years of age.

In this analysis, compared with other cardiometabolic parameters, there was no increase in the HbA1c levels during the COVID-19 pandemic. The results might be because of increased usage of potent novel antidiabetic agents such as SGLT-2 inhibitors and GLP-1 RAs. Indeed, the patients who started SGLT-2 inhibitors after September 2019 showed reductions in HbA1c levels in the spring of 2020 (data not shown). Importantly, SGLT-2 inhibitors should be avoided for severely ill patients because this agent can cause ketoacidosis and acute kidney injury [6]. The use of liraglutide also increased more than fivefold in the 2019–2020 season compared with previous seasons. Given that the beneficial roles of GLP-1 RAs for preventing cardiovascular and kidney diseases have been well established [38], these can be an ideal option for the treatment of patients with type 2 DM at such risk even during the COVID-19 pandemic [6].

Considering the deterioration in cardiometabolic profiles during the COVID-19 pandemic, physicians should focus on patients with metabolic impairments to prevent future adverse cardiovascular events. Elevated release of cytokines in metabolic syndrome status is likely to provoke a "cytokine storm" in those individuals infected with SARS-CoV-2, which may lead to multiorgan failure [39]. Governments and medical institutions must promote physical activity, healthy eating, and mental health care during such pandemics. Social media or web-based programs can provide convenient tools to guide such patients to have healthy lifestyles. Active counseling to help people with metabolic dysregulation cope with barriers against healthier lifestyles would be helpful in this critical situation [40].

Our research had advantages in that we exclusively included regularly attending outpatients, who were followed up for four years to reduce bias. Nonetheless, some limitations need to be mentioned. The study population was from a single center and only individuals who visited at least twice a year during 2016–2020 were included. Thus, the results reported might not be representative of the broader population in Korea. We did not investigate changes in physical activity or dietary habits in the study subjects. Moreover, it was not possible to observe the actual occurrence of CHD given the short observation period. Instead, we used the 10-year CHD risk estimated from the FRS, but this is a well-established tool that has been used widely for this purpose [17].

In conclusion, we found that the COVID-19 pandemic and its preventive measures had a negative influence on cardiometabolic profiles in subjects with metabolic impairments. This might be because of decreased physical activity and unhealthy dietary patterns linked to preventive principles such as social distancing and lockdown. According to the Community Mobility Reports released by Google (https://www.google.com/covid19/mobility/?hl = en-GB), the movement trends are decreasing in many countries during the COVID-19 pandemic. From this phenomenon, we can speculate that similar aggravation in cardiometabolic risks can be found in other countries struggling with the pandemic. At present, most patients who die from COVID-19 are in their 70s or 80s. Of note, it should be kept in mind that individuals with cardiometabolic risk factors are more vulnerable to SARS-CoV-2 infection and have a higher chance of mortality compared with those without. This means that the COVID-19 pandemic will lead to more serious collateral health problems in not-very-old populations through increasing comorbidity and mortality induced by aggravations of cardiovascular and metabolic disorders. From a long-term perspective, encouraging home exercise and healthy homemade meals is strongly recommended to mitigate the unfavorable impact of COVID-19 and the related government preventive policy on cardiometabolic risks.

Abbreviations

BMI: Body mass index; CDW: Clinical data warehouse; CHD: Coronary heart disease; CI: Confidence interval; COVID-19: Coronavirus disease 2019; CVD: Cardiovascular disease; DBP: Diastolic blood pressure; DM: Diabetes mellitus;

FPG: Fasting plasma glucose; FRS: Framingham risk score; GLP-1 RAs: Glucagon-like peptide-1 receptor agonists; HbA1c: Glycated hemoglobin; HDL-c: High-density lipoprotein-cholesterol; ICD-10: International Classification of Diseases Tenth Edition; LDL-c: Low-density lipoprotein-cholesterol; RR: Relative risk; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2; SBP: Systolic blood pressure; SD: Standard deviation; SGLT2: Sodium−glucose co-transporter 2; SNUBH: Seoul National University Bundang Hospital; TG: Triglyceride

Declarations

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None.

CONFLICTS OF INTEREST

No declaration.

AUTHOR CONTRIBUTIONS

Conception or design: MS, BKK, SL Acquisition, analysis, or interpretation of data: MS, SL Drafting the work or revising: MS, SL Final approval of the manuscript: MS, BKK, HIY, KHS, ESK, HBK, SL.

