ORIGINAL ARTICLE

Mortality trends from 2010-2023 and excess mortalities in Perak during the COVID-19 pandemic

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ABSTRACT

Introduction: COVID-19, caused by SARS-CoV-2 virus, is a respiratory infection that led to the 2020 pandemic. During the pandemic, mortality directly related to COVID-19 infection were classified as COVID-19 death based on case definition. However, excess mortality would be a more comprehensive method to look at the true impact of the pandemic rather than focusing only on COVID-19 deaths alone. The objective of this study was to determine the excess mortalities and top 5 causes of mortality that occurred during and after the COVID-19 pandemic in Perak.

Materials and Methods: Total and age-specific mortality data tabulated by the Department of Statistics Malaysia (DOSM) for the years 2010-2023 for the state of Perak was obtained. Data for the years 2010–2019 was re-grouped according to clustered age groups. This was used to generate the linear prediction line for mortality in 2020-2023 using Microsoft Excel 2010. Excess mortalities were calculated for 2020-2023 by subtracting the actual deaths from the predicted deaths. The top 5 common causes of mortality and COVID-19 deaths were also re-tabulated for the years 2020-2023 for the clustered age groups. "Positive Excess Mortality" (PEM) meant that the number of actual deaths were higher than predicted and "Negative Excess Mortality" (NEM) meant that the actual deaths were lower than the predicted number. Significant PEM meant that the value of the actual mortality was above the upper limit of the 95% confidence interval of the predicted mortality.

Results: All clustered age groups showed NEM for the year 2020. For the years 2021-2022, there was a PEM for all clustered age groups except those in the group "19 and below". The highest excess mortality was in the "65 and above" group with 343.44 and 685.56 per 100,000 age-specific population for 2021 and 2022 respectively. The mortality rate returned to the predicted value in 2023. In 2021 and 2022, there was a PEM for the "20-39" and "40-64" clustered age groups, however they were lower compared to the "65 and above" groups. Significant PEM was seen for all deaths in the "65 and above" in 2021 (237 per 100,000) and in 2022, 596 per 100,000. There was also a significant PEM after the removal of COVID-19 deaths in 2022 for the "65 and above" age groups- 366 per 100,000. Significant PEM was also seen in the "20-39" age groups and "40-64" age groups in 2021- 14 per 100,000 and 36 per 100,000 respectively. The other values that passed the 95%CI were deemed to be negligible. There were a few changes in the top 5 ranking for causes of death in Perak, the only obvious inclusion was deaths due to COVID-19 infections in 2021 in all groups except the "19 and below".

Conclusion: There was a PEM in all groups except "19 and below" after the year 2020, with the highest in the "65 and above" group. COVID-19 deaths were included in the top 5 causes of death and contributed only partly to the excess mortality across all groups except "19 and below".

KEYWORDS:
Excess mortality; COVID-19 deaths; mortality review; positive excess mortalities; negative excess mortalities; Malaysia

INTRODUCTION

COVID-19 infection is a respiratory infection caused by the virus SARS-CoV-2, a Coronaviridae family in the Nidovirales order and is known to be a single-stranded RNA virus.[1] It spreads through close contact via droplets and causes upper and lower respiratory tract illness. The severity ranged from being asymptomatic to having severe respiratory failure.[1] COVID-19 caused a pandemic in 2020 and resulted in many deaths globally.[1] The pandemic in Malaysia was officially declared from March 2020 to April 2022 with multiple waves hitting the country- the first being the alpha variant in 2020 followed by the beta, delta and finally the omicron variants.[1-3] Countries were forced into lock-downs and instituted various measures to reduce transmission such as masking, compulsory admission and self-isolation/quarantine.[1] Crowd control was applied to public areas especially in high-risk (ie hospitals and health clinics) to reduce transmission causing altering patient's regular time of follow up according to the standard of care.[4] COVID-19 pandemic impacted the

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management of other communicable and non-communicable diseases including mental health issues and could have contributed to deaths.[5] These were known as collateral damages that occurred with COVID-19 that might have resulted into a compromise of the healthcare system.[6]

A "COVID-19 death" was defined as a death that was caused by COVID-19 (confirmed via a recognized Rapid Test Kits or Reverse-Transcriptase Polymerase Chain Reaction test recognized by the Ministry of Health Malaysia), no period of complete recovery from COVID-19 at the point of death and/or death within 30-days of being COVID-19 positive with the absence of any other known or possible cause.[7] This was the definition of COVID-19 mortality that was used in Malaysia for death reviews. Deaths that occurred with evidence of COVID-19 infection but didn't meet the criteria of a "COVID-19 death", was classified as "deaths with COVID-19". Though the deaths of COVID-19 were recorded accordingly, it was said that world-wide, it might have been severely underestimated due to the potential capacity of testing, reporting mechanisms of cases/deaths, threshold capacities of healthcare systems and inaccessibility due to restrictions.[4] The other issue that contributed to inaccurate reporting at a global stage was the different definitions of "COVID-19 death" in different countries- as communicated in a research by the World Health Organization.[8]

