Misinformation about Covid-19 Vaccines on Social Media: Rapid Review

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Abstract

The development of COVID-19 vaccines has been crucial in fighting the pandemic. Misinformation about COVID-19 vaccines on social media is a major challenge, as this is thought to contribute to vaccine hesitancy. Here, we review the research on misinformation about COVID-19 vaccines spread on social media platforms. The review is registered with the PROSPERO international register of systematic reviews (CRD42021277524). We performed a literature search on 9 September 2021 and searched PubMed, PsycINFO, ERIC, Embase, Cochrane Library, and the Cochrane COVID-19 Study Register. We included publications in peer-reviewed journals that fulfilled all following criteria: Original empirical studies, studies that assessed social media and misinformation, studies that dealt with vaccine hesitancy, and studies about the COVID-19 vaccine. Publications were excluded if data were gathered before Phase III in the first COVID-19 vaccine development (from July 27 2020 to November 13, 2020). The narrative qualitative synthesis was undertaken with the guidance of the PRISMA 2020 Statement and the Synthesis Without Meta-analysis reporting guideline. The risk of bias was assessed according to The Joanna Briggs Institute (JBI) Critical Appraisal tool. Ratings of the certainty of evidence were based on recommendations from the GRADE Working Group. The search amounted to 757 records, with 45 articles selected for the review. There are many types of misinformation that are spread on social media platforms. We identified three main areas of misinformation: Medical misinformation, vaccine development, and conspiracies. To prevent these misconceptions from taking hold, health authorities should openly address and discuss these false claims with both cultural and religious awareness in mind. Our review showed that there is a need to examine the effect of social media misinformation on vaccine hesitancy with a more robust experimental design. Furthermore, our review also demonstrated that more studies are needed from the Global South and on other social media platforms than the major platforms such as Twitter.

Keywords

Social Media, Misinformation, COVID-19 Vaccines, Vaccination Hesitancy, Autism Spectrum Disorder

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Introduction

An unprecedented global effort has been undertaken to develop vaccines at an extraordinary speed. However, there is a grave concern that vaccine hesitancy will be a major obstacle to reaching herd immunity. In 2019, the WHO had already named vaccine hesitancy as one of ten threats to global health.¹ Global vaccine-distribution equity is a major challenge. Figures from December 2021 show that 54.8% of the world's population has received at least one dose of a COVID-19 vaccine.² However, only 6.2% of people in the Global South have received at least one dose.² The rate of people receiving the COVID-19 vaccine in some high-income countries where vaccines are available and free has dropped.³ The World Health Organization (WHO) reiterates that vaccines remain critical and are considered effective against severe disease and death.⁴

The reasons behind COVID-19 vaccine hesitancy are complex. Fear of side effects and concerns about the pace at which the vaccines were developed have been cited as primary reasons behind the hesitancy.⁵ In addition, misinformation about COVID-19 and vaccines is spread on social media platforms at a rate that has made the WHO coin the phrase “infodemic”.⁶ An Infodemic is “too much information including false or misleading information in digital and physical environments during a disease outbreak.”⁷ This infodemic plays a crucial role in public health when it comes to understanding the role of social media and COVID-19.⁸ A well-known false claim is that the Measles, Mumps, and Rubella vaccine (MMR) can cause autism.⁹ The claim has since been scientifically refuted many times but is still stated as a major concern for some parents.¹⁰ Motta and Steccula¹¹ examined American public opinion data on MMR safety collected before and after a retracted 1998 study that linked autism to MMR. The researchers detected a statistically significant rise in public concern about MMR safety following the retracted study and the media attention it received. This suggests that misleading vaccine information can impact public confidence in vaccines, and can cause skepticism about vaccines in general. Therefore, we also examined whether misinformation on social media now linked autism to the COVID-19 vaccines. Furthermore, vaccine hesitancy based on misinformation seems to be a worldwide phenomenon regardless of the uneven distribution of COVID-19 vaccines.⁴ Social media plays a crucial role in disseminating both information and misinformation about infectious diseases and vaccines.¹² Wilson and Wiyone showed in a global cross-national analysis of geographically-coded tweets and vaccination rates from 166 countries, that there was a significant relationship between social media

use and vaccine hesitancy.¹³ There has, however, been a joint effort by several of the largest social media platforms and technology companies to combat the spread of misinformation about COVID-19.¹⁴ In this study, we will review studies on social media misinformation on COVID-19 vaccines. The following questions guide our inquiry: What is known about misinformation regarding COVID-19 vaccines spread on social media platforms? What is known about the effects of misinformation about COVID-19 vaccines spread on social media platforms? What is known about social media misinformation on COVID-19 vaccines concerning autism spectrum disorder (ASD)?

Methods

Design

We followed the guidance from Cochrane Rapid Reviews.¹⁵ We chose a rapid review protocol in line with the recommendations by Cochrane, that is, the need “for timely evidence for decision-making purposes including to address urgent and emergent health issues and questions deemed to be of high priority”.¹⁵ The need to address vaccine hesitancy towards COVID-19 vaccines is an emergent health issue. The narrative qualitative synthesis was undertaken with the guidance of the PRISMA 2020 Statement¹⁶ and the Synthesis Without Meta-analysis (SWiM) reporting guideline.¹⁷

Search Strategy and Selection Criteria

We used the following search string in the rapid review:

“misinformation” OR “disinformation” OR “information” AND “social media” OR “Facebook” OR “Twitter” OR “Instagram” OR “WhatsApp” OR “Telegram” OR “Tumblr” OR “Pinterest” OR “YouTube” OR “VKontakte” OR “Snapchat” OR “TikTok” OR “Weibo” OR “WeChat” OR “Reddit” AND “covid*” OR “corona*” OR “pandemic” OR “Sars-CoV-2” AND “vaccine*” OR “vaccination*”. No date or language limitations were used. The full search strategy is available in supplementary appendix.

