Master's Thesis of Public Health

Effects of COVID-19 Pandemic on Sedentary Lifestyles and Subsequent Increase in Obesity Rates Among South Korean Adults

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Abstract

Background: Starting from March 2020, South Korea has enforced a strict "Social Distancing" in order to minimize the spread of COVID-19 pandemic. The plan included contact tracing, quarantine, social, and remote working, bringing significant changes to the lifestyles of Korean adults; people spent more time indoors and subsequent increase in sedentary time was found during the pandemic. Meanwhile, sedentary lifestyle is strongly associated with obesity and causes various serious medical complications. Therefore, this study aimed to investigate the effects of COVID-19 pandemic on sedentary lifestyles and subsequent changes in obesity rates among South Korean adults.

Methods: Data were included from the 2018, 2019, and 2020 Korean National Health and Nutrition Examination Survey of 9,476 Korean adults. The KNHANES is conducted by a national institution based on random cluster sampling, and therefore, the data gained from it is statistically reliable and representative in comparison to surveys performed by private institutions. COVID-19 pandemic and sedentary lifestyle were

the main independent variables. The dependent variable, presence of obesity, was categorized based on the Korean guideline using both BMI and waist circumference as the indicators. Multiple logistic regression and ordinary least squares regression analyses were performed to examine target associations.

Results: The rate of conducting sedentary lifestyles among the participants increased from 30.4% before COVID-19 to 36.6% during the pandemic. During COVID-19, the odd ratio of obesity increased for both BMI and waist circumference participants (Obesity (BMI): OR = 1.16, 95% CI = 1.04-1.30; Obesity (WC): OR = 1.31, 95% CI = 1.17-1.46). On the same token, sedentary lifestyles also increased obesity categorized by the two indicators (Obesity (BMI): OR = 1.17, 95% CI = 1.04-1.31; Obesity (WC): OR = 1.15, 95% CI = 1.03-1.29). Lastly, white collar workers who indicated the most increase in sedentary time during COVID-19 had the highest risk of obesity when compared to those of people from other occupations.

Conclusions: This study found that during COVID-19 pandemic,

sedentary lifestyles increased among South Korean adults, which eventually increased risk of obesity.

Keyword : Sedentary lifestyles, Covid-19, Obesity
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Chapter 1. Introduction

1.1. Study Background

The global outbreak of COVID-19 has caused devastating effects all around the world. Indeed, within 18 months since the onset of the pandemic, there are approximately two hundred million confirmed cases and four million deaths worldwide (Ndwandwe & Wiysonge, 2021).

South Korea was not an exception; starting from the first confirmed case on Jan 20, 2020, the pandemic spread rapidly with a total of 6284 confirmed cases including 42 deaths in less than a month (Shim, Tariq, Choi, Lee, & Chowell, 2020). The situation worsened as time passed and in order to control the outbreak and minimize its spread, the South Korean government enforced a strict "Social Distancing" from Feb 29, 2020 until the mid-2022 (이금숙, 박소현, & 함유희, 2021). The plan included contact tracing, quarantine, social distancing, and remote working, changing huge parts of people's lifestyles.

In fact, as a result of the social distancing, people spent more time indoors and subsequent increase in sedentary time was found during COVID-19 pandemic among South Korean adults (G. H. Kim et al., 2021) (J. H. Park, J. H. Moon, H. J. Kim, M. H. Kong, & Y. H. Oh, 2020). Meanwhile, sedentary behaviors reduce muscle glucose and protein transporter activities, alter circulation levels of sex hormones, and diminish carbohydrate metabolism, causing copious health problems, especially fat gain (J. H. Park et al., 2020; Jung Ha Park, Ji Hyun Moon, Hyeon Ju Kim, Mi Hee Kong, & Yun Hwan Oh,

2020). Therefore, increase in sedentary time during COVID-19 represents that social distancing rules may have severely affected the obesity rate of South Korean adults.

Replacing undernutrition, obesity nowadays is so common within the world's population that it has become one of the leading contributors to ill health (Kopelman, 2000). Certainly, obesity is prevalent, but a very serious problem that not only decreases a person's quality of life, but also causes serious medical complications like cardiovascular diseases, musculoskeletal disorders, and even some severe cancers (Mui, Ng, Tsung, Lam, & Yung, 2010).

In South Korea, the obesity rate of adults slowly increased from approximately 30% to 33% until 2015, and it has been stabilized at around 33-34% rate until 2019. Yet, after the outbreak of COVID-19, the rate drastically increased to 38.3% in 2020 according to KDCA (KDCA, 2020). Even though obesity is a problematic health burden upon modern society that requires special attention, only limited research has scrutinized on the reasons behind the increase in the obesity rate of South Korea. Furthermore, it is also not fully identified yet whether obesity rate of South Korean adults has been really increased during COVID-19 pandemic statistically significantly after adjusting for other confounding variables. Many prior studies have already reported sedentary lifestyle as the risk factor of obesity and hence, increased sedentary lifestyle during COVID-19 pandemic is highly likely related to the changed obesity rate of South Korean adults. Previous studies, however, have not yet scrutinized on the effect of sedentary time on obesity while taking COVID-19 pandemic into

account. Such discrepancy led us to investigate the effects of COVID-19 pandemic on sedentary lifestyles and subsequent changes in obesity rates among South Korean adults, including both body mass index and waist circumference as indicators.

1.2. Purpose of Research

This study aimed first to examine whether South Korean adults conducted more sedentary lifestyles during the COVID-19 pandemic. Next, we investigated the factors associated with obesity among South Korean adults, focusing on COVID-19 and sedentary lifestyle as risk factors of obesity. Lastly, the effects of COVID-19 pandemic in sedentary lifestyles and subsequent increase in obesity rates were investigated. The detailed study objectives are as follows:

(1) To investigate the changes in sedentary lifestyles of South Korean adults before and during Covid-19 pandemic.

(2) To investigate the association between COVID-19 pandemic and the risk of obesity among South Korean adults.

(3) To investigate the effect of COVID-19 pandemic on the sedentary lifestyles and subsequent changes in the risk of obesity among South Korean adults.

Chapter 2. Literature Review

2.1. Obesity and Problems associated with it

Obesity is caused by an imbalance between the food intake and the energy expended since the excess energy from the ingested food is then stored in fat cells that enlarge (Bray, 2004). Today, it is easier and cheaper to consume high-energy, affordable foods almost everywhere in the world, while at the same time the needs for the physical activities diminished (Finkelstein & Strombotne, 2010). Hence, obesity emerged as an epidemic not only in developed countries but also in some middle- and lower- income countries; as a result, an estimated 315 million people worldwide are obese today (James, 2004; Popkin & Doak, 1998). More importantly, the prevalence rates of obesity is keep increasing at a rapid pace that if the current trend persists, the global obesity prevalence is predicted to rise to 18% in men and surpass 21% in women by 2025 (Kyrou, Randeva, Tsigos, Kaltsas, & Weickert, 2018).

Similarly, obesity has developed to be a serious health challenge in South Korea as well. The obesity rate of South Korean adults increased drastically from 31.8% in 2013 to 34.6% in 2018 (Jeong & Jang, 2020). The previous studies suggest that the increasing Western-style eating-out culture together with the break-down of the traditional family culture leading people to eat alone increased the risk of obesity of South Koreans (Jeong & Jang, 2020; H. J. Kim, Oh, Choi, & Park, 2019). The obesity rate of South Korean maintained under 35% until 2019, but after the outbreak of COVID-19, the rate skyrocketed to 38.3% in 2020 (KDCA, 2020).

There are two most commonly used methods to determine obesity: body mass index and waist circumference. Rising BMI levels are associated with higher levels of chronic disease burdens and especially for hypertension, diabetes, and arthritis, even one-unit increments in BMI rose burdens significantly. Waist circumference is also widely used as an indicator of obesity because fat accumulation intra-abdominally and subcutaneously around the abdomen especially is associated with higher risks of diseases compared to fat accumulation in the subcutaneous regions of hips, thighs and lower trunk (Kyrou et al., 2018). Meanwhile, Asians, including South Koreans, have proportionally more total body fat content and abdominal fat distribution than Caucasians, thus leading to a bigger problem even in a relatively low BMI level (D. M. Kim, Ahn, & Nam, 2005). Certainly, obesity, no matter which methods are used, is a very serious problem that decreases a person's quality of life and causes serious medical complications like cardiovascular diseases, musculoskeletal disorders, and even some severe cancers (Mui et al., 2010). On top of that, a previous study even states that obesity causes 36% increase in inpatient and outpatient spending, and a 77% increase in medications. In short, sufficient attention to obesity and investigation of its risk factors are required in order to both prevent severe health outcomes of the general population and minimize excessive and unnecessarily health expenditures (Sturm, 2002).

2.2. Sedentary Lifestyle and Problems associated with it

Today, sedentary lifestyle is emerging as a global issue with its detrimental effects on health (Fang, Jing, Chen, Wu, & Wan, 2021). In fact, characterized by time spent sitting, sedentary lifestyle does not seem to be a serious problem at a first glance, but when carefully examined, various health problems ensue with it. Sedentary behaviors reduce lipoprotein lipase activity, muscle glucose, protein transporter activities and impair lipid metabolism, which are strongly related to obesity and metabolic syndrome (Jung Ha Park et al., 2020). Another study presents the negative association between quality of life (EQ-5D) and sedentary behavior; those sitting an extra hour had a 1.056 odd ratio of having trouble in walking, 1.299 odd ratio of incapability in daily activities, and 1.125 odd ratio of severe pain and discomfort (김유린, 2021). Furthermore, sedentarism is also associated with a wide range of chronic diseases and even premature deaths (JI, 2019). Lastly, there is also an association between sedentary behavior and mental health that sedentary time was positively associated with higher risk of psychological distress even after adjustments of related variables {Owen, 2010 #102}.

