The Geographic Distribution of Excess Mortality Rate due to COVID-19 in Iranian Population: An Ecological Study

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Abstract
Background: COVID-19 has raised a worldwide trajectory since it emerged in Wuhan, China in December 2019. The direct and indirect mortalities in the world and as in Iran have increased significantly after the occurrence of this pandemic.

Objectives: In this study, Excess Mortality Rate (EMR) was estimated by multilevel poison regression method and then this estimation was compared to the historical trends to obtain total deaths related to COVID-19. Additionally, the geographic distribution of EMR has also been presented for Iran.

Methods: All-cause mortality rates of each province of Iran from March 21, 2013 to September 22, 2021 was downloaded from National Organization for Civil Registration (NOCR). The data of COVID-19 pandemic period (spring 1399 SH (Mar 20, 2020) to summer 1400 SH (Sep 22, 2021)) was removed from the data and then the multilevel poison model was applied to estimate all-cause mortality in this period. Then, EMR=[real deaths/expected deaths] ratio was calculated.

Results: The results of this study showed that Iran’s EMR in COVID-19 pandemic was 36% (Male=35%, Female=36%, P-value=0.798). Our findings also revealed four category of EMR including low (EMR≤30%, n=9), moderate (30 %< EMR≤35%, n=8), high (35 %< EMR≤40%, n=10) and very high (40 %< EMR, n=4) in different provinces.

Conclusion: Due to the diverse EMR in different provinces of Iran, the type of disease management of provinces with low and moderate EMR can be used as an appropriate model to control EMR in provinces with high and very high EMR.

Keywords: Coronavirus, COVID-19, Excess deaths, Excess mortality, Iran, Mortality, SARS-CoV-2

1. Background

In late 2019, a wave of and acute respiratory diseases began in Wuhan (China). On March 11, 2020, according to the World Health Organization, the COVID-19, a pandemic was announced (1). The virus has been spreading from December 31, 2019 to September 22, 2021 around the world as it has infected 230,378,562 people and, to this day, has caused the death of more than 4,724,111 mortalities worldwide (2).

The number of diagnosed cases of COVID-19 in each country depends on the actual number of cases, the capacity of the health system to detect the cases, and its transparency in reporting the information. The health system’s capacity to diagnose cases is dependent to multiple factors. The factors such as affordability and accessibility of healthcare facilities and diagnostic (screening tests), the accuracy of laboratory tests, public awareness, and the development of a mechanism for easy access to care facilities (3-5). The challenge is that the number of confirmed diagnosed cases does not reflect the actual number of cases (3).

In fact, due to various reasons such as the small number of diagnostic laboratories, lack of access to appropriate diagnostic kits and, health services due to excessive visits to medical centers, and high cost and low sensitivity of COVID-19 diagnostic tests, the real infection of COVID-19 of a majority of cases has not necessarily been reported by the Ministry of Health and Medical Education (MoHME) in routine statistical reports (3, 6). Therefore, estimating Excess Mortality Rate (EMR) from the National Organization for Civil Registration (NOCR) (7, 8) can be used as a tool for an estimation of COVID-19-related mortalities. This accurate estimation would enable the health managers to handle the epidemic better and more precisely.

2. Objectives

In this study, EMR was estimated by multilevel poison regression and then this estimation was compared to the historical trends to obtain total mortality rate attributable to COVID-19. Additionally, the geographic distribution of EMR in Iran was presented.

3. Methods

This study is a longitudinal ecological study. All-cause mortality rate of all provinces of Iran from March 21, 2013 to September 22, 2021 was downloaded from Iranian National Organization for Civil Registration (INOCR). The data from spring
1399 SH (Mar 20, 2020) to summer 1400 SH (Sep 22, 2021) was removed from the data pool and then the multilevel Poison model was used to estimate all-cause mortality in the mentioned period (called expected death). After calculating the expected death, the EMR was calculated using the below formula:

$$\text{EMR} = \frac{\text{real deaths} - \text{expected death}}{\text{real deaths}}$$

For the comparison of the rates reported by MoHME, the statistics reported by Islamic Republic News Agency (IRNA.ir) was used.