We included publications in peer-reviewed journals that fulfilled all following criteria: Original empirical studies, studies that assessed social media and misinformation, studies that dealt with vaccine hesitancy, studies about the COVID-19 vaccine. There were no language restrictions set. Publications were excluded if data were gathered before Phase III in the first COVID-19 vaccine development (from July

27 2020 to November 13, 2020).¹⁸ The reason behind this particular criterion was that we wanted to include studies from the point when information about the forthcoming vaccines was reaching the public.

Data Collection Process and Extraction

The review is registered in PROSPERO (CRD42021277524). Systematic searches in the databases PubMed, PsycINFO, ERIC, Embase, Cochrane Library, Cochrane COVID-19 Study Register were conducted by an information retrieval specialist on 9 September 2021. Duplicates were identified and removed. We used Rayyan as the chosen screening tool. Titles and abstracts were screened by two reviewers. Conflicting assessments were solved through discussions. 120 titles qualified for full-text review. Two reviewers did a further assessment of the eligibility of these 120 full-text records and conducted a pilot exercise using the same 10 full-text articles to calibrate and test the review form. Subsequently, the two reviewers read 55 articles each. After the screening, both assessed the articles the other had excluded. Another reviewer assisted with conflicts and discussed doubts surrounding included or excluded articles. 45 articles were included for data extraction. The data extraction from the identified articles involved two reviewers, where one extracted data using a piloted form and the other checked for the correctness and completeness of extracted data. Data from the included articles were extracted with regards to design and study population, type of misinformation, the effect of misinformation, misinformation about autism, ethical considerations, and social media channel. The agreed evidence was then synthesized narratively.

To synthesize the gathered knowledge about types of misinformation, a thematic analysis was performed.¹⁹ The types of misinformation were analysed and coded and then categorized into main themes by one reviewer. The codes and themes were discussed and approved by two additional reviewers. The planned group of studies that involve autism was removed since only one study contained this information.

Assessment of Risk of Bias

The risk of bias was graded according to The Joanna Briggs Institute (JBI) Critical Appraisal tool “Checklist for Analytical Cross-sectional Studies”²⁰ by one experienced reviewer. The evaluation was

based on answers to eight questions. The studies were classified to have either low (score 7-8), moderate (score 4-6), or high (score 1-3) risk of bias.

Assessment of the Quality of the Evidence

One experienced reviewer assigned certainty of evidence ratings based on recommendations by the GRADE Working Group.²¹ The included studies that looked at associations were given a narrative GRADE score related to the outcome “Association between social media misinformation and vaccine hesitancy”. The level of quality of evidence was classified as very low, low, moderate, or high.

Data Synthesis

The narrative synthesis was undertaken with the guidance of the PRISMA 2020 Statement¹⁶ and the Synthesis Without Meta-analysis reporting guideline.¹⁷ In the synthesis, findings from our included studies were grouped according to study design, population, and social media sample, types of social media, reported types of misinformation, misinformation about autism, the reported effect of the misinformation on vaccine hesitancy, and the assessments of risk of bias and quality of evidence. When synthesizing the findings narratively, studies that have a low risk of bias or high quality of evidence will be highlighted on several occasions.

Role of the Funding Source

There was no specific funding source for this study.

Results

We identified 45 relevant studies (Figure 1). The list of excluded articles during the full-text review and the reasons for exclusion are reported in supplementary appendix. The risk of bias in 16 included studies was classified as low according to the JBI critical appraisal tool.²²⁻³⁷ Five studies showed a moderate risk of bias.^{38-41,44} Finally, 24 included studies showed a high risk of bias.^{42,43,45-66}

Figure 1: PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

Table 1: Studies where data was collected by surveys, observations, and/or interviews (n=22)

Author (year)	Country	Study Period	Study design	Type of Social Media	Social Media or population sample	Type of misinformation reported	Risk of bias (JBI)
Alibrahim & Awad (2021) ²²	Kuwait	26 March to 26 April 2021	Cross-sectional study	Not specified	4147 adults, 18 years or older	COVID-19 is not a serious infection that requires vaccination	Low
Allington et al (2021) ²³	United Kingdom	21 November to 21 December 2020	Cross-sectional study	Not specified	4343 UK residents, aged 18–75 years	Conspiracy theories (not specified)	Low
Aloweidi et al (2021) ²⁴	Jordan	22 January 2021 to 28 February 2021	Cross-sectional study	Not specified	646 adults	The vaccines are unsafe; effect of the vaccines on a genetic level; causes chronic illnesses; may lead to infertility; can affect their offspring; contains toxic heavy metals and neurotoxic materials; it is a part of a secret research	Low
Bhagianadh & Arora (2021) ²⁵	USA	October–November 2020	Longitudinal survey	Not specified	5784 Medicare enrollees, 65 years or older	Distrust of government narrative about vaccines; vaccine will cause COVID-19.	Low
Brodziak et al (2021) ²⁶	Poland	January 26, to February 28, 2021	Survey	Not specified	635 adult cancer patients	The vaccine contains bodies of aborted children; COVID-19 does not exist	Low
Chadwick et al (2021) ²⁷	United Kingdom	24 September to 17 October 2020.	Cross-sectional study	Not specified	5114 UK adults	Conspiracies (not specified)	Low
Ebrahimi et al (2021) ²⁸	Norway	January 23 to February 2, 2021.	Cross-sectional study	Not specified	4571 Norwegian adults	Not specified	Low
Kanyike et al (2021) ²⁹	Uganda	Monday 15 March and Sunday 21 March 2021	Cross-sectional study	Not specified	600 medical students, 18 years or older	Negative information about Covid-19	Low
Karabela et al (2021) ³⁰	Turkey	February 01, 2021, to February 28, 2021	cross-sectional study	Social Media What's App YouTube	1216 adults	Conspiracy theories (not specified)	Low
Park et al (2021) ³¹	USA	Between October and November 2020	Cross-sectional study	Not specified	6478 Medicare beneficiaries	The belief that COVID-19 is not that dangerous	Low
Petravic et al (2021) ³²	Slovenia	17-27 December 2020	Cross-sectional study	Not specified	12,042 Slovenian residents, 15 years or older. Analysis of responses from the 2320 respondents	The vaccines will cause a genocide; COVID-19 is the same as influenza	Low