According to the previous study, the average sedentary time of Korean adults in 2014-2017 were 7.49 hours per day (Lee, Son, Eum, & Kang, 2020). The average sedentary time, nevertheless, increased more during COVID-19 pandemic among South Korean adults highly likely due to the social distancing which included remote working and quarantine (G. H. Kim et al., 2021) (J. H. Park et al., 2020).

2.3. Obesity Interventions

Since obesity is such a serious problem all around the world, there are a copious of lifestyle treatment interventions for obesity. Most of the interventions, nevertheless, target change in diet and physical activity only. On top of that, most of the interventions were implemented in patient care settings while only few of them were used in the community settings, in contrast to the high prevalence of obesity regardless of countries, social classes, and occupations.

Furthermore, there were only limited interventions which advised obese people to conduct less sedentary lifestyles {Teixeira, 2015 #101}. In the systematic review which analyzed 29 scientific literatures on recommendations of physical activity during COVID-19, there were four physical activity recommendation criteria during the pandemic. The first was aerobic activity recommendation; a total of 28 guidelines out of 29 included aerobic exercise such as walking, running and climbing stairs, as a recommendation during the pandemic. Next, strength activity was recommended from 21 items. Balance and flexibility were also suggested by the recommendations, but no advise related to sedentary behavior was found in any of the guideline {Polero, 2021 #104}. According to a previous study, however, even when adults follow the designated physical activity guidelines, prolonged sitting might still compromise metabolic health {Owen, 2010 #102}.

Certainly, since obesity interventions are made based on the related theories and studies, it is crucial to thoroughly investigate the risk factors of obesity, especially under the pandemic when lifestyles of people are changing rapidly.

2.4. COVID-19 pandemic and Obesity

The coronavirus is causing widespread concerns that people from all around the world are extremely frightened by such uncertain situations. In fact, according to a previous study, children, as well as adults with underlying health conditions, are likely to experience worry, anxiety, and fear during the pandemic {Kontoangelos, 2020 #103}. Furthermore, both vigorous and moderate physical activity decreased significantly during the pandemic; the percent of people fulfilling the 75 minutes of vigorous physical activity recommendation decreased by approximately 10% in the study sample of a past study.

In terms of obesity, it is proven by various previous studies that there is a positive association between obesity and the risk of severe coronavirus disease. Hospitalization rates and the number of respiratory infections are higher in COVID-19 patients with obesity than the patients who are normal weight (Rychter, Zawada, Ratajczak, Dobrowolska, & Krela-Kaźmierczak, 2020). On top of that, higher BMI levels were also associated with a higher risk of contracting COVID-19; compared to the normal weight participants, the adjusted odd ratios of contracting the pandemic was 1.26 among the obese individuals (Jung et al., 2021). As such, obese people are both easier to contact the virus and have higher chance of experiencing more severe COVID-19 compared to the normal weight people. Hence, it is very important for people to maintain good levels of body fat especially during COVID-19 pandemic. Meanwhile, due to the social distancing which include quarantine and remote working, people are spending more time indoor with less activities, which presumably causes obesity. In fact, the use of

lockdowns to combat the pandemic spread might be effective from in an epidemiological perspective, but might contain negative consequences especially on metabolic health {Clemmensen, 2020 #100}. Yet, there is only limited research which examined COVID-19 pandemic as a risk factor of obesity among South Korean adults. Therefore, this discrepancy has led us to investigate COVID-19 as a risk factor of obesity among South Korean adults using both waist circumference and body mass index.

Chapter 3. Materials and Methods

3.1. Framework of the Study Design

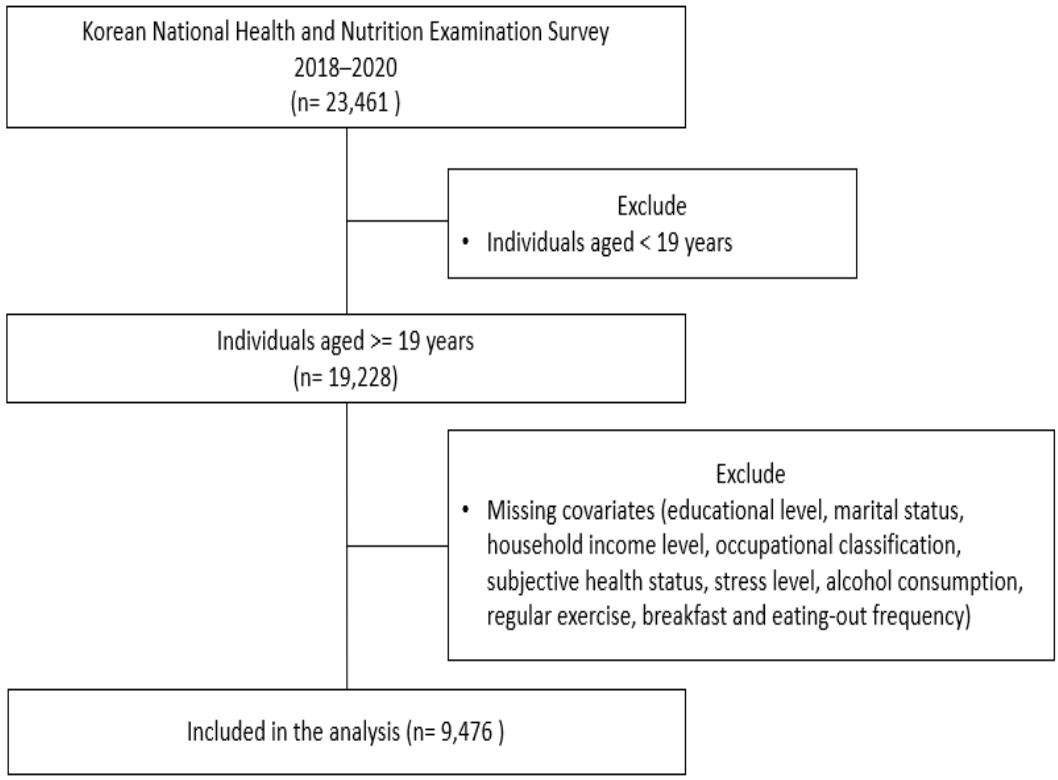
This study aimed to examine the factors associated with sedentary lifestyles among the general population to emphasize the importance of managing their health behaviors. Furthermore, this study investigated the effect of COVID-19 on obesity risks among the South Korean adults, who are highly likely influenced not only from the pandemic itself, but also from the strict social distancing. Lastly, this study investigated the effects of COVID-19 pandemic on sedentary lifestyles and subsequent increase in obesity rates among South Korean adults to highlight the importance of conducting appropriate governmental interventions which both prevent further spread of pandemic and hold promise for improving the health of the society.

3.2. Data and Study Population

Data for this study was taken from a sample of the Korean National Health and Nutrition Examination Survey (KNHANES), which collects information on the health of the public, the status of chronic diseases, and health behaviors including smoking status, dietary pattern, and sedentary time spent throughout a day. The KNHANES is conducted by a national institution, the Korea Centers for Disease Control and Prevention, based on a complex, stratified, multistage, probability-cluster survey with rolling sampling designs to analyze a representative, civilian, noninstitutionalized South Korean population (Jeong, 2022). Along with stratification of the geographic areas (16 provinces of South Korea), probability-clustered sampling methods were performed in two steps. First, the primary sampling units were formed by sex, 26 age groups, and 24 land and housing classes. Second, 20 families were randomly sampled in each primary sampling unit. Then, each member of the sampled family provided written informed consent. Thus, the data from KNHANES can be considered to represent the entire population of South Korea (D. W. Lee et al., 2020).

Of the 23,461 individuals who participated in the surveys, I first excluded those aged <19 years (n=19,228); those under 19 years were excluded since the study aimed to focus on the adults only. Nobody was excluded from the dependent and independent variables: BMI, sedentary time, and waist circumference. Among 19,228, 9,476 remained due to the missing covariates such as educational level, marital status, household income level, occupational classification, subjective health status, stress level, alcohol consumption, regular exercise, breakfast and eating-out frequency.

Figure 1. Flowchart of the participant selection



3.3. Variables

The primary independent variables were the COVID-19 pandemic and sedentary lifestyles. Since the first patient with COVID-19 in South Korea was diagnosed on January 20, 2020, and the "Social Distancing" has been conducted from the early 2020, the study compared obesity rate of the participants between 2018, 2019 (before COVID-19) and 2021 (during COVID-19)(S. Y. Kim, Kim, Park, & Choi, 2021). Next, sedentary lifestyles were categorized as Yes (>=10 hours) and No (<10 hours) following the definition of World Health Organization (Organization, 2020).

The demographic characteristics included in the study were participants' age (19-39, 40-59, >=60) and gender. Socioeconomic factors included participants' educational level (middle school or less, high school, and college or over), marital status (married, separated or divorced, unmarried), household income level, and occupational classification (white-collar, pink-collar, blue-collar, and none). Household income was used in quartiles (1, low; 2, lower middle; 3, upper middle; 4, high).

