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Research Letter


# Annual All-Cause Mortality Rate in Germany and Japan (2005 to 2022) With Focus on The Covid-19 Pandemic: Hypotheses And Trend Analyses

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Abbreviations

95%-CI or (. , .): 95%-confidence interval; LL / UL: 95%-confidence lower / upper limits; Chi2: Chi-squared distributed test statistic; Covid-19: Coronavirus disease 2019; DESTATIS: Statistisches Bundesamt, Germany; DF: Degree of freedom; NPI: Non-pharmaceutical intervention; OR: Odds Ratio; SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2; SE: Standard Error



## Introduction

Germany and Japan are highly industrialized countries, which have large and aging populations in common. In 2022, total population sizes were 84.3 million in Germany and 125.0 million in Japan. From 2005 through 2019, both countries present essentially linearly increasing all-cause mortality base line trends, whereby the increase in Japan is twice that in Germany. In Germany the overall mortality odds ratio per year was 1.010, with 95%-confidence interval (1.009, 1.012), while in Japan it was 1.019, (1.018, 1.020). Therefore, in terms of the Covid-19 pandemic, it is interesting how much the annual all-cause mortality rates 2020 to 2022 in Germany and Japan deviate from the trends estimated from the preceding years 2005 to 2019. In Germany, the total number of deaths in 2020 was essentially in line with the previous mortality upward trend [1,2]. The Japanese data have not yet been studied in much detail. In two analyses of life expectancy covering 37 countries [3] and 29 countries [4], Japan was not included. Also, at the time of this writing, for many countries the 2022 figures had not yet been compiled or published, e.g., https://www.mortality.org/, or the excess mortality had only been assessed for the combined years 2020 and 2021 [5], which obscures differences of the excess mortalities in 2020 and 2021. Schöley et al. concluded that '*even in 2021, registered COVID-19 deaths continued to account for most life expectancy losses*' [4]. However, this claim is premature since *COVID-19* as cause of death is subject to considerable artefacts and imponderability [6]. Increased mortality and decreased life expectancy in 2020 to 2022 could well be due to a multitude of other causes.

Trend analyses of demographic and epidemiological data are an obvious statistical approach for operationalizing and investigating scientific questions. Especially in environmental risk research, hypotheses about the spatial-temporal course of ecological and demographic variables and their changing determinants and interactions are a motivation for scrutinizing corresponding data and trends [7,8]. Hypotheses concerning trends and change-points can be visualized naturally, and possible effects can be tested and quantified by point- and interval-estimation using a wide range of methods [9-12]. An example of hypothesis testing in the time series of birth sex ratios before and after the atomic bombing of Japan in 1945 can be found in [13,14]. Accordingly, the impact of natural events, environmental pollution, pandemics, or social changes on mortality can be investigated employing spatial-temporal trend modelling [6]. In contrast to the more abstract and hypothetical concepts of life expectancy, years of live lost, or premature mortality [3,15], graphical display of annual mortality and corresponding trend analyses are direct and vivid.

Morfeld and Erren [16] and Morfeld et al. [17] emphasized the need to consider excess mortality possibly due to SARS-CoV-2 or Covid-19 in 2020 in the fair context of previous years. Giattino et al. warned against underestimating or overestimating the surplus when mortality trends are falling or rising. For example, in countries with ageing populations and increasing mortality such as Germany, Japan, the USA, or South Korea the five-year average will overestimate excess mortality; while countries with declining trends such as Russia will be underestimated [18]. Unfortunately, German DESTATIS compares the number of deaths in 2020 with the median of the four previous years, without taking into account the secular upward trend, see https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Sterbefaelle-Lebenserwartung/sterbefallzahlen.html.

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Nevertheless, it should be noted: "*The total number of deaths in Germany in 2020 corresponds to the previous upward trend from 2005-2019*" [1]; and more specifically: "*The annual deaths per 1000 inhabitants in Germany from 1990 to 2019 follow a cubic logistic trend, which trend was exceeded by 1.3% in 2020, which arithmetically corresponds to 12,667 (-20,886, 45,115) excess deaths, p-value 0.4543*" [6].