After considering the shortcomings and inaccuracy of looking at COVID-19 deaths alone, measuring the overall effect of the pandemic might not be as accurate- especially when intending to describe the impact of the pandemic on mortality trends in Perak.[4] This is where tracking all-cause mortalities during the pandemic might be a more accurate way to measure the effect of COVID-19 on deaths in total.[4]

The tracking of all-cause mortality has become an acceptable way of measuring disease burden on a particular event especially in the case of infectious diseases.[4] Excess mortalities refers to excess deaths, more than what is anticipated over a period of time and have been used for the surveillance of infectious diseases such as influenza and COVID-19.[2,4]

Excess mortalities can be measured and classified as "Positive Excess Mortality" (PEM) which means that the number of deaths that occurred were higher than what was predicted and a "Negative Excess Mortality" (NEM) refers to the number of deaths lower than what was predicted. When done with predicting deaths based on models, excess mortalities (actual mortalities minus the predicted morality- regardless of yielding PEM or NEM) can be used to see if particular significant events over time have led to an increase in the number of anticipated deaths or reduced it.[4] The mortality burden before, during and after the COVID-19 pandemic can offer a perspective of the mortality rates- if it were higher, the same or reduced.[9-10]

In a mathematical study conducted in Malaysia, the statistical modeling done with mortality data from 1995-2018 predicting potential excess mortalities after COVID-19 reported that Malaysia would see an increase in PEM especially in the elderly groups (age 60 and above).[7] In the initial phase, COVID-19 deaths were low but increased over a period of time especially with the ease of restrictions.[10] However, after vaccine coverage was achieved to a large population, the number of deaths began stabilizing before being reduced to lower numbers.[1,11] The excess mortalities might have differed according to countries (due to definitions, testing availability, acceptable sensitivity of testing and access to healthcare systems), and within a country, the dynamics of the population in each state may have caused difference rates of excess mortalities.[2] Though excess mortalities of Malaysia data was studied, very few studies focusing on state stratified results were done, especially looking at data according to age specific groups.

In Perak, the population dynamics slightly differ especially in the number of elderly people (ageing city potentially by 2030) when compared to average national numbers.[12] Thus, the difference of excess mortalities and reasons of causes of deaths can differ. In the earlier papers of excess mortalities in Malaysia, it showed that, there was no PEM but when fragmenting the data into different age groups, there was a PEM in those aged 60 and above.[4,10]

Perak is a state in northern Peninsula Malaysia and it is the 4th largest state. It has a population of about 2.5 million and it is known to be an ageing population. Perak has a major tertiary referral hospital and 4 other smaller tertiary hospitals.[13]

The primary objective of this study was to determine the excess mortalities in Perak during (2020-2021) and after (2022-2023) the COVID-19 pandemic. Another objective was to determine the top 5 mortality causes during and after the COVID-19 pandemic years.

MATERIALS AND METHODS

The researchers obtained secondary data from the database managed by the Department of Statistics, Malaysia (DOSM), for Perak. These were age specific population and mortality for the years 2010-2023. We also received data for the total number of COVID-19 deaths (2020-2023) and the causes of mortality based on the ICD-10 coding from 2020-2023. Age-specific data obtained was for the following age groups were separated : ages week (w) 1, w2,w3,w4,w5,w6, 1 year,2,3,4, 5-9 years, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84 and ≥85. The researchers then re-grouped the data into the following categories: "19 and below", "20-39", "40-64" and "65 and above". We then tabulated the mortality rate results according to "number of deaths", "population" and the "crude mortality rate per 100,000". The crude mortality rate per 100,000 population was calculated as "number of deaths" divided by "number of population" times 100,000 yielding the crude mortality rate per 100,000 population. The researchers then applied a linear regression predictive line for each age standardized group using data from 2010-2019 (pre- COVID-19 era) and this was matched against the actual mortality that occurred in 2020-2023. For the years 2020, 2021, 2022 and 2023- the researchers also tabulated data to generate mortality lines that included and excluded COVID-19 deaths as reported by the Department of Statistics Malaysia (DOSM). The graph and prediction lines were plotted using Microsoft Excel 2010.

The researchers tabulated the results according to the age groups and according to each year from 2010-2023. The deaths and population were tabulated into Table I and the Crude Mortality Rate per 100,000 population including the Crude Mortality Rate per 100,000 population after the removal of COVID-19 related deaths (2020-2023) was tabulated into Table II.

Deaths and Population numbers according to age standardized groups
Table I depicts the trends of deaths and population (in 1,000s) of the different age groups

Population
From Table I, that the population number for the different age groups. From 2020-2023, the "≤19" population decreased whilst the other age groups ("20-39", "40-64" and "≥65") grew in number.