					(12%) who answered the open-ended question.		
Sallam et al (2021) ³³	Jordan	19 January 2021 to 23 January 2021	Cross-sectional study	Not specified	1106 university students	Covid-19 was man-made to enforce vaccinations; Covid-19 vaccinations intends to implant microchips into people to control them; COVID-19 vaccination will lead to infertility;	Low
Sallam et al (2021) ³⁴	Jordan, Kuwait, Saudi Arabia	4 December 2020 to 18 December 2020	Cross-sectional study	Facebook, Instagram, Twitter, WhatsApp	3414 respondents	An artificial origin of the virus; the disease was man-made to enforce vaccination; microchip implanting and infertility claims	Low
Sharevski & Gover (2021) ³⁵	USA	January and February 2021.	Cross-sectional quasi-experimental study	Twitter	304 respondents, 18 years or older	Exaggeration of rare side-effects of the COVID-19 vaccines	Low
Zhang et al (2021) ³⁶	China	September 1-7, 2020	Cross-sectional study	WeChat, WeChat moments, Weibo, TikTok	2053 Chinese factory workers full-time employees 18 years or older	Negative information about Covid-19 vaccines	Low
Zhang et al (2021) ³⁷	China	September 1 to 7, 2020.	Cross-Sectional study	WeChat, WeChat moments, Weibo, TikTok	2053 Chinese parents, 18 years or older	Negative information about Covid-19 vaccines	Low
Costantino et al (2021) ³⁸	Italy	December 2020 to March 2021	Cross-sectional study	Not specified	363 adults	Unfavourable information about Covid-19 vaccines	Moderate
El-Far Cardo et al (2021) ³⁹	Germany	August and November 2020	cross-sectional study	Facebook, Twitter, Telegram	808 persons	COVID-19 is not a health threat.	Moderate
Jennings et al (2021) ⁴⁰	UK	Survey: 12 to 18 December 2020. Focus groups: 30 November to 7 December 2020	Cross-sectional qualitative and quantitative (Mixed Method)	Tik Tok, Instagram, Snapchat, Twitter; Facebook, Youtube	1476 UK adults participated in the survey 29 UK adults participated in the focus groups	Conspiracy theories (not specified)	Moderate
Knights et al (2021) ⁴¹	United Kingdom	18 June and 30 November 2020	Cross-sectional qualitative study	Not specified	64 Primary Care Professionals and administrative staff, and 17 recently-arrived migrants	5G conspiracy theory	Moderate
Berry et al (2021) ⁴²	USA	December 30, 2020, to January 15, 2021	Qualitative observational study	Not specified	193 skilled nursing facility workers	Vaccines cause COVID-19; microchip; the virus has been around for a long time and killed many people since 1918; fear of racist motives and the safety of the vaccines; the vaccines have foetal cells from abortions	High

Choudhary et al (2021) ⁴³	India	February 18 to February 28, 2021	Cross-sectional study	Not speci- fied	272 Indian adults, 18 years or older	COVID-19 is a conspiracy	High
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Table 2: Studies in which data was collected from social media platforms (n=23)

Author (year)	Country	Study Period	Study design	Type of Social Media	Social Media or population sample	Type of misinformation reported	Risk of bias (JBI)
Chan et al (2021) ⁴⁴	United Kingdom	December 10, 2020	Cross-sectional (Social media data extraction)	YouTube	48 COVID-19 vaccine-related videos on YouTube	Misinformation about the COVID-19 vaccines (not specified). Only 2 (4.2%) videos made nonfactual claims.	Moderate
Alliheibi et al (2021) ⁴⁵	Saudi Arabia	15 December 2020 to 25 May 2021	Cross-sectional (Social media data extraction)	Twitter	37,467 tweets from 23,748 users	COVID-19 vaccination is a cover for a plan devised by Bill Gates to implant trackable microchips to control people	High
Baines et al (2021) ⁴⁶	USA	20 November 2020, to 6 January 2021	Cross-sectional (Social media data extraction)	Parler	400 random parleys from a large sample of 7000 Parleys	Sterilization possibilities for men and women; COVID-19 vaccine to control the population; Bill Gates and Anthony Fauci had instigated measures (i.e., microchips and enzymes in the vaccine) to control the population through the administration of the COVID-19 vaccine; governments and certain powerful individuals “planned” this health crisis to vaccinate children without parental consent as part of the new world order to control future populations	High
Basch et al (2021) ⁴⁷	USA	December 2020	Cross-sectional (Social media data extraction)	TikTok	100 videos studied garnered 35,338,600 views	38 videos discouraged the vaccine. 3 videos claimed that the vaccine is a hoax.	High
Boucher et al (2021) ⁴⁸		November 19 and 26, 2020	Cross-sectional (Social media data extraction)	Twitter	636,516 English and French Tweets	COVID-19 vaccines are poison and the mRNA technology has not been tested yet and is harmful.	High
Chriss et al (2021) ⁴⁹	USA	October 2020 to January 2021.	Cross-sectional (Social media data extraction)	Twitter	1110 tweets	Misleading information that countered scientific research about the vaccines; the government using vaccines to insert microchips and control the population; the immune system is stronger than the vaccines; race extermination conspiracy that claims that the vaccine was created to “kill off [people of color] POC.”	High
Doyno et al (2021) ⁵⁰	USA	January to April 2021.	Quasi-experimental	YouTube, Twitter, Facebook, and Instagram	Information campaign with 79 COVID-19 vaccine-related videos in English, Cantonese, Spanish, Mandarin, and Polish	Misinformation (not specified)	High
Guntuku et al (2021) ⁵¹	USA	December 1, 2020 to February 28, 2021	Cross-sectional (Social media data extraction)	Twitter	78.1 million vaccine-related tweets	Evangelical hubs posted conspiracy theories about Bill Gates and China	High
Hernández-García et al (2021) ⁵²	Spain	9 February 2021	Cross-sectional (Social media data extraction)	YouTube	118 YouTube videos	Hoaxes and conspiracy theories (not specified)	High
Herrera-Peco et al (2021) ⁵³	Spain	8 to 23 December 2020	Cross-sectional (Social media data extraction)	Twitter	6080 Twitter interactions (n=499 of those are single tweets)	Deny the existence of the virus; the vaccine will modify the DNA of human beings; industry lobbies to kill the elderly and leave the young with Bells syndrome.	High

