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The COVID-19 Outbreak in South Korea: Lessons to Be Learned

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Abstract

The Coronavirus 2019 (COVID-19) is a novel type of coronavirus-related disease that has over 4 million confirmed cases worldwide as of May 13th, 2020. With over 200 countries impacted by the pandemic, many countries have taken drastic measures such as temporary closure of international borders. The purpose of this thesis is to examine the South Korean response to COVID-19 and the keys to successful containment of the disease. Real time analysis was performed on data provided by the Centers for Disease Control (CDC). Comparisons of disease containment among countries with the highest confirmed cases were normalized for population size differences by taking the proportion of confirmed cases to population size. We further compared the disease outbreak in Seoul, a very urban environment, to the whole country of South Korea, to compare public health in urban and rural environments. We found that the efficient partnership between the private sector and the state led to rapid development in testing kits, which was integral to the South Korean response to COVID-19. In addition, the South Koreans' community spirit, approval of government-led interventions, and societal norm of wearing masks were also efficient social responses to the spreading disease. In this paper, we navigate the impacts of a universal healthcare system and its ability to battle infectious diseases and the efficacy of various governmental actions in response to a public health crisis.

Keywords

Infectious Diseases, Respiratory Viral Infections, Public Health,

Disease Prevention

1. Introduction

Over the past decade, South Korea has dealt with multiple epidemics of viral respiratory diseases. Among those, the most notable were Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS). First reported in 2002 in southern China, SARS, caused by SARS-associated coronavirus (SARS-CoV), was a pandemic that spread rapidly worldwide and infected more than 8000 people from 29 countries [1]. Yet South Korea was able to remain essentially unaffected with thorough preparation by the government. Seeing the damage caused by the outbreaks in China and Hong Kong, the Korean government placed restrictions on all forms of travel to countries with known cases of SARS such as China, Taiwan, and Canada. Additionally, it tracked body temperatures of every person coming from overseas through the use of computer-based thermometer systems in airports and seaports. It then immediately isolated any patients with symptoms suggestive of potential SARS infection in designated hospitals until symptom resolution [2]. Through these efforts, South Korea only had 3 confirmed cases by the time the SARS outbreak was declared to be over.

On the other hand, South Korea was severely afflicted by the MERS epidemic. The outbreak initially began in May 2015 when a 68-year-old male returned back home after a visit to the Middle East. Within days after his return, he developed symptoms that suggested of possible MERS infection, including fever and respiratory distress. Despite seeking care immediately, he was not officially diagnosed with the disease until 9 days later [3]. By then, he had visited multiple clinics and large hospitals for treatment. Due to this ease of moving from one hospital to another under South Korea's universal healthcare system, many cases of secondary infection among patients and medical staff who came in contact with the patient arose. By June 2015, a total of 108 people became infected through this initial chain of transmission, with 9 deaths. Furthermore, due to lack of a proper national response to the disease with proper protocol, oversight, and ability to facilitate communication between medical institutions, several secondary patients were transferred to other hospitals without being quarantined. This led to additional cases of infections [2] [4]. By the time the MERS outbreak was considered to be over, South Korea became the country that was most heavily affected by MERS outside of the Middle East with 186 laboratory-confirmed cases and 38 deaths. The MERS crisis also led to mask-wearing to become a norm of infection prevention within South Korea.

Coronavirus disease 2019 (COVID-19), was first identified from patients with clinical presentations greatly resembling viral pneumonia in December 2019 in the city of Wuhan, China [5]. The disease is caused by a type of Betacoronavirus called the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), from

the same family as SARS and MERS, but displays a number of notable differences compared to the two. Unlike SARS, which becomes infectious only after the symptom onset, and MERS, which has low human-to-human transmission rate, COVID-19 is characterized by high transmissibility and is known to be passed even from patients who remain asymptomatic [6] [7]. As a comparison, the basic reproductive number (R_0) of COVID-19 is calculated to be as high as 5.7 in some studies, which is considerably higher than that for MERS (<1) [8] [9]. Furthermore, in patients with COVID-19, viral loads are found to be the highest at the time of symptom onset. This deviates from the pattern observed in patients with SARS or MERS in which the peak loads occur at around 7 - 10 days after symptom onset [10] [11] [12]. COVID-19 also has less severe clinical manifestations, as evidenced by lower fatality rate (2.3% - 4.2%) compared to SARS (9.5%) or MERS (34.4%). These combined characteristics of peak viral-shedding at symptom onset and more mild symptoms allow COVID-19 to have a great efficiency for community infection and spread [9] [13] [14].