Deaths
From Table I, that the deaths amongst the standardized groups were rather stagnant for the "20- 39" groups and down-going for the age groups of "≤19" through-out the years of 2010-2023. Though the "≤19" increased slightly from 2021-2023, it did not surpass the numbers before 2020. The deaths for the "40-64" and "≥65" were steadily going up and in 2021, there was a noticeable increase in deaths for both age groups.

Full details are shown in Table I. The border was to demarcate the COVID-19 and non-COVID-19 years.

The study was registered with the National Medical Research Register and Medical Research Ethical Committee (NMRR ID-22-00344-S8C (IIR)). Data used in the study/obtained data were anonymised.

RESULTS

All-cause mortality (per 100,000 population) by age standardized groups from 2010-2023 in Perak
The all-cause mortality (per 100,000 population) by age-standardized groups from the year 2010 till 2023 was tabulated (Table II) and included in 2 graphs. We included data of mortality before and after the removal of COVID-19 deaths from 2020-2023 to see if deaths due to COVID-19 had affected the mortality rate. For each age standardized group, we calculated a linear regression predictive line (utilising data from 2010-2019) to predict deaths that were anticipated in 2020-2023. Actual mortality rates from 2020-2023 were then compared with the predicted number of deaths.

The subtraction of the actual deaths from the predicted deaths then yielded the Excess Mortality (either a PEM or NEM) of the specific age-group. A negative yield (NEM) meant that the deaths that occurred were lower than anticipated number and positive (PEM) yields meant that more deaths were seen than the anticipated number.

To determine if the actual deaths were significantly higher than the predicted values, it should be higher than the upper limit of the 95% confidence interval of the predicted value. These values were then reviewed to see if they were negligible or not.

• Ages ≤19
The linear regression predicted line was generated and the trend line gradient was negative in nature (decreasing prediction in deaths).

• 20-39
The liner regression predicted line was generated and the trend line gradient was negative in nature- meaning that from the prediction analysis, we expect deaths in this age group to reduce in the coming years.

• 40-64
The linear regression predicted line was generated and the trend line gradient was positive in nature- meaning to say that it is expected that the number of deaths will increase every year after 2019.

• ≥65
The linear regression predicted line was generated and the trend line gradient was positive in nature- meaning to say that we expect the number of deaths to increase every year.

Figure 1 ("40-64" and "≥65") and Figure 2 ("19 and below" and "20-39") depicts the Crude Mortality Rate per 100,000 that was calculated from the deaths and population according to the age standardized categories. The graphs were first plotted with data from 2010-2019. Data from 2020-2023 were plotted in 3 different ways:
1. The prediction line of deaths (linear regression line) plotted using data from 2010-2029.
2. The actual number of deaths recorded from 2020-2023
3. The number of deaths recorded after the removal of "COVID-19 deaths" from 2020-2023

The "y-axis" represented the mortality in the age specific group per 100,000 population. The "x-axis" represented data used in the formula to calculate the mortality per 100,000 population represented the chronological order of the year (i.e.: 2010 was year 1, so x=1, 2011 was year 2, so x=2 etc.). The excess mortalities that were of interest were from 2020-2023. Special markings to denote data used for the linear regression prediction line (2010-2019) and the occurrence of COVID-19 were made. To accommodate the 2 different age groups into a single graph, Figure 1 had 2 "y-axes" with that on the left demarcating the mortality per 100,00 for the "≥65" age group and that on the right demarcating the mortality per 100,000 for the "40-64" age groups.

For the "20-39" age groups, there was a significant PEM in 2021 (for all deaths- about 14 per 100,000 from the upper predicted limit or 112 excess deaths from the age-specific population) (Table II). For all deaths and deaths excluding COVID-19 in 2022 for the "20-39" age group, the excess was 1 to 3 per 100,000 from the upper predicted limit or 8 to 24 excess deaths from the age-specific population- this was considered negligible. For the "40-64" age groups, there was a significant PEM of 36 per 100,000 or 249 excess deaths from the age -specific group population. For the "≥65 and above: groups, there was significant PEM (for all deaths) in 2021-

Table I: All-cause mortality numbers and the population numbers (in 1,000s) by age standardized groups in the state of Perak from 2010-2023

Age	Status	Years													
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
≤19	Deaths	702	635	660	616	592	565	631	584	536	521	400	378	469	464
	Population	889	873.2	861.5	853.2	844.9	837.9	833.5	828.3	825.8	818.7	801.2	792.7	781.5	766.4
20-39	Deaths	1069	1026	1065	996	1031	1050	1053	1034	1020	1017	943	1151	1063	1052
	Population	663.2	683.1	702.7	725	736.4	746.7	754.6	763.4	762.9	764.8	789.6	799.5	800.5	826.6
40-64	Deaths	4646	4814	4915	4984	5065	5234	5403	5493	5520	5529	5281	6446	6238	5845
	Population	644.2	646	648.2	651	649.7	651.8	655.9	657.5	664.9	667.2	682.1	689.3	692.7	701.1
≥65	Deaths	9023	9537	9755	9790	10237	10310	10733	10936	11524	11673	11335	13365	14588	13478
	Population	182.6	186.8	191.3	195.8	200.1	205	208.7	212.2	215.6	218.2	223.3	234.2	239.7	247.2