Using death and population figures from the EUROSTAT database, Kowall et al. estimated the weekly and cumulative standardized mortality ratios (SMR) for the year 2020 for Germany, Sweden, and Spain using two approaches [2]. On the one hand, the mean weekly mortality rates from 2016 to 2019 were used as expected mortality rates for 2020. On the other hand, taking into account flattening increases in life expectancy (as described in more detail by Klenk et al. [19] and by Weiland et al. [20]), the expected mortality rates for 2020 were calculated by extrapolating the mortality rates from 2016 to 2019. Kowall et al. concluded that in Germany there was hardly any excess mortality in 2020 with both approaches [2]. In another paper, Klenk et al. emphasized: "*The development [of life expectancy] within specific countries is highly sensitive to changes in the political, social and public health environment*" [15]. From this point of view, the analysis of life expectancy to determine excess mortality about environmental or social changes appears more indirect and, in any case, more complex than the direct trend analysis of all-cause mortality rate, which is to be propagated and worked out as an example in this article. The aim of the present note is, therefore, a simple and robust synoptic consideration of Japanese and German overall mortality rates 2005-2022. Focus is put on whether the corona pandemic since spring 2020 and the corresponding immediate countermeasures including vaccination since December 2020 had a noticeable impact (negative or positive) on mortality, and to what extent possible changes can be determined already at the beginning of 2023. Since Japan and Germany have ageing populations, it is crucial to take the increasing all-cause mortality trend into due account for assessing possible excess mortality. An advantage of this straightforward albeit rarely published approach is that it implicitly or explicitly takes into account not only confounders such as age and gender distributions but also all other known or unknown (intrinsic) determinants of the mortality trends, e.g., in Japan the earthquake and the tsunami in 2011.

## Mortality rate in Japan

Using the annual Japanese population and the annual death rates in Table 1, one can test and estimate whether and how much the 2011 earthquake/tsunami and the 2020/2021/2022 coronavirus pandemic have eventually entailed deviations from the expected mortality derived from the unaffected years. So, are there negative or positive excess mortality rates associated with distinct events in certain years? Figure 1 shows the data of Table 1 in the form of deaths per 1000 inhabitants as well as a leap year-corrected trend analysis allowing for deviations from the secular trend in the earthquake/tsunami-years 2011-2013, and in the pandemic-years 2020-2022. For the leap years 2008, 2012, 2016, and 2020, corrected counts were obtained by subtracting the approximate proportional counts 3121, 3433, 3574, and 3751 for the respective 29th February of each leap year. A temporal indicator variable dx means a dummy variable with the value 1 for the year x and the value 0 for all other years. Dummy variables for individual years or periods are used to quantify and test effects. Peaks or jumps in trends are main effects of dummy variables. Kinks or smooth change-points in the curves correspond to interaction effects of time or