2. Methodology

The first confirmed case of COVID-19 in South Korea was recorded on January 20, 2020. The number of confirmed cases slowly increased over the next thirty days until February 17th at a rate of 1 - 2 cases per day. Upon inspection of the first thirty patients from January 20th to February 17th, most of the cases were either patients who were infected while abroad and diagnosed upon return or those who had contact with index patients [15]. Of the thirty patients, 40% (12/30), including the very first case, were found to have visited Wuhan, where the disease was first reported. Despite some secondary infections, no massive outbreaks were noted by that time. The situation quickly changed with the identification of a superspreading event in Daegu, a city of 2.5 million people in the southeastern part of South Korea. In the process of tracking people who had come in contact with patient #31, who was diagnosed with the disease on February 18th, it was discovered that she had visited the Shincheonji Church in Daegu to attend services on February 9th and 16th. With hundreds of members reported to have been present at these services, the possibility of mass infection was large. Inspection of every attendee revealed extensive chains of transmission that involved more than 3900 secondary cases [16] [17]. Soon after, another significant cluster of COVID-19 was identified in a nearby city of Cheongdo. A number of patients in a closed psychiatric ward of Daenam Hospital in Cheongdo started displaying symptoms related to COVID-19 in mid to late February. Upon investigation, a total of 118 patients in the ward were found to have been infected with the virus [18] [19]. With the occurrence of these massive outbreaks, the number of confirmed cases began to increase rapidly, reaching 6284 cases by March 6th [20]. The news that close to 100 countries around the world had decided to close their borders to anyone traveling from South Korea further added to the panic among the public. To respond to this dire situation, the national government raised the COVID-19 risk alert to the highest level (Level 4) and implemented a wide array

of social distancing measures, including restrictions on public transportation and closing of schools [16] [21].

When examining the COVID-19 outbreak trends around the world, densely populated cities were among those that were most heavily affected by COVID-19. In addition to Wuhan, the city with a population of over 11 million where the disease was first reported, dense urban centers including Madrid, Milan, and New York City have become epicenters of the pandemic [22]. In contrary to the situations in these cities, Seoul has largely been able to contain the virus without massive outbreaks mirroring those in these epicenters. As the capital and economic center of South Korea, Seoul is an extremely densely populated city. With just under 10 million people living within 600 square kilometers, it has a higher population density than most, if not all, of the major cities that have been heavily afflicted by COVID-19, including New York City [22]. Yet Seoul was able to limit the number of cases within the city to 621 confirmed cases as of April 17, 2020, equivalent to 62 cases per 1 million of population. This figure is lower than the national average in South Korea as well as the averages in the abovementioned cities. In this study, we aim to analyze the factors that allowed Seoul to effectively curb the spread of COVID-19 as well as the shortcoming that were observed during the outbreak. Through this assessment, we will identify important lessons that could be applied to better manage similar outbreaks in the future.