The health and obesity related characteristics included the self-reported health status (high, middle, and low), stress level (high, middle, and low), alcohol consumption (heavy alcohol consumption and light alcohol consumption), regular exercise (yes and no), breakfast frequency (more than 5 times a week, 1-4 times a week, and less than once a week), and eating-out frequency (more than 5 times a week, 1-4 times a week, and less than once a week). Male participants who drink more than 7 cups of alcohol and female participants who drink more than 5 cups of alcohol at least twice a week were categorized as heavy alcohol consumption

(Center, 2021). Also, participants who conduct 150 minutes of moderate or 75 minutes of vigorous exercises per week were categorized as Yes in regular exercise (Organization, 2020).

Obesity was included as the main dependent variable in this study. Obesity was classified by both body mass index and waist circumference. Obesity using waist circumference as an indicator was added to the study due to the heightened risks of various diseases especially when fats are accumulated around the abdomen (Kyrou et al., 2018). Participants with >= 25 kg/m^2 of BMI were defined as obesity and those with that of under 25 were categorized as normal according to the Korean guideline (Jeong & Jang, 2020). Similarly, using the same guideline, male participants with >=90cm and female participants with >=85cm of waist circumference were categorized as obese.

Table 1. Variable Description

Variable	Description
Obesity (BMI)	Obesity, Normal
BMI	Continuous Variable
Obesity (Waist Circumference)	Obesity, Normal
Waist Circumference	Continuous Variable
Sedentary Lifestyles	Yes, No
COVID-19	Yes (2020), No (2018, 2019)
Sex	Male, Female
Age	19-39, 40-59, >=60
Income	Low, Lower middle, Upper middle, High
Educational Level	Middle school or less, High school, College or over
Marital Status	Married, Separated or divorced, Unmarried
Occupational Classification	White-collar, Pink-collar, Blue-collar, None
Self-Reported Health Status	High, Middle, Low
Stress Level	High, Middle, Low
Alcohol Consumption	Heavy alcohol consumption, Light alcohol consumption
Regular Exercise	Yes, No
Eating-out Frequency	More than 5 times a week, 1-4 times a week, Less than once a week
Breakfast Frequency	More than 5 times a week, 1-4 times a week, Less than once a week

3.4. Statistical analysis

Chi-square tests were conducted to analyze the general characteristics of the study population. T-tests and analyses of variance were conducted to analyze BMI and waist circumference across different study population groups. The BMI and waist circumference's means and standard deviations of the study population were also stated. Multiple logistic regression analyses were performed to compare the risk of obesity depends on the independent variables, COVID-19 pandemic and sedentary lifestyles, after accounting for potential confounding variables, including demographic, socioeconomic, and health-related characteristics. Multiple logistic regression analyses used a stratified sampling (k strata) and a clustering variable (primary sampling units) provided by the KNHANES. Results were obtained from the weighted sample. Subgroup analyses were also performed with the multinomial logistic regression analysis to investigate the associations between COVID-19 pandemic and obesity focused on the occupational variables. The changes in the ratio of participants conducting sedentary lifestyles before and during COVID-19 by occupational classification were added next to the result of subgroup analysis in order to conveniently compare changes in sedentary behavior and the subsequent differences in odd ratios of obesity. Furthermore, multiple linear regression analyses were performed twice. First analysis aimed to examine the association between sedentary lifestyles, COVID-19 and BMI, while the second one examined interaction of sedentary lifestyles and COVID-19 on BMI. Every analysis was conducted twice using both BMI and waist circumference as indicators. The level of statistical significance was set to P value less than 0.05 and results are reported as odds ratios (OR) with a 95% confidence interval (CI). All data analyses were conducted using SAS 9.4 software (version 9.4; SAS Institute Inc., Cary, NC, USA).

3.5 Ethics Statement

This study was reviewed and approved by the Institutional Review Board of the Seoul National University Health System (IRB number: 22-11-005) and adheres to the tenets of the Declaration of Helsinki.

Chapter 4. Results

4.1. Differences in General Characteristics of the Study Population Before and During COVID-19

This study aimed to investigate the effect of COVID-19 on sedentary lifestyles and subsequent increase in obesity risk among South Korean adults. Samples of the Korean National Health and Nutrition Examination Survey (KNHANES) from 2018, 2019, and 2020 have been used.

Table 1 presents the general characteristics of the study population and the results of chi-square tests. First of all, the data includes 6,822 participants before COVID-19 and 2,654 participants during the pandemic, constituting total of 9,476 participants. Among the 9,476 participants, 3,351 (35.4%) were categorized as obese and 6,125 (64.6%) were normal according to their BMI. Similarly, among the 9,476 participants, 3,044 (32.1%) were categorized as obese and 6,432 (67.8%) were normal when waist circumference was used as an indicator. The results indicate the changes in obesity rates among South Korean adults for both indicators. Having sedentary lifestyle represented 57.9% of the participants: total of 3,992 (35.4%) of the participants were conducting sedentary lifestyle while other 5,484 (57.9%) were not. More importantly, in contrast to 40.9% of sedentary lifestyles conducting rate before the pandemic, it has increased to 45.2% during COVID-19. Indeed, the result of a chi-square test between sedentary lifestyle and COVID-19 presents the increase in sedentary lifestyle of the participants during COVID-19 pandemic. Those who reported high stress level increased from 26.5% to

29.2% during COVID-19. Lastly, there were decreases in the number of participants eating breakfast and eating-outs frequently.

Table 1. General characteristics of study population (n=9476)

Variables	Total		COVID-19				*P*-value
			Before		During		
Total	**9,476**		**6,822**		**2,654**		
BMI							<0.0001
Obesity	3,351	(35.4)	2,327	(34.1)	1,024	(38.6)	
Normal	6,125	(64.6)	4,495	(65.9)	1,630	(61.4)	
Waist Circumference							<0.0001
Obesity	3,044	(32.1)	2,073	(30.4)	971	(36.6)	
Normal	6,432	(67.9)	4,749	(69.6)	1,683	(63.4)	
Sedentary Lifestyle							0.0002
Yes	3,992	(42.1)	2,793	(40.9)	1,199	(45.2)	
No	5,484	(57.9)	4,029	(59.1)	1,455	(54.8)	
Age (years)							0.2642
19-39	3,271	(34.5)	2,321	(34.0)	950	(35.8)	
40-59	3,850	(40.6)	2,794	(41.0)	1,056	(39.8)	
≥ 60	2,355	(24.9)	1,707	(25.0)	648	(24.4)	
Gender							0.672
Male	4,605	(48.6)	3,306	(48.5)	1,299	(48.9)	
Female	4,871	(51.4)	3,516	(51.5)	1,355	(51.1)	
Educational level							0.0044
Middle school or less	1,584	(16.7)	1,190	(17.4)	394	(14.8)	
High school	2,671	(28.2)	1,930	(28.3)	741	(27.9)	
College or over	5,221	(55.1)	3,702	(54.3)	1,519	(57.2)	
Marital status							<0.0001
Married	6,473	(68.3)	4,758	(69.7)	1,715	(64.6)	
Separated or divorced	926	(9.8)	648	(9.5)	278	(10.5)	
Unmarried	2,077	(21.9)	1,416	(20.8)	661	(24.9)	
Household income level							0.0032
Low	1,183	(12.5)	882	(12.9)	301	(11.3)	
Lower middle	2,186	(23.1)	1,621	(23.8)	565	(21.3)	
Upper middle	2,762	(29.1)	1,954	(28.6)	808	(30.4)	
High	3,345	(35.3)	2,365	(34.7)	980	(36.9)	
Occupational classification							0.1281
White-collar	2,929	(30.9)	2,114	(31.0)	815	(30.7)	

Pink-collar	1,363	(14.4)	985	(14.4)	378	(14.2)	
Blue-collar	2,105	(22.2)	1,549	(22.7)	556	(20.9)	
None	3,079	(32.5)	2,174	(31.9)	905	(34.1)	
Self-Reported Health Status							0.1713
High	3,128	(33.0)	2,283	(33.5)	845	(31.8)	
Middle	4,967	(52.4)	3,568	(52.3)	1,399	(52.7)	
Low	1,381	(14.6)	971	(14.2)	410	(15.4)	
Stress Level							0.0006
High	2,584	(27.3)	1,809	(26.5)	775	(29.2)	
Middle	5,540	(58.5)	3,988	(58.5)	1,552	(58.5)	
Low	1,352	(14.3)	1,025	(15.0)	327	(12.3)	
Alcohol Consumption							0.8436
Heavy alcohol consumption	1,435	(15.1)	1,030	(15.1)	405	(15.3)	
Light alcohol consumption	8,041	(84.9)	5,792	(84.9)	2,249	(84.7)	
Regular Exercise							0.0026
Yes	1,684	(17.8)	1,108	(16.2)	522	(19.7)	
No	7,792	(82.2)	1,162	(17.0)	2,132	(80.3)	
Breakfast Frequency							<.0001
More than 5 times a week	5,282	(55.7)	3,902	(57.2)	1,380	(52.0)	
1-4 times a week	2,371	(25.0)	1,731	(25.4)	640	(24.1)	
Less than once a week	1,823	(19.2)	1,189	(17.4)	634	(23.9)	
Eating-out Frequency							<.0001
More than 5 times a week	4,397	(46.4)	3,291	(48.2)	1,106	(41.7)	
1-4 times a week	3,260	(34.4)	2,272	(33.3)	988	(37.2)	
Less than once a week	1,819	(19.2)	1,259	(18.5)	560	(21.1)	

4.1.1 Analyses of BMI across Different Study Population Groups

Table 2 presents means and standard deviations of the study population's body mass index along with the results of t-tests and analyses of variance. Mean BMI of the study population before and during COVID-19 were 23.95±3.57 kg/m^2 and 24.22±3.66 kg/m^2 respectively. In fact, there was a statistically significant increase in mean BMI among South Korean adults. Mean BMI of those conducting sedentary lifestyle was 24.12±3.76 kg/m^2, which is higher compared to 23.96±3.48 kg/m^2 of those who are not conducting sedentary lifestyle; those who sit long had higher mean BMI than those who do not. Furthermore, mean BMI increased as one gets older. Mean BMI was also higher in men, those with lower educational level, and those with highest self-reported health statuses. The mean BMI of heavy alcohol users was 24.71 kg/m^2, which is very high compared to 23.90kg/m^2 of light users. Those who conducted regular exercises showed higher BMI, but the result was not statistically significant. Finally, variables that represent eating habits of the participants, breakfast frequency and eating-out frequency, were not significantly related with mean body index.

