



## What We Learned from The Three Waves of The Covid-19 Pandemic In Indonesia

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### ABSTRACT

**Background:** The COVID-19 pandemic, which has hit the entire world, has so far experienced three peaks of rising cases, and Indonesia is no exception. However, no research discusses the factors that play a role in the three peaks of this wave, especially in Indonesia. **Objective:** To find out which of the factors affect the increase in the cumulative incidence and rate of deaths due to COVID-19 in the first, second and third waves in Indonesia. **Methods:** This research is analytic observational, using secondary data. The data is processed using cross-tabulation. **Results and Conclusion:** Mask use compliance factor, regardless of the correct use of masks, did not have much impact on reducing the cumulative incidence and the percentage of deaths due to COVID-19 in all three waves. Likewise, the increase in social distancing compliance factors, regardless of mobility restrictions and population density, did not affect the decrease in cumulative incidence and the percentage of deaths due to COVID-19. The percentage of the population at high risk was shown to be positively correlated with the percentage of deaths but not with the cumulative incidence. While the population density factor has a relationship with the cumulative incidence and percentage of deaths due to COVID-19 in almost all waves

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### Kata kunci:

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### ABSTRAK

**Latar Belakang:** Pandemi covid-19 yang melanda seluruh dunia, hingga saat ini telah mengalami tiga puncak gelombang kenaikan kasus, tak terkecuali di Indonesia. Namun, belum ada penelitian yang membahas faktor faktor apa saja yang berperan dari ketiga puncak gelombang ini, khususnya di Indonesia. **Tujuan:** Untuk mengetahui manakah faktor yang mempengaruhi terjadinya kenaikan insiden kumulatif dan persentase kematian akibat covid-19 pada gelombang pertama, kedua dan ketiga di Indonesia. **Metode:** penelitian ini bersifat observasional analitik, dengan menggunakan data sekunder. Data diolah dengan menggunakan tabulasi silang. **Hasil dan Kesimpulan:** Faktor kepatuhan pemakaian masker, tanpa memandang faktor pemakaian masker yang benar, tidak banyak memberi dampak terhadap penurunan insiden kumulatif maupun persentase kematian akibat covid-19 di ketiga gelombang. Begitu juga dengan peningkatan faktor kepatuhan social distancing tanpa memandang pembatasan mobilitas serta kepadatan penduduk tidak banyak berpengaruh pada penurunan insiden kumulatif serta persentase kematian akibat covid-19. Faktor persentase penduduk berisiko tinggi terbukti berkorelasi positif dengan persentase kematian, namun tidak dengan insiden kumulatif. Sedangkan faktor kepadatan penduduk memiliki hubungan dengan insiden kumulatif maupun persentase kematian akibat covid-19 pada hampir semua gelombang

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## INTRODUCTION

At the end of 2019, the world was shocked by the emergence of a new virus, namely SARS-CoV-2, which caused a pandemic. Corona Virus Disease 19, more commonly known as Covid-19, was declared by WHO as a global pandemic on March 11, 2020 (WHO, 2020). So far, several factors have been mentioned to impact the increase or decrease in cases in specific locations. These factors are the effectiveness of vaccination, human behavior, infection control policies, changes in the virus itself, and the number of people at risk because they cannot develop immunity either after being vaccinated or after being exposed to infection (Maragakis, 2021). The world has witnessed three waves of the virus pandemic, and the next wave will likely emerge. The word 'wave' implies the natural pattern of peaks and valleys associated with COVID-19 cases (Zhang et al., 2021). Empirical data show variable viral effects between the three periods. The severity of the disease, differences in symptoms, and behavior of people have been reported, but the differences in the characteristics of the three waves cannot be described with certainty (El-Shabasy et al., 2022)

Indonesia reported the first case of Covid-19 on March 2, 2020, and has experienced three peaks of the pandemic wave. The first wave of Covid-19 cases in Indonesia occurred in January-February 2021. At that time, the highest daily Covid-19 cases occurred on January 30, 2021, with 14,528. The second wave of Covid-19 cases occurred in Indonesia in June-July 2021 due to the Delta variant. Finally, the highest cases occurred on July 15, 2021, with the addition of 56,757 cases. Then Indonesia was faced with the third wave triggered by the Omicron variant. So far, the highest addition of Covid-19 cases occurred on February 17, 2022, with 63,956 cases (Wibowo, 2022). Until now, no research has discussed the comparison of what factors most influence the number of cases and the number of deaths due to COVID-19 in Indonesia during the first, second, and third waves. Therefore, this article aims to determine what factors influence the increase in cases of covid 19 and deaths due to covid 19 in Indonesia.

