Brief Report

An Assessment of Averted Mortality Modeling in the Context of COVID-19 Vaccines

Matthew Halma [*] , Ramiz Ahmed-Man , Cristof Plothe , Amrit Šorli

Brief Report

An Assessment of Averted Mortality Modeling in the Context of COVID-19 Vaccines

Matthew T.J. Halma [1], Ramiz Ahmed-Man [1], Cristof Plothe [1,2] and Amrit Šorli [3,*]

[1]   EbmC Squared, BA2 4BL, Bath, United Kingdom
[2]   Center for Biophysical Osteopathy, Am Wegweiser 27, 55232 Alzey, Germany
[3]   Bijective Physics Institute, Idrija, Slovenia
*   Correspondence: author: matt.halma@gmail.com
†   These authors contributed equally to this work.

Abstract: The question of how many deaths were averted by interventions during the COVID-19 pandemic carries important implications for policies going forward. Given that the interventions of lockdowns and mass vaccination carry acknowledged downsides, it is important to balance these against potential upsides, which were the putative reasons for health officials to implement these policies. Several attempts have been made to quantify the impact of mass vaccination on averted mortality both globally, and in specific countries/regions, using different methodologies. Here, we examine the assumptions of these models and look for areas of improvement, while understanding that simplifications are inherent in model building. We find that several assumptions greatly overstate the degree of averted mortality due to vaccination and perform an empirical analysis of country level data in Europe to test if vaccination was associated with lower excess mortality. We show a positive and statistically significant correlation between number of vaccine doses given and 2022 excess mortality, calling into question estimates of positive averted mortality due to mass vaccination. Our results show several assumptions which work to systematically overstate the level of averted mortality from Covid-19 vaccines. This work aims to improve epidemiological modeling on the impact of vaccination, and to ground the public health response to infectious diseases in robust and rigorous analysis.

Keywords: averted mortality; mass vaccinations; public health; COVID-19; epidemiological modeling

Introduction

Averted mortality estimates from the public health response to COVID-19 have been used as justification for public health measures, including masking, lockdowns and vaccination. Public health policies operate under the assumption that the putative positive impacts of health measures (averted mortality), more than balance out their costs. Lockdowns[1–4], masking[5–7] and vaccination[8] all carry downsides and risks. In this study, we identify 12 studies on the COVID-19 averted mortality due to vaccination [9–20], estimating a significant benefit in lives saved.

Claims that the Covid-19 vaccines saved lives are central to the policy of providing and/or mandating vaccines. However, claims that vaccines averted mortality are difficult to verify, relying on models. National comparisons of vaccination rate with excess mortality demonstrate a statistically significant positive correlation between vaccination uptake and 2022 excess deaths[21,22], putting claims of averted mortality from vaccines into question. This meta-analysis reviews the averted mortality models used as justification for the policies of vaccination and vaccine mandates and examines their methodological assumptions.

At a subcommittee hearing on oversight of the US Centers for Disease Control (CDC) policies and decisions during the Covid-19 pandemic, CDC director Rochelle Walensky cited a study by the Commonwealth fund, a US think tank, claiming that the vaccines had saved 3.2 million lives in the US, prevented 18.5 million hospitalizations and saved $1.15 trillion in health care costs [12,23]. This was a modeling study that was not peer reviewed, had significant conflicts of interest and did not include their basic parameters for building their model, including vaccine efficacy [12]. Given that these models are influencing the top echelons of policy making, it is important that they be based on

rigorous validation and are not merely used to justify a policy that one created beforehand. A similar debate emerges with regards to climate modeling, where model codes are often not shared according to best scientific practice[24].

We summarize the methodological assumptions that lead to the systematic overstatement of the benefits of vaccination.

Systemic Issues

Overstated danger from Covid-19

One issue with many of the averted mortality models is the case fatality rates assumed, which tend to be based off older, more dangerous variants, whereas Covid-19 variants became less deadly as time went on[25]. Using old, inflated CFRs results in a higher modelled mortality associated with Covid-19. For accurate modelling, the parameter used as case fatality rate must be current based on variants circulating at the time.

