PNAS Nexus, 2023, 2, 1–10
https://doi.org/10.1093/pnasnexus/pgad318
Advance access publication 4 October 2023
Research Report

Social media trust predicts lower COVID-19 vaccination rates and higher excess mortality over 2 years

Sylvia Xiaohua Chen [a,*], Frank Tian-fang Ye [a,*], Kai Lam Cheng [a], Jacky C. K. Ng [a], Ben C. P. Lam [b], Bryant P. H. Hui [a], Algae K. Y. Au [a], Wesley C. H. Wu [a], Danan Gu [c] and Yi Zeng [d]

[a]Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hong Kong, China
[b]Department of Psychology, Counselling and Therapy, La Trobe University, Melbourne, Australia
[c]Independent Researcher, New York, USA
[d]National School of Development, Peking University, Beijing, China
*To whom correspondence should be addressed: Email: ssxhchen@polyu.edu.hk; frank.ye@polyu.edu.hk
Edited By: Valerio Capraro

Abstract

Trust plays a crucial role in implementing public health interventions against the COVID-19 pandemic. We examined the prospective associations of interpersonal, institutional, and media trust with vaccination rates and excess mortality over time in two multinational studies. In study 1, we investigated the country-level relationships between interpersonal trust, vaccination rates, and excess mortality across 54 countries. Interpersonal trust at the country level was calculated by aggregating data of 80,317 participants from the World Values Survey in 2017–20. Data on vaccination rates and excess mortality were obtained from the World Health Organization. Our findings indicated that higher levels of interpersonal trust were linked to higher vaccination rates and lower excess mortality rates in both 2020 and 2021. In study 2, we collected data from 18,171 adults in 35 countries/societies, stratified by age, gender, and region of residence. At the country/society level, interpersonal trust and trust in local healthcare facilities, local healthcare services, and healthcare professionals were associated with higher vaccination rates and lower excess mortality, whereas social media trust was associated with lower vaccination rates and higher excess mortality across three time points over 2 years. Our findings are robust when controlling for country-level covariates of the government stringency index, population density, and medical resources (i.e. critical care beds) in both studies.

Keywords: COVID-19, vaccination rates, excess mortality, trust, social media trust

Significance Statement

Existing research has documented positive associations between interpersonal and institutional trust and COVID-19 vaccination acceptance. We show compelling evidence revealing that social media trust predicted lower vaccination rates and higher excess mortality across three time points over 2 years. Vast resources have been invested in developing vaccines against evolving coronavirus variants, while nonpharmaceutical interventions, such as quarantine, lockdowns, and border restrictions, entail significant costs to the global economy and mental health. It is crucial to prioritize the promotion of vaccination programs and the fight against misinformation on not only mainstream news media but also social media and alternative news platforms. Building trust in healthcare facilities, services, and professionals is of paramount importance in increasing awareness and enhancing the effectiveness of life-saving measures.

Introduction

Since its outbreak in December 2019, the impact of the COVID-19 global health crisis has continued to evolve, with increasing numbers of confirmed cases and cumulative deaths. However, variations in COVID-19 testing capacity, healthcare reporting systems, and death certification rules confound the reported death tolls. Excess mortality, the number of all-cause deaths above and beyond expected numbers under "normal" conditions before the pandemic, is thus regarded as a more accurate and reliable assessment (1, 2). These global estimates are far greater than the reported data, indicating the devastating impact of the pandemic worldwide.

The adverse effects of COVID-19 have been evident in social, economic, and behavioral aspects of human life (3). Nonpharmaceutical interventions, such as quarantine and lockdowns, social distancing, and border restrictions, have been effective in containing

Competing Interest: The authors declare no competing interest.
Received: January 27, 2023. **Accepted:** September 13, 2023

the spread of the coronavirus (4) but may exacerbate the negative impacts on mental health (5). The rapid transmission of the Omicron variant has posed increasing challenges to implementing nonpharmaceutical interventions, which has led to pandemic fatigue with cognitive depletion, exhaustion, and low motivation to follow preventive measures.

Achieving "herd immunity" through vaccination is considered to be one of the effective interventions in the fight against COVID-19 (6). Governments advocate vaccine uptakes to fight the pandemic, especially among vulnerable groups. The consequences of vaccine hesitancy can be a matter of life and death, as insufficient population vaccination levels can not achieve herd protection against COVID-19 (7).

Among the factors influencing vaccination rates, trust is one of the most important attributes affecting compliance with public health interventions (8). In the face of a global health crisis, trust in health care is essential to prevention implementation and containment measures. Trust refers to a belief or confidence in people, organizations, or systems that have the ability, integrity, and benevolence that can be relied on (9–11). Different types of trust exert differential effects on health behavior and vaccine hesitancy. Institutional trust, interpersonal trust, and media trust can significantly impact the public's response to COVID-19 vaccination campaigns and related health outcomes (12). Trust in institutions, including healthcare organizations and the government, plays a critical role. A high level of institutional trust may enhance vaccine acceptance and adherence to public health guidelines, potentially reducing death rates. Conversely, erosion of institutional trust can create suspicion and resistance to health advice (11). Interpersonal trust can be a crucial factor in how individuals perceive and act on vaccination advice from healthcare providers or family and friends. Further, personal trust in science and healthcare can impact vaccination decisions and, thus, related mortality.

Previous research has found that institutional trust is associated with lower case fatality rates through voluntary testing, whereas interpersonal trust is related to quicker epidemic control through reducing unnecessary outdoor activities (13). People who trust the government and its policies are more likely to take recommended actions and follow preventive measures (14). Institutional trust is also associated with lower COVID-19 mortality (15). Trust in collective targets and efforts provides individuals with social capital to buffer their feelings of powerlessness and helplessness in coping with the pandemic (9). Trust in others is foundational for positive relationships with healthcare professionals and beneficial to cooperation and prosocial behavior in response to the pandemic (16).

Institutional trust is a factor influencing vaccine hesitancy. People who have lower institutional trust would have higher vaccination hesitancy (17, 18). In contrast, those with higher institutional trust would be less hesitant to COVID-19 vaccination (19). Prior studies have demonstrated that trust in institutions such as scientific communities (20), governments (21), and healthcare professionals (22, 23) was a significant predictor of receiving at least the first dose of the COVID-19 vaccine. Based on previous literature, we hypothesize that interpersonal trust and trust in healthcare institutions and experts would be associated with higher vaccination rates and lower excess mortality.