Table 2. Descriptive Statistics of the Study Populations' BMI

Variables	BMI		P-value
	Mean	SD	
Covid-19			0.0004
During	24.22	±3.66	
Before	23.95	±3.57	
Sedentary Lifestyle			0.0261
Yes	24.12	±3.76	
No	23.96	±3.48	
Age (years)			<0.0001
19-39	23.65	±4.17	
40-59	24.10	±3.43	
≥ 60	24.35	±3.03	
Gender			<0.0001
Male	24.72	±3.39	
Female	23.36	±3.67	
Educational level			<0.0001
Middle school or less	24.47	±3.21	
High school	24.28	±3.59	
College or over	23.72	±3.71	
Marital status			<0.0001
Married	24.14	±3.41	
Separated or divorced	24.12	±3.39	
Unmarried	23.58	±4.22	
Household income level			<0.0001
Low	24.09	±3.58	
Lower middle	24.27	±3.72	
Upper middle	24.14	±3.64	
High	23.73	±3.47	
Occupational classification			0.0124
White-collar	23.86	±3.62	
Pink-collar	24.54	±3.39	
Blue-collar	24.15	±3.66	
None	23.76	±3.66	
Self-Reported Health Status			<0.0001
High	23.71	±3.31	
Middle	23.96	±3.54	

Low	24.90	±4.19	
Stress Level			0.1260
High	24.18	±4.00	
Middle	23.93	±3.46	
Low	24.08	±3.36	
Alcohol Consumption			<.0001
Heavy alcohol consumption	24.71	±3.52	
Light alcohol consumption	23.90	±3.60	
Regular Exercise			0.0704
Yes	24.16	±3.39	
No	23.99	±3.64	
Breakfast Frequency			0.1104
More than 5 times a week	24.05	±3.35	
1-4 times a week	24.07	±3.89	
Less than once a week	23.88	±3.94	
Eating-out Frequency			0.9329
More than 5 times a week	24.07	±3.58	
1-4 times a week	23.90	±3.70	
Less than once a week	24.13	±3.46	

4.1.2 Factors associated with Obesity (BMI)

Multivariable logistic regression has been used in order to examine factors associated with obesity using BMI as an indicator. Table 3 presents association between COVID-19, sedentary lifestyles, and other related variables and obesity. Compared to people not sitting long, those who are sitting more than ten hours a day had higher risks of developing obesity. This result was statistically significant (OR = 1.17, 95% CI = 1.04-1.31). Furthermore, participants during COVID-19 were at higher risk of obesity (During: OR = 1.16, 95% CI = 1.04-1.30). Only limited research has presented COVID-19 as an obesity risk factor among South Korean adults, which makes this finding more valuable. Heavy alcohol consumption as well as lower educational level were also related to higher risk of obesity (Heavy alcohol consumption: OR = 1.28, 95% CI = 1.11-1.47; Middle school or less: OR = 1.45, 95% CI = 1.20-1.76). Those who presented higher self-reported health status were at the lowest risk of obesity compared to those reported middle and low health status reports (High: OR = 0.57, 95% CI = 0.49-0.67; Middle: OR = 0.63, 95% CI = 0.54-0.72). In contrast to the common conception, regular exercise was not related to lower risk of obesity. Since BMI has been used as an indicator of obesity, it is possible those with high muscle masses were also categorized as obese. Lastly, Men had a higher risk of developing obesity than women (OR = 2.29, 95% CI = 2.05-2.56).

Table 3. Factors associated with Obesity (BMI >= 25 kg/m²)

Variables	Obesity		P-value
	OR	95% CI	
Covid-19			
During	1.16	(1.04 – 1.30)	0.0074
Before	1.00		
Sedentary Lifestyle			
Yes	1.17	(1.04 – 1.31)	0.0071
No	1.00		
Age (years)			
19-39	1.17	(0.96 – 1.43)	0.1286
40-59	1.16	(0.99 – 1.37)	0.0635
≥ 60	1.00		
Gender			
Male	2.29	(2.05 – 2.56)	<.0001
Female	1.00		
Educational level			
Middle school or less	1.45	(1.20 – 1.76)	0.0001
High school	1.16	(1.02 – 1.32)	0.0201
College or over	1.00		
Marital status			
Married	1.34	(1.15 – 1.56)	0.0002
Separated or divorced	1.27	(1.01 – 1.60)	0.0447
Unmarried	1.00		
Household income level			
Low	1.00	(0.82 – 1.22)	0.9862
Lower middle	1.17	(1.02 – 1.34)	0.0285
Upper middle	1.20	(1.06 – 1.35)	0.0041
High	1.00		
Occupational classification			
White-collar	1.18	(1.02 – 1.38)	0.0308
Pink-collar	1.11	(0.94 – 1.31)	0.2385

Blue-collar	1.23	(1.04 – 1.44)	0.0147
None	1.00		
Self-Reported Health Status			
High	0.57	(0.49 – 0.67)	<.0001
Middle	0.63	(0.54 – 0.72)	<.0001
Low	1.00		
Stress Level			
High	1.01	(0.84 – 1.20)	0.9575
Middle	0.83	(0.72 – 0.96)	0.0142
Low	1.00		
Alcohol Consumption			
Heavy alcohol consumption	1.28	(1.11 – 1.47)	0.0007
Light alcohol consumption	1.00		
Regular Exercise			
Yes	1.12	(0.98 – 1.27)	0.0983
No	1.00		
Breakfast Frequency			
More than 5 times a week	0.99	(0.85 – 1.15)	08723
1-4 times a week	1.16	(1.00 – 1.36)	0.0548
Less than once a week	1.00		
Eating-out Frequency			
More than 5 times a week	0.91	(0.77 – 1.07)	0.2416
1-4 times a week	0.97	(0.84 – 1.13)	0.7316
Less than once a week	1.00		

4.1.3 Factors associated with BMI

On top of investigating the risk of obesity using body mass index as a measure of obesity, factors associated with BMI itself also has been examined. Multiple linear regression analysis has been used accordingly. Table 4 summarizes the association between COVID-19, sedentary lifestyle, other related variables, and body mass index. BMI was significantly higher among participants sitting for more than ten hours a day than those who are not (β = 0.31, P < 0.0001). Participants during COVID-19 also showed higher BMI compared to that of those before COVID-19 (β = 0.28, P < 0.0004). Along with a result from table 3 about COVID-19 and obesity, COVID-19 increasing BMI of the participants is an important finding. Male participants and heavy alcohol users showed higher level of BMI compared to female and those who do not drink alcohol often. As the educational level decreased, individuals had a higher level of BMI. BMI decreased as participants reported lower self-health status. In contrast to the common belief, eating out frequency and breakfast frequency did not present statistically significant differences in BMI levels. These results were all statistically significant.

Table 4. Factors associated with BMI

Variables	β	SE	P-value
Covid-19			
During	0.28	0.0772	0.0004
Before	Ref.		
Sedentary Lifestyle			
Yes	0.31	0.0729	<.0001
No	Ref.		
Age (years)			
19-39	0.05	0.1395	0.6998
40-59	0.16	0.1094	0.1363
≥ 60	Ref.		
Gender			
Male	1.43	0.0775	<.0001
Female	Ref.		
Educational level			
Middle school or less	0.83	0.1313	<.0001
High school	0.49	0.0914	<.0001
College or over	Ref.		
Marital status			
Married	0.52	0.1086	<.0001
Separated or divorced	0.52	0.1571	0.0009
Unmarried	Ref.		
Household income level			
Low	-0.01	0.1283	0.9469
Lower middle	0.36	0.0973	0.0002
Upper middle	0.33	0.0883	0.0002
High	Ref.		
Occupational classification			
White-collar	0.26	0.1028	0.0116
Pink-collar	0.23	0.1027	0.0224
Blue-collar	0.49	0.1146	<.0001
None	Ref.		
Self-Reported Health Status			

High	-1.08	0.1132	<.0001
Middle	-0.90	0.1019	<.0001
Low	Ref.		
Stress Level			
High	0.09	0.1181	0.4622
Middle	-0.11	0.1023	0.2704
Low	Ref.		
Alcohol Consumption			
Heavy alcohol consumption	0.33	0.0987	0.0009
Light alcohol consumption	Ref.		
Regular Exercise			
Yes	0.25	0.0938	0.0068
No	Ref.		
Breakfast Frequency			
More than 5 times a week	-0.06	0.1003	0.5728
1-4 times a week	0.29	0.1066	0.0064
Less than once a week	Ref.		
Eating-out Frequency			
More than 5 times a week	-0.12	0.1093	0.2671
1-4 times a week	-0.01	0.1016	0.9427
Less than once a week	Ref.		