## METHOD

This research method is analytic observational, with secondary data collection techniques. This study has two dependent variables: the cumulative incidence of covid-19 and the percentage of deaths due to covid-19. Cumulative incidence indicates a person's risk of developing a disease in a given area (McNutt, n.d.). While the independent variables studied were 4, namely the percentage of compliance with the use of masks, the percentage of adherence to maintaining distance, the percentage of the high-risk population consisting of residents with comorbid hypertension, diabetes mellitus, heart disease, asthma, chronic kidney disease (CKD), central obesity, the elderly. Age>65 years, and the last variable is population density. Vaccination was not investigated because at the peak of wave 1, none of the provinces in Indonesia had vaccinated the second dose. Therefore, the second dose vaccination is also minimal in the second wave. However, in the third wave, the coverage of the second dose is good, so it cannot be used as a comparison to the previous wave.

The population of this study is 34 provinces in Indonesia. And researchers took data from the total population. Sources of data used by researchers are as below:

1. Data on the cumulative incidence of covid-19 cases and deaths due to covid-19 are taken from the Indonesian Covid-19 Data Analysis, which can be accessed from <https://covid19.go.id/>. The data used is updated as of January 31, 2021, to analyze the first wave, July 18, 2021, for the second wave, and February 20, 2022, for the third wave. The author chose this because data reporting is carried out every two weeks, and that date is data that can be obtained which is close to the peak date of cases (January 30, 2021, in the first wave, July 15, 2021, in the second wave, and February 17, 2022, in the third wave).
2. Data on mask use compliance and adherence to social distancing are taken from the National Health Protocol Compliance Monitoring, which can also be accessed from <https://covid19.go.id/> with the same date as the data on the covid 19 case in point 1 above.
3. Comorbid data is taken based on the prevalence of Hypertension, Diabetes mellitus, Heart Disease, Asthma, CKD, and central obesity obtained from Basic Health Research by Ministry of Health RI 2018 multiplied by the population obtained from the population census by the Central Statistics Agency in 2020 (for the first and second waves) and population data from the Ministry of Home Affairs of the Republic of Indonesia in 2021 (for the third batch). The data is then a percentage of the total population of Indonesia at the same time. For data on the elderly (population aged > 65 years) according to the data source obtained from population data in 2020 by the Central Statistics Agency and the prevalence of the elderly population in 2021 multiplied by data on the population in 2021 by the Ministry of Home Affairs. The percentage of the population with hypertension is then added up with the percentage of the population with diabetes mellitus, the percentage of the population with heart disease, and the percentage of the elderly population, which is the data for the high-risk population. The information is expected to be able to describe the condition of the Indonesian population, which is a vulnerable group when facing the peak of the first, second, and third wave of pandemics
4. Population density data is obtained by dividing the land area per province by the total population at the end of 2020 for population density data during the first and second waves. As for the third wave using land area data divided by population at the end of 2021

From the data collected, the researchers made a cross-tabulation of the independent variables studied on the cumulative incidence of cases and the percentage of deaths due to covid 19 in each wave of the pandemic.

## RESULTS AND DISCUSSION

The following are the results of the cross-tabulation of each independent variable on the dependent variable in each pandemic wave.

In the first wave, only 13 provinces reported compliance with the use of masks and social distancing. However, the available data shows no relationship between mask compliance and social distancing with cumulative incidents. Moreover, from the high-risk population and population density, it is not possible to see the relationship between the increase in population at risk and density with cumulative incidence.