3. Results

From **Figure 1**, we observe that South Korea experienced a brief period of

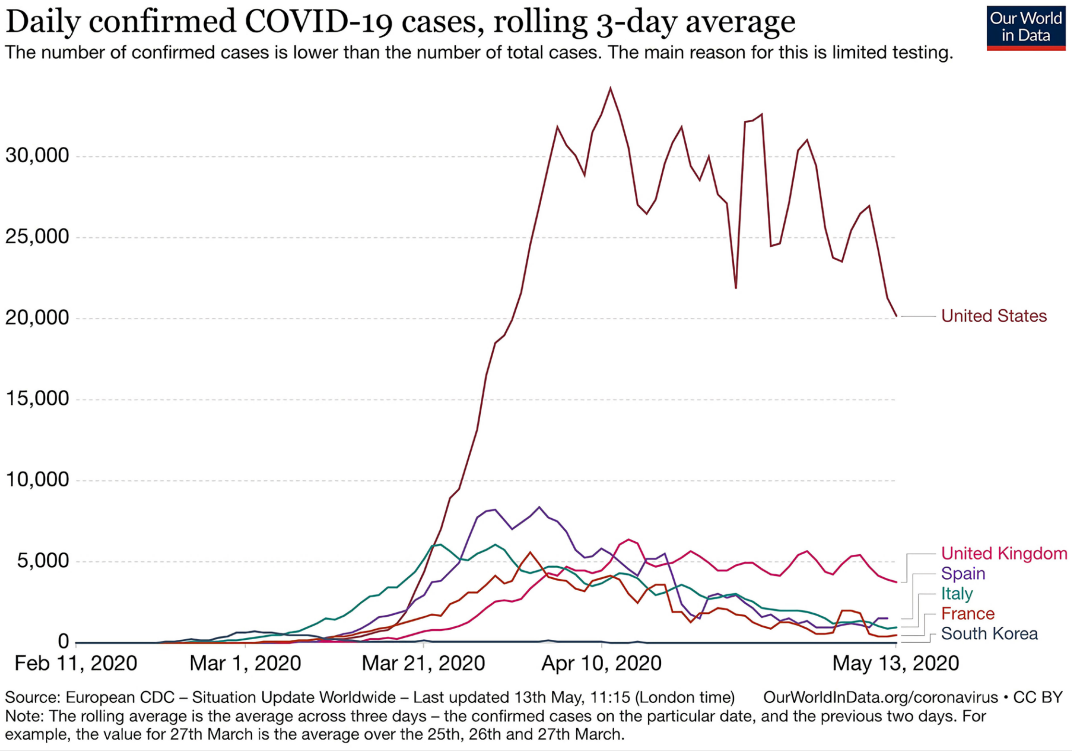

Figure 1. Daily confirmed COVID-19 cases (Rolling 3-Day Averages).

exponential increase in confirmed COVID-19 cases between February 24th, and March 8th, 2020. The country observed its peak on March 2nd, with 730 new cases. On the contrary, the United States observed a longer, more clearly defined exponential growth between March 14th, and April 5th, when it observed 31,839 new cases. It saw a slight decline to 28,857 on April 8th, before climbing back up to 34,250 new cases on April 11th, which currently are the maximum daily confirmed cases in one day in the United States.

Figure 2 and Figure 3 allow us to compare the overall pattern of increase in

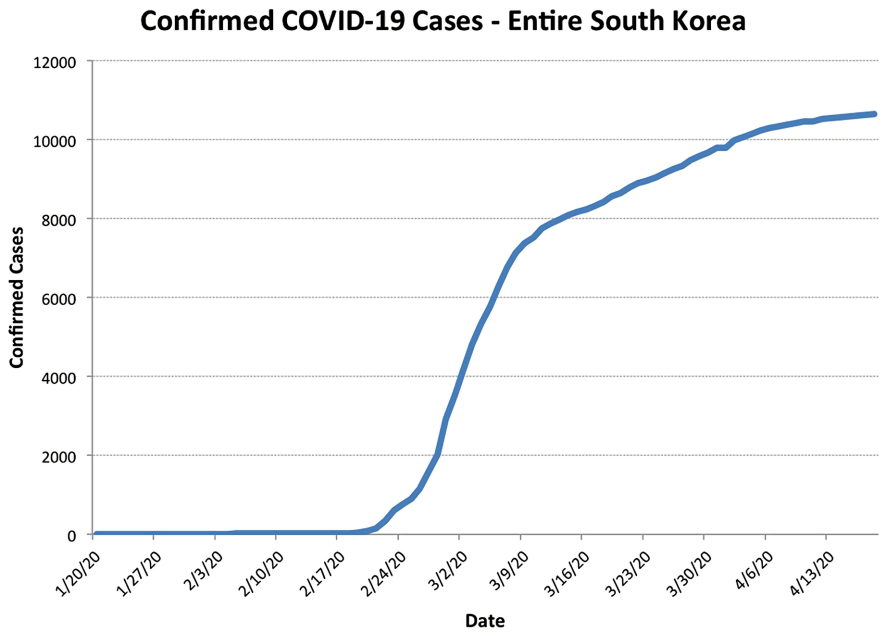

Figure 2. Cumulative confirmed COVID-19 cases (Entire South Korea).