While the health benefits of interpersonal and institutional trust have been documented, the role of trust in media sources is unclear. Survey and Twitter data in the United States and the United Kingdom showed a positive association between social media behavior (e.g. following, sharing, and interacting with low-quality information online) and vaccine hesitancy (24). A nationally representative survey of 1,476 adults in the United Kingdom found that trust in health institutions and experts was associated with vaccine willingness, but people who used social media, such as YouTube, Facebook, and Twitter, to obtain health information were less willing to get vaccinated (8). In contrast to mainstream news media, the content of social media platforms is relatively unregulated and may contain misinformation about the pandemic and vaccination (8). This UK survey was conducted in December 2020 before COVID-19 vaccines were widely adopted; thus, vaccine willingness vs. hesitancy reflects a behavioral tendency and calls for investigation into actual uptake. Moreover, algorithms in social media sites track users' past viewing history to recommend tailored content. People who acquire health information from social media may fall into echo chambers, where they seek and exchange information that confirms, rather than challenges, their beliefs and makes them unwitting consumers of one-sided information (24–26).

The COVID-19 "infodemic" has exacerbated skepticism toward vaccines and brought about social uncertainty (27). Even reliable news outlets have shown a bias against reporting negative events related to vaccination (26). Belief in COVID-19 conspiracy theories has exerted considerable influence on vaccination hesitancy. Previous studies found a strong positive correlation between conspiracy suspicions regarding the coronavirus and vaccine hesitancy, as an indicator of lower adherence to preventive measures (28, 29). "Conspiracy beliefs" was one of the key factors associated with COVID-19 vaccine hesitancy, as revealed by a systematic review (30). Conspiracy beliefs increase vaccination hesitancy over time (31) and negatively predict COVID-19 vaccination intention (32).

The increasing popularity of social media use poses a challenge to vaccination uptake. Research conducted before COVID-19 has revealed that even brief exposure to vaccine-critical websites and blogs increased perceived vaccine risk and decreased intention to take up a vaccine (33, 34). People who used social media were more likely to be misinformed about vaccines than those using traditional media, whereas a high level of trust in medical authorities was negatively related to vaccine misinformation across demographic groups and political beliefs, which affected the likelihood of changing the mistaken beliefs over time (35). Further, while misbeliefs about vaccination benefits are negatively associated with public policy support for vaccination, this association was stronger for those with a low level of trust (36). Public trust in expert groups and authoritative organizations enhances the positive impact of exposure to correct information about vaccination benefits (37). Specifically, having trust in organizations responsible for monitoring vaccine safety and effectiveness may counteract the spread of vaccine misinformation through social media (36). In light of the above reasoning, we hypothesize that social media trust would be associated with lower vaccination rates and higher excess mortality.

Thus far, some published studies have examined the associations between trust in the media and COVID-19 vaccination hesitancy. These studies used a cross-sectional design with small subsets of countries or examined vaccination hesitancy/acceptance rather than actual vaccination uptakes and death rates. Previous research focused on assessing interpersonal and institutional trust and analyzing confirmed cases and reported deaths due to COVID-19, but the impact of the pandemic has been much greater than the reported figures shown. Past studies have rarely investigated the role of institutional and interpersonal trust across many countries in predicting the objective measures of

vaccination uptake and excess mortality during the pandemic nor have they tested the impact of social media trust as a predictor. Therefore, we aimed to examine the effects of different types of trust (viz., interpersonal, institutional, and media trust) on COVID-19 vaccination and mortality (viz., three vaccination doses and excess mortality) over 2 years from April 2020 to April 2022 based on the country-level data in two multinational studies.

In study 1, we used their respective most recent wave of the World Values Survey (WVS) in 2017–20 in 54 countries (3), with 80,301 individuals, and explored whether country-level interpersonal and institutional trust were associated with vaccination rates and the average excess mortality over the 2 years derived from the World Health Organization (WHO). Trust in six other relevant organizations in the WVS was also examined: the press, television, the government, parliament, universities, and the WHO. In study 2, we collected data from 18,171 adults in 35 countries and regions around the world in April 2020 and measured their use of and trust in mainstream news media (e.g. newspapers and TV), alternative news media (e.g. blogs and citizen journalism), and social media sites, as well as trust in local healthcare facilities, local healthcare services, healthcare professionals, and scientists/researchers. In this study, we analyzed vaccination rates and excess mortality estimates at three time points: time 1 (T1), 2021 April 1, which was ~1 year after we administered the trust measures; time 2 (T2), 2021 November 24, which was approximately the outbreak of the Omicron variant with evolving and extensive impacts (38); and time 3 (T3), 2022 April 1, which was ~2 years after we administered the trust measures.

Study 1

Study 1 utilized several open-access health data sets online to conduct an exploratory examination of the impact of trust. Specifically, this study aimed to investigate the associations of interpersonal and institutional trust with vaccination rates and excess mortality across 54 countries. Country-level analyses were conducted by aggregating the interpersonal trust data for each of these 54 countries and linking them with the newly released COVID-19 data from the WHO in 2022. Data on the vaccination rates in the same 54 countries were obtained from the WHO Coronavirus (COVID-19) Dashboard (2). We adopted the latest available (April to May 2022) first dose rate, second dose rate, and booster dose rate as the vaccination indices. The country-level estimated excess mortality was obtained from the WHO (2) using the mean of 2-year excess mortality as the indicator of COVID-related deaths during 2020 and 2021. Excess mortality was measured as the discrepancy between all reported deaths and expected numbers of deaths. Expected deaths were estimated using the historical death data from 2015 to 2019 (39). Excess mortality is considered a more accurate count of mortality than the confirmed COVID-19 death count alone, as excess mortality captures unreported/misdiagnosed COVID-19 deaths and deaths attributable to conditions caused by the crisis (40).

These data sets were matched and combined based on country names and ISO Alpha-3 code. In this study, we controlled for a few factors related to COVID-19 vaccination at the country level. First, countries vary in their response measures to COVID-19, including vaccine policies. Government-mandated vaccination requirements boost COVID-19 vaccine uptakes rapidly and significantly (41). Second, population density affects infection spread (42). People in highly populated areas may perceive high risks and susceptibility for infectious diseases, which may be conducive to overall vaccination coverage. Third, vaccination rates are also affected by the availability of medical resources, which is operationalized as critical care beds by country. Therefore, government stringency index, population density, and medical resources (i.e. critical care beds) were included as covariates in the analyses.

Results

Interpersonal trust was positively correlated with first dose rate ($r = 0.37$, 95% CI [0.11, 0.58], $P = 0.007$, $N = 54$), second dose rate ($r = 0.44$, 95% CI [0.19, 0.63], $P = 0.001$, $N = 54$), and booster dose rate ($r = 0.51$, 95% CI [0.27, 0.69], $P = 0.0001$, $N = 51$). It was negatively correlated with the mean of 2-year excess mortality ($r = -0.38$, 95% CI [−0.59, −0.12], $P = 0.005$, $N = 53$).