Herrera-Peco et al (2021) ⁵⁴	Spain	14 to 28 December 2020	Cross-sectional (Social media data extraction)	Twitter	5040 Twitter users participated, generating a total of 1,664,261 impressions	mRNA vaccines will produce changes in human DNA; government and pharmaceutical industries are allies; adverse effects leading to genocide	High
Hughes et al (2021) ⁵⁵	USA	October 2020 to November 2020.	Cross-sectional (Social media data extraction + modelling)	Facebook, Twitter, YouTube, and Instagram	Using hashtag and keyword searchers, a team of subject matter experts identified 20 channels (i.e., bounded sources of content, such as a social media account), which appeared to contain a high degree of anti-vaccine content and/or COVID denialism.	Corrupt Elites; physical deformities; mental illness; microchips that violate your autonomy/privacy; the people who intentionally created the COVID vaccine are shadowy and suspicious	High
Islam et al (2021) ⁵⁶	Australia	31 December 2019–30 November 2020	Cross-sectional (Social media data extraction)	Facebook, YouTube, and Twitter	637 news articles, social media narratives, online reports, and/or blogs spread on social media	Daughter of the Russian president had died after receiving the second dose of COVID-19 vaccine; children and soldiers dying after receiving the vaccine in multiple countries; conspiracy theory about Bill Gates; COVID-19 vaccine can monitor the human population and take over the world; COVID-19 vaccines contain a microchip through which biometric data could be collected, and large businesses could send signals to the chips using 5G networks; crucial phases of the clinical trials were skipped; COVID-19 vaccine contains cells from aborted foetus or genes from pigs	High
Kwok et al (2021) ⁵⁷	Australia	January 22 and October 20, 2020.	Cross-sectional (Social media data extraction)	Twitter	31,100 COVID-19 vaccine-related tweets	Conspiracy theories such as the “mark of the beast” and microchips in vaccines.	High
Larrondo-Ureta (2021) ⁵⁸	Spanish-speaking countries	December 2020 and February 2021	Cross-sectional (Social media data extraction)	Twitter	62,045 tweets and 258,843 retweets	Anti-vaccine discourse (not specified)	High
Liu & Liu (2021) ⁵⁹	English-speaking countries	November 1-22, 2020	Cross-sectional (Social media data extraction)	Twitter	5000 COVID-19 vaccine-related tweets, which were posted by 4796 unique users.	Microchips; alters DNA; women become sterile	High
Melton et al (2021) ⁶⁰	USA	Dec 1, 2020, to May 15, 2021	Cross-sectional (Social media data extraction)	Reddit	13 Reddit communities	Misinformation about side-effects	High
Pascual-Ferra (2021) ⁶¹	USA	December 29, 2019, to January 2, 2021,	Cross-sectional (Social media data extraction)	Facebook, Instagram, Reddit, YouTube	Peaks and interactions	Viral video of a nurse fainting after vaccine uptake. Misinformation about COVID-19 vaccines (not specified)	High
Rotolo et al (2021) ⁶²	USA	March 19, 2020, and June 16, 2021,	Quasi-Experimental (Social media data extraction)	Facebook, Twitter, and Instagram	Aim: Share 49 infographics to counter vaccine hesitancy.	COVID-19 myths	High

Savolainen (2021) ⁶³	Finland	February 2021	Cross-sectional (Social media data extraction)	Reddit, from the subreddit VaxxHappened	40 threads contained in total 1877 messages	Misinformation about COVID-19 vaccines (not specified)	High
Sobkowicz & Sobkowicz (2021) ⁶⁴	USA and Poland	1 March 2021	Cross-sectional (Social media data extraction)	Reddit and Interia	Reddit and Interia Anti-vaccine groups	Anti-vaccination discussions about COVID-19 vaccines	High
Thelwall et al (2021) ⁶⁵	United Kingdom	10 March to 5 December 2020.	Cross-sectional (Social media data extraction)	Twitter	446 vaccine-hesitant Covid-19 tweets in English	Deep state conspiracy; depopulation; microchips; Bill Gates; fearing that people of colour are at risk for experimentation - motivated by the infamous US federal government Tuskegee Syphilis study ending in 1972 that secretly experimented on poor African American men	High
Wawrzuta et al (2021) ⁶⁶	Poland	1 November 2020 and 1 May 2021	Cross-sectional (Social media data extraction)	Facebook	3414 Facebook comments	The vaccine was created only for the profit of pharmaceutical companies; conspiracy theories, hidden vaccine effects (e.g., chips); the vaccine will be dangerous to health; the vaccine has existed before the COVID-19 pandemic	High

We grouped the studies into two major categories according to data sampling: One group gathered data through surveys, interviews, or focus groups (Table 1). The other group gathered data from social media (Table 2). The largest total population sample in the first group of 22 studies seen in Table 1 came from Europe with 27 975 respondents in total. European countries were represented by Poland,²⁶ Italy,³⁸ Norway,²⁸ Germany,³⁹ Slovenia,³² and the UK. The UK was represented with 9538 people from four studies.^{23,27,40,41} The US sample size amounted to 12 759 people from four studies.^{25,31,35,42} Middle Eastern countries were represented through studies from Kuwait,²² Jordan,^{24,33} and Saudi Arabia³⁴ and counted for 9313 people of the total sample. A total of 7082 participants came from Asian countries such as China,^{36,37} India,⁴³ and Turkey.³⁰ Only one included study in our review came from an African country.²⁹ **Feil! Bokmerke er ikke definert.** The study was from Uganda and included 600 participants. There were no studies from Middle- or South America or Pacific Island countries and Australia. All of the respondents were described as adults or older than 18 years except for two US studies where the participants were 65 years or older.^{25,31} Another exception was one study from Slovenia where participants 15 years or older were included.³² The participants' occupation was mentioned in some studies as being medical student,²⁹ university student,³³ Medicare enrollee,²⁵ Medicare beneficiary,³¹ factory worker,^{36,37} or skilled nursing facility worker.⁴² One Polish study focused on cancer patients.²⁶ In one of the few cross-sectional qualitative studies by Knights and colleagues, primary care professionals and recently arrived immigrants were interviewed.⁴¹ Gender has not been a focal point in any of the 45 included studies.