Ethics approval and consent to participate

Approval for this study was provided by the independent Ethics Committee/Institutional Review Board of Seoul National University Bundang Hospital (SNUBH: B-2008/630-102). Need for consent was waived in this study.

Consent for publication

Not applicable.

Availability of data and materials

All datasets used and analyzed during this study are available from the corresponding author on reasonable request.

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Tables

Table 1. Patients' characteristics

	Winter 2016	Winter 2017	Winter 2018	Winter 2019
Comorbid status				
Diabetes mellitus	1348 (90.8%)	1348 (90.8%)	1348 (90.8%)	1350 (90.9%)
Hypertension	814 (54.8%)	834 (56.2%)	840 (56.6%)	849 (57.2%)
Dyslipidemia	1162 (78.2%)	1158 (78.0%)	1163 (78.3%)	1169 (78.7%)
Obesity	740 (49.8%)	778 (52.4%)	753 (50.7%)	689 (46.4%)
Concomitant medications				
Antidiabetic agents, n (%)	1159 (78.0%)	1181 (79.5%)	1207 (81.3%)[a]	1212 (81.6%)[a]
Insulin, n (%)	190 (12.8%)	192 (12.9%)	188 (12.7%)	218 (14.7%)
Metformin, n (%)	1087 (73.2%)	1100 (74.1%)	1123 (75.6%)	1113 (74.9%)
DPP4 inhibitors, n (%)	590 (39.7%)	570 (38.4%)	561 (37.8%)	557 (37.5%)
SGLT-2 inhibitors, n (%)	79 (5.3%)	102 (6.9%)	174 (11.7%)[a,b]	209 (14.1%)[a,b]
Sulfonylureas, n (%)	485 (32.7%)	511 (34.4%)	519 (34.9%)	520 (35.0%)
Thiazolidinediones, n (%)	92 (6.2%)	84 (5.7%)	73 (4.9%)	68 (4.6%)
a-glucosidase inhibitors, n (%)	6 (0.4%)	5 (0.3%)	5 (0.3%)	4 (0.3%)
GLP-1 RAs, n (%)	4 (0.3%)	6 (0.4%)	14 (0.9%)	14 (0.9%)[a]
Antihypertensive agents, n (%)	726 (48.9%)	753 (50.7%)	763 (51.4%)	767 (51.6%)
ACE inhibitors, n (%)	65 (4.4%)	64 (4.3%)	64 (4.3%)	58 (3.9%)
ARBs, n (%)	554 (37.3%)	556 (37.4%)	570 (38.4%)	580 (39.1%)
CCB, n (%)	398 (26.8%)	421 (28.4%)	429 (28.9%)	431 (29.0%)
Diuretics, n (%)	92 (6.2%)	101 (6.8%)	103 (6.9%)	109 (7.3%)
b-blockers, n (%)	90 (6.1%)	108 (7.3%)	108 (7.3%)	96 (6.5%)
Lipid-lowering agents, n (%)	887 (59.7%)	888 (59.8%)	891 (60.0%)	907 (61.1%)
Statins, n (%)	878 (59.1%)	877 (59.1%)	880 (59.3%)	893 (60.1%)
Ezetimibe, n (%)	160 (10.8%)	171 (11.5%)	186 (12.5%)	182 (12.3%)
PCSK9 inhibitors, n (%)	0 (0%)	0 (0%)	0 (0%)	1 (0.1%)
Fibrates, n (%)	36 (2.4%)	57 (3.8%)	28 (1.9%)[b]	33 (2.2%)[b]
Cholestyramine resin, n (%)	1 (0.1%)	0 (0%)	1 (0.1%)	1 (0.1%)
Nicotinic acid, n (%)	1 (0.1%)	0 (0%)	0 (0%)	0 (0%)
Omega 3 fatty acid, n (%)	15 (1.0%)	12 (0.8%)	15 (1.0%)	21 (1.4%)
Anti-obesity agents, n (%)	1 (0.1%)	2 (0.1%)	7 (0.5%)[a]	41 (2.8%)[a,b,c]

Liraglutide 3 mg, n (%)	0 (0%)	0 (0%)	7 (0.5%)[a,b]	40 (2.7%)[a,b,c]
Orlistat, n (%)	1 (0.1%)	0 (0%)	0 (0%)	0 (0%)
Phentermine/Topiramate, n (%)	0 (0%)	1 (0.1%)	0 (0%)	0 (0%)
Naltrexone/Bupropion, n (%)	0 (0%)	1 (0.1%)	0 (0%)	1 (0.1%)