**Table 1.**  
 The independent variable on the dependent variable is the cumulative incidence in the first wave

Mask use compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
	<223	224-346	347-494	>494	
>93%	0 0%	0 0%	1 33%	2 67%	3 100%
84-93%	0 0%	1 50%	1 50%	0 0%	2 100%
75-84%	1 17%	2 33%	1 17%	2 33%	6 100%
<75%	1 50%	0 0%	1 50%	0 0%	2 100%
Social distancing compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
>92%	0 0%	0 0%	1 33%	2 67%	3 100%
83-92%	1 33%	1 33%	1 33%	0 0%	3 100%
72-83%	2 50%	1 25%	0 0%	1 25%	4 100%
<72%	0 0%	0 0%	2 67%	1 33%	3 100%
High-risk population percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
>1,9%	2 25%	4 50%	0 0%	2 25%	8 100%
1,1-1,9%	4 45%	0 0%	3 33%	2 22%	9 100%
0,5-1,0%	2 29%	1 14%	2 28%	2 28%	7 100%
<0,5%	0 0%	4 40%	4 40%	2 20%	10 100%
Population density (in hectare)	The cumulative incident of covid-19 (per 100.000 population)				Total
>2,7	1 12%	4 50%	0 0%	3 38%	8 100%
1,1-2,7	3 33%	0 0%	4 45%	2 22%	9 100%
0,5-1,0	3 33%	4 45%	2 22%	0 0,00%	9 100%
<0,5	1 12%	1 12%	3 38%	3 38%	8 100%

**Table 2.**  
 The independent variable on the dependent variable is the percentage of deaths due to covid-19 in the first wave

Mask use compliance percentage	Death percentage due to covid-19				Total
	<1,6	1,6-2,4	2,4-3,6	>3,6	
>93%	0 0%	1 33%	1 33%	1 33%	3 100%
84-93%	0 0%	1 50%	0 0%	1 50%	2 100%
75-84%	3 60%	0 0%	1 20%	1 20%	5 100%
<75%	1 33%	0 0%	0 0%	2 67%	3 100%
Social distancing compliance percentage	Death percentage due to covid-19				Total
>92%	0 0%	1 33%	1 33%	1 33%	3 100%
83-92%	0 0%	1 33%	0 0%	2 67%	3 100%
72-83%	2 50%	0 0%	1 25%	1 25%	4 100%
<72%	2 67%	0 0%	0 0%	1 33%	3 100%
High-risk population percentage	Death percentage due to covid-19				Total

	<1,6	1,6-2,4	2,4-3,6	>3,6	
>1,9%	2	1	1	2	<b>6</b>
	33%	17%	17%	33%	<b>100%</b>
1,1-1,9%	1	1	1	5	<b>8</b>
	12%	12%	12%	63%	<b>100%</b>
0,5-1,0%	3	4	4	1	<b>12</b>
	25%	33%	33%	8%	<b>100%</b>
<0,5%	2	3	3	0	<b>8</b>
	25%	37%	37%	0%	<b>100%</b>
Population density (in hectare)	Death percentage due to covid-19				<b>Total</b>
	<1,6	1,6-2,4	2,4-3,6	>3,6	
>2,7	2	2	1	3	<b>8</b>
	25%	25%	12%	37%	<b>100%</b>
1,1-2,7	1	1	5	2	<b>9</b>
	11%	11%	56%	22%	<b>100%</b>
0,5-1,0	1	4	1	3	<b>9</b>
	11%	45%	11%	33%	<b>100%</b>
<0,5	4	2	2	0	<b>8</b>
	50%	25%	25%	0%	<b>100%</b>

If you look at the first wave, there is no relationship between compliance with the use of masks and social distancing compliance with the percentage of deaths due to

COVID-19. Likewise, with the portion of the population at high risk. However, a relationship between population density and the rate of fatalities from COVID-19 was found

**Table 3.**  
 The independent variable on the dependent variable of the cumulative incidence of covid-19 in the second wave