In the second group, where data was gathered from social media platforms, we found 23 studies. Ten studies harvested data from Twitter. Five of these examined English language tweets,^{49,51,57,59,65} three studies gathered tweets in Spanish,^{53,54,58} one study examined tweets in both English and French⁴⁹ and one study examined Arabic tweets.⁴⁵ Five studies gathered data from several social media platforms, most commonly combining Twitter, Facebook, Instagram, and YouTube.^{50,55,56,61,62} These studies looked at English language messages or videos. Two studies examined English language messages or discourse on Reddit.^{60,63} One study looked at anti-vaccine discussions on both Reddit and the Polish social media platform Interia.⁶⁴ Two studies examined YouTube videos in English⁴⁴ and in Spanish.⁵² One US study looked at English language TikTok messages⁴⁷ and another US study examined English language messages on the American social media platform Parler.⁴⁶ Finally, one Polish study examined Facebook comments.⁶⁶

Many of the studies did not name social media platforms in the first group (Table 1), but rather discussed social media platforms in general. However, some studies did specify which social media platforms they were assessing. The studies with low risk of bias that specified the social media platform they were assessing focused on Twitter only³⁵ and several platforms, such as Facebook, Instagram, YouTube, WhatsApp, WeChat, Weibo, and TikTok.^{30,34,36,37} Among the studies that collected data from social media (Table 2), ten studies extracted data from Twitter,^{45,48,49,51,53,54,57-59,65} two from YouTube,^{44,52} one from TikTok,⁴⁷ one from Reddit,⁶⁰ one from Parler,⁴⁶ and one from Facebook.⁶⁶ Seven studies that collected data from social media utilized two or more platforms.^{50,55,56,61-64} Figure 2 summarizes the types of social media platforms used in the 45 included studies.

Social Media Platforms		Number
Twitter	18
Facebook	9
YouTube	7
Instagram	6
TikTok	4
Reddit	4
WeChat	2
Wechat Moments	2
Weibo	2
WhatsApp	2
Interia	1
Parler	1
Snapchat	1
Telegram	1

Figure 2: Social Media Platforms

Figure 3 gives an overview of three overarching themes of misinformation identified from the thematic analysis, and examples of topics of misinformation within the three themes.

Figure 3: Types of misinformation about the COVID-19 vaccine on social media platforms

Of the 45 included studies, 18 studies reported misinformation across all three categories.^{24-26,32-}

34,42,45,46,48,49,53-56,59,65,66 Nine studies reported on conspiracies only.^{23,27,30,40,41,43,51,52,57} Six studies were

concerned specifically with medical misinformation.^{22,31,35,39,60,61} 12 studies reported on COVID-19 vaccine misinformation or anti-vaccine discourse without going into further detail.^{28,32,36-38,44,47,50,58,62-64}

We identified 19 studies that made assumptions about the effects of social media misinformation on vaccine hesitancy (Table 4). The evaluation of the certainty of evidence of these 19 studies that measured the “Association between social media misinformation and COVID-19 vaccine hesitancy” was classified as moderate or low-moderate according to GRADE in two cases.^{35,62} For the rest of the studies, the certainty of the evidence according to GRADE was considered low or very low (see Table 3).

The two studies with a higher certainty of the evidence had an experimental design. Rotolo and colleagues⁶² aimed at developing and distributing infographics that addressed COVID-19 vaccine hesitancy and misinformation. Although their infographics reached thousands of people, they were unable to conclude the impact on vaccine hesitancy. Sharevski & Gover³⁵ analyzed the perceived accuracy of COVID-19 vaccine Tweets when they were moderated by smart device technology that Twitter applies to COVID-19 misinformation. The results from the 304 participants suggested that the vaccination hesitant users ignored warnings as long as the Tweets aligned with their personal beliefs.

Allington and colleagues²³ analysed findings from an online survey conducted with a sample of 4343 UK adults. They found a positive correlation between trust in social media and vaccine hesitancy, and the strongest link was found concerning YouTube and Facebook. Conspiracy suspicions about COVID-19 and general vaccine attitudes appeared to be uniquely predictive, jointly explaining 35% of the variance. Boucher and colleagues⁴⁸ analysed 636,516 English and French Tweets. 23.4% (n=146,191) of conversations on Twitter during the study period could be directly attributed to vaccine hesitancy. A British study²⁷ of 5114 adults found that social media dependence and high levels of conspiracy mentality were most likely to be associated with online discouragement of vaccination. In a study of 4571 Norwegian adults, individuals who preferred social media platforms had a near twofold (i.e., 1.64) odds of being hesitant toward COVID-19 vaccination compared to those preferring source-verified media platforms.²⁸ In addition, those who held the belief in the superiority of natural immunity over vaccination were more vaccine-hesitant (OR=2.663; 95% CI=2.350,3.028, p<0.001). Petravic and colleagues³² asked 12,042 Slovenian residents about attitudes on COVID-19 vaccines. Those who

trusted alternative media sources and alternative explanations on social media were more vaccine-hesitant.