Abbreviations: DPP4, dipeptidyl peptidase-4; SGLT-2, sodium–glucose co-transporter 2; GLP-1 RA, glucagon-like peptide-1 receptor agonist; ACE, angiotensin-converting enzyme; ARB, angiotensin II receptor blocker; CCB, calcium channel blocker; PCSK9, proprotein convertase subtilisin/kexin type 9

[a]$p < 0.05$ compared with the fall and winter of 2016; [b]$p < 0.05$ compared with the fall and winter of 2017; [c]$p < 0.05$ compared with the fall and winter of 2018

Table 2. Changes of metabolic syndrome components before (winter) and during (spring) the South Korea COVID-19 pandemic

Variables	Winter 2016	Spring 2017	2016-2017 changes	Winter 2017	Spring 2018	2017–2018 changes	Winter 2018	Spring 2019	2018–2019 changes	Winter 2019	Spring 2020	2019–2020 changes
Bwt, kg	66.9 ± 12.3	66.8 ± 12.2	-0.07 ± 5.12	67.5 ± 11.4	66.6 ± 12.2	-0.89 ± 5.94[a]	67.2 ± 12.7	66.2 ± 11.7	-1.04 ±7.75[a]	65.8 ± 11.7	66.0 ± 12.0	0.21 ± 3.05[b,c]
BMI, kg/m^2	25.2 ± 3.3	25.2 ± 3.3	-0.02 ± 1.98	25.4 ± 3.0	25.1 ± 3.2	-0.34 ± 2.18[a]	25.3 ± 3.6	25.0 ± 3.10	-0.39 ± 3.03[a]	24.8 ± 3.1	24.9 ± 3.2	0.09 ± 1.16[b,c]
SBP, mmHg	133.0 ± 14.7	132.3 ± 14.9	-0.7 ± 14.3	134.3 ± 14.1	131.5 ± 14.5	-2.8 ± 14.3[a]	135.4 ± 15.1	133.9 ± 16.3	-1.4 ± 16.5	136.3 ±15.6	138.9 ± 18.3	2.6 ± 18.2[a,b,c]
DBP, mmHg	77.6 ± 10.6	76.5 ± 10.4	-1.2 ± 10.5	77.8 ± 9.8	75.2 ± 10.2	-2.6 ± 9.6[a]	76.8 ± 11.0	75.0 ± 11.9	-1.7 ± 11.8	76.5 ± 11.8	76.1 ± 12.5	-0.4 ± 11.9[b,c]
FPG, mg/dl	140.1 ± 40.9	139.4 ± 38.9	-0.7 ± 36.8	143.3 ±41.6	139.8 ± 39.5	-3.5 ± 37.4	141.6 ± 42.8	141.3 ± 41.9	-0.3 ± 41.6	138.8 ± 37.8	136.5 ± 40.3	-2.3 ± 36.2
HbA1c, %	7.16 ± 1.26	7.12 ± 1.22	-0.04 ± 0.82	7.17 ± 1.17	7.19 ± 1.24	0.03 ± 0.79	7.18 ± 1.18	7.23 ± 1.17	0.05 ± 0.78[a]	7.12 ± 1.23	7.19 ± 1.25	0.07 ± 0.93[a]
TC, mg/dl	165.9 ± 36.2	164.8 ± 35.4	-1.1 ± 25.9	166.7 ± 37.6	166.5 ± 36.4	-0.2 ± 30.4	163.3 ± 35.4	162.1 ± 35.7	-1.2 ± 29.4	161.9 ± 37.8	166.1 ± 37.8	4.1 ± 33.2[a,b,c]
TG, mg/dl	148.2 ± 86.0	141.0 ± 94.9	-7.1 ± 80.8	147.6 ± 96.1	140.5 ± 90.4	-7.1 ± 76.3	139.0 ± 79.3	140.5 ± 91.9	1.5 ± 72.6[a,b]	137.8 ± 91.9	142.6 ± 83.3	4.8 ± 69.4[a,b]
HDL-c, mg/dl	50.4 ± 10.7	50.1 ± 10.6	-0.3 ± 6.9	51.1 ± 11.4	49.7 ± 12.3	-1.4 ± 6.7[a]	49.6 ± 11.7	50.8 ± 12.5	1.2 ± 7.4[a,b]	52.2 ± 12.8	51.6 ± 13.0	-0.6 ± 7.9[b,c]
LDL-c, mg/dl	90.8 ± 26.0	89.7 ± 25.0	-1.1 ± 18.7	90.7 ± 27.0	98.1 ± 26.5	7.4 ± 21.6[a]	96.9 ± 25.6	96.8 ± 26.2	-0.1 ± 20.9[b]	96.1 ± 27.0	99.4 ± 27.5	3.4 ± 24.1[a,b,c]