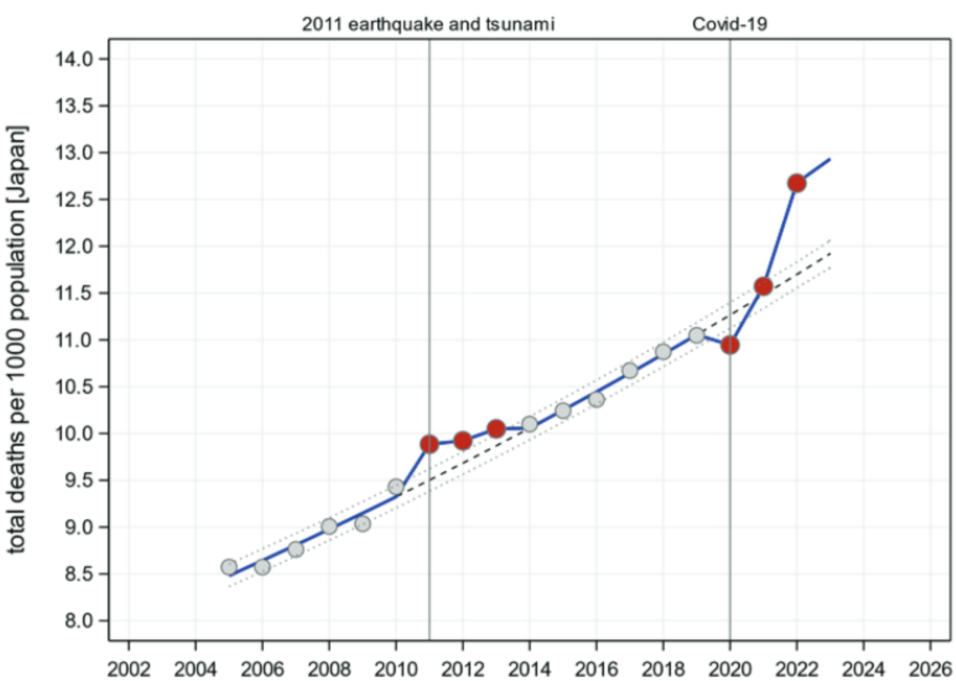


***Figure 1.*** *Annual leap year-corrected total deaths in Japan per 1000 total population, see Table 1 for the data, Table 2 for the estimates and confidence intervals, and Table 3 for the corresponding absolute numbers; the linear logistic regression trend (blue line) allows estimating and testing undershoots or overshoots in 2011 to 2013, 2020 to 2022; dashed line: expected trend; dotted lines: 95% forecast range for each year;*

***Table 1.*** *Annual total population and total deaths in Japan 2005-2022; population counts on October 1 of each year.*

| Year | Population | Deaths | Deaths/1000 Population |
|---|---|---|---|
| 2005 | 127687000 | 1094598 | 8.6 |
| 2006 | 127770000 | 1095393 | 8.6 |
| 2007 | 127771000 | 1119492 | 8.8 |
| 2008 | 127692000 | 1153266 | 9.0 |
| 2009 | 127510000 | 1152176 | 9.0 |
| 2010 | 128057000 | 1207651 | 9.4 |
| 2011 | 127799000 | 1263318 | 9.9 |
| 2012 | 127515000 | 1268705 | 9.9 |
| 2013 | 127298000 | 1279257 | 10.0 |
| 2014 | 127083000 | 1283560 | 10.1 |
| 2015 | 127095000 | 1301824 | 10.2 |
| 2016 | 126933000 | 1319012 | 10.4 |
| 2017 | 126706000 | 1352198 | 10.7 |
| 2018 | 126443000 | 1374765 | 10.9 |
| 2019 | 126167000 | 1393917 | 11.0 |
| 2020 | 126146000 | 1384544 | 11.0 |
| 2021 | 125502000 | 1452289 | 11.6 |
| 2022 | 124830000 | 1582033 | 12.7 |

https://www.e-stat.go.jp/en/stat-search/?page=1
https://en.wikipedia.org/wiki/Demographics_of_Japan

functions of time (t) over the dummy variables. Table 2 shows that in Japan in the years 2011-2013 following the earthquake and tsunami significant ($p<0.05$) excess mortalities occurred. The excess odds ratios were decreasing from 1.041, 1.025, to 1.018 in the years 2011 to 2013, respectively. According to the Japanese reconstruction authority, the number of deaths was 19,747 as confirmed in December 2021. More than 2,500 people are still missing, see: https://www.livescience.com/39110-japan-2011-earthquake-tsunami-facts.html. Table 3 compiles the corresponding absolute excess deaths with 95%-confidence limits. From the estimation accuracy view point of approximately 30,000 to 67,000 possible excess deaths, the excess of 49,000 in 2011 is not quite compatible with the official number of victims of approximately 20,000 cases. The significantly higher estimate of around 49,000 cases based on our trend analysis indicates that in 2011 more people may have died because of indirect disaster stress than were officially attributed explicitly to the earthquake and the tsunami. The further significant increases in mortality in 2012 and 2013 could as well be related to the aftermath of the earthquake and tsunami in 2011.