Population in 1,000s

Table II: All-cause mortality rate (per 100,000 population) of the age standardized groups in the state of Perak from 2010-2023. Data from 2020-2023 included data of All-cause mortality and excluding COVID-19 deaths

Age	Years																	
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		2021		2022		2023	
											All	Exc COVID	All	Exc COVID	All	Exc COVID	All	Exc COVID
≤19 [a]	78.97	72.72	76.61	72.20	70.07	67.43	75.70	70.51	64.91	63.64	49.93	49.93	47.69	47.05	60.01	59.50	60.54	60.54
≤19 [b]											64.10		62.79		61.49		60.18	
95%CI											60.0-70.0		60.0-70.0		60.0-70.0		50.0-70.0	
≤19 [c]											**-14.17**		**-15.11**		**-1.48**		**+0.36**	
20-39 [a]	161.19	150.20	151.56	137.38	140.01	140.62	139.54	135.45	133.70	132.98	119.43	119.43	143.96	129.21	132.79	130.42	127.27	127.15
20-39 [b]											127.50		124.81		122.13		119.45	
95%CI											120-140		120-130		110-130		110-130	
20-39 [c]											**-8.07**		**+19.15**		**+10.66**		**+7.82**	
40-64 [a]	721.20	745.20	758.25	765.59	779.59	803.01	823.75	835.44	830.20	828.69	774.23	773.35	**935.15**	859.42	900.53	885.81	833.69	831.69
40-64 [b]											860.63		873.63		886.64		899.65	
95%CI											840-880		850-900		860-910		880-920	
40-64c											**-86.40**		**+61.52**		**+13.89**		**-65.96**	
≥65 [a]	4941.40	5105.46	5099.32	5000.00	5115.94	5029.27	5142.79	5153.63	5345.08	5349.68	5076.13	**5074.34**	5706.66	5349.27	**6085.94**	**5855.65**	5452.27	5434.06
≥65 [b]											5327.07		5363.22		5399.38		5435.53	
95%CI											5230-5420		5190-5470		5310-5490		5350-5530	
≥65 [c]											**-250.94**		**+343.44**		**+686.56**		**+16.74**	

a= actual, b= predicted value [via linear regression with 95% CI listed below], c=difference [between actual and predicted (a - b)]
Within the 95%CI Below the 95% CI Above the 95%CI [Bolded= Significant PEM- not negligible]
Numbers listed are per 100,000 population

Table III: The top 5 mortality causes per 100,000 population by the age standardized groups in the state of Perak from 2020-2023

Age	Rank	2020		2021		2022		2023	
		Cause of death	Per 100,000 population	Cause of death	Per 100,000 population	Cause of death	Per 100,000 population	Cause of death	Per 100,000 population
≤19	1	Certain conditions originating in the perinatal period	10.73	Certain conditions originating in the perinatal period	11.23	Certain conditions originating in the perinatal period	11.00	Certain conditions originating in the perinatal period	11.00
	2	Congenital malformations, deformations and chromosomal abnormalities	9.11	Congenital malformations, deformations and chromosomal abnormalities	8.83	Congenital malformations, deformations and chromosomal abnormalities	8.45	Congenital malformations, deformations and chromosomal abnormalities	8.45
	3	All other diseases	5.24	All other diseases	5.05	Transport accidents	8.19	Transport accidents	8.19
	4	Transport accidents	4.12	Transport accidents	4.67	All other diseases	6.01	All other diseases	6.01
	5	All other external	3.37	All other external	3.15	All other external	5.12	All other external	5.12
20-39	1	Transport accidents	16.97	Transport accidents	15.38	Transport accidents	20.49	Transport accidents	20.49
	2	Ischemic heart diseases	13.68	COVID-19 infection (due to)	14.76	Uncertified	14.87	Uncertified	14.87
	3	All other external	11.02	All other diseases	13.88	Ischemic heart diseases	11.12	Ischemic heart diseases	11.12
	4	All other diseases	10.76	Ischemic heart diseases	10.51	All other diseases	10.62	All other diseases	10.62
	5	Uncertified	9.75	Uncertified	10.38	All other external	10.12	All other external	10.12
40-64	1	Ischemic heart diseases	144.11	Ischemic heart diseases	155.38	Uncertified	272.85	Uncertified	272.85
	2	Uncertified	136.93	Uncertified	150.30	Ischemic heart diseases	121.26	Ischemic heart diseases	121.26
	3	All other diseases	66.71	COVID-19 infection (due to)	75.73	All other diseases	76.51	All other diseases	76.51
	4	Pneumonia	58.35	All other diseases	71.96	Pneumonia	63.66	Pneumonia	63.66
	5	Cerebrovascular diseases	47.65	Pneumonia	67.17	Cerebrovascular diseases	42.59	Cerebrovascular diseases	42.59
≥65	1	Uncertified	1924.76	Uncertified	2026.47	Uncertified	3296.62	Uncertified	3296.62
	2	Ischemic heart diseases	717.87	Ischemic heart diseases	793.77	Pneumonia	526.91	Pneumonia	526.91
	3	Pneumonia	437.08	Pneumonia	453.89	Ischemic heart diseases	373.80	Ischemic heart diseases	373.80
	4	All other diseases	367.22	All other diseases	358.24	All other diseases	336.25	All other diseases	336.25
	5	Cerebrovascular diseases	312.14	COVID-19 infection (due to)	357.39	COVID-19 infection (due to)	230.29	COVID-19 infection (due to)	230.29