We also conducted multiple linear regression analyses to test the robustness of these associations by controlling for the country-level covariates of government stringency index, population density, and medical resources (i.e. critical care beds). For each country, the data on government response stringency were retrieved from the Oxford COVID-19 Government Response Tracker (OxCGRT) (43) to control for COVID-19 containment and closure policies. The population density was obtained from the United Nations (44) to control for the potential confounding of infection spread. Lastly, as an indicator of medical resources, the number of critical care beds was obtained from Phua et al. (45). Results indicated that interpersonal trust consistently predicted vaccination rates positively (first dose: $\beta = 0.43$, 95% CI [0.12, 0.74], $P = 0.008$, $N = 49$; second dose: $\beta = 0.45$, 95% CI [0.15, 0.75], $P = 0.004$, $N = 49$; booster: $\beta = 0.43$, 95% CI [0.15, 0.72], $P = 0.004$, $N = 46$) and the mean of 2-year excess mortality negatively ($\beta = -0.48$, 95% CI [−0.78, −0.17], $P = 0.003$, $N = 49$; see Table 1 for more details).

For other trust measures (i.e. trust in the press, television, the government, parliament, universities, and the WHO), the results showed only significant correlations between trust in universities and vaccination rates (first dose: $r = 0.38$, 95% CI [0.12, 0.58], $P = 0.005$, $N = 54$; second dose: $r = 0.38$, 95% CI [0.13, 0.59], $P = 0.004$, $N = 54$; booster: $r = 0.33$, 95% CI [0.06, 0.55], $P = 0.019$, $N = 51$).

Study 2

Extending beyond interpersonal and institutional trust, we conducted a multinational study and further examined the prospective associations of media trust and healthcare-related institutional trust with vaccination rates and excess mortality across three time points over 2 years.

We partnered with the world's leading data analytics company Kantar to collect data on the trust measures from 2020 April 9 to 20 in 35 countries and regions (3). The initial sample consisted of 25,605 adults. Three check questions were used to screen inattentive participants, and after excluding those who failed any of the 3 directed questions for attention checks, the final sample included 18,171 adults (50.2% female, $M_{age} = 43.66$, $SD = 15.97$, with age ranged from 18 to 91). The sample size of each society ranged from 507 (New Zealand) to 530 (Brazil). The data set was processed using the stratified sampling technique and closely matched the United Nations Database (46).

We used country-level data on vaccination rates (including the percentage of the population who received at least one dose, two doses, and booster dose) and the excess mortality rates retrieved from Our World in Data (40), which provides daily updates of global COVID-19-related statistics. To examine the effects of the trust variables, data on three time points were extracted: 2021 April 1, 2021 November 24, and 2022 April 1. The first time point

Table 1. Regression results of study 1.

	Two-year mean excess mortality			First dose rate			Second dose rate			Booster rate		
	B	Beta	95% CI	B	Beta	95% CI	B	Beta	95% CI	B	Beta	95% CI
Intercept	133.60	—	—	56.13	—	—	46.16	—	—	8.23	—	—
Stringency index	0.41	0.07	(−0.22, 0.35)	−0.01	−0.01	(−0.30, 0.28)	−0.02	−0.01	(−0.29, 0.27)	0.00	0.00	(−0.27, 0.27)
Population density	−0.01	−0.09	(−0.37, 0.18)	0.00	0.09	(−0.18, 0.37)	0.00	0.13	(−0.14, 0.40)	0.00	0.22	(−0.05, 0.48)
Critical care beds	8.81	0.24	(−0.07, 0.55)	−0.85	−0.12	(−0.43, 0.20)	−0.06	−0.01	(−0.31, 0.30)	1.20	0.15	(−0.14, 0.45)
Interpersonal trust	−342.19**	−0.48	(−0.78, −0.17)	59.33**	0.43	(0.12, 0.74)	64.9**	0.45	(0.15, 0.75)	64.06**	0.43	(0.15, 0.72)
R^2		0.20			0.18			0.23			0.33	
Adjusted R^2		0.13			0.10			0.16			0.27	
N		49			49			49			46	

**$P < 0.01$.

was selected to evaluate the 1-year-lagged effects of trust variables; the second time point was chosen as the outbreak of the Omicron variant (47); the last time point was selected to evaluate the 2-year-lagged effects of trust variables. The first dose rate at T1 (April 2021), second dose rate at T2 (November 2021), and third dose rate at T3 (April 2022) exhibited the largest variance across societies within each time point, which was consistent with vaccination coverage at that time (i.e. third dose was not available at T1; most societies in the data had a high first dose rate at T3. See Table S2). Hence, we mainly focused on the vaccination rates at these three time points. Data on media trust and healthcare-related institutional trust were collected from participants in April 2020, during the early stage of the COVID-19 outbreak when globally accessible vaccines were not yet available. Consequently, individual vaccination status was not measured in the current studies. As such, the associations between trust and vaccination rates examined in both studies were at the country level. To ensure the robustness of our findings, we extracted country-level vaccination data from multiple time points and incorporated information from diverse data sources.

We controlled for the same covariates as in study 1. The stringency index and population density were extracted to align closely with the dependent variables. Additionally, the number of critical care beds and trust variables was included in their original form, measured only once. Descriptive statistics of the trust measures at the country level are shown in online supplementary material (see Table S1). To account for the influence of individual-level variables, we incorporated specific covariates such as age, gender, education level, and socioeconomic status (SES). We then implemented a multilevel regression analysis to test the robustness of the association between social media use and trust in social media. The results are reported in Table S5.

Results

The bivariate correlations between trust variables and vaccination rates for each time point are shown in Table 2. We observed moderate, negative correlations between social media trust and vaccination rates (see also Fig. 1). In particular, social media trust was negatively associated with first dose rate at T1 ($r = -0.45$, 95% CI [−0.68, −0.13], $P = 0.008$, $N = 34$), second dose rate at T2 ($r = -0.48$, 95% CI [−0.70, −0.18], $P = 0.003$, $N = 35$), and booster dose rate at T3 ($r = -0.52$, 95% CI [−0.73, −0.22], $P = 0.002$, $N = 34$). No significant correlation between mainstream media trust and vaccination rates was observed across all time points. Furthermore, social media trust was positively correlated with excess mortality at T1 ($r = 0.47$, 95% CI [0.10, 0.73], $P = 0.014$, $N = 26$) and T3 ($r = 0.48$, 95% CI [0.11, 0.74], $P = 0.014$, $N = 25$), but such correlations were absent for the mainstream media trust. The alternative media trust demonstrated the same pattern as social media trust and was reported in Table S6.