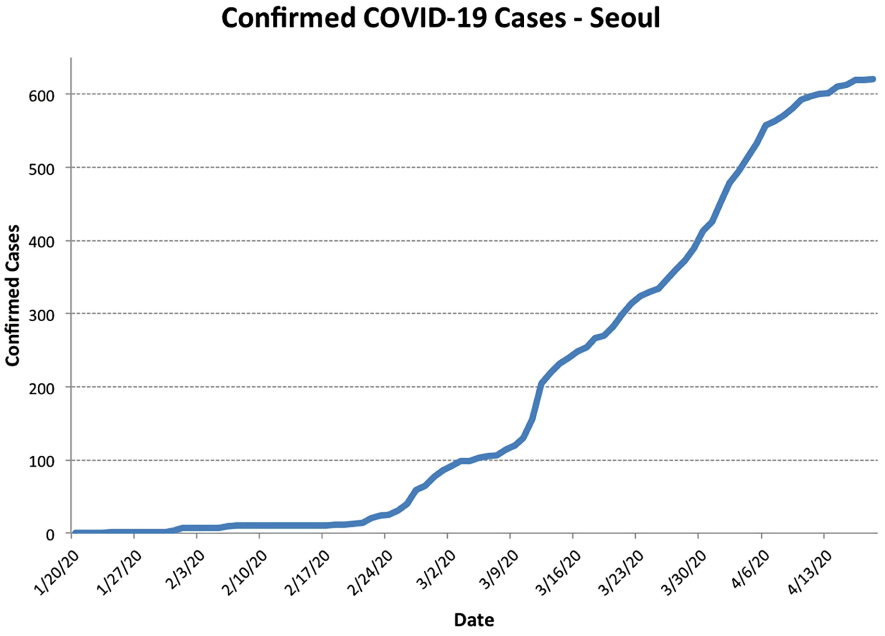

Figure 3. Cumulative confirmed COVID-19 cases (Seoul).

confirmed COVID-19 cases between the entire South Korea and Seoul. We can again note that South Korea as a whole did experience a brief spike in number of cases from 1146 cases on February 26th to 7382 cases on March 9th. On the other hand, Seoul only experienced a steady increase in confirmed cases with the exception of a brief, 2-day spike between March 10th and March 12th. These data points were further supported by our findings in Figure 4 and Figure 5.

In Figure 4 and Figure 5, we compared the density of confirmed cases per 10,000 people in the whole country, as well as Seoul. In Figure 5, we observed

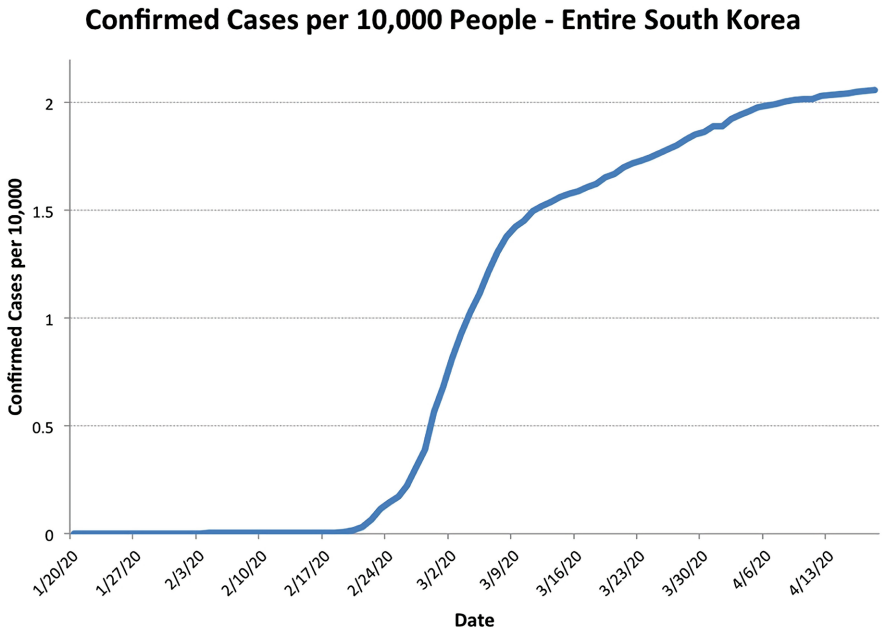

Figure 4. Confirmed cases per 10,000 people (Entire South Korea).

