Excess All-Cause Mortality and COVID-19 Reported Fatality in Iran (April 2013 - September 2021): Age and Sex Disaggregated Time Series Analysis

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Abstract

Objective: The actual impact of the pandemic on COVID-19 specific mortality is still unclear due to the variability in access to diagnostic tools. This study aimed to estimate the excess all-cause mortality in Iran until September 2021 based on the national death statistics.

Results: The autoregressive integrated moving average used to predict seasonal all-cause death in Iran ($R^2=0.45$). We observed a 38.8% (95% confidence interval (CI): 29.7%-40.1%) rise in the all-cause mortality from 22 June 2020 to 21 June 2021. The excess all-cause mortality per 100,000 population were 178.86 (95% CI: 137.2 - 220.5, M:F ratio = 1.3) with 49.1% of these excess deaths due to COVID-19. Comparison of spring 2019 and spring 2021 revealed that the highest percent increase in mortality was among men, aged 65-69 years old (77%) and women, aged 60-64 years old (86.8%). Moreover, the excess mortality among 31 provinces of Iran ranged from 109.7 (Hormozgan) to 273.2 (East-Azerbaijan) per 100,000 population.

In conclusion, there was a significant rise in all-cause mortality during the pandemic. Since COVID-19 fatality explains about half of this rise, the rise in other causes of death and underestimation in reported data should be concerned by further studies.

Introduction

In recent years, cardiovascular diseases, cancers, and injuries were the leading causes of death worldwide. In Iran, the cardiovascular disease (44%), Cancers (17%), and kidney disease (7%) were the most common cause of deaths followed by road injury (6%) which declined in the recent years. (1).

The ongoing COVID-19 pandemic drastically challenged our healthcare system and caused over 4.5 million deaths worldwide and has made a considerable impact on all-cause excess mortality (2–4). The lack of adequate health system infrastructure, inequity in healthcare accessibility, poor public health education, decentralized decision making, and the nature of SARS-CoV-2 as an emerging virus all resulted in increased mortality during the COVID-19 pandemic (5–7). Excess all-cause mortality would be a better indicator of COVID-19 impact on the health care system than the COVID-19 reported mortality rate as it provides a comparing context between different management strategies and can guides policy-making strategies more efficiently (8, 9). There was an increased in all-cause mortality rate (excess death) in Iran since winter 2020 in comparison to the expected mortality rate based on previous year data which is likely attributed to COVID-19 pandemic (10, 11). Nonetheless, the real impact of the COVID-19 pandemic on mortality is still unclear as it can be easily affected by the availability and accessibility of diagnostic tools and reporting systems (9, 12). This study aimed to investigate the gap between predicted mortality and observed mortality from the start of the pandemic in Iran from January 2020 to June 2021 based on the national statistics of mortality.

Material And Methods

Data Set

This study used publicly available data provided by the Ministry of Health and Medical Education (MOHME) and the National Organization of Civil Registration (NOCR) of Iran. Daily number of COVID-19 cases and mortality reported by MOHME was gathered from Iran Data Administration (IRDA) (13). Weekly all-cause death counts from 21 March 2013 to 22 September 2021 were gathered from NOCR website for 31 provinces of Iran (variables: Gender, Death Count, Date, Province, 5-year increment age group) (14). Additional File 1: Figure S1 shows the flow of data in national death registration system in Iran. The national death registration program of NOCR and MOHME gather the mortality data from provincial health centers. Jafari et al. described this program in more detail (15). We calculated the 2020 population of Iran and that for the 31 provinces based on the 2011 and 2016 census and assuming that the mode of increase observed between two dates in the past has been constant. The 2021 Iranian population were used to estimate the age-specified all-cause mortality rate and all-cause mortality rate per 100,000 population.

Statistical Analysis

Expected seasonal mortality and 95% confidence interval (CI) from winter 2019 until spring 2021 was estimated based on a time series analysis of seasonal mortality of spring 2013 to autumn 2019. Time series modeler selected the best-fitting Auto Regressive Integrated Moving Average (ARIMA) or exponential smoothing model for forecasting based Bayesian Criterion Information (BIC) measure. Seasonal additive effect and outliers were considered for time series analysis. The forecasting was carried out for all-cause seasonal deaths among men and women, by age-group, as well as for the total population for the 31 provinces of Iran.