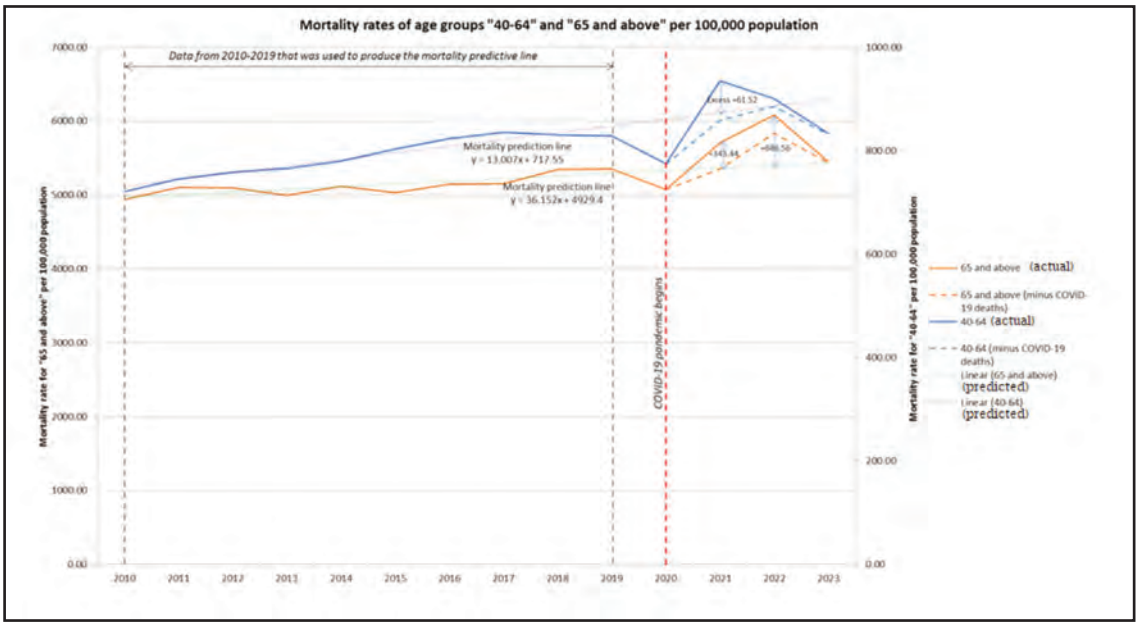

Fig. 1: Age standardized All-Cause Mortality Rate and COVID 19 Mortalities in Perak per 100,000 population from 2010-2023 for age groups of "40-64" and "65 and above" with predictive lines plotted utilising data from 2010-2019