Concerning the Corona pandemic in Japan, we see a significant under-mortality in 2020 with odds ratio 0.971 (0.956, 0.987), see Table 2. Therefore, similar to the previously published findings for Germany [1,2,6] there is no significant excess mortality in Japan in 2020. However, in 2021 we see a small in-significant mortality increase with odds ratio 1.008 (0.992, 1.025), p-value 0.3325, see Figure 1 and Table 2. This percentage excess of 0.80% translates into 11,547 (-11,902, 34,625) additional cases, see Table 3. The classical characteristic of a pandemic, i.e.,

***Table 2.*** *Leap year-corrected estimates and confidence intervals for the linear logistic trend analysis in Figure 1 of annual total deaths per 1000 total population in Japan 2005-2022; t time in years, dx indicator variable for year x.*

| Maximum Likelihood Estimates | | | | | Odds Ratio Estimates | | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Standard-Error | Wald ChiSq | Pr > ChiSq | Point estimate | 95%-lower limit | 95%-upper limit |
| Intercept | -4.8006 | 0.0049 | 979630.6 | <0.0001 | . | . | . |
| t | 0.0191 | 0.0005 | 1747.9 | <0.0001 | 1.019 | 1.018 | 1.020 |
| d2011 | 0.0399 | 0.0079 | 25.8 | <0.0001 | 1.041 | 1.025 | 1.057 |
| d2012 | 0.0246 | 0.0078 | 9.9 | 0.0017 | 1.025 | 1.009 | 1.041 |
| d2013 | 0.0183 | 0.0078 | 5.5 | 0.0187 | 1.018 | 1.003 | 1.034 |
| d2020 | -0.0291 | 0.0083 | 12.4 | 0.0004 | 0.971 | 0.956 | 0.987 |
| d2021 | 0.0081 | 0.0083 | 0.9 | 0.3325 | 1.008 | 0.992 | 1.025 |
| d2022 | 0.0814 | 0.0083 | 95.6 | <0.0001 | 1.085 | 1.067 | 1.103 |

***Table 3.*** *Observed and expected leap year-corrected deaths in Japan during exposed periods and corresponding absolute and relative excess deaths with 95% confidence intervals.*

| Period in Japan | year | Deaths | | | | | Percent | | |
|---|---|---|---|---|---|---|---|---|---|
| | | observed | expected | excess | LL | UL | excess | LL | UL |
| Earthquake and tsunami | 2011 | 1263318 | 1214356 | 48962 | 30299 | 67345 | 4.03 | 2.50 | 5.55 |
| | 2012 | 1265239 | 1234812 | 30427 | 11525 | 49046 | 2.46 | 0.93 | 3.97 |
| | 2013 | 1279257 | 1256263 | 22994 | 3859 | 41845 | 1.83 | 0.31 | 3.33 |
| Covid-19 pandemic | 2020 | 1,380,761 | 1,421,087 | -40,326 | -63,315 | -17,698 | -2.84 | -4.46 | -1.25 |
| | 2021 | 1,452,289 | 1,440,742 | 11,547 | -11,902 | 34,625 | 0.80 | -0.83 | 2.40 |

***Table 4.*** *Annual total population and total deaths in Germany 2005-2022.*

| Year | Population | Deaths | Deaths/1000 population |
|---|---|---|---|
| 2005 | 82437995 | 830227 | 10.1 |
| 2006 | 82314906 | 821627 | 10.0 |
| 2007 | 82217837 | 827155 | 10.1 |
| 2008 | 82002356 | 844439 | 10.3 |
| 2009 | 81802257 | 854544 | 10.4 |
| 2010 | 81751602 | 858768 | 10.5 |
| 2011 | 80327900 | 852328 | 10.6 |
| 2012 | 80523746 | 869582 | 10.8 |
| 2013 | 80767463 | 893825 | 11.1 |
| 2014 | 81197537 | 868356 | 10.7 |
| 2015 | 82175684 | 925200 | 11.3 |
| 2016 | 82521653 | 910899 | 11.0 |
| 2017 | 82792351 | 932263 | 11.3 |
| 2018 | 83019213 | 954874 | 11.5 |
| 2019 | 83166711 | 939520 | 11.3 |
| 2020 | 83155031 | 985572 | 11.9 |
| 2021 | 83237124 | 1023687* | 12.3 |
| 2022 | 84270625 | 1063560* | 12.6 |