Mask use compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
	<524	524-756	757-1223	>1223	
>93%	0	1	1	6	<b>8</b>
	0%	12%	12%	75%	<b>100%</b>
89-93%	2	4	3	0	<b>9</b>
	22%	45%	33%	0%	<b>100%</b>
80-88%	2	2	3	1	<b>8</b>
	25%	25%	38%	12%	<b>100%</b>
<80%	3	3	1	2	<b>9</b>
	33%	33%	11%	22%	<b>100%</b>
Social distancing compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				<b>Total</b>
	<524	524-756	757-1223	>1223	
>91%	1	0	2	4	<b>7</b>
	14%	0%	29%	57%	<b>100%</b>
89-91%	2	3	2	1	<b>8</b>
	25%	38%	25%	12%	<b>100%</b>
81-88%	4	2	3	1	<b>10</b>
	40%	20%	30%	10%	<b>100%</b>
<81%	1	5	1	2	<b>9</b>
	11%	56%	11%	22%	<b>100%</b>
High-risk population percentage	The cumulative incident of covid-19 (per 100.000 population)				<b>Total</b>
	<524	524-756	757-1223	>1223	
>1,9%	2	1	4	1	<b>8</b>
	25%	12,5%	50%	12,5%	<b>100%</b>
1,1-1,9%	3	0	3	2	<b>8</b>
	37,5%	0%	37,5%	25%	<b>100%</b>
0,5-1,0%	1	4	2	3	<b>10</b>
	10%	40%	20%	30%	<b>100%</b>
<0,5%	1	4	0	3	<b>8</b>
	12,5%	50%	0%	37,5%	<b>100%</b>
Population density (in hectare)	The cumulative incident of covid-19 (per 100.000 population)				<b>Total</b>
	<524	524-756	757-1223	>1223	
>2,7	1	1	4	2	<b>8</b>
	12,5%	12,5%	50%	25%	<b>100%</b>
1,1-2,7	1	3	4	1	<b>9</b>
	11%	33%	45%	11%	<b>100%</b>
0,5-1,0	4	3	0	2	<b>9</b>
	45%	33%	0%	22%	<b>100%</b>
<0,5	1	3	1	3	<b>8</b>
	12,5%	37,5%	12,5%	37,5%	<b>100%</b>

In the second wave, all provinces reported compliance with the use of masks and social distancing. There has not been a relationship between the increase in compliance with the help of masks and compliance with social distancing

with a decrease in cumulative incidence. However, more cumulative incidents were found in provinces with a higher percentage of the population at high risk. And in provinces with higher densities, more cumulative incidents were found

**Table 4.**  
 The independent variable on the dependent variable is the percentage of deaths due to covid-19 in the second wave

Mask use compliance percentage	Death percentage due to covid-19				Total
	<1,7%	1,7-2,2%	2,3-2,9%	>2,9%	
>93%	2 25%	1 12,5%	5 62,5%	0 0%	8 100%
89-93%	3 33%	2 22%	1 11%	3 33%	9 100%
80-88%	3 33%	1 11%	2 22%	3 33%	9 100%
<80%	0 0%	4 50%	2 25%	2 25%	8 100%
Social distancing compliance percentage	Death percentage due to covid-19				Total
	<1,7%	1,7-2,2%	2,3-2,9%	>2,9%	
>91%	2 25%	2 25%	4 50%	0 0%	8 100%
89-91%	3 37,5%	2 25%	0 0%	3 37,5%	8 100%
81-88%	2 18,2%	2 18,2%	3 27,3%	4 36,4%	11 100%
<81%	1 14,3%	4 57%	1 14,3%	1 14,3%	7 100,%
High-risk population percentage	Death percentage due to covid-19				Total
	<1,7%	1,7-2,2%	2,3-2,9%	>2,9%	
>1,9%	3 33%	1 11%	0 0%	5 56%	9 100%
1,1-1,9%	0 0%	1 12,5%	5 62,5%	2 25%	8 100%
0,5-1,0%	1 11%	4 45%	3 33%	1 11%	9 100%
<0,5%	4 50%	3 37,5%	1 12,5%	0 0%	8 100%
Population density (in hectare)	Death percentage due to covid-19				Total
	<1,7%	1,7-2,2%	2,3-2,9%	>2,9%	
>2,7	2 25%	1 12,5%	2 25%	3 37,5%	8 100%
1,1-2,7	1 10%	2 20%	4 40%	3 30%	10 100%
0,5-1,0	1 12,5%	4 50%	1 12,5%	2 25%	8 100%
<0,5	4 50%	2 25%	2 25%	0 0%	8 100%