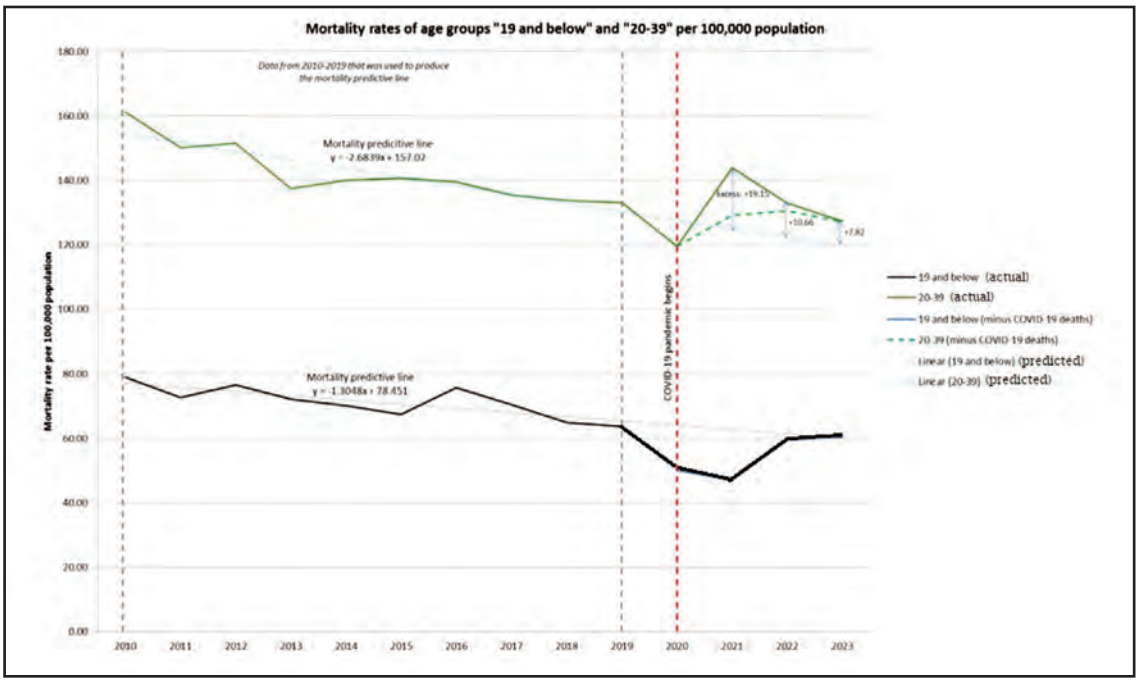

Fig. 2: Age standardized All-Cause Mortality Rate and COVID 19 Mortalities in Perak per 100,000 population from 2010-2023 for age groups of "19 and below" and "20-39" with predictive lines plotted utilising data from 2010-2019

237 per 100,000 from the upper predicted limit (555 excess deaths from the age-specific group). There were 596 per 100,000 (for all deaths) or 1430 excess mortalities in the age-specific population and 366 per 100,000 (for deaths after the removal of COVID-19 deaths) or 879 excess mortalities in the age-specific population in 2022.

The prediction line was down-going in trend as shown in Fig 1. It was also found that a PEM was generally seen amongst the "≥65" group for the year 2021 (+343.44) and 2022 (+686.56). The mortality in 2020 was below the predicted number or a NEM. In 2021, the number of deaths recorded after the removal of "COVID-19 deaths" was similar to the value of the predicted deaths. However, in 2022, there was a PEM even after the removal of the COVID-19 deaths. The mortality in 2023 was nearly similar as the predicted number. For the "40-64" group, PEM was seen through-out, however, after removing "COVID-19 deaths", the net yield resulted in NEM. These NEM numbers were however a very small number

Fig 2 depicts the mortality for age groups of "≤19" as well as the "20-39" age groups. The prediction trend-line was generally down-going in nature. Both mortality graphs were depicted on the same y and x-axes. From the graph, the "≤19" had NEM for the 2020-2022 (the COVID-19 related deaths were negligible). In 2023, the mortality became a PEM- a slight excess compared to the predicted (however, this is a very small value that is negligible). Fig 2 also shows the mortality of the age group of "20-39". When plotted for the COVID-19 years (2020-2023), it was found that there were PEM from 2021-2023. After the removal of the deaths due to COVID-19, the PEM remained, but the numbers were relatively small (between about 8-20 people per 100,000 population of the age standardised group).

Top 5 causes of mortality rate per 100,000 population by age groups in Perak from 2020-2023.

The researchers also tabulated the top 5 causes of mortality per 100,000 population for the causes of mortality in 2020 to 2023. This is listed in Table III in a descending order.

≤19 years

For this age group, we calculated that the 2 general causes of deaths namely "Certain conditions originating in the perinatal period" and "Congenital malformations, deformations and chromosomal abnormalities" for 2020-2023.

20-39 years

For this age group, "Transport accidents" were the main cause of death for the years 2020 till 2023. For 2020, "Ischemic Heart Disease" was the number 2 cause before dropping to the 4th (2021), 3rd (2022) and 5th (2023). In 2021, "COVID-19" was the 2nd cause of mortality in this age group causing about 15 deaths per 100,000 age standardised population.

40-64 years

For this age group, we can see that "Ischemic Heart Disease" was the common cause of death except in 2022 and 2023 where the common cause of death was "Uncertified". Deaths due to "COVID-19" was only seen in 2021 as the 3rd common cause of deaths where about 76 per 100,000 age standardised population succumbed. "Pneumonia", "Cerebrovascular events" and "All other diseases" were the causes of deaths from number 3 to number 5 changing sequence in between the years of 2020-2023.

≥65 years

For this age group, the common causes of deaths were "Uncertified" deaths from 2020-2023. "Ischemic heart disease" and "Pneumonia" related deaths were 2nd and 3rd placing (interchangeable over the years of 2020-2023). "All other diseases" were the 4th common cause of deaths for 2020-2023. However, for 2021 (about 356 people per 100,000 age standardised population) and 2022 (about 231 per 100,000 age standardised population) deaths were due to "COVID-19"- being the 5th common cause of deaths. For 2020 and 2023, "Cerebrovascular accidents" were the 5th common cause of deaths. The full data can be seen in Table III.