Excess death (with 95% CI) was considered as the gap of expected (with 95% CI) and observed seasonal deaths. The excess death rate per 100,000 population was measured by proportion of excess deaths divided by the specified population. A total excess death of the year from summer 2020 to spring 2021 was then evaluated. We excluded the winter 2020 excess death data because of possible immaturity of COVID-19 reporting system. To define age-specified excess mortality rate, the gap of mortality between spring 2019 and spring 2021 was estimated and then by using 5-year age group population of 2021 in Iran the age-specified excess mortality rate was calculated (16). The percent change of each 5-year age group was provided comparing spring 2019 and spring 2021.

R software version 3.6.3 was used for the statistical analysis. Linear regression was performed to evaluate relation of weekly all-cause death with weekly COVID-19 death. Durbin-Watson statistic to check independence of observations. Significance level was considered as $P < 0.05$.

Results

The best-fitted model for male, female and total population at national level was ARIMA model. Additional File 1: Table S1 shows the model fit statistics for forecast models among genders and

provinces. The selected model for mortality at national level was ARIMA ($p=0, d=0, q=0$)($sp=0, sd=1, sq=0$) which is especial case of ARIMA named random walk model.

As Fig. 1 depicted, based on the prediction of all-cause mortality, the expected death count was 385,778 deaths for summer 2020 until spring 2021. However, 535,570 deaths occurred in Iran during the study period, which is 38.8% (95% Confidence Interval (CI): 29.7% – 40.1%) higher than the predicted value. As shown in Additional File 2: Table S2, the rise in deaths is evident in all seasons during the pandemic and was higher among the male population. From summer 2020 to spring 2021, the excess deaths per 100,000 population was 178.86 (95% CI: 137.20-220.51) with male to female ratio of 1.3. In addition, summer 2021 showed the highest excess death of 85.13 (95% CI: 97.33-72.93) per 100,000 people. COVID-19 reported fatality accounted for 49.1% of excess deaths, and it ranges from 22.9% in winter 2019 to 73.4% in winter 2020 during the pandemic (Additional File 2: Table S2).

Figure 2 shows the gap of 2019 spring and 2021 spring mortality among 5-year age groups. The age-specific mortality for per 100,000 population older than 85 years was the highest mortality, compared to other age-groups. Moreover, the highest percent change was among men, aged from 65 to 69 years old (77%) and women, aged from 60 to 64 years old (86.8%). The mortality percent rise in 10 to 20 years old age group (14.7%) was higher than 20 to 30 years old population (8.4%). Bimodal age pattern was presented with a low peak in 10–20-year age-group followed by a significant peak in the 60-70 years old group.

The weekly all-cause deaths, COVID-19 reported deaths, and COVID-19 reported cases from 23 March 2019 until 22 September 2021 is shown in Additional File 3: Figure S2. Weekly COVID-19 reported deaths coverage of all-cause death ranged from 4–32%, and there was statistically significant relation between COVID-19 death and all-cause death as demonstrated in Additional File 3: Figure S3 (P-value= 0.001, Beta coefficient 95% CI = 1.57-2.06, R-squared=0.75).

As presented in Fig. 3, all 31 provinces of Iran showed a rise in all-cause mortality. Men's excess death rate was not statistically significantly different among regions (P-value = 0.09, mean difference 95% CI: -3.9 – 49.7). Excess death rate ranged from 109.7 (Hormozgan) to 273.2 (East Azerbaijan) per 100,000 population, and showed higher rates among men than women in 26/31 provinces (Additional File 2: Table S3).

Discussion

Investigations of mortality statistics worldwide have demonstrated an increased mortality rates during COVID-19 pandemic compared to previous years (17, 18). While the COVID-19 pandemic has an undeniable impact on excess mortality, it should be highlighted that the rise in mortality linked to COVID-19 is not the only explanation for the increased total mortality (19–21). Our age and sex disaggregated time series analysis of seasonal mortality from summer 2020 to spring 2021 in Iran revealed excess all-cause mortality rate of 178.8 (95% CI: 137.2-220.5) per 100,000 population with higher increase among males and older adults. In consistent with other studies, COVID-19 fatality showed a significant relation

with all-cause excess mortality (22). The excess death rate in the USA, the UK, Italy, and Spain was 136, 121, 179, 166 (per 100,000 population), respectively, aligning with the excess death rate of 178 in Iran (22).