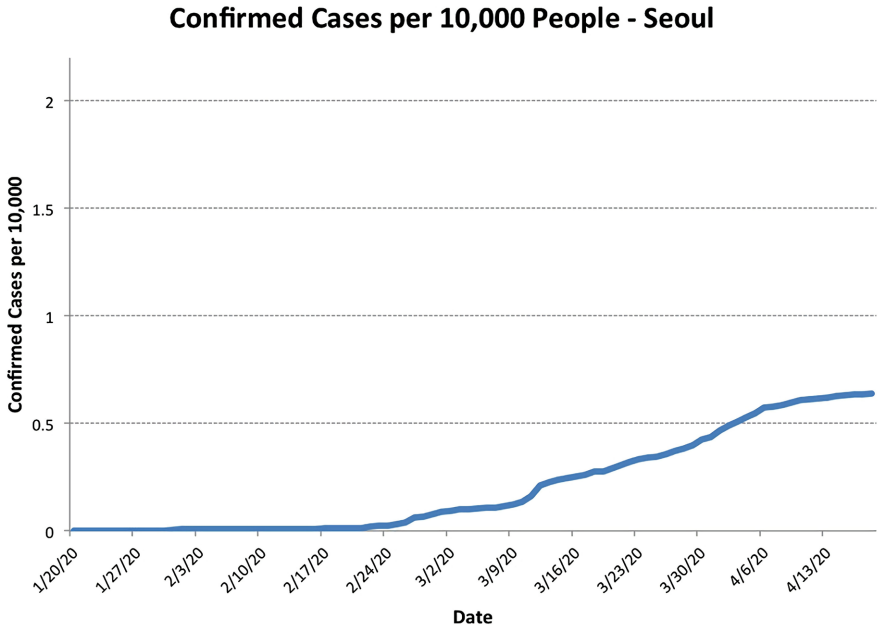

Figure 5. Confirmed cases per 10,000 people (Seoul).

the 2-day spike between March 10th and March 12th as the only noticeable deviation from the overall trend of relatively slow increase for the city of Seoul. We also note that the ratio of confirmed cases to the overall population in Seoul is much lower than that for the entire South Korea. The rate barely exceeds 0.6 cases per 10,000 people by mid-April in Seoul in contrary to the rate for South Korea, which was nearly 1.5 cases per 10,000 people by March 9th and surpassed 2 cases per 10,000 people by mid-April.

In Figure 6, we examine the number of COVID-19 tests performed each day in South Korea and other nations. We see that South Korea was able to perform a high number of diagnostic testing at a much earlier date than other nations that were heavily affected by COVID-19. South Korea performed more than 1000 tests per day consistently since February 18th and more than 5000 tests since February 24th. In comparison, the other nations only started performing more than 1000 tests per day since late February (Italy and United Kingdom) or early March (United States) and more than 5000 tests per day since after March 7th. These data highlight that South Korea performed mass testing more than a week earlier than other nations.

From Figure 7, we observe that South Korea was able to test higher proportion of its population than other nations as it was consistently increasing the number of diagnostic testing performed per day until from early to mid-March. South Korea tested more than 0.1% of its population (equivalent to 1 per 1000 people on the figure) by February 27th, which is about two weeks earlier than Italy and more than 3 weeks earlier than United States and United Kingdom. Similarly, South Korea tested more than 0.5% of its population (equivalent to 5 per