3.1. Data Analysis

In this study, due to the dependence of observations, it was not possible to use the Poisson model. Therefore, to model and estimate the number of deaths in the absence of COVID-19 pandemic, the multilevel Poison model was applied. Lower type one error and higher efficiency are two advantages of multilevel models in comparison with conventional models in the comparison of correlated data (9).

Subsequently, the multilevel Poison regression model was applied to predict the number of all-cause mortalities in COVID-19 pandemic, if this pandemic was not really occurred.

For this purpose, the data of the death of each province of Iran in the study time period (March 21, 2013 to Sep 22, 2021) was downloaded from the INOCR website (https://www.sabteahval.ir) and then the multilevel Poison model (10) was run and to estimate the number of mortalities.

$$\text{Death}_{t,i} \sim \text{Poisson}(\mu \text{Death}_{t,i})$$

$$\ln(\mu \text{Death}_{t,i}) = \beta_0 + \beta_1 \text{Year}_{t,i} - 1391 + \text{Season}_{t,i} + \text{Province}_{t,i} + u_i$$

Where index i varies from 1 to 31 (number of provinces of Iran), index t varies from 1 to 8 (2013 to 2021) and index s ranges from 1 to 4 (4 seasons; spring, summer, autumn, and winter).

In the above model, u_i is a normal random effect to control the dependence among observations. In the current study, for model estimation, Quasi-Likelihood (PQL) and Marginal Quasi-Likelihood (MQL) (11) were used. Moreover, MLwiN (version 2.1) and SPSS (version 2.1) were used to analyze the data. Finally, the geographical distribution of the EMR maps were prepared by online application of Paintmaps(12).

3.2. Ethical considerations

Ethical approval was not needed for this study, as it was based on surveillance data only and the confidential information of cases was not used or disclosed.

4. Results

According to the rates reported by the INOCR until summer 1400 SH (Sep 22, 2021), 797,755 deaths was reported. After fitting the multilevel Poison model (R2=99%), the model estimated 587,614 deaths in absence of COVID-19 pandemic. This is while according to the MoHME statistics, 117,905 deaths were found to be relevant to the pandemic. This means that the mortality rates related to the pandemic would be 1.78 times more than the statistics informed by MoHME.

The results of this study also demonstrated that EMR of Iran in COVID-19 pandemic was 36% (Male=35%, Female=36%, P-value=0.798).

In Table 1, the real and expected mortalities and EMR according to gender in the provinces of Iran is reported. As presented in this table the EMR of Iran in COVID-19 pandemic was 36% (Male=35%, Female=36%, P-value=0.798). Our findings also revealed four categories of EMR which included low (EMR≤30%, n=9, including provinces of Sistan & Baluchestan, Chahar Mahall & Bakhtiari, Gilan, South Khorsan, North Khorsan, Hormozgan, Kerman, Khorasan, Kordestan, Razavi Khorasan, Zanjan, East Azarbaijan, Khuzestan, Golestan, Ardebil and Qazvin) and very high (40 %< EMR, n=4, including provinces of West Azarbaijan, Esfahan, Tehran and Alborz).

The GIS map for EMR in addition to the mortality trend with and without the COVID-19 pandemic is presented in Figure 1 and Figure 2, respectively. In Figure 2, the trend line shows that the worst and the best pandemic controls were in the summer of 1400 and then the winter of 1399, respectively.

Table 1. The real and expected death and EMR according to gender and provinces of Iran in spring 1399 SH (Mar 20, 2020) to summer 1400 SH (Sep 22, 2021).