Data presented as mean ± SD, Abbreviations: Bwt, body weight; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HbA1c, glycated hemoglobin; TC, total cholesterol; TG, triglyceride; HDL-c, high-density lipoprotein-cholesterol; LDL-c, low-density lipoprotein-cholesterol.

[a]adjusted $p < 0.05$; compared with changes in 2016–2017; [b]adjusted $p < 0.05$ compared with changes in 2017–2018; [c]adjusted $p < 0.05$ compared with changes in 2018–2019.

Figures
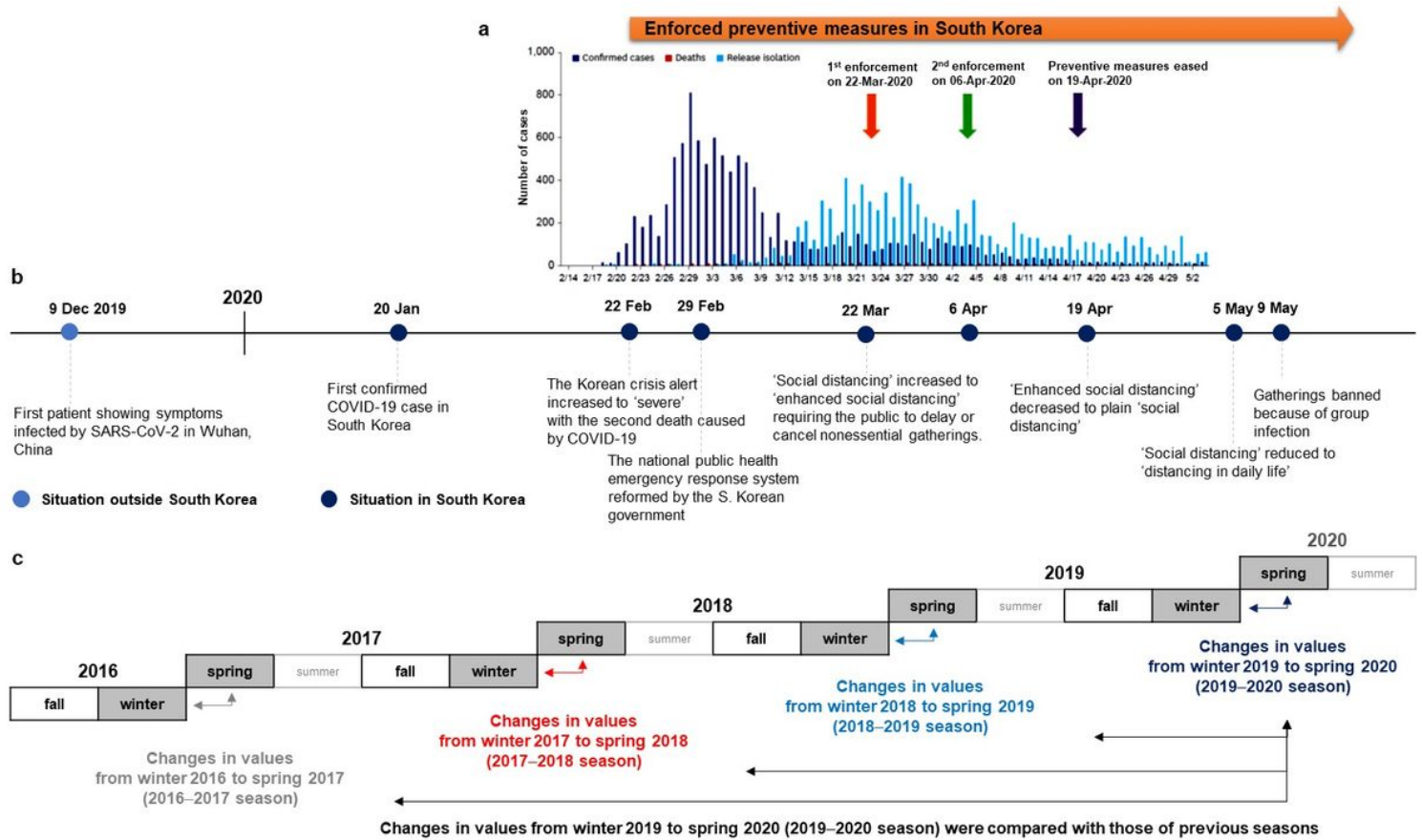
Figure 1

Timeline of the South Korea COVID-19 outbreak and our research design reflecting it. (A) The effect of strengthening social distancing (from Korea Centers for Disease Control and Prevention, as of May 6, 2020). (B) The timeline of the COVID-19 pandemic in South Korea, (C) The research design to analyze the impact of preventive measures.
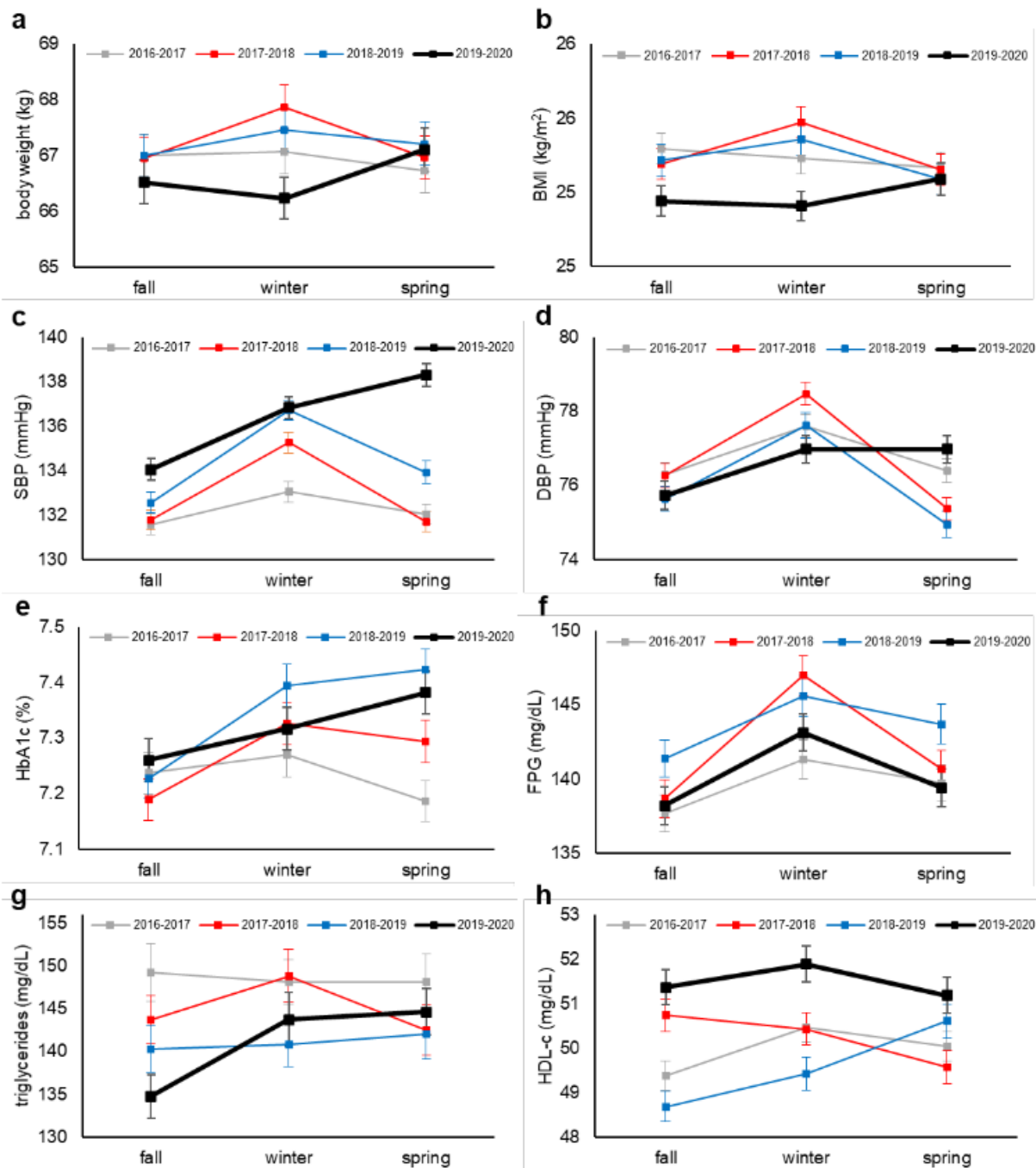
Figure 2