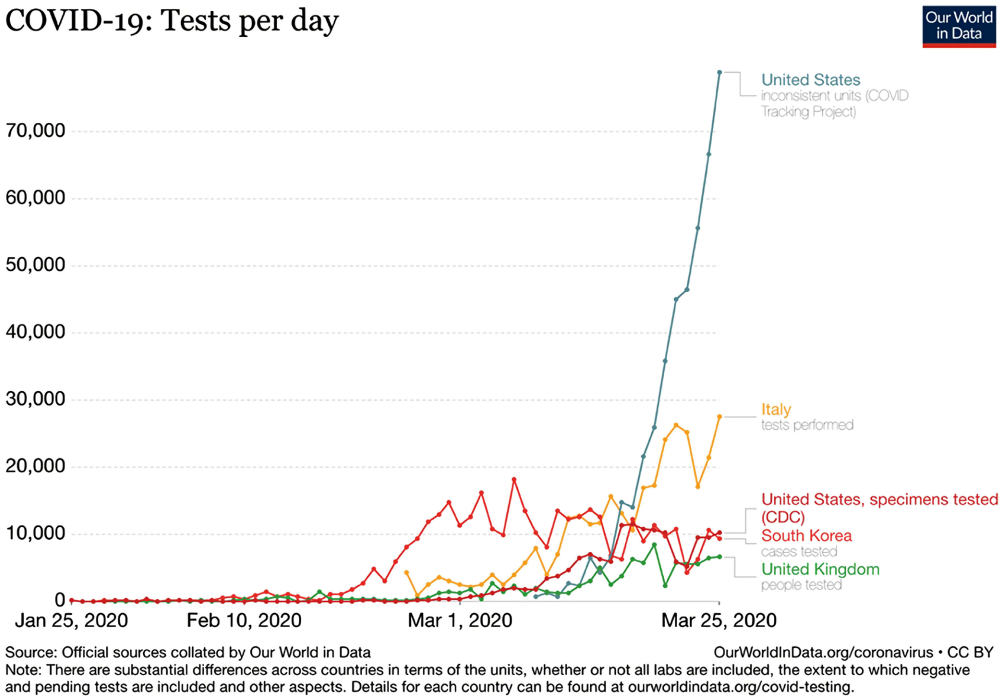

Figure 6. COVID-19 tests per day in South Korea and Other Nations.

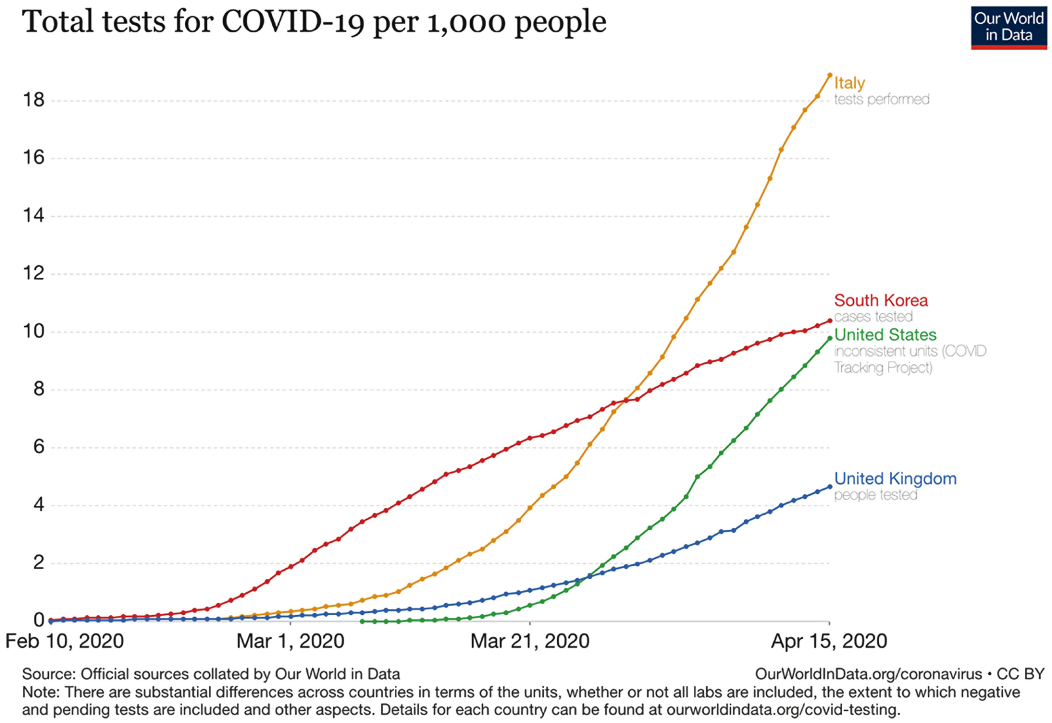

Figure 7. Total test for COVID-19 per 1000 people.