<table>
<thead>
<tr>
<th>Province</th>
<th>Male Expected Death</th>
<th>Male Real Death</th>
<th>Male EMR</th>
<th>Female Expected Death</th>
<th>Female Real Death</th>
<th>Female EMR</th>
<th>Total Expected Death</th>
<th>Total Real Death</th>
<th>Total EMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Azarbaijan</td>
<td>13040</td>
<td>29374</td>
<td>29%</td>
<td>14939</td>
<td>36756</td>
<td>36%</td>
<td>27084</td>
<td>56128</td>
<td>37%</td>
</tr>
<tr>
<td>West Azarbaijan</td>
<td>29374</td>
<td>13040</td>
<td>29%</td>
<td>36756</td>
<td>29374</td>
<td>29%</td>
<td>57650</td>
<td>36129</td>
<td>33%</td>
</tr>
<tr>
<td>Ardebil</td>
<td>29374</td>
<td>13040</td>
<td>29%</td>
<td>36756</td>
<td>29374</td>
<td>29%</td>
<td>57650</td>
<td>36129</td>
<td>33%</td>
</tr>
<tr>
<td>Esfahan</td>
<td>29374</td>
<td>13040</td>
<td>29%</td>
<td>36756</td>
<td>29374</td>
<td>29%</td>
<td>57650</td>
<td>36129</td>
<td>33%</td>
</tr>
</tbody>
</table>

**Figure 1.** The geographical distribution of the EMR in Iran.

**Figure 2.** The trend line shows that the worst and the best pandemic controls were in the summer of 1400 and then the winter of 1399, respectively.
Table 1. Continued

<table>
<thead>
<tr>
<th>Province</th>
<th>Spring 3663</th>
<th>Summer 4477</th>
<th>Fall 3737</th>
<th>Winter 3509</th>
<th>Spring 2022</th>
<th>Summer 2839</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alborz</td>
<td>9230</td>
<td>11840</td>
<td>10290</td>
<td>9240</td>
<td>10450</td>
<td>13200</td>
</tr>
<tr>
<td>Azadshahr</td>
<td>4510</td>
<td>5950</td>
<td>5120</td>
<td>4450</td>
<td>5000</td>
<td>6200</td>
</tr>
<tr>
<td>Bushehr</td>
<td>3610</td>
<td>4630</td>
<td>3950</td>
<td>3400</td>
<td>3900</td>
<td>4500</td>
</tr>
<tr>
<td>Chahar Mahal &amp; Bakhtiari</td>
<td>2850</td>
<td>3650</td>
<td>3050</td>
<td>2650</td>
<td>2950</td>
<td>3500</td>
</tr>
<tr>
<td>Khorasan</td>
<td>5350</td>
<td>6750</td>
<td>5650</td>
<td>4950</td>
<td>5450</td>
<td>6500</td>
</tr>
<tr>
<td>Kermanshah</td>
<td>7800</td>
<td>9800</td>
<td>8300</td>
<td>7100</td>
<td>8000</td>
<td>9500</td>
</tr>
<tr>
<td>Kohgiluyeh &amp; Boyer Ahmad</td>
<td>3200</td>
<td>4100</td>
<td>3400</td>
<td>2800</td>
<td>3100</td>
<td>3700</td>
</tr>
<tr>
<td>Lorestan</td>
<td>7200</td>
<td>9200</td>
<td>7800</td>
<td>6500</td>
<td>7300</td>
<td>9000</td>
</tr>
<tr>
<td>Mazandaran</td>
<td>14600</td>
<td>18400</td>
<td>15600</td>
<td>12800</td>
<td>15200</td>
<td>18500</td>
</tr>
<tr>
<td>Markazi</td>
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<td>8800</td>
<td>7100</td>
<td>5800</td>
<td>6600</td>
<td>8200</td>
</tr>
<tr>
<td>Hormozgan</td>
<td>5650</td>
<td>7600</td>
<td>6200</td>
<td>5000</td>
<td>5700</td>
<td>6900</td>
</tr>
<tr>
<td>Hamadan</td>
<td>9020</td>
<td>11990</td>
<td>8790</td>
<td>7200</td>
<td>8400</td>
<td>10200</td>
</tr>
<tr>
<td>Yazd</td>
<td>4200</td>
<td>5570</td>
<td>4580</td>
<td>3800</td>
<td>4300</td>
<td>5300</td>
</tr>
<tr>
<td>Total</td>
<td>330676</td>
<td>447719</td>
<td>35036</td>
<td>30506</td>
<td>350036</td>
<td>447719</td>
</tr>
</tbody>
</table>