The changes in metabolic syndrome components before (i.e., fall and winter, 2019) and during (i.e., spring, 2020) the COVID-19 pandemic in South Korea: (A) body weight, (B) BMI, (C) SBP, (D) DBP, (E) HbA1c, (F) FPG, (G) triglycerides, (H) HDL-c. Abbreviations: SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; HbA1c, glycated hemoglobin; FPG, fasting plasma glucose; HDL-c,
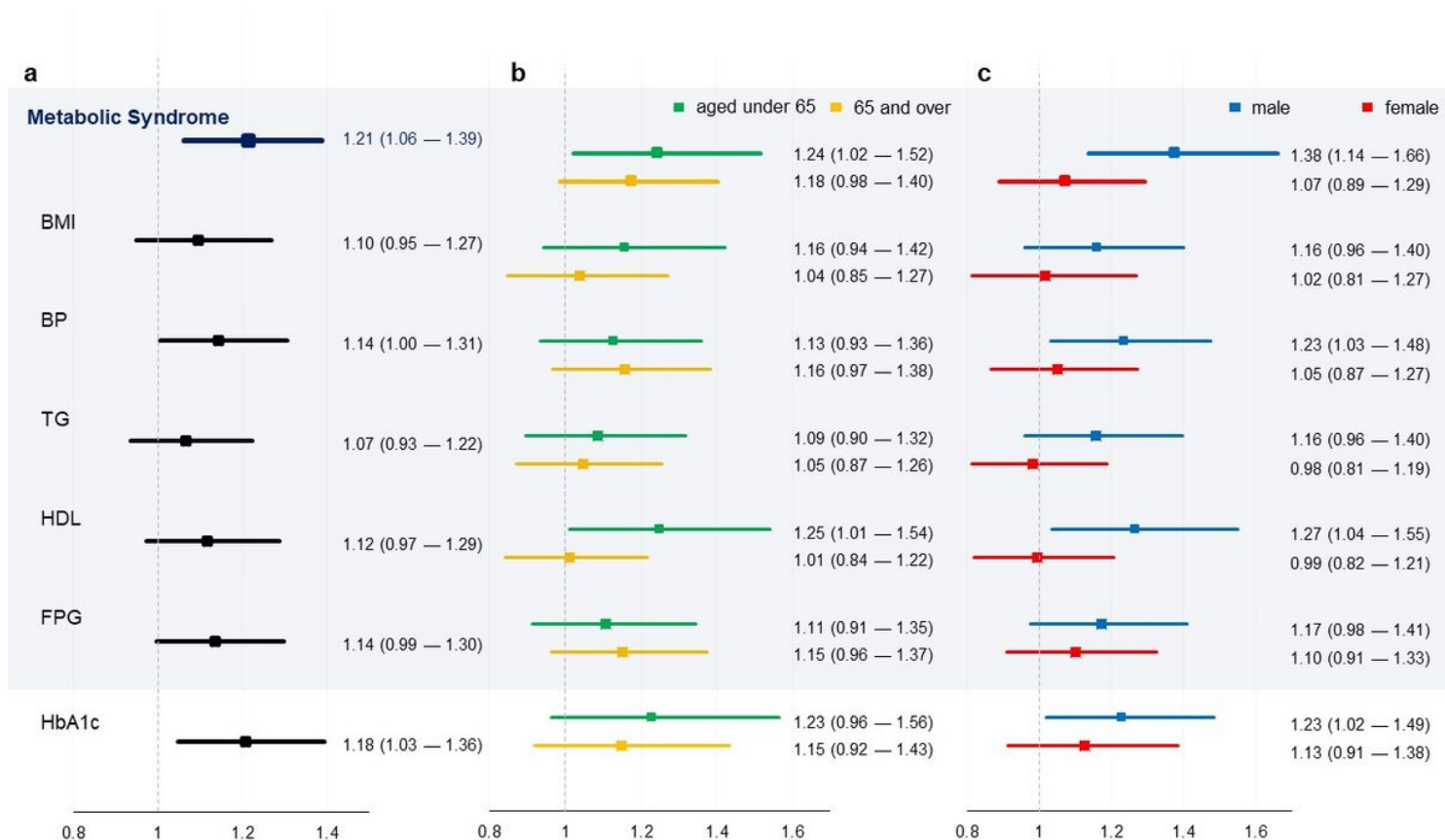
Figure 3