12 studies^{24-26,30,31,33,36-40,56} discussed social media misinformation, vaccine uptake, and vaccine intentions. In a study of 646 Jordanians²⁴, social media were found to affect the decision to get a vaccine (OR = 1.21; 95% CI = 1.04, 1.41; $p = 0.012$) and 43.8% ($n=238$) believed that it was unsafe while 15.6% ($n=101$) believed that the vaccination was part of secret research. Bhagianadh & Arora²⁵ examined the prevalence and predictors of vaccine hesitancy among 5784 older (>65 years) US citizens. Those depending on social media as the main source of information on COVID-19 expressed higher negative vaccine intent (OR=3.36; 95% CI=1.44, 7.82). Among those who expressed a negative vaccine intent, 40% ($n=298$) expressed no trust in the government and 10% ($n=74$) said that the vaccines cause COVID-19. In a Polish study by Brodiziak and colleagues²⁶ of 635 adult cancer patients, they found that the use of social media as an information source was associated with unwillingness to be vaccinated (OR=1.42; 95% CI= 0.72, 2.80). 68% ($n=432$) used social media every day. 37.6% ($n=239$) said that they were afraid of the composition of the vaccine, 7.7 % ($n=49$) believed that the vaccines contained bodies of aborted children, and 6.6 % ($n= 42$) believed that COVID-19 did not exist. In an Italian study of 363 adults,³⁸ 71.4 % ($n=60$) answered that unfavourable information about COVID-19 vaccines obtained from the Internet/social media/media was associated with the decision to not take the vaccine. El-Far Cardo and colleagues³⁹ asked 808 Germans to complete a questionnaire about media preference and vaccine willingness. Using social media as an information source was negatively associated with getting vaccinated against COVID-19 ($p < 0.01$). Believing that COVID-19 is not dangerous was also associated with an unwillingness to get vaccinated. A UK study by Jennings and colleagues⁴⁰ found that users of Instagram, Snapchat, and TikTok were less likely to express willingness to be vaccinated. However, YouTube users were the most vaccine-hesitant. Holding conspiracy beliefs was also a significant predictor of vaccine hesitancy. The study involved 1476 UK adults who participated in a survey and 29 in focus groups. Karabela and colleagues³⁰ investigated attitudes towards vaccines and their trust in information sources among 1216 Turkish adults. The participants who stated that they would have the COVID-19 vaccine were less likely to trust social media sites such as Facebook, Twitter, and Instagram ($p < 0.005$). On the other hand, those who were undecided were more likely to trust YouTube as a reliable source of information. The researchers also found a positive

relationship between attitudes towards the COVID-19 vaccines and conspiracy theories ($r=0.214$). Liu and Liu⁵⁹ examined 5000 COVID-19 vaccine-related tweets and found that 182 tweets contained negative behavioural intentions meaning they would not choose to get vaccinated, and 97 tweets were labelled with positive behavioural intentions. Park and colleagues³¹ examined how the source of information shaped perceptions of COVID-19 severity and the likelihood of COVID-19 vaccine uptake among 6478 Medicare beneficiaries. Those relying on social media had the lowest levels in all measures. The likelihood of COVID-19 vaccine uptake was significantly lower among those relying on social media (OR = 0.40; 95% CI=0.25, 0.65). Sallam and colleagues³³ evaluated 1106 Jordanian university students' COVID-19 vaccine acceptance and examined the association between vaccine conspiracy beliefs and vaccine hesitancy. The lowest rate of intention to get the vaccine was among those who depended on social media platforms (19.8%) compared to those who trusted doctors, scientists, and scientific journals (47.2%, $p < 0.001$). The researchers also found that beliefs in conspiracy theories were correlated with reluctance to take the vaccine ($p < 0.001$). In a Chinese study of 2053 factory workers and their behavioural intentions to receive COVID-19 vaccination, Zhang and colleagues³⁶ found that a higher frequency of exposure to positive information on social media related to COVID-19 vaccination was associated with a higher intention to receive a COVID-19 vaccination at the market rate (AOR=1.53; 95% CI=1.39, 1.70) or a free vaccination (AOR=1.52; 95% CI 1.35, 1.71). Zhang and colleagues³⁷ also investigated the parental acceptability of free COVID-19 vaccination for children under the age of 18 in China. The sample was the same as above, as this was a secondary analysis of a closed online survey among the 2053 factory workers. Higher exposure to positive information related to COVID-19 vaccination on social media was associated with higher parental acceptability of COVID-19 vaccination (AOR= 1.35; 95% CI= 1.17, 1.56). Higher exposure to negative information related to COVID-19 vaccination was negatively associated with the dependent variable (AOR 0.85; 95% CI= 0.74, 0.99).

Table 3: Studies in which the effect of social media misinformation on vaccine hesitancy is measured or discussed (n=19).

Author (year)	Reported effect of misinformation	Certainty of evidence (GRADE)
Sharevski & Gover (2021) ³⁵	Amazon Alexa was not able to dispel any biases that were rooted in personal beliefs. One's hesitancy from COVID-19 vaccination sufficed for biased perception of the information from Alexa despite any labelling as long as the Tweets echoed their sceptic outlook on the whole COVID-19 vaccination effort.	Moderate