4.1.4 Subgroup Analysis for Obesity Risk (BMI) according to the Occupational Classification

Subgroup analysis was performed with the multinomial logistic regression analysis to investigate the associations between COVID-19 pandemic and obesity focused on the occupational variables. Table 5 presents both the result of subgroup analysis and general characteristics of participants by sedentary lifestyle in order to conveniently compare changes in sedentary behavior and the subsequent differences in odd ratios of obesity. White-collar workers presented the highest risk of developing obesity (BMI) compared to pink-collar workers, blue-collar workers, and those without a job (OR = 1.36, 95% CI = 1.14-1.63). Those without a job also showed increased risk of obesity (OR = 1.24, 95% CI = 1.06-1.46), but the other groups did not present statistically different results. Furthermore, in accordance with the result of subgroup analysis, white-collar workers illustrated the biggest difference in the percentages of participants conducting sedentary lifestyle before and during COVID-19 (7.2%). Those without an occupation followed with 5.7%, while pink and blue-collar workers showed only 1.4% and 1.9% of differences respectively; in fact, general characteristics of sedentary lifestyles among participants by occupational classifications presented a unified result with the subgroup analysis. Since other related variables of obesity were adjusted, the accordance between the differences in odd ratios by occupations and changes in percentages of those conducting sedentary lifestyles partially substantiates the effect of COVID-19 pandemic on sedentary lifestyles and subsequent increase in obesity risks.

Table 5. Changes in Sedentary Lifestyles by Occupations and respective Obesity Risks (BMI)

Variable	[a] OR	95% CI	[a] OR	Sedentary Lifestyle					
	During		Before	During			Before		
Occupational classification				**Yes**	**No**		**Yes**	**No**	
White-collar	1.36	(1.14 – 1.63)	1.00	509	306	(62.5)	1170	944	(55.3)
Pink-collar	1.11	(0.86 – 1.44)	1.00	110	268	(29.1)	273	712	(27.7)
Blue-collar	1.13	(0.94 – 1.37)	1.00	134	422	(24.1)	402	1147	(26.0)
None	1.24	(1.06 – 1.46)	1.00	446	459	(49.3)	948	1226	(43.6)

[a] Adjusted for age, gender, educational level, marital status, household income level, self-reported health status, stress level, alcohol consumption, regular exercise, breakfast frequency, eating-out frequency.

4.1.5 Factors associated with BMI with an interaction term

Multiple linear regression analysis was performed again in order to verify if the effect of sedentary lifestyles has been changed or not during the pandemic. Table 6 summarizes the associations between the interaction of COVID-19 and sedentary lifestyle on body mass index after adjustment of other related variables. Statistically significant interaction of COVID-19 and sedentary lifestyle represents the heightened impact of sedentary lifestyle on BMI during the pandemic. The β coefficient for the interaction term, however, was not significant, even though was positive. This presents that the effect of sedentary lifestyle on BMI did not change statistically significantly before and during COVID-19 pandemic.

Table 6. Interaction effect of Covid-19 and Sedentary Lifestyle on BMI

Variables	β	SE	P-value
Covid-19 * Sedentary Lifestyle			
During * Yes	0.04	0.1542	0.7749
Before * No	Ref.		
Covid-19			
During	0.26	0.0849	0.0004
Before	Ref.		
Sedentary Lifestyle			
Yes	0.30	0.1028	0.0126
No	Ref.		
Age (years)			
19-39	0.05	0.1396	0.7007
40-59	0.16	0.1094	0.1371
≥ 60	Ref.		
Gender			
Male	1.43	0.0775	<.0001
Female	Ref.		
Educational level			
Middle school or less	0.83	0.1314	<.0001
High school	0.49	0.0914	<.0001
College or over	Ref.		
Marital status			
Married	0.52	0.1086	<.0001
Separated or divorced	0.52	0.1571	0.0009
Unmarried	Ref.		
Household income level			
Low	-0.01	0.1283	0.9464
Lower middle	0.36	0.0973	0.0002
Upper middle	0.33	0.0883	0.0002

High	Ref.		
Occupational classification			
White-collar	0.26	0.1028	0.0116
Pink-collar	0.24	0.1028	0.0221
Blue-collar	0.49	0.1147	<.0001
None	Ref.		
Self-Reported Health Status			
High	-1.08	0.1132	<.0001
Middle	-0.90	0.1020	<.0001
Low	Ref.		
Stress Level			
High	0.09	0.1181	0.4622
Middle	-0.11	0.1023	0.2713
Low	Ref.		
Alcohol Consumption			
Heavy alcohol consumption	0.33	0.0987	0.0009
Light alcohol consumption	Ref.		
Regular Exercise			
Yes	0.25	0.0938	0.0068
No	Ref.		
Breakfast Frequency			
More than 5 times a week	-0.06	0.1003	0.5732
1-4 times a week	0.29	0.1066	0.0064
Less than once a week	Ref.		
Eating-out Frequency			
More than 5 times a week	-0.12	0.1093	0.2655
1-4 times a week	-0.01	0.1016	0.9403
Less than once a week	Ref.		

4.2.1 Analyses of Waist Circumference across Different Study Population Groups

Table 7 presents means and standard deviations of the study population's waist circumferences along with the results of t-tests and analyses of variance. Mean waist circumference of the study population before and during COVID-19 were 82.99±10.44 cm and 84.36±10.74 cm respectively. Mean waist circumference of those conducting sedentary lifestyle was 83.63±11.13 cm, which is higher compared to 83.19±10.10 cm of those who are not conducting sedentary lifestyle. Mean waist circumference increased as one gets older. The mean waist circumference of heavy alcohol users was 82.64cm, which is very high compared to 82.79cm of light users. Mean waist circumference was also higher in men, those with lower educational level, and those with highest self-reported health statuses. Those who conducted regular exercises showed lower BMI, but the result was not statistically significant. In contrast to the common belief of having breakfast, those who ate breakfast frequently showed higher waist circumference. Also, those who ate out less than once a week presented the highest mean waist circumference.

Table 7. Descriptive Statistics of the Study Populations' Waist Circumference (in cm)

Variables	Waist Circumference		P-value
	Mean	SD	
Covid-19			<0.0001
During	84.36	±10.74	
Before	82.99	±10.44	
Sedentary Lifestyle			0.0347
Yes	83.63	±11.13	
No	83.19	±10.10	
Age (years)			<0.0001
19-39	80.39	±11.65	
40-59	83.22	±9.89	
≥ 60	87.09	±8.79	
Gender			<0.0001
Male	87.83	±9.20	
Female	79.11	±9.97	
Educational level			<0.0001
Middle school or less	86.48	±9.04	
High school	84.12	±10.19	
College or over	81.83	±10.95	
Marital status			<0.0001
Married	84.18	±10.02	
Separated or divorced	84.40	±9.94	
Unmarried	80.20	±11.83	
Household income level			<0.0001
Low	85.15	±10.43	
Lower middle	84.06	±10.37	
Upper middle	83.32	±10.58	
High	82.23	±10.54	
Occupational classification			0.1717
White-collar	82.31	±10.93	
Pink-collar	86.05	±9.37	
Blue-collar	82.49	±10.59	
None	82.84	±10.63	
Self-Reported Health Status			<0.0001
High	82.14	±10.04	

Middle	83.29	±10.35	
Low	86.23	±11.64	
Stress Level			0.0005
High	83.20	±11.40	
Middle	83.14	±10.24	
Low	84.61	±10.03	
Alcohol Consumption			<.0001
Heavy alcohol consumption	86.64	±10.22	
Light alcohol consumption	82.79	±10.50	
Regular Exercise			0.3291
Yes	83.15	±9.90	
No	83.42	±10.67	
Breakfast Frequency			<.0001
More than 5 times a week	84.29	±9.95	
1-4 times a week	82.32	±11.12	
Less than once a week	81.91	±11.26	
Eating-out Frequency			0.0018
More than 5 times a week	83.37	±10.65	
1-4 times a week	82.65	±10.73	
Less than once a week	84.58	±9.89	

4.2.2 Factors associated with Obesity (Waist Circumference)

Multivariable logistic regression has been used in order to examine factors associated with obesity using waist circumference as an indicator. Table 8 shows association between COVID-19, sedentary lifestyles, other related variables and obesity. Compared to people not sitting long, those who are sitting more than ten hours a day had higher risks of developing obesity. This result was statistically significant (OR = 1.15, 95% CI = 1.03-1.29). Furthermore, participants during COVID-19 were at higher risk of obesity (During: OR = 1.31, 95% CI = 1.17-1.46). Heavy alcohol consumption as well as lower educational level were also related to higher risk of obesity (Heavy alcohol consumption: OR = 1.37, 95% CI = 1.18-1.59; Middle school or less: OR = 1.49, 95% CI = 1.23-1.81; High school: OR = 1.16, 95% CI = 1.01-1.33). Men had a higher risk of developing obesity than women (OR = 2.20, 95% CI = 1.97-2.47). Those who presented higher self-reported health status were at the lowest risk of obesity compared to those reported middle and low health status reports (High: OR = 0.48, 95% CI = 0.41-0.57; Middle: OR = 0.61, 95% CI = 0.53-0.70). In contrast to the result from obesity using body mass index as an indicator, regular exercise was related to lowered risk of obesity when waist circumference was used (OR = 0.83, 95% CI = 0.71-0.97). Lastly, compared to unmarried participants, participants who are married, and separated or divorced, showed higher risk of obesity (Separated or divorced: OR = 1.54, 95% CI = 1.22-1.94; Married: OR = 1.44, 95% CI = 1.22-1.69).