The relative risk (RR) of the patients who have worsened in metabolic syndrome components in the 2019–2020 season (COVID-19 pandemic period) when compared with that in the 2018–2019 season: (A) all patients, (B) age groups divided at 65 years, (C) sex. Abbreviations: MetS, metabolic syndrome; BMI, body mass index; BP, blood pressure; TG, triglyceride; HDL, high-density lipoprotein; FPG, fasting plasma glucose.
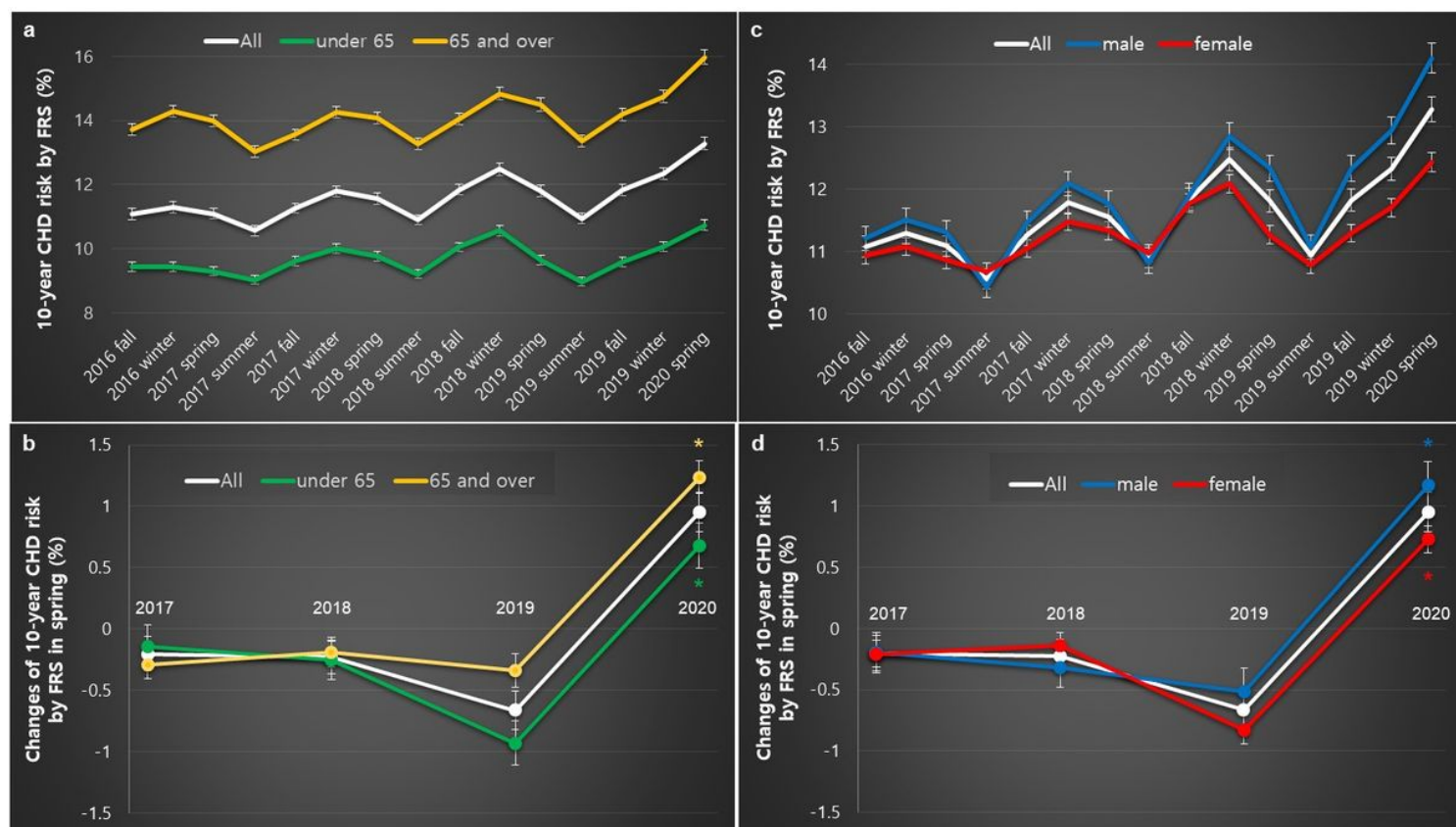
Figure 4