Rotolo et al (2021) ⁶²	Each infographic reached thousands to tens of thousands of people. We do not know whether those who viewed these infographics changed their perspective on vaccination, so we are unable to conclude their impact on vaccine hesitancy based on this study alone.	Low-Moderate
Allington et al (2021) ²³	Informational reliance on all social media platforms was positively correlated with vaccine hesitancy, this correlation was strongest concerning Facebook and YouTube (RS = 0.15 and RS = 0.18, respectively). Coronavirus conspiracy suspicions and general vaccine attitudes appear uniquely predictive, jointly explaining 35% of variance.	Low
Bhagianadh & Arora (2021) ²⁵	Those depending on social media as the main source of information on COVID-19 expressed higher negative vaccine intent (OR=3.36; 95% CI=1.44, 7.82). Among those who expressed a negative vaccine intent, 40% (n=298) expressed no trust in government, 10% (n=74) said that the vaccines cause COVID-19.	Low
Boucher et al (2021) ⁴⁸	The study showed two clusters opposite to these vaccine acceptant clusters exhibiting more vaccine-hesitant narratives. There were 23.4% (n=146,191) of conversations on Twitter during this period of observation that can be directly attributed to vaccine hesitancy.	Low
Chadwick et al (2021) ²⁷	Combinations of news avoidance and high levels of the news-finds-me attitude and social media dependence and high levels of conspiracy mentality are most likely to be associated with online discouragement of vaccination.	Low
Jennings et al (2021) ⁴⁰	Holding conspiracy beliefs is a significant predictor of vaccine hesitancy. In the bivariate analysis, there is some support for a relationship between social media use Snapchat, TikTok, YouTube, and Instagram) and increased vaccine hesitancy. YouTube users were significantly less willing to be vaccinated, with a two-thirds likelihood of vaccine willingness compared to non-users.	Low
Liu & Liu (2021) ⁵⁹	279 tweets stated their behavioural intentions. A total of 97 tweets were labelled with positive behavioural intentions, while 182 tweets contained negative behavioural intentions.	Low
Park et al (2021) ²⁸	The study found that social media dependence and high levels of conspiracy mentality were most likely to be associated with online discouragement of vaccination. The likelihood of COVID-19 vaccine uptake was significantly lower among those relying on social media (OR = 0.40; 95% CI=0.25,0.65)	Low
Zhang et al (2021) ³⁶	Regarding social media influence, higher frequency of exposure to positive information related to COVID-19 vaccination was associated with a higher intention to receive a COVID-19 vaccination at market rate (AOR 1.53; 95% CI 1.39-1.70) or a	Low

	free vaccination (AOR 1.52; 95% CI 1.35-1.71).	
Zhang et al (2021) ³⁷	Higher exposure to positive information related to COVID-19 vaccination on social media was associated with higher parental acceptability of COVID-19 vaccination (AOR= 1.35; 95% CI=1.17-1.56). Higher exposure to negative information related to COVID-19 vaccination was negatively associated with the dependent variable (AOR= 0.85; 95% CI= 0.74-0.99).	Low
Aloweidi et al (2021) ²⁴	The effect of social media (OR = 1.21; 95% CI = 1.04, 1.41; p = 0.012) were significantly associated with the willingness to take COVID-19 vaccine. Circulated information about COVID-19 vaccines on social media platforms that they believed in: It is unsafe n=283 (43.8%); Effect of the vaccines on a genetic level n=87 (13.5%); Causes chronic illnesses n=60 (9.3%); May lead to infertility n=43 (6.7%); Can affect their offspring n=56 (8.7%) Toxic heavy metals and neurotoxic materials n=47 (7.3%); It is a part of a secret research 101 (15.6%)	Very Low-Low
Brodziak et al (2021) ²⁶	N=432 (68 %) used social media every day. Unwilling to Vaccinate against COVID-19: Social media as a source of information about vaccinations (OR=1.42; 95% CI= 0.72, 2.80). Not a significant predictor Attitudes to COVID-19 vaccines: Afraid of the vaccine's side effects n= 284 (44.7%); afraid of the composition of the vaccine n=239 (37.6%); contains bodies of aborted children n=49 (7.7%); Coronavirus does not exist n=42 (6.6 %)	Very Low-Low
Ebrahimi et al (2021) ²⁸	Individuals with a preference for social media platforms as compared to those preferring source-verified media platforms had a near 2fold (i.e., 1.64) odds of being hesitant toward vaccination. Belief in superiority of natural immunity: OR=2.663 (95% CI=2.350, 3.028) p<0.001	Very Low-Low
El-Far Cardo et al (2021) ³⁹	Factors that were negatively associated to get vaccinated were using social media in general as an information source about COVID-19 (p < 0.01), and the use of Facebook (p < 0.05) or Telegram (p < 0.05). However, using Twitter was not significantly associated with adverse vaccination intentions (p < 0.56). Believing that COVID-19 is not dangerous was associated with unwillingness to get vaccinated.	Very Low-Low
Petravic et al (2021) ³²	Those who trusted alternative media sources (alternative explanations on social media) and had a distrust of the government were more vaccine-hesitant.	Very Low-Low
Sallam et al (2021) ³³	The lowest rate of intention to get the vaccine was among those who depended on social media platforms (19.8%) compared to dependence on medical doctors, scientists, and scientific journals (47.2%, p<0.001). Conspiracy beliefs were evaluated using the validated Vaccine Conspiracy Belief Scale (VCBS), with higher scores implying	Very Low-Low

	embrace of conspiracies. A significantly higher VCBS score was correlated with reluctance to get the vaccine ($p < 0.001$).	
Costantino et al (2021) ³⁸	71.4 % (n=60) responded that unfavourable information about COVID-19 vaccines obtained from the Internet/social media/media was associated with the decision to not take the vaccine.	Very Low
Karabela et al (2021) ³⁰	Although the correlation was not significant, of the participants, those who considered having vaccination mostly trusted YouTube as their source of information. On the other hand, the participants who stated that they would have the COVID-19 vaccine did not trust social media sites such as Facebook, Twitter, and Instagram ($p < 0.005$) There was a positive and low-level relationship between attitudes towards COVID-19 vaccine, and conspiracy theories ($r: 0.214$)	Very Low

Only one study mentioned autism.⁶⁰ In the study by Melton and colleagues, 13 Reddit communities were examined to elucidate COVID-19 related vaccine discussions on social media. They found that the discussions had a more positive than negative sentiment in total. From one of the negative threads, they found comments about autism and misinformation about the COVID-19 vaccine and the technology behind it: “MRNA can do/mean literally anything from protecting you from COVID to sterilization all the way into making you autistic.”⁶⁰

Discussion

The 45 included studies about misinformation on social media platforms and the link to vaccine hesitancy suggest that there should be great concern about the association between the two. We identified three overall categories of misinformation, namely medical misinformation, conspiracies, and distrust in vaccine development, although the three are connected and sometimes overlapping, as distrust in the vaccine development might be founded in conspiratorial beliefs about hidden power structures and corrupt elites. The included studies were predominantly from Europe and the US, and there is, therefore, a lack of information from especially African and South American countries. Twitter was the most studied platform, with Facebook and YouTube in second and third place.

