Efficacy, Safety, and Public Attitude toward COVID-19 Vaccines: A Systematic Review

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Abstract

Background: This paper reviews some of the literature on the safety and efficacy of different COVID-19 vaccines, the attitudes, and perceptions of people towards the vaccines, and the factor underlying such perceptions and behavior. **Methods:** Two major databases (PubMed and Epistemonikos) were checked using search expansion mechanisms and several search strings. After the title, abstract, and full-text analysis, 19 studies were selected for review. **Results:** The seven different vaccines studied all have supporting data on their efficacy in the reduction of COVID-19 cases, prevention of hospitalization after infection, and reduction in the mortality rate of COVID-19 patients. There was high hesitancy about the COVID-19 vaccine and the perceived efficacy and safety of the vaccines are less than recorded in clinical data. Distrust of the vaccines, their manufacturers and different institutions and governments, personal beliefs and feelings, age, gender, education, and socioeconomic status were identified factors affecting behaviors towards the COVID-19 vaccines. **Conclusion:** Several articles support the efficacy of COVID-19 vaccines, but general awareness and conception about them vary, including hesitancy, distrust, and some acceptance. Many factors affected the perception and attitude of people toward these vaccines. More clinical data on the efficacy and safety of COVID-19 vaccines should be generated to help boost confidence among users.

Keywords: Attitude, COVID-19, COVID-19 vaccines, efficacy, safety

Résumé

Contexte: Cet article passe en revue une partie de la littérature sur l'innocuité et l'efficacité de différents vaccins COVID-19, les attitudes et les perceptions des personnes à l'égard des vaccins, ainsi que les facteurs sous-jacents et le facteur sous-jacent à ces perceptions et comportements. **Méthode:** Deux bases de données majeures (PubMed et Epistemonikos) ont été vérifiées à l'aide de mécanismes d'expansion de la recherche et de plusieurs chaînes de recherche. Après l'analyse du titre, du résumé et du texte intégral, 19 études ont été sélectionnées pour examen. **Résultat:** Les 7 vaccins différents étudiés ont tous des données à l'appui sur leur efficacité dans la réduction des cas de COVID-19, la prévention des hospitalisations après infection et la réduction du taux de mortalité des patients COVID-19. Il y avait une grande hésitation à propos du vaccin COVID-19 et l'efficacité et l'innocuité perçues des vaccins sont inférieures à celles enregistrées dans les données cliniques. La méfiance à l'égard des vaccins, de leurs fabricants et des différentes institutions et gouvernements, les croyances et sentiments personnels, l'âge, le sexe, l'éducation et le statut socio-économique ont été identifiés comme des facteurs affectant les comportements à l'égard des vaccins COVID-19. **Conclusion:** Plusieurs articles soutiennent l'efficacité des vaccins COVID-19, mais la sensibilisation et la conception générales à leur sujet varient, y compris l'hésitation, la méfiance et une certaine acceptation. De nombreux facteurs ont affecté la perception et l'attitude des gens envers ces vaccins. Plus de données cliniques sur l'efficacité et l'innocuité des vaccins COVID-19 devraient être générées pour aider à renforcer la confiance des utilisateurs.

Mots-clés: Attitude, COVID-19, vaccins COVID-19, efficacité, innocuité

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Introduction

The COVID-19 pandemic affected several aspects of human life worldwide, shutting down businesses and social life, and taking so many lives along with it.[1] In response, several companies and organizations got to work setting up and developing a vaccine to curb the menace.[2] It was a sigh of relief to most people all around the world when the trials began, and vaccines were confirmed for use. Several nations struggled to get the first doses to enable their nations to get back to a sort of normalcy.[3] However, the response to the COVID-19 vaccine has not been uniform across the board. As the vaccines spread around the world, so did misinformation and fears, leading to widespread hesitancy and objection to them.[4] Although many countries reported positive news following vaccination, people and groups refused the vaccines for themselves, their children, and loved ones, stating several reasons, including a lack of faith in the efficacy of the vaccine.[5] As more data emerges from clinical trials and practice, a reality check becomes important to help in public health and administrative decision-making. It is therefore important to assess the literature showing adequate efficacy and safety of vaccines. It is important to carry out investigations to help stakeholders address hesitancy and enable informed decision-making among people. This paper reviews some of the literature on the safety and efficacy of different COVID-19 vaccines, the attitudes, and misconceptions of people toward the vaccines, and the factors underlying such beliefs and behaviors.

Objectives

The objectives of the study are the following:

- To explore the efficacy of COVID-19 vaccines
- To review the safety and adverse effects of different COVID-19 vaccines
- To review the attitudes toward the COVID-19 vaccines
- To explore the factors driving hesitancy toward the COVID-19 vaccines.

Methods

To meet the objectives, two themes were chosen: COVID-19 vaccines' efficacy and safety and people's beliefs and behaviors and their underlying factors. The data collection was split into these two categories: The efficacy and safety of the COVID-19 vaccines; the behaviors surrounding the COVID-19 vaccines, and the underlying factors.

Search strategy

To assess a wide array of the available literature, two major databases (PubMed and Epistemonikos) were searched using search expansion mechanisms such as Boolean operators and several search strings. A final search string ([efficacy of COVID-19 vaccines] OR [challenges of COVID-19 vaccines]) OR (safety of COVID-19 vaccines) was used to gather the needed literature for the objectives of the study.

Eligibility criteria

Eligible papers were published after March 2020 (the date the guidelines for conducting clinical trials were published).[6] These papers were open access, primary studies, written in the English language, and published in a peer-reviewed journal. The aim, population, beliefs, behaviors, factors, the vaccine studied, and the efficacy/safety results were extracted and tabulated in two different tables according to their themes.