Overstated vaccine efficacy against death

Standard categorizations of people into the camp 'vaccinated' typically require the last of the initial series to be administered two [26] or three[27] weeks or more prior to the current date.

To demonstrate how vaccine efficacy can be overstated given this delay in categorizing people as vaccinated, we assume an inert placebo 'vaccine' with a real effectiveness of 0%. If someone is infected during the categorization delay of two weeks (3 weeks in the UK), they will be classified as unvaccinated, thereby redefining cases to unvaccinated and appearing to show vaccine efficacy, despite none in reality.

Lack of waning immunity in models

The majority of models did not take into account the observed waning of immunity in vaccinated populations. Some models did putatively account for waning immunity (Table 1), but here, assumptions are generous and err on the side of increasing the averted mortality estimate.

In most studies, we observe the following trend. A rapid waning of protection against infection[28], a less rapid waning of protection against severe outcomes, and a slower still waning of protection against death[29]. Waning immunity can both be due to factors in the individual's immune system and susceptibility, as well as changes in the circulating virus form previous strains. Waning of vaccine protection is a significant factor, and ignoring it will drastically overstate averted mortality due to vaccination.

Ignoring of vaccine adverse events

One overlooked aspect of these counterfactual scenarios is that none of those mentioned in Table 1 take into account the deleterious impacts of vaccination[8], which include death in some autopsy-confirmed cases [30–32]. The number needed to vaccinate (NNV) to prevent one death can be calculated as a function of vaccine efficacy against death. For original pre-delta SARS-COV-2 strain, the NNV was calculated as 1840[33]. Since both vaccine efficacy and infection fatality rate declined for delta[34] and later omicron[35], the NNV to prevent one death rose.

The UK Office of National Statistics (ONS), estimated the NNV for prevention of severe hospitalization to be 2,500 for those 70 and older and 18,700 for those 50-59[36]. For those not in a risk group, the numbers become truly remarkable; 51,600 for those aged 50-59 and 318,400 for those aged 30 to 39[36]. Note that these NNVs are preventing severe hospitalization and would be even higher for NNVs preventing deaths. Based on trial data, mRNA vaccination was associated with 12.5 extra serious adverse events per 10,000 recipients, or 1 in 800 vaccine recipients [8].

Lack of comparator group

The official narrative of covid vaccines saving lives was never proved. All articles that are dealing with this subject are using inappropriate methodologies where only the vaccinated part of population is examined, whereas the unvaccinated part of population is taken out of the model. If vaccinated part of population has lower mortality rate than unvaccinated part of population, vaccines are saving lives, if it is opposite vaccines are taking lives. The only methodologically acceptable evaluation of covid vaccines efficacy is comparing the mortality rate of vaccinated population with the mortality rate of unvaccinated population [37].

Data of England are confirming that mortality rate of vaccinated population is higher by about 15% regarding the unvaccinated part of population. Direct causal correlation between intensity of vaccination and excess mortality rate is seen when we compare the graph of number of vaccinations per day with the graph of excess mortality per day. Comparison was done for countries and has shown that intense vaccination in a given period is causing high mortality rate in following period. After the end of massive vaccination always happened that also hight mortality rate has vanished [37].

Age structure of averted mortality

One consideration for averted mortality modeling is that it provides a number of deaths. However, these are not differentiated by expected life years. Disability adjusted life years (DALYs) are a population health metric which account for the expected number of life years saved[38]. Vaccination disproportionately saved more lives in elderly people, as they were at the highest risk of death from COVID-19[39]. However, an averted death in an elderly person only amounts to a few life years saved, as opposed to an averted death in a younger person.

Averting the death of an elderly person carries considerable benefit, though they will likely at most live a few more years. The death of a young person is a loss of multiple decades of healthy life. These should not be weighted the same as their impact is considerably different.