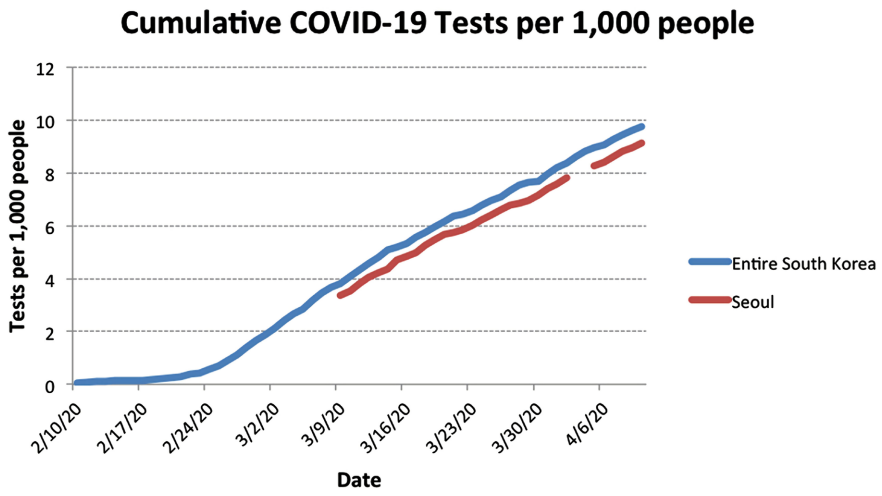

Figure 8. Cumulative COVID-19 tests per 1000 people in Entire South Korea and Seoul.

1000 people) by March 14th, which is 10 days earlier than Italy, the next country to reach the 0.5% of population mark.

Figure 8 allows us to compare the overall number of COVID-19 tests performed per 1000 people between the entire South Korea and Seoul. It shows that the number for Seoul closely mirrors that for South Korea. Seoul tested more than 0.5% of its population by March 17th, which is earlier than any other nations represented in the previous figures.

The fact that the ratio of total tests to the overall population in Seoul is lower than that for South Korea may be explained by the fact that lower proportion of

Seoul's population was infected by COVID-19. This is supported by **Figure 4** and **Figure 5** as well by the fact that the ratio of confirmed cases to tests performed was considerably lower in Seoul than for entire South Korea—0.6% in Seoul and 1.9% in South Korea.

4. Discussion

Situated right next to China, South Korea was one of the first countries to be affected by COVID-19. With the SARS-CoV-2 easily spreading through close contact with respiratory droplets produced by infected individuals, Seoul, being a densely populated city with approximately 17,000 people per square kilometer, faced a possible danger of becoming one of the epicenters of the pandemic [23] [24] [25]. Yet Seoul was able to contain the spread of the virus and remain relatively unaffected compared to other densely populated cities around the globe. As of April 17, 2020, Seoul has 621 confirmed cases (62 per 1 million of population) while New York City has close to 140,000 cases (16,289 per 1 million of population). What makes this feat even more remarkable is that Seoul was able to achieve this success despite the Korean government's delayed response in placing travel restrictions from countries with confirmed cases and the initial mask shortages.

4.1. Travel Restrictions

The national government's decision to not place heavy restrictions on foreigners traveling to South Korea due to concerns of economic damage received heavy criticism in the early stages of the epidemic. As the number of confirmed cases rose rapidly between late February to early March due to superspreading events, frustrations towards the government's reluctance to alter its lenient policy towards foreign visitors became more severe [26] [27] [28]. Eventually, the Korean government imposed stricter restrictions on foreign travel from overseas as the number of imported COVID-19 cases surpassed the number of new domestic infection cases in early April. The government also suspended visa waivers for citizens of countries that had put travel bans on South Korea [29]. Fortunately, unlike what the public had feared, no massive outbreaks occurred in South Korea secondary incoming COVID-19 cases. However, the Korean government's decision to leave the country open to foreigners even as the number of infections increased rapidly in late February caused considerable debate and public disapproval in Korean society.

4.2. Availability of Masks

Mask shortages also became a point of significant concern among the South Korean public. During the early stages of the pandemic, masks became nearly impossible to find in both local pharmacies and online stores due to massive purchasing of said items by the public [30]. At the end of February, the government intervened by limiting mask exports to less than 10% of the manufacturer total

output and purchasing 50% of manufactured masks to distribute at a discounted price to the public. Despite these measures, many people faced difficulties purchasing much-needed masks even after waiting in lines for hours. Lack of oversight led to individuals taking advantage of loopholes such as standing in line multiple times to purchase masks despite limits placed on masks purchased per customer. As a result, the supply of masks could not meet the demand and the government received heavy criticism for breaking its promise to make masks readily available at an economic price to the public [31] [32].