* preliminary from raw data as of February 28, 2023
https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Sterbefaelle-Lebenserwartung/sterbefallzahlen.html

massive excess mortality is thus not observed in Japan, neither in 2020 nor in 2021. However, in 2022 we observe an escalated mortality rate with 122,158 (98,438, 145,504) absolute excess deaths corresponding to 8.37 (6.74, 9.97) percent above expectation, see Table 3.

## Mortality rate in Germany

Table 4 lists the annual population and annual death counts for Germany in the time period 2005-2022. Figure 2 shows the corresponding leap year-corrected annual mortality rates from 2005 to 2022 as well as a trend analysis, which allows for deviations from the secular trend in the years 2020 to 2022. In the leap years 2008, 2012, 2016, and 2020, corrected annual counts were obtained by subtracting from the annual totals the exact daily counts 2452, 2625, 2627, and 2829 of the respective 29th February of each leap year. In Germany in 2020, the mortality rate is increased relative to the extrapolated trend from 2005 to 2019 with an odds ratio of 1.019 (0.990, 1.049), p-value 0.2007, corresponding to 18,274 (-9,855, 45,615) absolute excess deaths and an excess percentage of 1.89 (-1.02, 4.73), see Table 5 and Table 6. Islam et al. reported "25 900 (24 000 to 27 800)" excess deaths for Germany in 2020 [21]. This might reflect an (unrealistic and by the way over-precise) overestimate as these authors considered the data from 2016 onward only, and they thereby underestimated the secular upward trend of the mortality rate in Germany, see Figure 2. In 2021 and 2022, the mortality rate excesses provided as percentages turn out to be 4.99 (2.04, 7.85) and 6.67 (3.69, 9.57), respectively. These excess percentages translate into 48,617 (19,895, 76,526) deaths in 2021, and 66,528, (36,743, 95,459) deaths above expectation in 2022, see Table 6.

It is interesting to put our approach and findings in perspective to Levitt et al. [5], who pinpointed the enormous variability of the published excess counts depending on the methods employed: "*Germany is a classic example. Our age-adjusted*

***Table 5.*** *Leap year-corrected estimates and confidence intervals for the linear logistic trend analysis in Figure 2 of annual total deaths per 1000 total population in Germany 2005-2022; t time in years, dx indicator variable for year x.*

| Maximum Likelihood Estimates | | | | | Odds Ratio Estimates | | |
|---|---|---|---|---|---|---|---|
| Parameter | Estimate | Standard-Error | Wald ChiSq | Pr > ChiSq | Point estimate | 95%-lower limit | 95%-upper limit |
| Intercept | -4.6171 | 0.0083 | 307816.1 | <0.0001 | . | . | . |
| t | 0.0101 | 0.0008 | 153.0 | <0.0001 | 1.010 | 1.009 | 1.012 |
| d2020 | 0.0190 | 0.0148 | 1.6 | 0.2007 | 1.019 | 0.990 | 1.049 |
| d2021 | 0.0492 | 0.0150 | 10.8 | 0.0010 | 1.050 | 1.020 | 1.082 |
| d2022 | 0.0654 | 0.0152 | 18.5 | <0.0001 | 1.068 | 1.036 | 1.100 |

***Table 6.*** *Observed and expected leap year-corrected deaths in Germany during the Covid-19 pandemic and corresponding absolute and relative excess deaths with 95% confidence intervals.*

| Period in Germany | year | Deaths | | | | | Percent | | |
|---|---|---|---|---|---|---|---|---|---|
| | | observed | expected | excess | LL | UL | excess | LL | UL |
| Covid-19 | 2020 | 982,743 | 964,469 | 18,274 | -9,855 | 45,615 | 1.89 | -1.02 | 4.73 |
| | 2021 | 1,023,687 | 975,070 | 48,617 | 19,895 | 76,526 | 4.99 | 2.04 | 7.85 |