Very little justification existed for vaccinating the non-elderly without serious co-morbidities, as these populations had very low risk from COVID[39]. One justification provided was that vaccinating the young was to protect the old, but vaccines provided only modest reduction in transmission against the delta variant, which was the circulating variant soon after the vaccine campaigns in 2021 [40]. For the Omicron variant, a full series of vaccination did not reduce breakthrough case viral load compared to an unvaccinated COVID-19 case[41], and had a negligible impact (<10% Vaccine efficacy) on transmission[35].

Other systemic issues

Black box Models-   code not available

For reproducibility as well as collaboration in research, it is important that code and parameters used to construct these models be available, as opposed to relying on black-box models with unknown assumptions[42]. To their credit, many of the models included in this review do publish code and parameters to replicate the models, though several notably do not.

Conflicts of interest

Conflicts of interest exist on several of the articles, including funding by the Bill and Melinda Gates Foundation, the Commonwealth fund and GAVI, who are strong supporters of pro-vaccination policy and hold conflicting interest. Additionally, several public health officials have acknowledged roles in promoting vaccination, which will influence their objectivity; these may be explicitly stated or implicit.

Reference	Region	Time frame	Recorded C19 deaths	AME	Model VE$_{death}$	Is VE assumed constant?	Code accessible?	Peer Review
[9]	Europe (age 60 years and older)	Up to Week 45,	442,116	469,186 [129,851 - 733,744]	95%	Yes	Yes	Yes

[10]	Global	2021 Week 50, 2020 to Week 49, 2021	5 469 000	14.4 million [13.7-15.9]	Adenovirus, 92%; mRNA, 95%; subunit, 96%; whole virus, 79%	Yes, accounts for decreased VE against variants	Yes	Yes
[11]	USA	Week 50, 2020 to Week 26, 2021	300, 081[43]	240,797 [200,665 - 281,230]	92%	Yes, accounts for decreased VE against variants	Yes	Yes, supported by Commonwealth fund
[12]	USA	Up to Week 48, 2021	800, 000	1,087,191 [950,101 - 1,231,195]	Not stated "drawn from published estimates"	Stated to account for waning immunity	No, parameters not available	No, published by private think tank (Commonwealth Institute)
[13]	USA	Up to Week 18, 2021	585,285	139,393	N/A	N/A	Model assumptions available	Yes
[14]	Canada	Up to Week	38,783	321,077 [175,157 - 764,917]	96%	Accounts for waning VE against infections	No, parameters available	No, Government

		16, 2022		[1]	and hospitalization, VE_{death} is constant			communication
[15]	USA	Week 51, 2020 to Week 22, 2021	250,000	123,200 [-74,300 - 403,000]	90% $VE_{infection}$ Does not use a separate VE_{death}	No	Yes	Yes
[16]	Northeastern and southern USA (hypothetical increase in daily vaccine doses by 50%)	Week 40, 2020 to Week 35, 2021	324,649	158,665 [144,640 – 172,690]	For severe disease: Original Strain, 92%; Alpha, 94%; Beta, 97.4%; Delta, 80%	Yes, after two weeks	Yes	Yes, Supported by Commonwealth fund
[17]	Israel	Week 51, 2020 to Week 14,	2,859	5,532 [3,085-7,982]	Calculated using rate differences, does not require VE. But VE at	Is not a modelled study	Code for data analysis (not simulation) is not available.	Yes

---

[1] Based on Table 3, scenario S3, considering the impact of maintaining public health measures but not performing vaccination for a population of 38.0 million Canadians (2021, Statistics Canada https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901&cubeTimeFrame.startMonth=01&cubeTimeFrame.startYear=2021&cubeTimeFrame.endMonth=01&cubeTimeFrame.endYear=2023&referencePeriods=20210101%2C20230101)

		2021			96.7% [44]			
[18]	USA	Week 11, 2021 to Week 20, 2022	351,777	1.4 million²	Regression analysis, does not use VE	Accounts	Code for data analysis (not simulation) is not available.	No
[19,47]	Finland	Week 52, 2020 to Week 13, 2022	1,753	7321[6602-8084]	Regression analysis, calculates VE at 98%.	Not dependent on modeling	N/A	Yes
[20]	New York City, NY, USA	Week 51, 2020 to Week 28, 2021	9,104	8,508[7,374-9,543]	For severe disease: Original Strain, 92%; Alpha, 94%; Beta, 97.4%; Delta, 97.4%	Yes, after two weeks	Yes	Yes, supported by Commonwealth fund