DISCUSSION

Excess mortalities capture the true burden of the pandemic

The working definition of a COVID-19 death could have caused an over or underestimation of deaths due to COVID-19 because of the variations in testing strategies used across the pandemic. However, in contexts of all deaths - any death captured regardless of the cause. This will reflect on the direct and indirect impact of the COVID-19 infection on the population. The indirect impact includes the disruption to health care services and restriction of movement caused by mitigation plans to stop transmission.

Generally, many studies conducted had seen that the hardest hit of mortalities during COVID-19 especially in the cases of excess mortalities were seen increase in nature with the age groups.[6,14] In this study, we found similar results- but it must highlighted that "≤19" had experienced lesser deaths than expected, the "20-39" as well as the "40-64" saw a slight increase and finally the "≥65" group showed the biggest number of excess mortalities. The elderly age group were the ones largely affected as co-morbids are common amongst them (especially uncontrolled comorbidities) and susceptibility of the immune system in response to infections are rather slower than the younger age group- that might eventually cause death.[1,2,9,15-16] This reflected on the mortalities seen in Perak as the state has a high number of elderly population in the country. However, after the pandemic, it was found that the mortality rates of the elderly returned to the predicted numbers. This might imply that the COVID-19 pandemic had claimed the lives of the elderly earlier rather than later. The mortality rate for those above 40 has not returned to the normal predicted values implying that perhaps the effects of the pandemic is now over.

Missed appointments, re-scheduled appointments, delayed procedures (especially due to strict precautions) that were in-place to stop the spread, might have been some of the many causes that resulted in many patients presenting after surpassing the critical intervention time-frame.[17] This was where the true burden of the pandemic was as the after-effects of it has resulted in healthcare services dealing with prolonged disease complications especially with non-communicable diseases.[17] Thus it is ever so important that even with mitigation restrictions (for future pandemics), it will not cause an overcrowding of our facilities that might affect the intervention of healthcare.[18]

Causes of all-cause mortality might have been due to policies during COVID-19

During the pandemic, there was a disruption of health care services due to system overload, resource diversion and shortages. There were changes in health seeking behaviours especially among patients because of travel restrictions and the fear of contracting COVID-19 from healthcare centers. These factors could have contributed to the death increase-caused by the effects of the COVID-19 pandemic rather than directly from COVID-19. One of the major problems was to identify the areas of spread or hot-spots.[1] This was due to the fact that reporting mechanisms, lockdown policies to different industries and contact tracing methods had drawbacks into identifying actual areas of spread.

Areas/industries that were allowed to operate during the pandemic had a higher spread as they were allowed to function at a restricted capacity, allowing for person-to-person contact if there was a case of COVID-19, especially in the pre-symptomatic phase. This might have made a difference to the counts of COVID-19 cases as well as mortality.[1]

Therefore, looking at all-cause mortality would be a more accurate way to analyse the effect of the pandemic on mortality patterns.[2,6,16] In this paper, we predicted the mortality based on historical death data and compared it with actual mortality during the pandemic to determine positive or negative excess mortality.

According to a paper that reported PEM during the COVID-19 pandemic in Germany, the "COVID-19 deaths" were said to have been highly associated with the response of the government in terms of tight regulations and adherences.[9] However, due to political pressure and difference of opposed views in Germany, the difference in regulated mitigation coupled with poor coordination resulted in poor control as well as deaths.[16]

Though Malaysia did control the first wave well (as depicted by the low number of deaths in 2020), however, due to the change in variants and economically unsustainable methods- just like Germany- policies were revised and spread patterns changed.[16] Due to different preventive methods applied (compared to other leading countries) and perhaps a possible delay in screening/detection/therapeutics for other diseases, it might have resulted to an increase in all-cause mortalities especially in the elderly groups.[1,4] Some of the causes of increase in PEM could be attributed to the delay in diagnosing and treating other conditions especially those relating to non-communicable diseases as well as a change in human-behaviour that refrained from seeking medical care for the fear of being infected with COVID-19.[1,4,15]

NEM in 2020

A German study conducted on a weekly analysis of PEM and NEM during the early COVID-19 period (2020), reported that for the groups 30-49 and 50-59 years of age had a minimal increase in excess mortalities (PEM) was observed.[2] However the obvious increase in comparisons of excess mortalities (PEM) were observed in those groups above the age of 60 (except the 70-79 age group).[9] This was slightly different than what was found in our study. In this study, all age groups had a NEM during the year 2020. This might have been due to the stringent lockdown and mitigation mechanisms that were put into place. In some countries of the European Union, UK and US- generally there was an increase by more than 10 in 100,000 population for mortalities during the COVID-19 period for all ages (no age specific data but estimated to be at 1.4 million in excess deaths (PEM) globally in 2020- largely attributed to non- "COVID-19 deaths").[14]