Percent of excess deaths attributed to COVID-19 (calculated by dividing COVID-19 deaths by excess deaths) varies worldwide. While the COVID-19 deaths explains more than half of excess deaths in the USA (77%), UK (87%), Italy (67%), Spain (65%), and Brazil (79%); percent of excess deaths attributed to COVID-19 was low in Kazakhstan (9%), Russia (16%), Kyrgyzstan (20%), Ecuador (36%) (22). The malignancies and cardiac associated mortalities, which have been the leading causes of mortality during recent years, also have been increased during the pandemic, mainly due to public fear of referring to hospitals and delay in critical state management (23–28). Since we found half of the excess deaths in Iran have been attributed to COVID-19, the underreporting and rise in other causes of death may explain the other half. Causes of deaths in Iran during the pandemic are not available, further studies should assess the trend of other causes of death during the pandemic.

The gap of excess mortality is more prominent in males in almost all countries. In consistent with other studies, we found a male to female excess death ratio of 1.3, and almost all provinces had higher excess mortality among male population than females (Additional File 2: Table S3). COVID-19 affects male population and older adult the most, therefore, the prominent change during the pandemic among male and older population can be explained by the impact of COVID-19 (29).

In addition, our results showed 60-70 years-old population influenced the most and had a highest excess death percent increase (Fig. 2). Other studies also showed similar age pattern (30). It is also noteworthy to imply that we have found the 65-69 years old males and 60-64 years old females, to be the most affected age groups by COVID-19. There is a discrepancy among the studies from different countries about the most affected age group. Although the number of infections were the highest among the 20–40-year age group in India, South Korea, and the U.S.A (31, 32), in China and Italy the highest number of infections were in elderlies (33). We observed 10-20 years-old age group have a slightly higher excess death than 20-30 years-old group. Further studies are helpful to evaluate the cause of this slight peak within 10-20 years-old age group.

All provinces of Iran showed a rise in total number of deaths during the pandemic, but the excess death rate varies widely among provinces; excess death ranges from 273.2 in East Azerbaijan to 99.2 in Hormozgan per 100,000 population. The death census in Iran faces underreporting and late reporting of death data (34). The disruption of registrations during the pandemic may cause higher underreporting, especially in under-developed provinces. Since many provinces with majority Turk ethnicity (East Azarbaijan, Zanjan, Ardabil, West, Azarbaijan) showed a high excess mortality, the ethnicity may explain some extent of this variation (35). To our best knowledge the current literature has not evaluated the risk of COVID-19 mortality among ethnicity groups in Iranian population.

In conclusion, there was a significant rise in all-cause mortality during the pandemic, especially in older adults and male gender. Although COVID-19 fatality explains some extent of the rise in all-cause deaths,

the rise in other causes of death and underestimation in reported data should be concerned by further studies.

Limitations

The different causes of deaths during the pandemic were not available. Moreover, COVID-19 fatality was not available by age or sex in each province and just available for the total population. Existence of these dataset can provide a better evaluation of the COVID-19 pandemic impact. The death registration may get disrupted by the pandemic itself as there were some previous issues in underreporting and late registration of deaths.

Abbreviations

COVID-19

Coronavirus disease 2019

MOHME

Ministry of health and medical education

NOCR

National organization of civil registration

CI

Confidence interval

ARIMA

Auto regressive integrated moving average

BIC

Bayesian criterion information

Declarations

Ethics approval and consent to participate

Not applicable. We analyzed government statistics data that are publicly available. No administrative permissions were required to access the data used in this study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets supporting the conclusions of this article is(are) available in the Iran's National Civil Registration office repository, [<https://www.sabteahval.ir/Page.aspx?mId=49826&ID=3273&Page=Magazines/SquareshowMagazine>].

Competing interests

The authors have no conflict of interest associated with the material presented in this paper.

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Authors' contributions

Conceptualization: MAP and SAASN, Data extraction and analysis: SAASN, Methodology: MAP, SAASN, YF and WQA, writing—original draft: YF and SAASN, writing—review and editing: YF, MAP, WQA, AS and SAASN. All authors read and approved the final manuscript

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Figures

Figure 1

Observed versus expected seasonal mortality from spring 2013 to summer 2021 in Iran.

Figure 2

Age specified mortality rate (gap of spring 2021 compared to spring 2019) among male and females.

Excess Mortality Rate per 100,000 population

Created with Datawrapper

Figure 3

Density map of all-cause mortality rate per 100,000 population among 31 provinces of Iran in a year from summer 2020 to spring 2021.

Supplementary Files

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