Discussion

Of the models explored, most had systematic biases towards overstating the effectiveness of Covid-19 vaccines in averting mortality. These estimates vary widely and are not directly

---

² Based on his postulated claim that one death was averted for every 127 primary series vaccinations given. Between 3/19/2021 and 5/22/2022, 53.9% of the total US population was vaccinated [45], and US population was 331,893,745[46].

comparable, but we do have access to the time periods of the estimates and the reported number of Covid-19 deaths during that time periods. As the difference between the no-vaccine situation with the vaccine situation can only manifest after vaccination begins, and the model assumptions create more divergent outcomes with the greater passage of time, the model predictions cannot be directly compared. However, most of the averted mortality estimates are on the order of the number of Covid-19 related fatalities in the region and time frame of the estimation. One major exception is the Canadian study[14], which provided an averted mortality estimate 8.3 times that of the recorded number of Covid-19 deaths in Canada during the same time period.

Given that vaccination has downsides, and the imposition of emergency measures and mandates comes with severe downsides, it is important to know the actual benefit, if any, that vaccination brings. Thus far, the models that exist are set to systematically overstate the level of averted mortality, while downplaying or denying any costs and negative risks. In the context of making informed policy decisions, it is unacceptable to emphasize the benefits of a particular intervention while downplaying or ignoring the risks. Here, modelers show systemic bias towards showing the benefits of vaccination while downplaying the risks. This analysis shows that the models overstate the averted mortality through several distinct mechanisms, by using inflated case fatality rates which overstate the danger of Covid-19, by overstating the effectiveness of vaccines against death, as well as the transmission of the virus, and by ignoring waning vaccine immunity and vaccine adverse events. Another unappreciated factor is that the age structure of the averted mortality is concentrated in the elderly, who are at most risk for Covid-19, and averted mortality values correspond to at most a few extra years of life. While this may seem like ghoulish math to some, it has been widely accepted that elderly people have already lived a full life, and saving the lives of younger people is of higher priority.

In the case of Covid-19 policy, the case was made that the young should get vaccinated, despite being at almost negligible risk. When the cost benefit analysis is not in favor of vaccinating the young for their protection, the argument shifted to one of social duty to create herd immunity. This argument first had the issue of feasibility and fails even if you accept the alleged utilitarian argument, as the vaccines do little to stop transmission, and regular booster vaccination is associated with higher rates of infection. Secondly, while any supposed benefits accrue to the elderly, young people suffer the harms, violating bedrock bioethical principles. One cannot be coerced to undergo a medical procedure for the (supposed) benefit of another; while it may seem an extreme comparison, it is only a difference of magnitude that separates this practice from forced organ harvesting, which too purports to deliver a benefit to another at comparably minimal cost from one person. This practice is at odds with protection of human rights, and violations which are not immediately halted and punished countenance the destruction of bedrock principles of individual rights.

Additional issues that don't quite fit into methodological categories include the inaccessibility of several of the models. While many authors and models do provide their codes and parameters for replication, some of the models providing the most sway in terms of their impact on policy makers are black box models. The Commonwealth fund model [12] cited by Walensky was published by a think tank and did not undergo peer review before publication on their website, and modelling parameters, let alone code are not available (Table 1). In this case, public health policy makers are getting information from sources with conflicts of interest, and not unbiased and scientific sources.

Science must guide decision making, and not merely be used to provide support for a course of action already decided upon. The current literature on the cost-benefit analysis of vaccination is systematically skewed in favor of stating the benefits while ignoring the cost. Models must be grounded in reality, and not wishful thinking.