Table 8. Factors associated with Obesity (Waist Circumference >= 85cm & 90cm)

Variables	Obesity		P-value
	OR	95% CI	
Covid-19			
During	1.31	(1.17 – 1.46)	<.0001
Before	1.00		
Sedentary Lifestyle			
Yes	1.15	(1.03 – 1.29)	0.0178
No	1.00		
Age (years)			
19-39	0.59	(0.48 – 0.73)	<.0001
40-59	0.72	(0.61 – 0.85)	<.0001
≥ 60	1.00		
Gender			
Male	2.20	(1.97 – 2.47)	<.0001
Female	1.00		
Educational level			
Middle school or less	1.49	(1.23 – 1.81)	<.0001
High school	1.16	(1.01 – 1.33)	0.034
College or over	1.00		
Marital status			
Married	1.44	(1.22 – 1.69)	<.0001
Separated or divorced	1.54	(1.22 – 1.94)	0.0003
Unmarried	1.00		
Household income level			
Low	1.02	(0.83 – 1.24)	0.8944
Lower middle	1.15	(0.99 – 1.33)	0.0705
Upper middle	1.12	(0.98 – 1.28)	0.092
High	1.00		
Occupational classification			
White-collar	1.28	(1.10 – 1.49)	0.0012
Pink-collar	1.07	(1.05 – 1.46)	0.0124
Blue-collar	1.24	(0.92 – 1.25)	0.3928
None	1.00		

Self-Reported Health Status			
High	0.48	(0.41 – 0.57)	<.0001
Middle	0.61	(0.53 – 0.70)	<.0001
Low	1.00		
Stress Level			
High	1.13	(0.95 – 1.35)	0.1759
Middle	0.93	(0.79 – 1.09)	0.3357
Low	1.00		
Alcohol Consumption			
Heavy alcohol consumption	1.37	(1.18 – 1.59)	<.0001
Light alcohol consumption	1.00		
Regular Exercise			
Yes	0.83	(0.71 − 0.97)	0.016
No	1.00		
Breakfast Frequency			
More than 5 times a week	1.03	(0.88 – 1.20)	0.7445
1-4 times a week	1.11	(0.94 – 1.31)	0.2102
Less than once a week	1.00		
Eating-out Frequency			
More than 5 times a week	0.85	(0.72 – 1.01)	0.0592
1-4 times a week	1.01	(0.87 – 1.18)	0.870
Less than once a week	1.00		

4.2.3 Factors associated with Waist Circumference

On top of investigating the risk of obesity using waist circumference as a measure of obesity, factors associated with waist circumference itself also has been examined. Multiple linear regression analysis has been used accordingly. Table 9 summarizes the associations between COVID-19, sedentary lifestyle, other related variables and waist circumference. Waist circumference was significantly higher among participants sitting for more than ten hours a day than those who are not (β = 1.11, P < 0.0001). The result aligns with that of body mass index. Participants during COVID-19 also showed higher waist circumference compared to that of those before COVID-19 (β = 1.43, P < 0.0001). This also matches the result from BMI, further strengthening the logic of the paper. Men, as well as those who are older, showed higher waist circumference. As the educational level decreased, individuals had a higher level of waist circumference. Waist circumference decreased as participants reported lower self-health status. Heavy alcohol consumption was also related to increased waist circumference. These results were all statistically significant.

Table 9. Factors associated with Waist Circumference

Variables	β	SE	P-value
Covid-19			
During	1.43	0.2024	<.0001
Before	Ref.		
Sedentary Lifestyle			
Yes	1.11	0.1912	<.0001
No	Ref.		
Age (years)			
19-39	-2.93	0.3661	<.0001
40-59	-1.64	0.2866	<.0001
≥ 60	Ref.		
Gender			
Male	8.97	0.2030	<.0001
Female	Ref.		
Educational level			
Middle school or less	2.63	0.3443	<.0001
High school	1.31	0.2394	<.0001
College or over	Ref.		
Marital status			
Married	2.75	0.2848	<.0001
Separated or divorced	3.03	0.4117	<.0001
Unmarried	Ref.		
Household income level			
Low	0.08	0.3363	0.8137
Lower middle	0.68	0.2551	0.0079
Upper middle	0.61	0.2314	0.0088
High	Ref.		
Occupational classification			
White-collar	0.38	0.2695	0.159
Pink-collar	0.73	0.3005	0.0152
Blue-collar	-0.08	0.2692	0.7683
None	Ref.		
Self-Reported Health Status			

High	-3.26	0.2968	<.0001
Middle	-2.53	0.2672	<.0001
Low	Ref.		
Stress Level			
High	0.19	0.3098	0.5481
Middle	-0.37	0.2684	0.1664
Low	Ref.		
Alcohol Consumption			
Heavy alcohol consumption	1.39	0.2586	<.0001
Light alcohol consumption	Ref.		
Regular Exercise			
Yes	-0.35	0.2457	0.1585
No	Ref.		
Breakfast Frequency			
More than 5 times a week	0.08	0.2630	0.7552
1-4 times a week	0.76	0.2796	0.0069
Less than once a week	Ref.		
Eating-out Frequency			
More than 5 times a week	-0.39	0.2864	0.1723
1-4 times a week	0.02	0.2662	0.9421
Less than once a week	Ref.		

4.2.4 Subgroup Analysis for Obesity Risk (Waist Circumference) according to the Occupational Classification

Subgroup analysis was performed with the multinomial logistic regression analysis to investigate the associations between COVID-19 pandemic and obesity using waist circumference as a measure focused on the occupational variables. Table 10 presents both the result of subgroup analysis and general characteristics of participants by sedentary lifestyle in order to conveniently compare changes in sedentary behavior and the subsequent differences in odd ratios of obesity. White-collar workers presented the highest risk of developing obesity (waist circumference) compared to pink-collar workers, blue-collar workers, and those without a job (White-collar: OR = 1.50, 95% CI = 1.25-1.81; Pink-collar: OR = 1.44, 95% CI = 1.10-1.88; Blue-collar: OR = 1.50, 95% CI = 1.10-1.62; None: OR = 1.32, 95% CI = 1.12-1.55;). On the same token, white-collar workers illustrated the biggest difference in the percentages of participants conducting sedentary lifestyle before and during COVID-19 (7.2%). Those without an occupation followed with 5.7%, while pink and blue-collar workers showed only 1.4% and 1.9% of differences respectively.

Table 10. Changes in Sedentary Lifestyles by Occupations and respective Obesity Risks (Waist Circumference)

Variable	[a] OR	95% CI	[a] OR	Sedentary Lifestyle					
	During		Before	During			Before		
Occupational classification				Yes	No		Yes	No	
White-collar	1.50	(1.25 – 1.81)	1.00	509	306	(62.5)	1170	944	(55.3)
Pink-collar	1.44	(1.10 – 1.88)	1.00	110	268	(29.1)	273	712	(27.7)
Blue-collar	1.34	(1.10 – 1.62)	1.00	134	422	(24.1)	402	1147	(26.0)
None	1.32	(1.12 – 1.55)	1.00	446	459	(49.3)	948	1226	(43.6)

[a] Adjusted for age, gender, educational level, marital status, household income level, self-reported health status, stress level, alcohol consumption, regular exercise, breakfast frequency, eating-out frequency.

4.2.5 Factors associated with Waist Circumference with an interaction term

Multiple linear regression analysis was performed again in order to verify if the effect of sedentary lifestyles on waist circumference has been changed or not during the pandemic. Table 11 summarizes the associations between the interaction between COVID-19 and sedentary lifestyle on waist circumference. Statistically significant interaction of COVID-19 and sedentary lifestyle represent the heightened impact of sedentary lifestyle on waist circumference during the pandemic. The β coefficient for the interaction term was not significant, even though was positive. This presents that the effect of sedentary lifestyle on waist circumference did not change statistically significantly before and during COVID-19 pandemic.

Table 11. Interaction effect of Covid-19 and Sedentary Lifestyle on Waist Circumference

Variables	β	SE	P-value
Covid-19 * Sedentary Lifestyle			
During * Yes	0.08	0.4042	0.8393
Before * No	Ref.		
Covid-19			
During	1.40	0.2694	<.0001
Before	Ref.		
Sedentary Lifestyle			
Yes	1.08	0.2226	<.0001
No	Ref.		
Age (years)			
19-39	-2.93	0.3661	<.0001
40-59	-1.64	0.2867	<.0001
≥ 60	Ref.		
Gender			
Male	8.97	0.2031	<.0001
Female	Ref.		
Educational level			
Middle school or less	2.63	0.3444	<.0001
High school	1.31	0.2395	<.0001
College or over	Ref.		
Marital status			
Married	2.75	0.2848	<.0001
Separated or divorced	3.03	0.4118	<.0001
Unmarried	Ref.		
Household income level			
Low	0.08	0.3363	0.814
Lower middle	0.68	0.2552	0.0079
Upper middle	0.61	0.2314	0.0088
High	Ref.		