On March 5th, the government implemented more aggressive measures by fully banning the exports of masks and increasing its share of mask purchases to 80% of the total national production. To better manage the distribution process, it introduced a 5-day rotation system where citizens and registered non-citizens could buy two masks per week on an assigned weekday, with the day determined based on the year of birth. It also set up a computerized system to prevent repeated sales to the same person in the same week [30] [33]. Through these policies, the government was able to resolve the mask shortage crisis in the nation.

→ Conclusion section is material that should be included in the discussion.

4.3. Testing: Public and Private Sector Cooperation

Another key factor in the control of COVID-19 by South Korea was the close cooperation between the state and the private sector to allow for rapid development of test kits for mass testing. Within days of the first case of COVID-19 on January 20th in South Korea, Health Ministry officials met with representatives from more than 20 medical companies to develop and prepare diagnostic tests in short order. Fortunately, several of these companies had been preparing to make test kits by that meeting [34]. Within weeks, beginning with Kogene Biotech's Powercheck RT PCR kit on February 4th, the government reviewed and approved RT-PCR test kits developed by a large number of companies [34] [35]. By late February diagnostic kits from four different companies (Kogene, Seegene, Solgent, and SD Biosensor) were in full production and South Korea was able to perform thousands of tests per day with Seegene producing up to 60% - 80% of South Korea's total testing, processing up to 15,000 samples each day [34] [36]. The RT-PCR kits had an accuracy of over 95%, with Seegene's Allplex nCOV Assay in particular being able to detect all three COVID-19 target genes with specificity as high as 98% [36] [37]. Testing efficiency also improved as turnaround time of these test results shortened from 2 days to as fast as 6 hours.

Due to this efficient state-private sector partnership, South Korea was able to accurately test thousands of people daily by the end of February, as shown from the data in **Figure 7**. To better make use of its high diagnostic testing capacity, Seoul, together with other parts of South Korea, began operating drive-through screening stations from the beginning of March. By allowing individuals to remain in their vehicles for the entire screening procedure, time spent for specimen collection as well as exposure-risk was kept to a minimum [37]. Moreover,

recognizing that COVID-19 can be spread even by asymptomatic individuals, Seoul, tested everyone who had come in contact with confirmed cases in addition to symptomatic patients. Furthermore, it tested all previously infected individuals a week after discharge to monitor for SARS-CoV-2 virus reactivation and prevent further community outbreaks [38]. We observe from **Figure 1** that South Korea's swift and thorough response to COVID-19 was highly effective. We note that Seoul did not experience any massive outbreaks that led to rapid spike in number of cases like the ones suffered by other densely populated cities around the world. We also can observe that with increased testing capabilities beginning in the end of February, the rate of new COVID-19 cases slowed substantially starting from mid-March

4.4. Public Trust in Government Interventions

Another main factor that contributed to Seoul's incredible feat was the citizens' respect of the community spirit and approval of government-led interventions. With public endorsement, the government was able to employ a relatively high degree of state surveillance to limit the spread of the virus. This allowed for rapid contact tracing through close monitoring of the movements of COVID-19 patients through their smartphones and credit cards [26]. In addition to identifying and notifying people who have come in close contact with confirmed patients through this use of technology, the government shared information with the public about the patients' whereabouts through emergency text alerts. This measure helped individuals living or working near areas where new cases were detected to better protect themselves against the potential risk of infection [39].

The citizens' regard for the community spirit was also reflected by their willingness to engage in voluntary participation in two-week social distancing measures if they had recently returned from foreign countries. Through the combination of effective government interventions and mature citizenship displayed by the general public, Seoul, and to a larger extent South Korea, was able to withstand the COVID-19 pandemic without significant mortality and infection rates.

5. Conclusion

South Korea's response to COVID-19 was one that had great trials. Through our investigation into their measures and responses, we discussed how despite a higher population density than other epicenters around the globe, Seoul has been able to contain the virus. Through methods such as 1) testing with cooperation between the private sector and the government, 2) travel restrictions, 3) mask purchasing and distribution by the government with proper oversight and protocol, and 4) public trust in government interventions, we found the effectiveness of South Korea's response during the first year of the pandemic.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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