References

1. Walmsley, T.; Rose, A.; Wei, D. The Impacts of the Coronavirus on the Economy of the United States. *EconDisCliCha* **2021**, *5*, 1–52, doi:10.1007/s41885-020-00080-1.
2. Evans, S.; Alkan, E.; Bhangoo, J.K.; Tenenbaum, H.; Ng-Knight, T. Effects of the COVID-19 Lockdown on Mental Health, Wellbeing, Sleep, and Alcohol Use in a UK Student Sample. *Psychiatry Res* **2021**, *298*, 113819, doi:10.1016/j.psychres.2021.113819.
3. Chaturvedi, K.; Vishwakarma, D.K.; Singh, N. COVID-19 and Its Impact on Education, Social Life and Mental Health of Students: A Survey. *Child Youth Serv Rev* **2021**, *121*, 105866, doi:10.1016/j.childyouth.2020.105866.
4. Bhavsar, V.; Kirkpatrick, K.; Calcia, M.; Howard, L.M. Lockdown, Domestic Abuse Perpetration, and Mental Health Care: Gaps in Training, Research, and Policy. *The Lancet Psychiatry* **2021**, *8*, 172–174, doi:10.1016/S2215-0366(20)30397-7.
5. Fitousi, D.; Rotschild, N.; Pnini, C.; Azizi, O. Understanding the Impact of Face Masks on the Processing of Facial Identity, Emotion, Age, and Gender. *Frontiers in Psychology* **2021**, *12*.
6. Engeroff, T.; Groneberg, D.A.; Niederer, D. The Impact of Ubiquitous Face Masks and Filtering Face Piece Application During Rest, Work and Exercise on Gas Exchange, Pulmonary Function and Physical Performance: A Systematic Review with Meta-Analysis. *Sports Medicine - Open* **2021**, *7*, 92, doi:10.1186/s40798-021-00388-6.
7. Bottalico, P.; Murgia, S.; Puglisi, G.E.; Astolfi, A.; Kirk, K.I. Effect of Masks on Speech Intelligibility in Auralized Classroomsa). *The Journal of the Acoustical Society of America* **2020**, *148*, 2878–2884, doi:10.1121/10.0002450.
8. Fraiman, J.; Erviti, J.; Jones, M.; Greenland, S.; Whelan, P.; Kaplan, R.M.; Doshi, P. Serious Adverse Events of Special Interest Following MRNA COVID-19 Vaccination in Randomized Trials in Adults. *Vaccine* **2022**, *40*, 5798–5805, doi:10.1016/j.vaccine.2022.08.036.
9. Meslé, M.M.; Brown, J.; Mook, P.; Hagan, J.; Pastore, R.; Bundle, N.; Spiteri, G.; Ravasi, G.; Nicolay, N.; Andrews, N.; et al. Estimated Number of Deaths Directly Averted in People 60 Years and Older as a Result of COVID-19 Vaccination in the WHO European Region, December 2020 to November 2021. *Eurosurveillance* **2021**, *26*, 2101021, doi:10.2807/1560-7917.ES.2021.26.47.2101021.
10. Watson, O.J.; Barnsley, G.; Toor, J.; Hogan, A.B.; Winskill, P.; Ghani, A.C. Global Impact of the First Year of COVID-19 Vaccination: A Mathematical Modelling Study. *The Lancet Infectious Diseases* **2022**, *22*, 1293–1302, doi:10.1016/S1473-3099(22)00320-6.