Interpersonal trust and institutional trust, on the other hand, exhibited positive associations with vaccination rates and negative associations with excess mortality. Specifically, trust in local healthcare facilities (e.g. T1, first dose: $r = 0.42$, 95% CI [0.10, 0.67], $P = 0.013$, $N = 34$; T2, second dose: $r = 0.48$, 95% CI [0.17, 0.70], $P = 0.004$, $N = 35$; T3, booster: $r = 0.43$, 95% CI [0.11, 0.67], $P = 0.010$, $N = 34$), local healthcare services (e.g. T1, first dose: $r = 0.44$, 95% CI [0.12, 0.68], $P = 0.009$, $N = 34$; T2, second dose: $r = 0.48$, 95% CI [0.17, 0.70], $P = 0.004$, $N = 35$; T3, booster: $r = 0.44$, 95% CI [0.12, 0.68], $P = 0.010$, $N = 34$), and healthcare professionals (e.g. T1, first dose: $r = 0.40$, 95% CI [0.07, 0.65], $P = 0.020$, $N = 34$; T2, second dose: $r = 0.36$, 95% CI [0.03, 0.62], $P = 0.04$, $N = 35$; T3, booster: $r = 0.32$, 95% CI [−0.02, 0.60], $P = 0.062$, $N = 34$) were positively correlated with vaccination rates across all three time points. Trust in local healthcare facilities ($r = -0.44$, 95% CI [−0.71, −0.06], $P = 0.025$, $N = 26$) and trust in healthcare services ($r = -0.45$, 95% CI [−0.71, 0.07], $P = 0.022$, $N = 26$) were negatively correlated with excess mortality rates at T1. Surprisingly, no significant correlation was observed for trust in scientists/researchers.

Multiple linear regressions were performed to test the robustness of the negative association between social media trust and vaccination rates after controlling for the covariates, including country-level government stringency index, population density, and medical resources (i.e. critical care beds). As shown in Table 3, three sets of regression analyses were conducted: In set 1, the first dose rate at T1 was regressed on the covariates at T1; in set 2, the second dose rate at T2 was regressed on the covariates at T2; and in set 3, the third dose rate at T3 was regressed on the covariates at T3.

The regression results showed consistent associations between trust and vaccination rates. Social media trust negatively predicted vaccination rates across all three time points after controlling for the stringency index, population density, and medical resources (T1, first dose: $\beta = -0.52$, 95% CI [−0.86, −0.18], $P = 0.004$, $N = 34$; T2, second dose: $\beta = -0.42$, 95% CI [−0.75, −0.09], $P = 0.014$, $N = 35$; T3, booster: $\beta = -0.45$, 95% CI [−0.79, −0.11], $P = 0.011$, $N = 34$).

Discussion

Across 2 multinational studies covering 54 countries ($N = 80{,}317$) and 35 societies ($N = 18{,}171$), respectively, we demonstrated the effects of different types of trust on COVID-19 vaccination and mortality from April 2020 to April 2022. In study 1, we analyzed newly released vaccination and mortality data and the new wave of WVS data to show that interpersonal trust was

Table 2. Bivariate correlations between trust variables, vaccination rate, and excess mortality in study 2.

Trust measure	Mainstream media trust	Social media trust	Interpersonal trust	Trust in local healthcare facilities	Trust in local healthcare services	Trust in healthcare professionals	Trust in scientists or researchers
2021 April 1 (T1)							
1 dose	−0.16 (−0.48, 0.19)	−0.45** (−0.68, −0.13)	0.14 (−0.21, 0.45)	0.42* (0.10, 0.67)	0.44** (0.12, 0.68)	0.40* (0.07, 0.65)	0.24 (−0.11, 0.54)
2 doses	−0.19 (−0.49, 0.16)	−0.25 (−0.54, 0.09)	−0.03 (−0.36,0.31)	0.38* (0.05,0.64)	0.39* (0.06, 0.65)	0.33 (−0.00, 0.60)	0.23 (−0.12, 0.53)
Excess mortality	0.03 (−0.36, 0.41)	0.47* (0.10, 0.73)	−0.59** (−0.79, −0.26)	−0.44* (−0.71, −0.06)	−0.45* (−0.71, −0.07)	−0.26 (−0.59, 0.14)	0.13 (−0.27, 0.49)
2021 November 24 (T2)							
1 dose	−0.11 (−0.43, 0.23)	−0.34* (−0.61, −0.01)	0.45** (0.14, 0.68)	0.52** (0.23, 0.73)	0.52** (0.23, 0.73)	0.39* (0.07, 0.64)	0.21 (−0.13, 0.51)
2 doses	−0.23 (−0.52, 0.11)	−0.48** (−0.70, −0.18)	0.36* (0.03, 0.62)	0.48** (0.17, 0.70)	0.48** (0.17, 0.70)	0.36* (0.03, 0.62)	0.11 (−0.23, 0.43)
Booster	0.18 (−0.26, 0.56)	0.12 (−0.32, 0.51)	−0.25 (−0.61, 0.19)	0.43* (0.01, 0.72)	0.48* (0.07, 0.75)	0.45* (0.03, 0.73)	0.38 (−0.05, 0.69)
Excess mortality	0.07 (−0.33, 0.44)	0.27 (−0.13, 0.60)	−0.32 (−0.63, 0.08)	−0.14 (−0.50, 0.26)	−0.14 (−0.50, 0.27)	−0.17 (−0.52, 0.23)	−0.05 (−0.43, 0.35)
2022 April 1 (T3)							
1 dose	−0.05 (−0.38, 0.29)	−0.22 (−0.51, 0.12)	0.44** (0.13, 0.67)	0.51** (0.22, 0.72)	0.52** (0.22, 0.73)	0.39* (0.07, 0.64)	0.25 (−0.09, 0.54)
2 doses	−0.04 (−0.37, 0.30)	−0.26 (−0.55, 0.08)	0.46** (0.15, 0.69)	0.52** (0.23, 0.73)	0.53** (0.24, 0.73)	0.40* (0.08, 0.65)	0.22 (−0.12, 0.52)
Booster	−0.17 (−0.48, 0.18)	−0.52** (−0.73, −0.22)	0.36** (0.02, 0.62)	0.43* (0.11, 0.67)	0.44** (0.12, 0.68)	0.32 (−0.02, 0.60)	0.08 (−0.26, 0.41)
Excess mortality	0.10 (−0.30, 0.48)	0.48* (0.11, 0.74)	−0.30 (−0.62, 0.11)	−0.30 (−0.62, 0.10)	−0.31 (−0.63, 0.10)	−0.35 (−0.65, 0.05)	−0.18 (−0.54, 0.23)