In the second wave, it can be seen that the higher the adherence to the use of masks, the less the percentage of deaths > 2.9%. The same thing also happened to social distancing compliance, where the higher the compliance, the lower the high rate of fatalities. The relationship between provinces with a high percentage of the population at high

risk has also been shown to be associated with an increase in the percentage of deaths from COVID-19. Population density is also related to the rate of deaths, where a higher percentage of deaths is found in provinces with a high population density.

**Table 5.**  
 The independent variable on the dependent variable of the cumulative incidence of covid-19 in the third wave

Mask use compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
	<899	899-1335	1336-2289	>2289	
>97%	1 14,3%	2 28,6%	1 14,3%	3 42,8%	7 100%
93-97%	2 20%	2 20%	3 30%	3 30%	10 100%
84-92%	2 25%	1 12,5%	4 50%	1 12,5%	8 100%
<84%	3	4	1	1	9

	33%	45%	11%	11%	100%
Social distancing compliance percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
	<899	899-1335	1336-2289	>2289	
>97%	1	1	1	2	5
	20%	20%	20%	40%	100%
90-97%	2	4	1	4	11
	18,2%	36,4%	9,1%	36,4%	100%
73-89%	3	0	4	1	8
	37,5%	0%	50%	12,5%	100%
<73%	2	5	3	0	10
	20%	50%	30%	0%	100%
High-risk population percentage	The cumulative incident of covid-19 (per 100.000 population)				Total
	<899	899-1335	1336-2289	>2289	
>2,3%	3	2	3	1	9
	33%	22%	33%	11%	100%
1,2-2,3%	3	0	2	3	8
	37,5%	0%	25%	37,5%	100%
0,5-1,1%	1	4	3	2	10
	10%	40%	30%	20%	100%
<0,5%	1	3	0	3	7
	14%	43%	0%	43%	100%
Population density (in hectare)	The cumulative incident of covid-19 (per 100.000 population)				Total
	<899	899-1335	1336-2289	>2289	
>2,6	1	2	3	3	9
	11%	22%	33%	33%	100%
1,0-2,6	2	2	3	1	8
	25%	25%	37,5%	12,5%	100%
0,5-0,9	4	2	1	1	8
	50%	25%	12,5%	12,5%	100%
<0,5	1	3	1	4	9
	11%	33%	11%	44%	100%

In the third wave, all provinces have also complied with reporting compliance with using masks and keeping their distance from the national COVID-19 task force. However, there was no relationship between increasing compliance with masks and maintaining a distance with a decrease in the cumulative incidence of COVID-19. Likewise, the percentage of the high-risk population and population density, where a high value is not related to an increase in the cumulative incidence of COVID-19

**Table 6.**  
 The independent variable on the dependent variable is the percentage of deaths due to covid-19 in the third wave

Mask use compliance percentage	Death percentage due to covid-19				Total
	<2%	2-2,5%	2,6-3%	>3%	
>97%	2	1	2	3	8
	25%	12,5%	25%	37,5%	100%
93-97%	2	1	3	3	9
	22%	11%	33%	33%	100%
84-92%	3	2	3	1	9
	33%	22%	33%	11%	100%
<84%	1	3	3	1	8
	12,5%	37,5%	37,5%	12,5%	100%
Social distancing compliance percentage	Death percentage due to covid-19				Total
	<2%	2-2,5%	2,6-3%	>3%	
>97%	3	1	1	3	8
	37,5%	12,5%	12,5%	37,5%	100%
90-97%	2	1	2	4	9
	22%	11%	22%	45%	100%
73-89%	2	2	4	1	9
	22%	22%	45%	11%	100%
<73%	1	5	2	0	8