11. Vilches, T.N.; Moghadas, S.M.; Sah, P.; Fitzpatrick, M.C.; Shoukat, A.; Pandey, A.; Galvani, A.P. Estimating COVID-19 Infections, Hospitalizations, and Deaths Following the US Vaccination Campaigns During the Pandemic. *JAMA Network Open* **2022**, *5*, e2142725, doi:10.1001/jamanetworkopen.2021.42725.
12. The U.S. COVID-19 Vaccination Program at One Year: How Many Deaths and Hospitalizations Were Averted? Available online: https://www.commonwealthfund.org/publications/issue-briefs/2021/dec/us-covid-19-vaccination-program-one-year-how-many-deaths-and (accessed on 13 May 2023).
13. Gupta, S.; Cantor, J.; Simon, K.I.; Bento, A.I.; Wing, C.; Whaley, C.M. Vaccinations Against COVID-19 May Have Averted Up To 140,000 Deaths In The United States. *Health Affairs* **2021**, *40*, 1465–1472, doi:10.1377/hlthaff.2021.00619.
14. Canada, P.H.A. of Counterfactuals of Effects of Vaccination and Public Health Measures on COVID-19 Cases in Canada: What Could Have Happened?, CCDR 48(7/8) Available online: https://www.canada.ca/en/public-health/services/reports-publications/canada-communicable-disease-report-ccdr/monthly-issue/2022-48/issue-7-8-july-august-2022/counterfactuals-effects-vaccination-public-health-measures-covid-19-cases-canada.html (accessed on 9 May 2023).
15. Yamana, T.K.; Galanti, M.; Pei, S.; Fusco, M.D.; Angulo, F.J.; Moran, M.M.; Khan, F.; Swerdlow, D.L.; Shaman, J. The Impact of COVID-19 Vaccination in the US: Averted Burden of SARS-COV-2-Related Cases, Hospitalizations and Deaths. *PLOS ONE* **2023**, *18*, e0275699, doi:10.1371/journal.pone.0275699.
16. Vilches, T.N.; Sah, P.; Moghadas, S.M.; Shoukat, A.; Fitzpatrick, M.C.; Hotez, P.J.; Schneider, E.C.; Galvani, A.P. COVID-19 Hospitalizations and Deaths Averted under an Accelerated Vaccination Program in Northeastern and Southern Regions of the USA. *The Lancet Regional Health - Americas* **2022**, *6*, 100147, doi:10.1016/j.lana.2021.100147.
17. Haas, E.J.; McLaughlin, J.M.; Khan, F.; Angulo, F.J.; Anis, E.; Lipsitch, M.; Singer, S.R.; Mircus, G.; Brooks, N.; Smaja, M.; et al. Infections, Hospitalisations, and Deaths Averted via a Nationwide Vaccination Campaign Using the Pfizer–BioNTech BNT162b2 MRNA COVID-19 Vaccine in Israel: A Retrospective Surveillance Study. *The Lancet Infectious Diseases* **2022**, *22*, 357–366, doi:10.1016/S1473-3099(21)00566-1.
18. Barro, R.J. Vaccination Rates and COVID Outcomes across U.S. States. *Economics & Human Biology* **2022**, *47*, 101201, doi:10.1016/j.ehb.2022.101201.
19. Baum, U.; Poukka, E.; Leino, T.; Kilpi, T.; Nohynek, H.; Palmu, A.A. High Vaccine Effectiveness against Severe COVID-19 in the Elderly in Finland before and after the Emergence of Omicron. *BMC Infectious Diseases* **2022**, *22*, 816, doi:10.1186/s12879-022-07814-4.