Occupational classification			
White-collar	0.38	0.2695	0.1592
Pink-collar	-0.08	0.2692	0.7714
Blue-collar	0.73	0.3006	0.0151
None	Ref.		
Self-Reported Health Status			
High	-3.26	0.2968	<.0001
Middle	-2.53	0.2672	<.0001
Low	Ref.		
Stress Level			
High	0.19	0.3098	0.548
Middle	-0.37	0.2684	0.1669
Low	Ref.		
Alcohol Consumption			
Heavy alcohol consumption	1.39	0.2586	<.0001
Light alcohol consumption	Ref.		
Regular Exercise			
Yes	-0.35	0.2457	0.1586
No	Ref.		
Breakfast Frequency			
More than 5 times a week	0.08	0.2630	0.7548
1-4 times a week	0.76	0.2797	0.0069
Less than once a week	Ref.		
Eating-out Frequency			
More than 5 times a week	-0.39	0.2864	0.1714
1-4 times a week	0.02	0.2662	0.9437
Less than once a week	Ref.		

4.3. Falsification Test

The results of the falsification tests are given in the Appendix 1 and 2 in order to check if there is any trend in the obesity risk before the COVID−19 pandemic. Multivariable logistic regressions have been used to examine risk of obesity using both waist circumference and BMI as indicators before COVID−19 (2016,2017,2018).

In Appendix 1, BMI has been used as a measure of obesity. 2017 and 2018 Participants did not present statistically significant different odd ratios of obesity compared to those from 2016 (2017: OR = 0.93, 95% CI = 0.82−1.06; 2018: OR = 0.93, 95% CI = 0.82−1.06). On the same token, waist circumference has been used as a measure of obesity in Appendix 2. The risk of obesity among 2017 and 2018 participants were not significantly higher than that of the 2016 participants when waist circumference has been used as an indicator. In fact, according to the results of the falsification tests, the positive odd ratios of obesity during COVID−19 compared to that of the participants before the pandemic which are indicated in the table 3 and 8, represent the COVID−19 as a risk factor of obesity among South Korean adults.

Chapter 5. Discussion

5.1. Discussion of the Study Methods

Ultimately, this study aimed to examine the factors associated with obesity among Korean populations during and before COVID-19 pandemic. Furthermore, this study investigated the impact of COVID-19 on conducting sedentary lifestyle among the Korean adults. The sedentary behavior changes were divided into those who sit more than ten hours a day and those who sit less then it. Obesity classified by both waist circumference and BMI, as well as waist circumference and BMI themselves as continuous variables have been used. Additionally, we also showed the results of sedentary lifestyle changes and the risk of obesity during COVID-19 among different job classifications. Lastly, the associations between interaction term of COVID-19 and sedentary lifestyles and BMI and waist circumference were investigated.

Both multinomial logistic regression and the multiple linear regression were required to identify the target associations. Furthermore, interaction effect of the two independent variables had to be identified using multiple linear regression. Lastly, subgroup analyses were also needed to compare the changes in sedentary behaviors and risks of obesity for participants with different jobs. In fact, as our study includes various study designs, multiples of proper statistical analyses were necessary. Therefore, we used the multinomial logistic regressions and multiple linear regressions to analyze the factors associated with COVID-19 and sedentary lifestyles. Subgroup analyses were also used to analyze the effect of COVID-19 on sedentary lifestyles and subsequent

changes in obesity rates. All investigations were conducted twice by using body mass index and waist circumference in order to fully scrutinize the associations between obesity, COVID-19, and sedentary lifestyles. As a result, this study could provide much information about participant during COVID-19 with the proper methods. Thus, this could help policy makers to provide accurate guidance to people who are undergoing the pandemic.

5.2. Discussion of the Results

This study describes the connections between COVID-19 pandemic with the "stay-at-home" orders and subsequent changes in sedentary behaviors and obesity rates of Korean adults, using demographic, socioeconomic, and health-related variables gained from the 2018, 2019, and 2020 KNHANES data.

Our findings indicate that participants who conducted sedentary lifestyles tend to have increased risk of obesity during COVID-19 pandemic. Compared to those who did not sit for a long time, those who sat longer than ten hours a day had higher odds of obesity. All the results were on the same direction using both BMI and waist circumference as the indicators of obesity. Similarly, participants showed increase BMI and waist circumference as they sat longer. With regard to COVID-19, we found that COVID-19 has played as a risk factor of obesity among South Korean adults even after adjusting related variables; participants during COVID-19 showed higher odds of obesity compared to those before the pandemic. Also, according to the falsification tests, no difference in risk of obesity before the pandemic was found, therefore substantiating the founding.

The higher odds of obesity during COVID-19 classified by waist circumference were consistent in all subgroups by occupational classification. Meanwhile, white-collar workers who showed the highest odd ratio of obesity also presented the most changes in sedentary behaviors; this partially demonstrates how COVID-19 affected prevalence of obesity differently depending on the sedentary lifestyles.

When the odds of obesity were classified by BMI, not every result was consistent; for pink- and blue-collar workers who showed relatively low changes in sedentary time did not present statistically significant odd ratio of obesity, while white-collar workers who began sedentary lifestyles the most during the pandemic accordingly showed the highest odds of obesity. The result aligns with a previous study. According to the previous study, during COVID-19, desk workers especially had more sedentary and less active work; they presented an increase in sedentary time, reduce in sleep quality and quality of life (Barone Gibbs, Kline, Huber, Paley, & Perera, 2021). Certainly, work from home policies, along with the lockdown, impaired sedentary behavior level of the desk workers, highly likely leading them to be obese. Furthermore, those without a job who showed second highest changes in the percentage of conducting sedentary lifestyle correspondingly presented second highest odds of obesity during COVID-19. Another study states that compared to those whose employment remained unchanged, participants who lost jobs due to the pandemic reported higher sitting time (McDowell, Herring, Lansing, Brower, & Meyer, 2020). In fact, this also substantiates the result of the subgroup analysis. As a result, this study proves the association between COVID-19 pandemic and sedentary lifestyles, and subsequent increase in obesity rates due to the changed lifestyles among South Korean adults.

Lastly, interactions between COVID-19 and sedentary lifestyle on waist circumference and BMI were not both statistically significant. Hence, there was no additional effect of sedentary behaviors on obesity before and during COVID-19.

5.3. Policy Implications

To reduce the health risk of the general populations during COVID-19, interventions must be developed to both prevent further spread of pandemic and manage individuals to conduct appropriate behaviors during the rapid changes. Engagement in unhealthy behavior, including excessive time spent sited, exacerbates the vulnerabilities and places people at the risk of obesity, which possibly lead to various adverse health outcomes later in life. Therefore, to prevent them from longer-term adverse outcomes of obesity and sedentary behavior such as cardiovascular diseases, musculoskeletal disorders, and even some severe cancers, establishing the prevalence and risk factors of obesity is important. Especially during pandemic where maintaining good levels of fat is critical to the health of the individuals, aggressive health educations and effective campaign considering the changed circumstances of the target population is necessary.

Korean adults may encounter a range of potential effects during and after COVID-19 not only from the pandemic itself but also from the changed health behaviors during the pandemic. Social distancing which includes contact tracing, quarantine, and remote working that do not take account of health behaviors changes of the participants are unseemly. Understandably, as the focus of the government officials has been on minimizing the spread of the virus, there are significant changes in the lifestyles of the population that are left unattended. Meanwhile, there is a lack of evidence to provide the guidance regarding implementing social distancing appropriately owing to important questions such as how people should behave under the restriction and how often, in what way they better maintain their health while following the instructions.

Indeed, only statistic information of obesity rate is provided as national indicators, and there is only limited research that identified COVID-19 as the actual risk factor of obesity while adjusting related variables. Moreover, even though it is proven by the previous study that there was an increase in sedentary time during COVID-19 pandemic among South Korean adults, the effects from such changes were not identified. Therefore, it is essential to have the evidence of how things have changed during COVID-19 and what results the pandemic has brought to the people in order for the government to provide necessary guidance.

To design effective interventions for the population while minimizing spread of the virus, it is important to know the exact number of changes occurred in behaviors and the increasement in the risks of the diseases. This paper can provide pieces of evidence that the policy makers might refer to when organizing a guidance for the future social distancing and providing necessary information to sustain healthy living for the publics who are still going through harsh changes in their lives.

5.4. Limitations

Because only few studies investigated the factor associated with sedentary lifestyles changes, and examine the effects of health behavior changes on obesity risk among South Korean adults during COVID-19 pandemic, our study provides the necessary information about the behaviors changed during the pandemic. Yet, there are several limitations for the current study. First of all, the data in this study are based on self-reported measures, and health status measurements might be subject to recall bias. Therefore, caution should be taken when interpreting these results. Also, due to this study's cross-sectional design, cause and effect, as well as the direction of the relationships observed, could not be determined. Hence, the effect of COVID-19 pandemic on sedentary lifestyle and subsequent increase in obesity rate could not be fully explained. Lastly, cultural aspects could have influenced the impact of the COVID-19 pandemic on sedentary lifestyle of Korean adults.