Figure 1. The GIS map for the rate of EMR

Figure 2. The report of the trend of real death in comparison with the expected death related to the COVID-19 pandemic
5. Discussion

The study of the overall effect of the COVID-19 pandemic on national mortality rate is a crucial method in estimating the impairment caused by this disease. However, the lack of different types of death coding, false negative of diagnostic tests, and the inability of health systems to perform widespread COVID-19 tests tend to offset the COVID-19 pandemic mortality analysis (13, 14). One way to overcome this challenge is to use EMR index .

This index estimates the amount of deaths added in the community based on the records provided by the NOCR. Due to the simplicity and availability of data need to apply in this index, it can be used for calculation in all countries and it can provide an accurate estimate of the COVID-19-related mortalities.

The results of this study showed that the EMR of Iran in COVID-19 pandemic was 36% (Male=35%, Female=36). The EMR reported in this study is lower than the EMRs reported by Freitas et al. (15) and Strang et al. (16) and higher than those reported by Michelozzi et al. (17), Woolf et al. (18), Weinberger et al. (19), and Vieira et al. (20).

In particular, Strang et al. (16) showed EMR of 23% and 113% in Sudan, in March and April 2020, respectively. Moreover, Freitas et al. (15) reported EMR of 66% in six Brazilian (COVID-19 period up until May 2, 2020), Michelozzi et al. (17) reported EMR of 19% in Italian cities (COVID-19 period starts on February 29, 2020), and Woolf et al. (18) demonstrated EMR of 20.8% in fifty US states and the District of Columbia (January to April 2020). Furthermore, Freitas et al. (15) reported EMR of 66% in six Brazilian capitals (COVID-19 period until May 2, 2020), Weinberger et al. (19) showed EMR of 18.5% in the United States (March to May, 2020), and Vieira et al. (20) showed EMR of 15.8% in Portugal (March to May, 2020).

Furthermore, the results of this study revealed that the provinces of Alborz and Qazvin had the highest EMR indices compared to the other provinces. This finding can be justified by the fact that these two provinces are the busiest areas in Iran, especially for the citizens of Tehran, the capital of Iran. Therefore, the high EMR index might be due to the passengers transport among these areas. The evidences also have introduced travel as a major risk factor for spreading of SARS-CoV-2 (21-23).

Our findings also revealed that the provinces of the southern strip of Iran, which are generally non-industrial, have a lower EMR index than other provinces. The reason for this might be due to air pollution and also the low movement of the habitants of these provinces with Qom and Tehran (the first provinces that reported COVID-19 in Iran). Previous studies have reported a negative correlation between air quality and COVID-19-related death (24-26).

Our study also demonstrated that the provinces of Khuzestan and Bushehr had high EMR indices compared to the other provinces. I can be justified by the fact that these two provinces are the southeast provinces of Iran and have low health system. Another reason might be the high rate of travels from the Arab countries of southern border of Persian Gulf to these provinces.

The limitation of this study was lack of access to the reports of MoHME on COVID-19 mortality rates by province. Hence, there are several strong points in this study that should be considered, including applying the complex and powerful statistical methods for mortality rate estimation and the geographical presentation of the EMR by a GIS method.

6. Conclusion

Due to the diversity of EMR in different provinces of Iran, the type of management of the provinces with low and moderate EMR can be deliberated as a suitable model to control EMR in provinces with high and very high EMR.

Acknowledgments

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Footnotes

Conflicts of Interest: The authors declare no conflict of interests.

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