Fear of side effects is a major concern when it comes to vaccine-hesitancy, and as our review shows this concern can easily turn into medical misinformation and exaggerations of side effects. Knowing that the side effects of the vaccines are one of the major concerns, medical misinformation has the potential to do a lot of harm. When we examined types of reported misinformation, we also found that a lot of misinformation is grounded in conspiracy theories. For example, we found three studies from the US that mentioned the fear of racist motives by official health authorities as a reason for vaccine hesitancy.^{42,49,65} Some of this fear has historical roots in the US, as one of these studies,⁶⁵ for instance, brought up The Tuskegee Syphilis Study. This was a clinical study (1932-1972) where the US Public Health Service used African Americans to observe untreated syphilis and therefore denied them treatment.⁶⁷ This exemplifies that lack of trust in public health institutions might have deep historical roots in some countries and cultures. Other issues to be aware of are religious concerns and vaccine hesitancy. We found several studies that reported on misinformation about the content and development of the vaccines and used very explicit language (e.g. ‘pigs’ and ‘cells from aborted children’). Such wording can cause worry in some religious communities.

The 19 identified studies in table 3 interpreted results as associations between social media use, misinformation, and vaccine hesitancy. According to the JBI and GRADE evaluations, there is a need for more robust designs to become more certain regarding the actual effect of social media misinformation on vaccine hesitancy. Only one study, an intervention study regarding the impact of addressing misinformation on Twitter users, was assessed to have a low risk of bias and moderate quality of evidence.³⁵ In addition, four studies reported significance levels of associations, but the effect size was not reported.^{28,29,32,58} Other studies in this review showed that social media platforms did not necessarily spread misinformation to a great extent, perhaps reflecting that the effort made by some of the social media platforms to halt misinformation has worked. Chan and colleagues⁴⁴ examined 48 COVID-19 vaccine-related videos on YouTube during December 2020 and only found two videos (4.2%) that made non-factual claims. Hernandez-Garcia and colleagues⁵² also looked at YouTube videos during February 2021 and found that only two out of 110 videos contained COVID-19 vaccine hoaxes or conspiracy theories. Pascual-Ferra and colleagues⁶¹ examined social media data from Facebook, Instagram, Reddit, and YouTube and did not find evidence of the dominance of misinformation. However, what is being spread and discussed in closed groups is another question that needs to be examined further. Another valid approach would also be to look at the comment sections. Even though anti-vaccine

content has been prevented to surface in searches, it does not prevent people from commenting on their beliefs or posting other types of information in the comment section. It is not without controversy to de-platform people⁶⁸, and might even do harm, as these people might be seen as someone speaking against the establishment which is in essence some of the core beliefs of some conspiracy theorists.

Surprisingly, there was a dearth of studies examining misinformation about autism and COVID-19 vaccines. Considering the history of misinformation about vaccines and autism during the past two decades, more research should focus on this topic. Future research should also aim at examining social media platforms such as TikTok, which is a very popular platform worldwide, and often used by younger people than for instance the average Twitter user.⁶⁹ Our review shows that more studies are needed from Global South nations.

When addressing vaccine hesitancy, one should be careful before labeling all vaccine-hesitant people as anti-vaxxers or as misinformed. Primary concerns from people who say that they are vaccine-hesitant are the safety of the vaccines and the rapid pace of development.⁷ However, to be hesitant and skeptical does not mean that these people are not willing to take the vaccines, but rather that they have some concerns that should be addressed adequately to convince them of the safety and efficacy of the vaccines. To understand a complex issue such as vaccine hesitancy, knowledge about sociodemographic conditions and cultural awareness is key. In addition, countries with a more un-democratic regime will suffer from a lack of trust in official authorities which may damage an official vaccine campaign. On the other hand, such countries can use authoritarian measures to reach a high vaccination rate. These are issues that need to be addressed and analysed in future studies of vaccine hesitancy.

Limitations

We did not include grey literature or preprints in our review. The rapid pace at which the pandemic is moving makes preprint research especially relevant. Therefore, including preprints would have been a valid approach. Neither did we contact researchers with potential projects on the subject matter. Further, the databases searched were selected because of the topic at hand. There will always be a chance that other, more specified or general databases would capture other studies.

A limitation of the evidence included in this review is that in our assessment, all but one got a low score in the assessment of risk of bias. Furthermore, there is a poor correlation between self-reported social media use and actual use.⁷⁰ A high proportion of these studies harvested data from Twitter because Twitter has opened up access for researchers to extract data from its platform, making it more accessible compared to other social media platforms. The Twitter sample may not be representative of a random sample of the population, as its users tend to range from the age of 25 to 34 years, and are predominantly from the US.^{71,72} Furthermore, we did not assess the potential presence of social media bots (automated accounts) spreading wrong information in these studies. Neither did we discuss how social media algorithms partake in creating echo chambers.⁷³ These are well-known challenges when researching data gathered from social media.⁷⁴

Conclusion

Many studies showed that there is a link between misinformation on social media and COVID-19 vaccine hesitancy. However, there is a need to examine this with a more robust experimental design to assess this effect. There are many types of misinformation that are spread on social media platforms, and to prevent these myths from taking hold health authorities should openly address and discuss these false claims with both cultural and religious awareness in mind. Although some of the major tech companies have taken steps to prevent misinformation, more action is needed to stop this infodemic. Misinformation about COVID-19 vaccines is still thriving on social media platforms. This undertaking must, however, represent a balance between people's right to speak their minds and strategies to counter the spread of misinformation.

Contributors

IS, EG, and ANH conceived the idea for this study. Data search was carried out by KEJ. IS and ANH screened titles and abstracts. IS and EG full-text screened the articles. IS did the data extraction, with EG's verification. DQ assessed risk of bias and RW evaluated the quality of evidence. IS took the lead in writing the manuscript. All authors discussed, revised, and contributed to the final manuscript. All authors have read and agreed to the final published version.

Declaration of Interest

We declare no competing interests.

Data sharing

Data will be made available immediately following publication with no end date.

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