High-risk population percentage	12,5%	62,5%	25%	0%	100%
	Death percentage due to covid-19				Total
	<2%	2-2,5%	2,6-3%	>3%	
>2,3%	4	1	0	3	8
	50%	12,5%	0%	37,5%	100%
1,2-2,3%	0	3	3	3	9
	0%	33%	33%	33%	100%
0,5-1,1%	2	3	4	1	10
	20%	30%	40%	10%	100%
<0,5%	2	2	2	1	7
	28,6%	28,6%	28,6%	14,2%	100%
Population density (in hectare)	Death percentage due to covid-19				Total
	<2%	2-2,5%	2,6-3%	>3%	
>2,6	3	1	2	2	8
	37,5%	12,5%	25%	25%	100%
1,0-2,6	1	4	2	2	9
	11%	45%	22%	22%	100%
0,5-0,9	0	2	4	3	9
	0%	22%	45%	33%	100%
<0,5	3	3	1	1	8
	37,5%	37,5%	12,5%	12,5%	100%

In the third wave, compliance with masks and social distancing did not show a relationship with a decrease in the percentage of deaths due to COVID-19. However, a high percentage of the population at high risk and a high population density are associated with an increase in the rate of deaths from COVID-19

Compliance with the use of masks in the first, second and third waves has not shown a relationship that increasing the use of masks can reduce the cumulative incidence. This phenomenon is in line with several previous studies which state that the role of wearing masks in preventing virus transmission is negligible, non-existent, or inconclusive

(Jefferson et al., 2020). A European study also stated that countries with higher levels of mask compliance did not show better case prevention than countries with low levels of adherence (Spira, n.d.). However, in the second wave, high compliance with mask use reduces the high percentage of deaths. Several studies that found the same thing were stated by (A. K. Wong & Balzer, 2022) that implementing the policy of wearing masks could reduce deaths by 16%. Another study also says mandatory wearing of masks can reduce deaths by 13% (Adjodah et al., 2021). But in the first and third waves, they were not found. Several factors can cause this phenomenon are the various types of masks used in Indonesia. In the report of the national covid-19 task force, there was no explanation about the type of mask used. There are six types of masks in Indonesia: cloth masks, 2-layer medical masks, 3-layer medical masks, N95 masks, reusable facepiece respirators, and hybrid masks (CNBC, n.d.). We know that the effectiveness of each mask is very different. Cloth masks were declared only to reduce the transmission of covid-19 by 56%, while medical masks were 66% and N95 masks were 83% (Andrejko, 2022). In the first wave, there was a shortage of masks in Indonesia (Sandi, n.d.). From the news and observations of the author, during the first wave, many people used cloth masks, because of the high price of surgical masks (Febriyanta, 2021). A study in one city in Indonesia in 2021 stated that 79.3% of respondents wore reusable masks/cloth masks, and 24.8% were wrong in choosing the type of mask, even 19.5% of respondents did not wash reusable masks before wearing them (Prajitno et al., 2021). In the third wave, actually the price of masks has fallen, and compliance with the use of masks is higher than the first and second waves. However, the nature of the omicron corona virus which has mutated into a variant that is more easily transmitted than other variants (Putri, n.d.) This causes the accuracy of wearing masks to be a factor that greatly affects the prevention of virus transmission, in addition to just compliance with usage. The CDC even issued a recommendation about the importance of fitting a mask so that the protection you get can be maximized ("Considerations for the Use of Face Masks in the Community in the Context of the SARS-CoV-2 Omicron Variant of Concern," n.d.). Another factor that causes this phenomenon is the observation of mask compliance is only carried out in public places, community compliance in wearing masks at home is not carried out. Another study on compliance with the use of masks in Indonesia, which was collected by the Johns Hopkin Center for Communication Programs, stated that in July 2021, compliance with the use of masks in Indonesia was only 71%, and in February 2022, compliance with the use of masks was only 67% (*COVID Behaviors Dashboard - Johns Hopkins Center for Communication Programs.*, n.d.). It can be concluded that compliance with the use of masks alone without being followed by the correct way of wearing and types of masks cannot stem the rate of transmission and the severity of COVID-19 cases.