The 10-year CHD risk by FRS: (A, C) 10-year CHD risk by FRS for four years, (B, D) Changes in 10-year CHD risk by FRS before (winter 2019) and during (spring 2020) the COVID-19 pandemic in South Korea. Abbreviations: CHD, coronary heart disease; FRS, Framingham risk score. Asterisk (*) refers to p < 0.05 of changes in 2019−2020 compared with changes in 2018−2019.
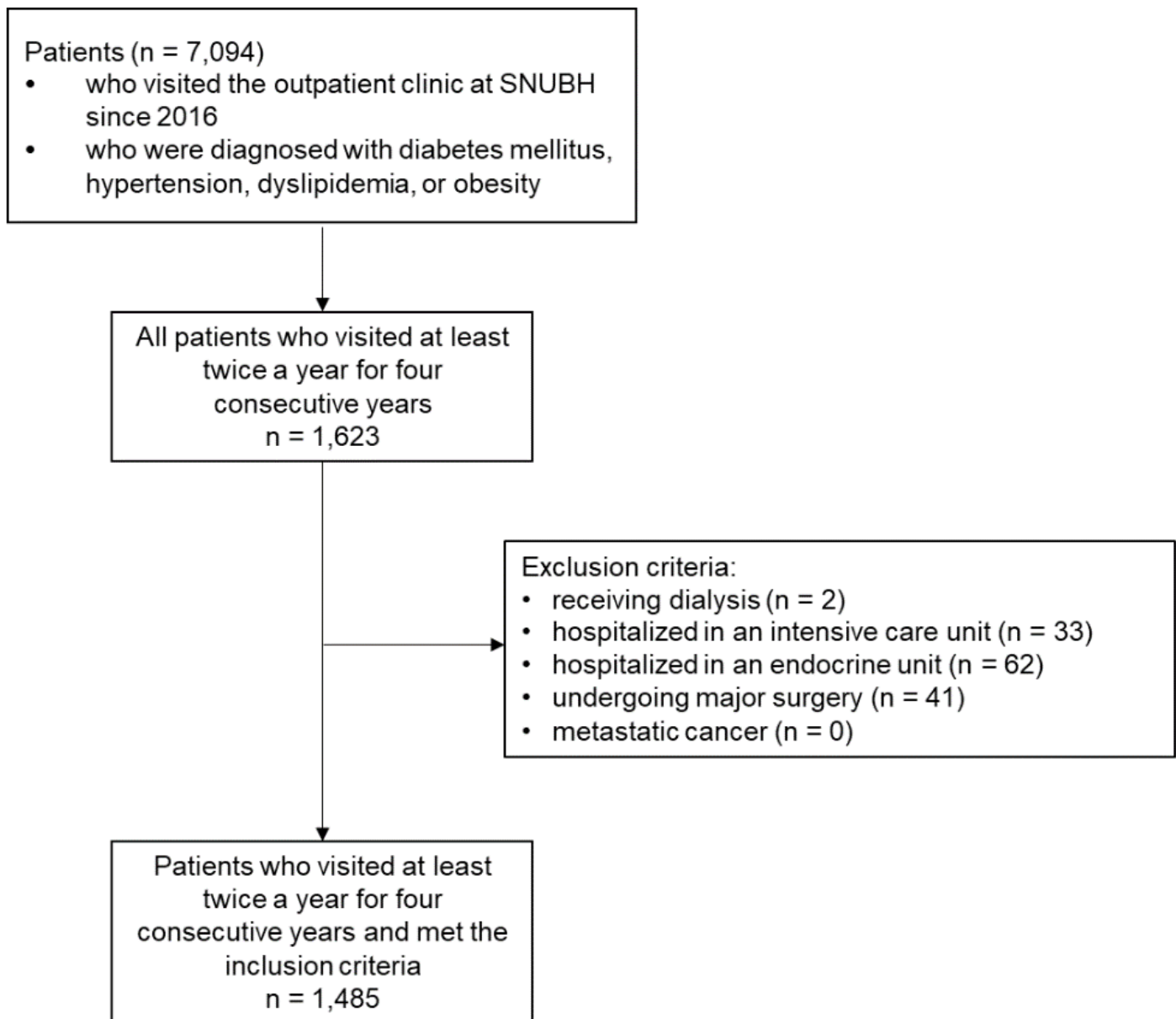
Figure 5

Flow chart of study population selection