Despite these limitations, our study does possess several strengths. First of all, the Korean National Health and Nutrition Examination Survey (KNHANES) is conducted by a national institution based on random cluster sampling, and therefore, the data gained from it is statistically reliable and representative in comparison to surveys performed by private institutions. Moreover, as this study was conducted for over three years, the representativeness of the sample was improved upon. Furthermore, KNHANES data is derived from health interviews, which includes both physical examinations and nutrition surveys, that form a reliable base for the creation of health-related policies and programs (Kweon et al., 2014). Lastly, many covariates, including

age, sex, educational level, marital status, household income level, occupations, stress level, subjective health status, alcohol consumption, regular physical exercise, breakfast and eating-out frequency were included to reduce the possible confounding effects.

Chapter 6. Conclusion

6.1. Conclusion

The current study investigates the association between obesity rate, sedentary lifestyle, and COVID-19 among South Korean adults. Based on our results, COVID-19 pandemic has increased the risk of obesity of South Koreans. Our findings also indicates that participants were more likely to stay sited during COVID-19 and while sedentary lifestyle was positively correlated with obesity. In fact, excessive sedentary lifestyle, more than 10 hours a day, has a significant impact on obesity. The results were identical using both body mass index and waist circumference. As our study also found out that white collar workers who had the most increase in sedentary behavior also has the most increase in the risk of obesity using BMI as an indicator, this may emphasize the effects of COVID-19 on sedentary lifestyles and subsequent increase in obesity rates among South Korean adults. Therefore, this highlights the importance of managing health behaviors among the general Korean population especially during COVID-19.

As well as the health outcomes from the pandemic, long-term health consequences from obesity and sedentary lifestyle are also very important public health concerns. A lot of studies, however, are mostly focused on the direct health outcomes from the pandemic. Hence, this study found that the risk of obesity increased in South Korea, partially due to the mounting sedentary behavior during COVID-19. We believe this study can bring economic, social, and political advantages by raising awareness about importance of conducting appropriate health behaviors under the restriction of

inevitable social distancing. In fact, it is crucial for the government officials to understand the social and behavioral changes caused by the pandemic, and direct attention of the population toward conducting healthy behaviors by providing necessary subject of recommendation. Further research related to diverse health behaviors changes during COVID-19 are needed, and the guidelines to prevent further negative health outcomes must be provided accordingly.

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Appendix 1. Factors associated with Obesity (BMI >= 25 kg/m²) Before COVID-19

Variables	Obesity		P-value
	OR	95% CI	
Year			
2018	1.04	(0.92 – 1.18)	0.5026
2017	0.93	(0.82 – 1.06)	0.2261
2016	1.00		
Sedentary Lifestyle			
Yes	1.23	(1.11 – 1.36)	<.0001
No	1.00		
Age (years)			
19-39	1.24	(1.04 – 1.49)	0.0199
40-59	1.27	(1.09 – 1.47)	0.0021
≥ 60	1.00		
Gender			
Male	2.30	(2.08 – 2.54)	<.0001
Female	1.00		
Educational level			
Middle school or less	1.34	(1.12 – 1.60)	0.0014
High school	1.09	(0.96 – 1.24)	0.1892
College or over	1.00		
Marital status			
Married	1.38	(1.19 – 1.61)	<.0001
Separated or divorced	1.45	(1.16 – 1.82)	0.0012
Unmarried	1.00		
Household income level			
Low	0.99	(0.82 – 1.19)	0.9299
Lower middle	1.12	(0.97 – 1.28)	0.1221
Upper middle	1.17	(1.04 – 1.31)	0.0118
High	1.00		
Occupational classification			

White-collar	0.94	(0.81 – 1.08)	0.3878
Pink-collar	1.05	(0.90 – 1.22)	0.5353
Blue-collar	1.17	(1.00 – 1.37)	0.0493
None	1.00		
Self-Reported Health Status			
High	0.58	(0.49 – 0.67)	<.0001
Middle	0.68	(0.59 – 0.78)	<.0001
Low	1.00		
Stress Level			
High	1.02	(0.87 – 1.20)	0.8122
Middle	0.86	(0.75 – 0.99)	0.0395
Low	1.00		
Alcohol Consumption			
Heavy alcohol consumption	1.28	(1.12 – 1.46)	0.0004
Light alcohol consumption	1.00		
Regular Exercise			
Yes	1.19	(1.05 – 1.35)	0.0079
No	1.00		
Breakfast Frequency			
More than 5 times a week	1.03	(0.89 – 1.20)	0.7000
1-4 times a week	1.19	(1.03 – 1.39)	0.0231
Less than once a week	1.00		
Eating-out Frequency			
More than 5 times a week	0.91	(0.78 – 1.07)	0.2398
1-4 times a week	0.96	(0.83 – 1.10)	0.5350
Less than once a week	1.00		

Appendix 2. Factors associated with Obesity (Waist Circumference >= 85cm & 90cm) Before COVID-19

Variables	Obesity		P-value
	OR	95% CI	
Year			
2018	1.04	(0.92 – 1.19)	0.5169
2017	0.93	(0.81 – 1.07)	0.2920
2016	1.00		
Sedentary Lifestyle			
Yes	1.28	(1.16 – 1.43)	<.0001
No	1.00		
Age (years)			
19-39	0.83	(0.68 – 1.01)	0.0624
40-59	0.86	(0.73 – 1.02)	0.0813
≥ 60	1.00		
Gender			
Male	2.12	(1.90 – 2.36)	<.0001
Female	1.00		
Educational level			
Middle school or less	1.40	(1.16 – 1.69)	0.0006
High school	1.83	(1.48 – 2.28)	0.1013
College or over	1.00		
Marital status			
Married	1.65	(1.40 – 1.95)	<.0001
Separated or divorced	1.84	(1.48 – 2.28)	<.0001
Unmarried	1.00		
Household income level			
Low	1.14	(0.94 – 1.38)	0.1755
Lower middle	1.15	(1.00 – 1.33)	0.0526
Upper middle	1.20	(1.05 – 1.37)	0.0069
High	1.00		
Occupational classification			

White-collar	0.96	(0.83 – 1.12)	0.6350
Pink-collar	0.86	(0.73 – 1.00)	0.0440
Blue-collar	1.02	(0.87 – 1.19)	0.8340
None	1.00		
Self-Reported Health Status			
High	0.49	(0.42 – 0.58)	<.0001
Middle	0.67	(0.58 – 0.72)	<.0001
Low	1.00		
Stress Level			
High	0.96	(0.80 – 1.15)	0.6419
Middle	0.92	(0.79 – 1.08)	0.2939
Low	1.00		
Alcohol Consumption			
Heavy alcohol consumption	1.31	(1.13 – 1.51)	0.0004
Light alcohol consumption	1.00		
Regular Exercise			
Yes	0.89	(0.77 – 1.04)	0.1388
No	1.00		
Breakfast Frequency			
More than 5 times a week	0.99	(0.84 – 1.17)	0.8961
1-4 times a week	1.03	(0.86 – 1.23)	0.7832
Less than once a week	1.00		
Eating-out Frequency			
More than 5 times a week	0.93	(0.80 – 1.09)	0.3513
1-4 times a week	0.98	(0.85 – 1.13)	0.7699
Less than once a week	1.00		

Korean Abstract

이론적 배경: 2020년 3월부터 한국은 코로나-19 확산을 방지하기 위해 사회적 거리두기 정책을 시행하였다. 해당 정책은 확진자 동선 추적, 격리, 원격 근무 등을 포함하였고, 이는 한국 성인들의 생활에 많은 변화를 불러 일으켰다. 사람들은 실내에서 많은 시간을 보내게 되었고, 이에 앉아서 시간을 보내는 좌식 생활이 증가하였다. 좌식 생활은 비만과 밀접한 상관관계가 있는데, 비만은 많은 의학적 합병증을 야기하는 심각한 문제이다. 그러므로 해당 연구는 코로나-19가 좌식 생활에 미치는 영향과 그에 따른 한국 성인의 달라진 비만율을 분석하고자 한다.

연구 방법: 해당 연구는 2018, 2019, 2020년 국민건강영양조사 데이터를 사용해, 9,476명의 대상자를 포함하였다. 코로나-19와 좌식 생활이 주된 독립 변수로 사용되었다. 종속 변수인 비만은 대한비만학회의 기준에 따라 BMI와 허리둘레를 모두 사용하여 정의하였다. 종속변수와 독립변수 간의 상관관계를 구하기 위해 Multiple logistic regression analysis 과 ordinary least squares regression analysis 가 사용되었다.

연구 결과: 좌식 생활을 하는 대상자의 비율이 코로나-19 이전 30.4%

에서 동안에 36.6%로 증가하였다. 코로나-19 기간동안 각각 BMI와 허리 둘레를 이용한 비만 변수 모두에서 증가된 위험을 확인하였다 (Obesity (BMI): OR = 1.16, 95% CI = 1.04-1.30; Obesity (WC): OR = 1.31, 95% CI = 1.17-1.46). 또한, 좌식 생활에서 역시 두 기준을 따른 비만에서 증가된 위험을 확인할 수 있었다 (Obesity (BMI): OR = 1.17, 95% CI = 1.04-1.31; Obesity (WC): OR = 1.15, 95% CI = 1.03-1.29). 마지막으로 화이트 칼라 근무자가 코로나-19 기간동안 가장 많은 좌식 생활인의 증가가 있었는데, 기타 다른 근무자 그룹에 비해 가장 높은 비만의 위험을 확인할 수 있었다.

결론: 해당 연구는 코로나-19 기간동안 대상자의 좌식 생활 증가를 확인하였다. 또한, 좌식 시간 변화로 인해 증가한 비만의 위험을 확인할 수 있었다.

Keyword : 좌식 생활, 코로나-19, 비만
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