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

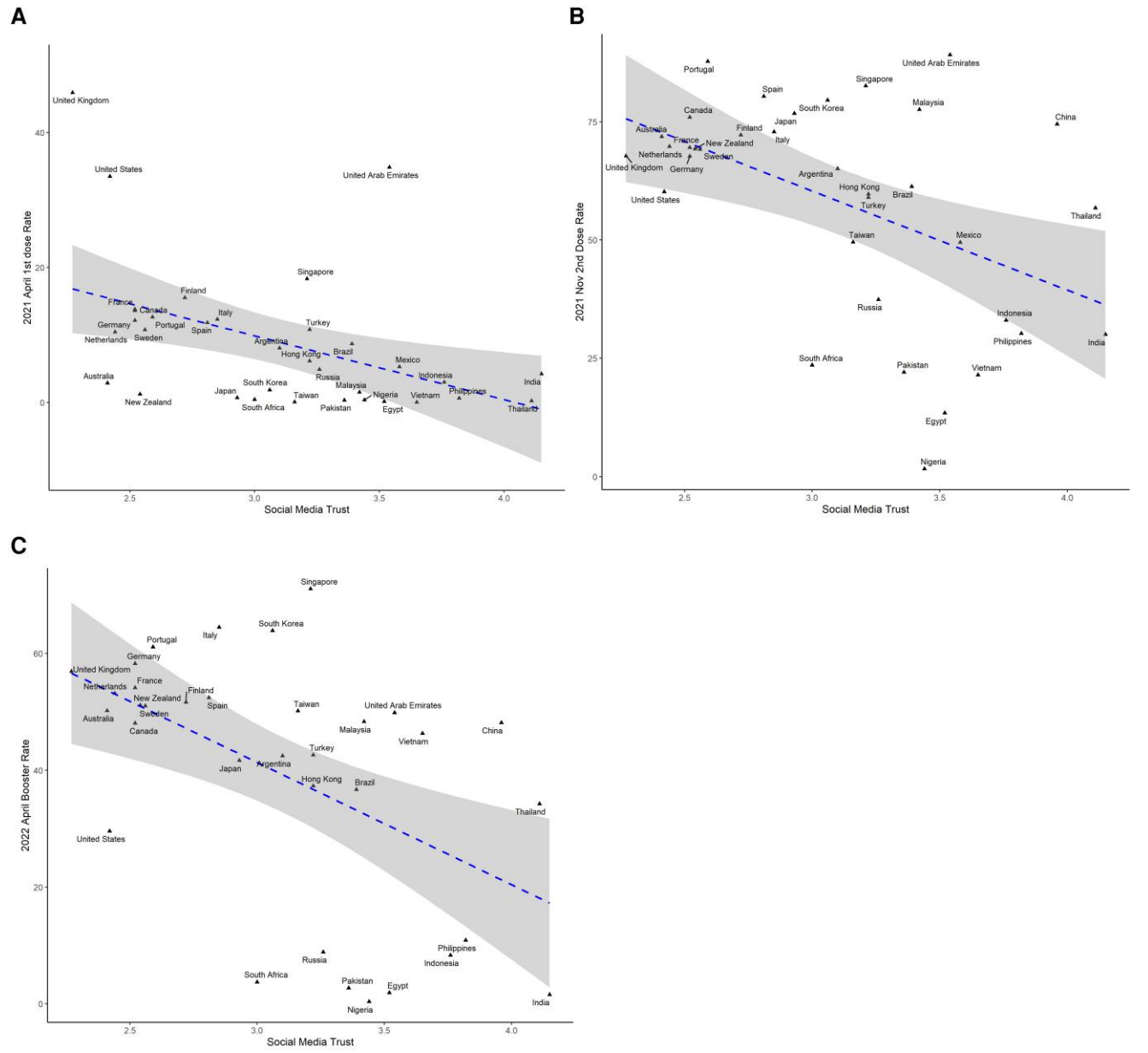

Fig. 1. Bivariate correlations between social media trust and vaccination rates in study 2. A) Vaccination rates on 2021 April 1. B) Vaccination rates on 2021 November 24. C) Vaccination rates on 2022 April 1.

Table 3. Regression results of study 2.

	First dose rate at T1			Second dose rate at T2			Third dose rate at T3		
	B	Beta	95% CI	*B*	Beta	95% CI	*B*	Beta	95% CI
Intercept	38.43	—	—	103.71	—	—	90.76	—	—
Stringency index	0.12	0.17	(−0.16, 0.49)	0.06	0.04	(−0.28, 0.35)	−0.08	−0.07	(−0.41, 0.28)
Population density	0.00	0.11	(−0.20, 0.43)	0.00	0.17	(−0.15, 0.48)	0.00	0.25	(−0.07, 0.56)
Critical care beds	−0.92	−0.26	(−0.59, 0.08)	1.83	0.23	(−0.09, 0.56)	1.67	0.23	(−0.08, 0.54)
Social media trust	−10.88**	−0.52**	(−0.86, −0.18)	−18.19*	−0.42*	(−0.75, −0.09)	−18.00*	−0.45*	(−0.79, −0.11)
R^2		0.32			0.31			0.38	
Adjusted R^2		0.22			0.22			0.30	
N		34			35			34	

*$P < 0.05$, **$P < 0.01$.

consistently associated with vaccination rates across 3 doses across 54 countries. These country-level results were robust after controlling for government stringency index, population density, and medical resources (i.e. critical care beds). In study 2, across 35 countries and regions, trust in local healthcare facilities, local healthcare services, and healthcare professionals was

significantly associated with higher vaccination rates and lower excess mortality, whereas social media trust was significantly associated with lower vaccination rates and higher excess mortality across 3 time points over 2 years. These country-level results remained robust after controlling for the same covariates as in study 1.

This research provides new evidence showing the role of trust in the mainstream news media and social media sites in the prediction of vaccine uptakes, extending previous work on differentiating the roles of interpersonal and institutional trust in pandemic control (13) and informing public health policy in a timely way. Information about COVID-19 vaccines has proliferated in a range of media outlets, but social media and alternative news media (e.g. citizen journalism sites) are less regulated than mainstream media sources (e.g. TV, printed newspapers, and radio). In addition, personal views about vaccinations are being spread through social media and alternative news media, with plentiful vaccine misinformation, conspiracy theories, and anti-vax beliefs, and this can reduce vaccine willingness (8). According to the inattention-based account (48), people pay little attention to the accuracy of content when they decide whether to share it on social media, focusing on factors other than truth discernment. Promoting information accuracy on social media with increased moderation and fact-checking and improving the presence of healthcare professionals on social media are important digital health strategies (25). Caution is warranted when research findings in social and behavioral sciences are applied to inform decision-making and address policy issues (49).