The higher level of social distancing compliance in the first, second and third waves is also not associated with a decrease in cumulative incidence. However, the high level of social distancing compliance in the second wave prevented a high percentage of deaths from COVID-19. A study stated that increasing social distancing compliance and mobility restrictions decreased cases and deaths from COVID-19 (Mahmoudi & Xiong, 2022). However, this phenomenon was not found in the first and third waves. This phenomenon can be because the data taken is only social distancing, but there is no discussion about restrictions on mobility. It is possible

that people only adhere to social distancing when there are officers. Data on observing compliance with the use of masks and compliance with social distancing were carried out by the regional Covid-19 task force team consisting of the civil service police unit and the police. In a survey conducted by John Hopkin, it was only 35% during the second wave, while in the third wave, it was 41%.

The percentage of the population at high risk influences the cumulative incidence and rate of deaths in the second wave. The higher the population at high risk also increases the percentage of fatalities from COVID-19 in the third wave. Meanwhile, in the first wave, the higher rate of the population at high risk was not related to the increasing cumulative incidence and percentage of deaths. The cumulative incidence is also not influenced by the percentage of the population at high risk in the third wave. Several previous studies support the association of old age with an increase in the mortality rate of COVID-19 (Edrus, 2022), (Karyono & Wicaksana, 2020), hypertension, diabetes mellitus, and heart disease with the percentage of deaths due to covid-19 (Karyono & Wicaksana, 2020) (Gesmalah & Hidajah, 2021) (Wardani et al., 2022) (Adhani et al., 2022), asthma, chronic kidney failure and central obesity with the risk of getting COVID-19 and the severity of getting COVID-19 (Komite Penanganan Covid 19, 2020) (Mayo Clinic, 2022). The phenomenon that occurred in the first wave can be attributed to fewer cases than in the second and third waves. However, we can see that the percentage of Covid-19 deaths in the first wave in areas with a low percentage of the high-risk population (<0.5%) has no cases of death >3.6%. We can conclude that the higher the percentage of the high-risk population in an area, the higher the percentage of deaths due to COVID-19 will increase. However, the percentage of the population at high risk is not necessarily associated with an increase in cumulative incidence

A study in Indonesia states that a higher population density is associated with a higher number of COVID-19 cases (R. Azizah et al., 2021). One study said that countries with high density would have higher Covid-19 cases, too (Sy et al., 2021). Other studies suggest that population density effectively predicts cumulative incidence at the country level (D. W. S. Wong & Li, 2020) (Martins-Filho, 2021). In the first and second waves, the increase in the population of an area causes a higher cumulative incidence of COVID-19. The higher population in the first, second and third waves also led to higher deaths from COVID-19. The exception occurred in the third wave, where higher population density did not correlate with an increase in the cumulative incidence of COVID-19. However, in the third wave, there has been a decline in social distancing compliance in almost all provinces in Indonesia. It can be concluded that the population density factor, along with social distancing compliance, affects the cumulative incidence and percentage of deaths due to covid-19

## CONCLUSIONS AND SUGGESTIONS

From the discussion above, we can conclude that the factor that affects the increase in the cumulative incidence of COVID-19 and the percentage of deaths due to COVID-19 in the first wave is the high population density. In the second wave, the increase in the cumulative incidence of COVID-19 is influenced by the high percentage of the high-risk population and population density. The decrease affects the rate of Covid-19 deaths in the second wave in compliance with the use of masks, the decline in compliance with social distancing, and the high percentage of high-risk populations

and high population density. The third wave of cumulative incidents is not influenced by the independent factors studied, but the high rate of the population affects the higher percentage of deaths due to COVID-19 at high risk and population density. Regardless of correct use, the compliance factor with the help of masks did not have much impact on reducing the cumulative incidence and the percentage of deaths due to COVID-19. Likewise, the increase in the social distancing compliance factor, regardless of mobility restrictions and population density, did not have much effect on decreasing the cumulative incidence and the percentage of deaths due to COVID-19. The percentage of the population at high risk was shown to be positively correlated with the percentage of deaths but not with the cumulative incidence. While the population density factor has a relationship with the cumulative incidence and percentage of deaths due to COVID-19 in almost all waves

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There is no conflict of interest in this paper

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