The main all-cause mortality PEM was seen mainly in the elderly

A Malaysian study with national data from 1995-2020 had reported that the authors predicted PEM in Malaysia would increase after the COVID-19 pandemic but it was suggested that this would be mainly among those who were above the age of 60 years.[19] Similarly, a study conducted in Iran utilising mortality data from 2019-2022 similarly reported that they saw an increased PEM among those who were above the age of 75.[10] Even after removing "COVID-19 deaths", the PEM seen in the Iranians in multiple studies at different points, were high among those aged 75 and above.[2,10,16] This was similarly found in this current study- that PEM were higher in the "65 and above" (older group) compared to the other groups- though there were minimal increases in the "20-39" and the "40-64" groups.

Obtaining higher numbers of COVID-19 deaths after the declaration of the pandemic was also reported in another paper. A paper published in 2022, utilising data at the peak of COVID-19, a predictivity analysis done in Iran showed that the excess mortality was due to increase 2 years after the height of COVID-19 (2021-2022) with the elderly mainly being affected to suffer from PEM.[16] This was nearly similar to the current study where an increase in PEM were seen after the peak of COVID-19 (2021) but mainly affected the elderly age group (65 and above- 687 per 100,000 population) compared to minimal PEM changes from the predicted mortality numbers in other groups. In another 2021 study conducted in South Korea, it was reported that the majority of PEM were seen as age increased (especially the 65- 79 age groups) and NEM were seen in the younger age groups.[6]

When the World Health Organization conducted an analysis utilising world-wide data, it was reported that the largest PEM occurred in 2021 and that the total PEM were nearly 3 times higher than "COVID-19 deaths" for the same requisite period of time.[8] This was similarly seen in this current study for the years 2021-2022.

In a paper written in Malaysia regarding PEM during the early COVID-19 period, it was reported that the PEM for Malaysians (86.2-100%) in 2021 was attributed solely to COVID-19.[4] Though the same paper reported that Perak matched the predicted mortality rate, the authors of that paper calculated mortality in the state of Perak based on data from 2017- in contrast with this research that calculated the mortality prediction line based on age groups and data ranging from 2010- 2019.[4] However, the 2021 paper looked at mortality from a month-to-month basis during the pandemic whereas this current study looks at the yearly data.

Causes of death

From this research, though PEM was high in the older age groups for all the years from 2020-2023. However, it cannot be attributed to direct deaths caused by COVID-19 infections. In a study conducted in Malaysia in 2021 (during the initial phase of COVID-19), it was reported that though age was not a factor that determined the type of deaths during the early days of COVID-19 (2020-2021), from the descriptive data, those who died in hospital were about 65 years old.[8] Amongst the causes of mortality for the non-"COVID-19 deaths" matched the findings of this study, mostly being causes from metabolic conditions and undefined deaths.[6]

Some of the reasons of the causes of PEM could be explained via literature from different papers. Another study conducted in South Korea reported differently- that the deaths from

respiratory linked diseases were reduced, whereas in this current study (especially those of 65 and above), the cause of death from pneumonia rose from the 3rd to 2nd highest cause of deaths.[6] Most countries did not see a PEM during the initial phase of the pandemic (2020) but saw a PEM in 2021.[6]

In a world-wide (140 World Health Organization countries) data study conducted, excess mortalities (PEM) were seen around the world with some being nearly as high as 10%- with many attributing the deaths to non-communicable diseases like diabetes, ischemic heart diseases and cardiovascular related diseases than to COVID-19.[14] The reason for excess deaths (PEM) could be explained that those who had a COVID-19 infection remained at higher risk to develop de novo cardiovascular and metabolic disorders.[14] Amongst some of the reasons stated for such events happening is because of the constriction of services due to the focus on healthcare services towards COVID-19.[14]

This study has several strengths. It used cleaned data from the Department of Statistics Malaysia, which improves the reliability of the analysis. It also focused on the top five causes of death in Perak, allowing the findings to address the main contributors to mortality in the state. Additionally, the researchers applied linear predictive analysis using 10 years of mortality data to estimate deaths from 2020 to 2022.

However, several limitations should be acknowledged. The findings are representative only of Perak and may not be generalisable to other Malaysian states. The prediction period was also limited to three years; a longer prediction period may have provided a more robust model. The study also assumed that deaths remained constant throughout each year from 2010 to 2022, which may not reflect seasonal or temporal variation. Finally, ARIMA analysis was not performed because there were insufficient time points, as ARIMA modelling generally requires approximately 50 to 100 observations.

CONCLUSION

There was a PEM in all groups except "19 and below" after the year 2020, with the highest in the "65 and above" group. Mortalities returned to normal predicted values in 2023. COVID-19 deaths were included in the top 5 causes of death and contributed only partly to the excess mortality across all groups except "19 and below".

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