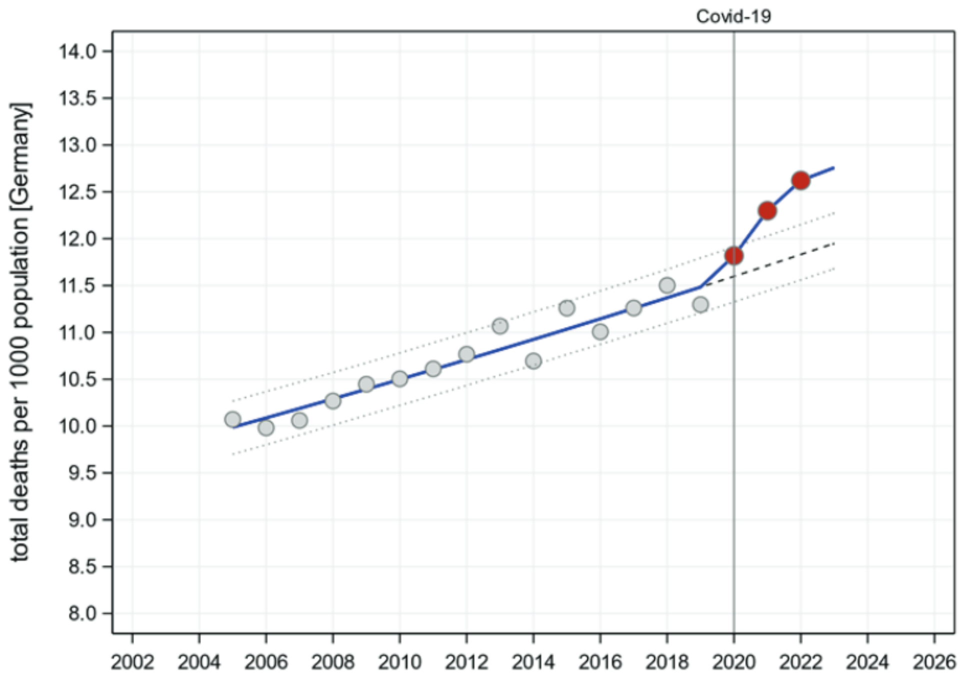


***Figure 2.*** *Annual leap year-corrected total deaths in Germany per 1000 total population, see Table 4 for the data, Table 5 for the estimates and confidence intervals, and Table 6 for the corresponding absolute numbers; the linear logistic regression trend (blue line) allows estimating and testing the undershoots or overshoots in 2020 to 2022; dashed line: expected trend; dotted lines: 95% forecast band for each year; scaling accounting for overdispersion with deviance/DF 162.6.*

*estimate is 55,000 excess deaths, while without age-adjustment we calculated 129,000 excess deaths and Lancet calculated 203,000 excess deaths – compared with 111,000 COVID-19 reported deaths. Baum calculated only 22,000 excess deaths after age adjustment, while Koenig without age adjustment found more excess deaths than recorded COVID-19 deaths*." Note, the wide range of excess-mortality estimates found in the literature undermines their credibility and is also in sharp contrast to the extremely narrow confidence limits reported by Islam et al. [21]. This large variability can easily be explained by the natural intrinsic or 'random' variability, and in a sense imponderability, of the underlying highly aggregated annual national counts. With our trend analysis method, we can well disentangle the insurmountable high variability of mortality excess estimates. For example, we see a significant excess mortality in percent of the expectation of 3.45 (1.13, 5.72), p-value 0.0037, in Germany in the combined years 2020 and 2021; we excluded 2022 from this consideration. This excess translates to 66,922 (21,919, 110,915) absolute cases. Although we see a significant excess here, we nevertheless face a 90,000-deaths-wide confidence interval from approximately 20,000 to 110,000. This is compatible with the data under a probabilistic point of view, which is based on the all-cause mortality secular trend and on the natural year-to-year (random) variability of the data, taking overdispersion into account. Note also that our rather wide interval-estimate of excess mortality in 2020/2021 of ca. (20,000, 110,000) covers many point-estimates in the literature so far. These point estimates were often published without confidence limits. Therefore, we emphasize again that our trend analysis method automatically or intrinsically adjusts the that systematically or incidentally affect the mortality over time. Notably, the significant excess in all-cause mortality in Germany in 2020 and 2021 of 3.45% is not evenly distributed in the years 2020 and 2021. In 2020, a year with no COVID-19 mass vaccinations, the excess mortality amounts to 1.89 (-1.02, 4.73) percent of the expectation, p-value 0.2007. This excess in 2020 is less than half the excess mortality percentage under the COVID-19 vaccination campaign in 2021 of 4.99 (2.04, 7.85) percent, p-value 0.0010. For the pertinent relative and absolute point and interval-estimates of our trend analyses of the German data see Table 6.