20. Shoukat, A.; Vilches, T.N.; Moghadas, S.M.; Sah, P.; Schneider, E.C.; Shaff, J.; Ternier, A.; Chokshi, D.A.; Galvani, A.P. Lives Saved and Hospitalizations Averted by COVID-19 Vaccination in New York City: A Modeling Study. *The Lancet Regional Health - Americas* **2022**, *5*, 100085, doi:10.1016/j.lana.2021.100085.

21. Halma, M.T.J.; Guetzkow, J. Public Health Needs the Public Trust: A Pandemic Retrospective. *BioMed* **2023**, *3*, 256–271, doi:10.3390/biomed3020023.

22. Aarstad, J.; Kvitastein, O.A. Is There a Link between the 2021 COVID-19 Vaccination Uptake in Europe and 2022 Excess All-Cause Mortality? *25-31* **2023**, doi:10.21276/apjhs.2023.10.1.6.

23. TESTIMONY OF ROCHELLE P. WALENSKY, M.D., M.P.H. 2023.

24. Añel, J.A.; García-Rodríguez, M.; Rodeiro, J. Current Status on the Need for Improved Accessibility to Climate Models Code. *Geoscientific Model Development* **2021**, *14*, 923–934, doi:10.5194/gmd-14-923-2021.

25. Wang, C.; Liu, B.; Zhang, S.; Huang, N.; Zhao, T.; Lu, Q.-B.; Cui, F. Differences in Incidence and Fatality of COVID-19 by SARS-CoV-2 Omicron Variant versus Delta Variant in Relation to Vaccine Coverage: A World-Wide Review. *Journal of Medical Virology* **2023**, *95*, e28118, doi:10.1002/jmv.28118.

26. Griffin, J.B. SARS-CoV-2 Infections and Hospitalizations Among Persons Aged ≥16 Years, by Vaccination Status — Los Angeles County, California, May 1–July 25, 2021. *MMWR Morb Mortal Wkly Rep* **2021**, *70*, doi:10.15585/mmwr.mm7034e5.

27. COVID-19 Vaccine Effectiveness Estimated Using Census 2021 Variables, England - Office for National Statistics Available online: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/covid19vaccineeffectivenessestimatedusingcensus2021variablesengland/31march2021to20march2022 (accessed on 24 August 2023).

28. Patalon, T.; Saciuk, Y.; Peretz, A.; Perez, G.; Lurie, Y.; Maor, Y.; Gazit, S. Waning Effectiveness of the Third Dose of the BNT162b2 MRNA COVID-19 Vaccine. *Nat Commun* **2022**, *13*, 3203, doi:10.1038/s41467-022-30884-6.

29. Zhuang, C.; Liu, X.; Chen, Q.; Sun, Y.; Su, Y.; Huang, S.; Wu, T.; Xia, N. Protection Duration of COVID-19 Vaccines: Waning Effectiveness and Future Perspective. *Frontiers in Microbiology* **2022**, *13*.

30. Gill, J.R.; Tashjian, R.; Duncanson, E. Autopsy Histopathologic Cardiac Findings in 2 Adolescents Following the Second COVID-19 Vaccine Dose. *Archives of Pathology & Laboratory Medicine* **2022**, *146*, 925–929, doi:10.5858/arpa.2021-0435-SA.

31. Suzuki, H.; Ro, A.; Takada, A.; Saito, K.; Hayashi, K. Autopsy Findings of Post-COVID-19 Vaccination Deaths in Tokyo Metropolis, Japan, 2021. *Legal Medicine* **2022**, *59*, 102134, doi:10.1016/j.legalmed.2022.102134.

32. Schwab, C.; Domke, L.M.; Hartmann, L.; Stenzinger, A.; Longerich, T.; Schirmacher, P. Autopsy-Based Histopathological Characterization of Myocarditis after Anti-SARS-CoV-2-Vaccination. *Clin Res Cardiol* **2023**, *112*, 431–440, doi:10.1007/s00392-022-02129-5.

33. COVIDSurg Collaborative, G.C. SARS-CoV-2 Vaccination Modelling for Safe Surgery to Save Lives: Data from an International Prospective Cohort Study. *British Journal of Surgery* **2021**, *108*, 1056–1063, doi:10.1093/bjs/znab101.

34. Lopez Bernal, J.; Andrews, N.; Gower, C.; Gallagher, E.; Simmons, R.; Thelwall, S.; Stowe, J.; Tessier, E.; Groves, N.; Dabrera, G.; et al. Effectiveness of Covid-19 Vaccines against the B.1.617.2 (Delta) Variant. *New England Journal of Medicine* **2021**, *385*, 585–594, doi:10.1056/NEJMoa2108891.

35. Gardner, B.J.; Kilpatrick, A.M. Estimates of Reduced Vaccine Effectiveness against Hospitalization, Infection, Transmission and Symptomatic Disease of a New SARS-CoV-2 Variant, Omicron (B.1.1.529), Using Neutralizing Antibody Titers 2021, 2021.12.10.21267594.

36. Appendix 1: Estimation of Number Needed to Vaccinate to Prevent a COVID-19 Hospitalisation for Primary Vaccination, Booster Vaccination (3rd Dose), Autumn 2022 and Spring 2023 Booster for Those Newly in a Risk Group Available online: https://www.gov.uk/government/publications/covid-19-vaccination-programme-for-2023-jcvi-interim-advice-8-november-2022/appendix-1-estimation-of-number-needed-to-vaccinate-to-prevent-a-covid-19-hospitalisation-for-primary-vaccination-booster-vaccination-3rd-dose-au (accessed on 27 May 2023).