Collective action to achieve herd immunity through vaccination needs a multidisciplinary approach to understand and address the factors influencing vaccine hesitancy. We found that trust in the press, television, the government, and parliament was not related to vaccination rates for three doses in study 1 and that mainstream media trust was not significantly associated with vaccination rates across all time points in study 2. These results consistently suggest the low efficacy of mainstream media and authority in promoting vaccination. Rather, interpersonal trust, a general tendency to trust other people, predicted vaccination rates, highlighting the importance of social capital. Policymakers should work with not only healthcare professionals but also social scientists to promote collective social trust. Strategic interventions may be devised to advocate the benefits of vaccination and debunk misconceptions about its risks using social media platforms rather than relying on mainstream media outlets.

More testing of specific interventions for debunking misconception is needed before implementing such interventions in the public sphere. Accuracy prompts and nudges decrease the sharing of misinformation through accuracy salience but may not increase real news sharing, whereas endorsing accuracy can achieve both objectives through prompting people to consider their sharing decisions more carefully (50). A more integrated framework is needed to understand the psychological mechanisms (e.g. motivated reasoning account or cognitive inattention account) underlying the spread of misinformation on social media (51).

Interestingly, trust in healthcare institutions and experts was associated with vaccination rates across 2 years, but the effect of trust in scientists/researchers was not significant in study 2. It is not surprising that people trust local healthcare facilities, local healthcare services, and healthcare professionals who perform medical treatment for COVID-19 patients and provide vaccination services to the public. These trust variables are associated with higher vaccination rates and lower excess mortality across countries. However, the views about scientists/researchers are less straightforward. Research on COVID-19 has been growing exponentially due to the extraordinary efforts of scientists and researchers, but some people lack confidence in the speedy development of COVID-19 vaccines and worry about their long-term side effects (2, 8). While it is important for health experts to present clear and consistent scientific information, communicating uncertainty about facts and numbers has complex effects on public trust. Provided that cues indicating the high quality of the evidence are given, people perceive the presented information as more certain and more trustworthy and are more likely to use it in their decision-making. On the other hand, when information on the quality of evidence is ambiguous, it reduces the perception of trustworthiness and the extent to which it is used in decision-making (52). Nevertheless, the decrease in trust in numbers and trustworthiness of the source is small, which suggests the importance of open and transparent communication while presenting scientific uncertainty (53).

Using different vaccination and mortality data in the 2 studies, we found that interpersonal trust was positively related to vaccination rates and negatively related to excess mortality across 54 countries (study 1) and 35 societies (study 2), demonstrating the robustness of our findings. Both trust in the government and interpersonal trust exhibit consistent health benefits, such as lower infection and death rates (54, 55), whereas the role of social capital, which encompasses trust and other variables that may be operationalized differently, is mixed. Social trust was associated with more COVID-19-related deaths in the early stages (56, 57). When the pandemic was more serious and physical distancing was crucial to stop transmission, community attachment and group affiliations were incongruent with compliance with lockdown and social distancing. Our analyses tracked death rates for 2 years, including the period after the spread of the Omicron variant, which has different characteristics to the early stages of the pandemic, to offer a more nuanced understanding of the relationships between different types of trust and health outcomes over time, with novel findings on social media trust.

This research has several limitations. First, we administered the measures of social media usage and trust in 35 societies at the individual level but collected data on vaccination rates and excess mortality at the country/societal level in both studies. Multiple linear regression was conducted by aggregating the scores of the variables at the country/societal level. Future research using vaccination data at the individual level is needed to replicate the patterns found in this research, though the relations between trust and excess mortality can only be collected and analyzed at the country level. Second, only one wave of the trust measures in study 2 was collected in the early stages of the pandemic. The ecological threat of the pandemic may change different types of trust. Our findings converge with multiple data sources on trust, vaccination, and mortality across various times points over 2 years, but further studies may employ a repeated-measures design to assess different types of trust among the same individuals at multiple time points. Third, the positive relationship that we observed between social media use and social media trust may be reciprocal. Being exposed to more alternative views and false beliefs, frequent users of social media are likely to be affected by confirmation bias and exist in an echo chamber. Our findings highlight the importance of social media

in affecting health behavior and provide evidence-based implications for public health policy to fight the pandemic and manage the "infodemic."

Materials and methods

Study 1

Measures

To assess interpersonal trust, we used the item "Generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?" from the latest wave of the WVS (seventh wave) (38) collected between 2017 and 2020. A total of 80,301 responses from 54 societies were collected for this item. The item was binary coded (0 indicated *trust* whereas 1 indicated *do not trust*). The responses were recoded, and an aggregated mean score was calculated for each country. In addition, we tested the association between vaccination rates and trust in six organizations extracted from the WVS, including mainstream media (i.e. the press and television) and institutions (i.e. the government, parliament, universities, and the WHO). Participants were asked to indicate how much confidence they have in these organizations on four-point scales (1, *a great deal*; 2, *quite a lot*; 3, *not very much*; 4, *none at all*). The mean scores of the items were computed for each society.

We conducted a power analysis for the multiple regression analysis. Based on the available 49 countries in the current regression analyses, we observed that only 4 predictors could be included to achieve 80% power at a 5% alpha level for detecting a medium-to-large effect size ($f^2 = 0.27$, $R^2 = 0.37$), akin to the effect size observed in our study. With more predictors, the regression analyses would be underpowered or result in nonsignificant findings. Consequently, we focused on incorporating relevant covariates alongside our predictor of interest (e.g. trust) and controlled for government stringency index, population density, and medical resources (i.e. critical care beds) in the analyses.

Study 2

Measures

In addition to interpersonal trust from the WVS (38), we used 3 items from the 20-country project on digital influence by Gil de Zúñiga et al. (58) to measure the level of trust in media. Participants were asked how much they trusted news from mainstream news media (e.g. newspapers and TV), alternative news media (e.g. blogs and citizen journalism), and social media sites. Besides, healthcare-related institutional trust was assessed using four items. Participants were asked to indicate the extent to which they trusted local healthcare facilities, local healthcare services, healthcare professionals, and scientists/researchers. All items were rated on a seven-point Likert scale (1, *do not trust at all*; 7, *trust completely*). The mean scores of trust items were computed for each society.