## Discussion

In Japan, we see a significantly elevated mortality in the earthquake and tsunami era from 2011 to 2013, and no other significant mortality overshot before and including 2021. The all-cause mortality in 2020 lies below, and in 2021 it falls within the expected limits of the annual random fluctuations in the mortality trend from 2005-2019, see Figure 1. This indicates neither a classical pandemic characterized by an unusually high mortality, nor does it imply personal mass injuries because of the Corona measures in Japan in 2020 and 2021. However, in 2022 the death rate is extremely elevated by 8.37% (6.74, 9.97), which is more than twice the average excess in the earthquake and tsunami years in Japan. This effect in Japan in 2022 warrants thorough investigation and clarification.

A somewhat different picture emerges in Germany. In contrast to Japan, there are no significant deviations from the secular mortality trend over the entire period from 2005 to 2020. In well outside the detection limit of the trend analysis method used. This method allows an estimation accuracy of the under- or over-mortality in individual years from approx. ±2% (Japan) to ±3% (Germany): see the width of the confidence intervals in Tables 3 and Table 6. This accuracy is, therefore, sufficient to detect or rule out over- or under-mortality of ±2% to ±3% beyond expectation. This holds for countries with populations in the range of 100 million and with an 'undisturbed' annual data variability such as found in Japan or in Germany, respectively. If the corresponding gender and age stratified data are available, the proposed method can also be applied in a gender-age-specific manner. This could and should be done to examine how the significant excess mortality found in Germany in 2021 and 2022 is distributed among the various gender and age groups.

In conclusion, the official fear-mongering forecasts and the allegedly confirmed high death toll in 2020 from Covid-19 in high income countries [21,22] did not come true, neither in Japan nor in Germany. Based on early investigations in 2020 and 2021, however, great damage was not to be expected [23,24]. Therefore, it should be investigated to what extent the about 5 to 10 percent highly significantly increased mortalities in Germany and Japan in 2021 and 2022 might be due to the pandemic counter measures, including the vaccinations with their possibly underestimated immediate or protracted side effects [25-27]. In a study from the Maltese Mater Dei Hospital, the vaccination rate in the population was positively correlated with the frequency of emergency admissions over time [27]. From this point of view, it seems possible that a high vaccination rate has contributed to an increased all-cause mortality in some countries. It is thus important to keep a close eye on national secular mortality trends over the next few years and to examine the possible causes of significant excess mortality [25,28-30].

## Declarations

### Ethical approval and consent to participate

Not applicable. Ethics approval and consent to participate are not required and not necessary, since only publicly available data and previously published information is being used.

### Consent for publication

Not applicable. Only anonymous highly-aggregate national data is being used.

### Availability of supporting data

The employed data has exclusively been published previously and/or it is contained in the Tables and in the Figures included in this paper.

### Competing interests

The authors declare that they have no conflicts of interest.

### Funding

The authors declare that they have no funding for this study.

### Authors' contributions

KH and HS contributed detailed most recent demographic information specific for Japan and Germany, respectively. HS carried out the statistical analyses. Both authors wrote and approved the final manuscript.

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### Reporting guidelines

Reporting of the study conforms to broad EQUATOR guidelines (Simera et al. January 2010 issue of EJCI).

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