37. Šorli, S.; Makovec, T.; Krevel, Z.; Gorjup, R. Forgotten "Primum Non Nocere" and Increased Mortality after Covid-19 Vaccination 2023.

38. Devleesschauwer, B.; Havelaar, A.H.; Maertens de Noordhout, C.; Haagsma, J.A.; Praet, N.; Dorny, P.; Duchateau, L.; Torgerson, P.R.; Van Oyen, H.; Speybroeck, N. DALY Calculation in Practice: A Stepwise Approach. *Int J Public Health* **2014**, *59*, 571–574, doi:10.1007/s00038-014-0553-y.

39. Ioannidis, J.P.A. Infection Fatality Rate of COVID-19 Inferred from Seroprevalence Data. *Bull World Health Organ* **2021**, *99*, 19-33F, doi:10.2471/BLT.20.265892.

40. Prunas, O.; Warren, J.L.; Crawford, F.W.; Gazit, S.; Patalon, T.; Weinberger, D.M.; Pitzer, V.E. Vaccination with BNT162b2 Reduces Transmission of SARS-CoV-2 to Household Contacts in Israel. *Science* **2022**, *375*, 1151–1154, doi:10.1126/science.abl4292.

41. Puhach, O.; Adea, K.; Hulo, N.; Sattonnet, P.; Genecand, C.; Iten, A.; Jacquérioz, F.; Kaiser, L.; Vetter, P.; Eckerle, I.; et al. Infectious Viral Load in Unvaccinated and Vaccinated Individuals Infected with Ancestral, Delta or Omicron SARS-CoV-2. *Nat Med* **2022**, *28*, 1491–1500, doi:10.1038/s41591-022-01816-0.

42. Leipzig, J.; Nüst, D.; Hoyt, C.T.; Ram, K.; Greenberg, J. The Role of Metadata in Reproducible Computational Research. *Patterns* **2021**, *2*, 100322, doi:10.1016/j.patter.2021.100322.

43. Ritchie, H.; Mathieu, E.; Rodés-Guirao, L.; Appel, C.; Giattino, C.; Ortiz-Ospina, E.; Hasell, J.; Macdonald, B.; Beltekian, D.; Roser, M. Coronavirus Pandemic (COVID-19). *Our World in Data* **2020**.

44. Haas, E.J.; Angulo, F.J.; McLaughlin, J.M.; Anis, E.; Singer, S.R.; Khan, F.; Brooks, N.; Smaja, M.; Mircus, G.; Pan, K.; et al. Impact and Effectiveness of MRNA BNT162b2 Vaccine against SARS-CoV-2 Infections and COVID-19 Cases, Hospitalisations, and Deaths Following a Nationwide Vaccination Campaign in Israel: An Observational Study Using National Surveillance Data. *The Lancet* **2021**, *397*, 1819–1829, doi:10.1016/S0140-6736(21)00947-8.

45. COVID-19 Vaccination Age and Sex Trends in the United States, National and Jurisdictional | Data | Centers for Disease Control and Prevention Available online: https://data.cdc.gov/Vaccinations/COVID-19-Vaccination-Age-and-Sex-Trends-in-the-Uni/5i5k-6cmh (accessed on 26 June 2023).

46. World Bank Open Data Available online: https://data.worldbank.org (accessed on 26 June 2023).

47. Tutkimus: Koronarokotuksilla estettiin Suomessa noin 7 300 koronataudista johtuvaa kuolemaa maaliskuun 2022 loppuun mennessä - Tiedote - THL Available online: https://thl.fi/fi/-/tutkimus-koronarokotuksilla-estettiin-suomessa-noin-7-300-koronataudista-johtuvaa-kuolemaa-maaliskuun-2022-loppuun-mennessa (accessed on 15 May 2023).