To examine whether media trust was related to frequent use, the frequency of media use was measured by seven dedicated items (58), including TV, printed newspapers, online news sites, radio, social media, citizen journalism sites (nonprofessional journalism, e.g. blogs), and word of mouth. Participants were asked to indicate how often they get news from these sources on a seven-point Likert scale (1, *never*; 7, *always*). Ethics approval for the project was obtained from the Human Subjects Ethics Sub-committee of the Department of Applied Social Sciences, Hong Kong Polytechnic University (#HSEARS20200402995).

Supplementary material

Supplementary material is available at *PNAS Nexus* online.

Funding

The work described in this paper was substantially supported by the funding for Projects of Strategic Importance (1-ZE1L) and the Mental Health Research Centre Seed Fund (P0040456), The Hong Kong Polytechnic University.

Author contributions

S.X.C. secured the grants and designed the study with coauthors. S.X.C., B.P.H.H., A.K.Y.A., W.C.H.W., and J.C.K.N. implemented the study. F.T.-f.Y. analyzed the data. S.X.C. and F.T.-f.Y. wrote the first draft of the manuscript. All authors contributed to the conceptualization of the study, interpretation of the data, and revision of the draft.

Data availability

In study 1, data on interpersonal trust were obtained from the WVS (seventh wave; https://www.worldvaluessurvey.org/WVSDocumentationWV7.jsp). Data on the vaccination rates were obtained from the WHO Coronavirus (COVID-19) Dashboard (https://covid19.who.int/data). Data on excess mortality were obtained from the WHO (https://www.who.int/data/sets/global-excess-deaths-associated-with-covid-19-modelled-estimates). In study 2, data on vaccination rates and excess mortality were obtained from Our World in Data (https://ourworldindata.org/). The data on all trust measures and additional measures are available at https://doi.org/10.17605/OSF.IO/SY7JF. In both studies, data on the stringency index were obtained from the OxCGRT (https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker). Data on population density were obtained from the United Nations (44) (https://data.un.org/). Data on critical care beds were obtained from Phua et al. (45).

References

1 COVID-19 Excess Mortality Collaborators. 2022. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21. *Lancet*. 399: 1513–1536.
2 World Health Organization. WHO Coronavirus (COVID-19) Dashboard. [Accessed 31 August 2023]. https://covid19.who.int/data.
3 Chen SX, *et al.* 2021. Dual impacts of coronavirus anxiety on mental health in 35 societies. *Sci Rep*. 11:8925.
4 Cowling BJ, *et al.* 2020. Impact assessment of non-pharmaceutical interventions against coronavirus disease 2019 and influenza in Hong Kong: an observational study. *Lancet Public Health*. 5:e279–e288.
5 Aknin LB, *et al.* 2022. Policy stringency and mental health during the COVID-19 pandemic: a longitudinal analysis of data from 15 countries. *Lancet Public Health*. 7:e417–e426.
6 World Health Organization. Coronavirus disease (COVID-19): herd immunity, lockdowns and COVID-19; 2020 [Accessed 14 June 2022]. https://www.who.int/news-room/questions-and-answers/item/herd-immunity-lockdowns-and-covid-19.

7 Cheung PHH, Chan CP, Jin DY. 2022. Lessons learned from the fifth wave of COVID-19 in Hong Kong in early 2022. *Emerg Microbes Infect*. 11:1072–1078.
8 Jennings W, *et al.* 2021. Lack of trust, conspiracy beliefs, and social media use predict COVID-19 vaccine hesitancy. *Vaccines (Basel)*. 9:593.
9 Au AKY, Ng JCK, Wu WCH, Chen SX. 2023. Who do we trust and how do we cope with COVID-19? A mixed methods sequential exploratory approach to understanding supportive messages across 35 cultures. *Humanit Soc Sci Commun*. 10:272.
10 Trust. In APA dictionary of psychology (n.d.). [Accessed 17 May 2023]. https://dictionary.apa.org/trust.
11 Gilson L. 2003. Trust and the development of health care as a social institution. *Soc Sci Med*. 56:1453–1468.
12 Fancourt D, Steptoe A, Wright L. 2020. The Cummings effect: politics, trust, and behaviours during the COVID-19 pandemic. *Lancet*. 396:464–465.
13 Yuan H, Long Q, Huang G, Huang L, Luo S. 2022. Different roles of interpersonal trust and institutional trust in COVID-19 pandemic control. *Soc Sci Med*. 293:114677.
14 Clark C, Davila A, Regis M, Kraus S. 2020. Predictors of COVID-19 voluntary compliance behaviors: an international investigation. *Glob Transit*. 2:76–82.
15 Oksanen A, *et al.* 2020. Regulation and trust: 3-month follow-up study on COVID-19 mortality in 25 European countries. *JMIR Public Heal Surveill*. 6:e19218.
16 Chen SX, *et al.* 2023. Global consciousness predicts behavioral responses to the COVID-19 pandemic: empirical evidence from 35 cultures. *Soc Psychol Personal Sci*. 14:662–671.
17 Pires C. 2022. Global predictors of COVID-19 vaccine hesitancy: a systematic review. *Vaccines (Basel)*. 10:1349.
18 Kyprianidou M, *et al.* 2022. Profiling hesitancy to COVID-19 vaccinations in six European countries: behavioral, attitudinal and demographic determinants. *Behav Med*. 0:1–12.
19 Lau BHP, Yuen SWH, Yue RPH, Grépin KA. 2022. Understanding the societal factors of vaccine acceptance and hesitancy: evidence from Hong Kong. *Public Health* 207:39–45.
20 Bagasra AB, Doan S, Allen CT. 2021. Racial differences in institutional trust and COVID-19 vaccine hesitancy and refusal. *BMC Public Health*. 21:1–7.
21 Yu Y, Lau MMC, Jiang H, Lau JTF. 2021. Prevalence and factors of the performed or scheduled COVID-19 vaccination in a Chinese adult general population in Hong Kong. *Vaccines (Basel)*. 9:847.
22 Viskupič F, Wiltse DL, Meyer BA. 2022. Trust in physicians and trust in government predict COVID-19 vaccine uptake. *Soc Sci Q*. 103:509–520.
23 Yan E, Lai DWL, Ng HKL, Lee VWP. 2022. Predictors of COVID-19 actual vaccine uptake in Hong Kong: a longitudinal population-based survey. *SSM Popul Health*. 18:101130.
24 Rathje S, He JK, Roozenbeek J, Van Bavel JJ, van der Linden S. 2022. Social media behavior is associated with vaccine hesitancy. *PNAS Nexus*. 1:pgac207.
25 Puri N, Coomes EA, Haghbayan H, Gunaratne K. 2020. Social media and vaccine hesitancy: new updates for the era of COVID-19 and globalized infectious diseases. *Hum Vaccin Immunother*. 16: 2586–2593.
26 Galeazzi A, Peruzzi A, Brugnoli E, Delmastro M, Zollo F. 2023. Unveiling the hidden agenda: biases in news reporting and consumption. PsyArXiv, https://doi.org/10.48550/arXiv.2301.05961
27 Pertwee E, Simas C, Larson HJ. 2022. An epidemic of uncertainty: rumors, conspiracy theories and vaccine hesitancy. *Nat Med*. 28: 456–459.
28 Allington D, McAndrew S, Moxham-Hall V, Duffy B. 2023. Coronavirus conspiracy suspicions, general vaccine attitudes, trust and coronavirus information source as predictors of vaccine hesitancy among UK residents during the COVID-19 pandemic. *Psychol Med*. 53:236–247.
29 Kowalska-Duplaga K, Duplaga M. 2023. The association of conspiracy beliefs and the uptake of COVID-19 vaccination: a cross-sectional study. *BMC Public Health*. 23:672.
30 Roy DN, Biswas M, Islam E, Azam MS. 2022. Potential factors influencing COVID-19 vaccine acceptance and hesitancy: a systematic review. *PLoS One* 17:e0265496.
31 Coelho P, Foster K, Nedri M, Marques MD. 2022. Increased belief in vaccination conspiracy theories predicts increases in vaccination hesitancy and powerlessness: results from a longitudinal study. *Soc Sci Med*. 315:115522.
32 Van Oost P, *et al.* 2022. The relation between conspiracism, government trust, and COVID-19 vaccination intentions: the key role of motivation. *Soc Sci Med*. 301:114926.
33 Betsch C, Renkewitz F, Betsch T, Ulshöfer C. 2010. The influence of vaccine-critical websites on perceiving vaccination risks. *J Health Psychol*. 15:446–455.
34 Ahmed N, Quinn SC, Hancock GR, Freimuth VS, Jamison A. 2018. Social media use and influenza vaccine uptake among White and African American adults. *Vaccine* 36:7556–7561.
35 Stecula DA, Kuru O, Hall Jamieson K. 2020. How trust in experts and media use affect acceptance of common anti-vaccination claims. *Harvard Kennedy School Misinformation Review*. 1:1–11.
36 Oh SH, Lee CJ, Park A. 2022. Trust matters: the effects of social media use on the public's health policy support through (mis)beliefs in the context of HPV vaccination. *Health Commun*. 00:1–12.
37 Yaqub O, Castle-Clarke S, Sevdalis N, Chataway J. 2014. Attitudes to vaccination: a critical review. *Soc Sci Med*. 112:1–11.
38 R. Inglehart, *et al.* 2021. World Values Survey: round seven—country-pooled datafile. https://doi.org/10.14281/18241.18
39 World Health Organization. Methods for estimating the excess mortality associated with the COVID-19 pandemic, 2022. Available from: https://www.who.int/publications/m/item/methods-for-estimating-the-excess-mortality-associatedwith-the-covid-19-pandemic
40 Mathieu E, *et al.* 2021. A global database of COVID-19 vaccinations. *Nat Hum Behav*. 5:947–953.
41 Karaivanov A, Kim D, Lu SE, Shigeoka H. 2022. COVID-19 vaccination mandates and vaccine uptake. *Nat Hum Behav*. 6: 1615–1624.
42 Martins-Filho PR. 2021. Relationship between population density and COVID-19 incidence and mortality estimates: a county-level analysis. *J Infect Public Health*. 14:1087–1088.
43 Hale T, *et al.* 2021. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav*. 5:529–538.
44 UN Department of Economic and Social Affairs Population Division. World population prospects 2019; 2019 [Accessed 12 May 2022]. https://population.un.org/wpp/Download/Standard/Population/.
45 Phua J, *et al.* 2020. Critical care bed capacity in Asian countries and regions. *Crit Care Med*. 48:654–662.
46 UN Secretariat the Data Development Section. UNdata; 2022 [Accessed 15 June 2022]. http://data.un.org/Host.aspx?Content=About.
47 World Health Organization. Classification of Omicron (B.1.1.529): SARS-CoV-2 variant of concern; 2021 [Accessed 14 April 2022]. https://www.who.int/news/item/26-11-2021-classification-of-omicron-(b.1.1.529)-sars-cov-2-variant-of-concern.

48 Pennycook G, *et al.* 2020. Understanding and reducing the spread of misinformation online. In: Argo J, Lowrey TM, Schau HJ, editors. *NA—Advances in consumer research volume 48*. Duluth, MN: Association for Consumer Research. p. 863–867.
49 IJzerman H, *et al.* 2020. Use caution when applying behavioural science to policy. *Nat Hum Behav*. 4:1092–1094.
50 Capraro V, Celadin T. 2022. "I think this news is accurate": endorsing accuracy decreases the sharing of fake news and increases the sharing of real news. *Pers Soc Psychol Bull*. https://doi.org/10.1177/01461672221117691.
51 van der Linden S. 2022. Misinformation: susceptibility, spread, and interventions to immunize the public. *Nat Med*. 28: 460–467.
52 Schneider CR, Freeman ALJ, Spiegelhalter D, van der Linden S. 2022. The effects of communicating scientific uncertainty on trust and decision making in a public health context. *Judgm Decis Mak*. 17:849–882.
53 van der Bles AM, van der Linden S, Freeman ALJ, Spiegelhalter DJ. 2020. The effects of communicating uncertainty on public trust in facts and numbers. *Proc Natl Acad Sci U S A*. 117: 7672–7683.
54 Chang D, Chang X, He Y, Tan KJK. 2022. The determinants of COVID-19 morbidity and mortality across countries. *Sci Rep*. 12:5888.
55 COVID-19 National Preparedness Collaborators. 2022. Pandemic preparedness and COVID-19: an exploratory analysis of infection and fatality rates, and contextual factors associated with preparedness in 177 countries, from Jan 1, 2020, to Sept 30, 2021. *Lancet*. 399:1489–1512.
56 Imbulana Arachchi J, Managi S. 2021. The role of social capital in COVID-19 deaths. *BMC Public Health*. 21:434.
57 Elgar FJ, Stefaniak A, Wohl MJA. 2020. The trouble with trust: time-series analysis of social capital, income inequality, and COVID-19 deaths in 84 countries. *Soc Sci Med*. 263:113365.
58 Gil de Zúñiga H, Diehl T, Huber B, Liu J. 2017. Personality traits and social media use in 20 countries: how personality relates to frequency of social media use, social media news use, and social media use for social interaction. *Cyberpsychology Behav Soc Netw*. 20:540–552.