Quality assessment

The qualities of the papers were also considered when making decisions on eligibility. Only peer-reviewed studies published in a PubMed-indexed journal were included in the review. Papers had to fall within the core scope of the review and had a clear description of the methods used with a proper discussion of the derived findings. Authors also had to have followed an ethical and meticulous data collection process and presented or cited all relevant data referred to.

Results

Initial search results from Epistemonikos returned 34,071,384 articles conducted within the eligible period, 1222 articles were primary studies, 360 articles were excluded for being duplicates from PubMed search, and a total of 862 results were left for consideration. PubMed yielded 7884 articles, out of which 5043 had free publicly available full-text articles which matched some eligible period of study. A total of 155 articles of these were primary studies (clinical and randomized controlled trials), but 55 did not fit the title requirements. The results were sorted according to relevance and the top 100 were exported from each of the databases. These 200 articles were then imported into Zotero referencing software. After further title, abstract, and full-text analyses were done, and 19 studies were selected for this review [Figure 1].

Study summary

For studies related to vaccine efficacy and safety, the total number of participants for the 12 selected studies was 720,110. The study with the highest population included 658,428 participants in Jordan,[7] while the study with the least number of participants included 54 patients in the UK.[8]

Data were gathered from several different countries – Canada, China, Chile, Jordan, Iraq, Russia, Saudi Arabia, the United Kingdom, and the United States. One study included data obtained from 3 different countries including Brazil, South Africa, and the UK. Data for the studies were gathered between November 2020 and January 2022 and published between 2021 and 2022. Their objectives ranged from investigating or comparing the safety of certain vaccines to measuring the severity of adverse effects on the public or certain groups (e.g., People Living with HIV (PLWH), pregnant women, etc.) [Table 1].

For attitudes towards COVID-19 vaccines, the total number of participants for the 7 selected studies is 18,441. The study with the highest number of participants included 11,478 parents in the USA,[9] and the study with the smallest number of participants involved 73 adults living with diabetes mellitus (DM) in 11 Sub–Saharan Africa (SSA) countries [Table 2].[10]

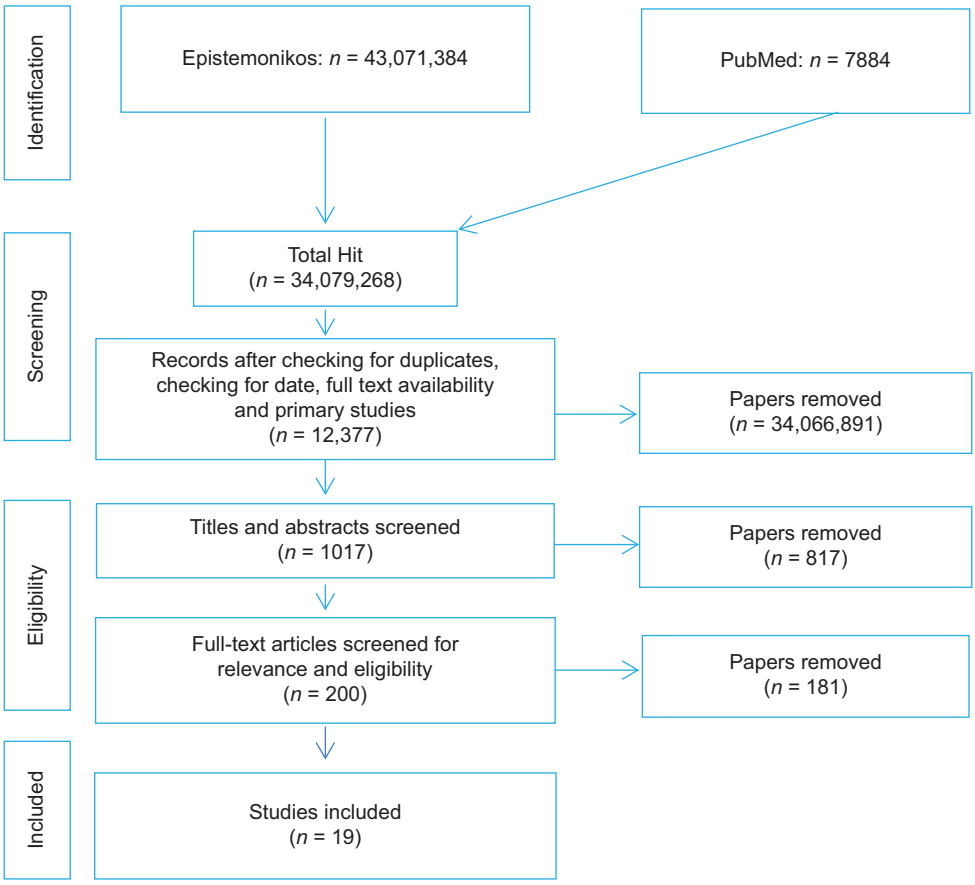

Figure 1: Flow diagram showing study selection results following PRISMA recommendations

Data for the studies were gathered between 2021 and 2022 from countries including the United States, Saudi Arabia, Ireland, Iran, and Egypt, while one study had an international participants population. All study objectives were centered on investigating general vaccine hesitancy by certain groups (parents, healthcare workers [HCWs], etc.), and the underlying factors.

Vaccines studied

A total of 7 vaccines were studied by the 12 papers including BNT162b2, BBIBP-CorV, WIBP-CorV, ChAdOx1 nCoV-19, CoronaVac, Gam-COVID-Vac, and mRNA-1273. Five papers compared data between vaccines. The most studied vaccines were BNT162b2 and ChAdOx1 nCoV-19 which were investigated by 6 studies. BNT162b2 is the mRNA vaccine developed by Pfizer and approved for use against COVID-19,[11] and ChAdOx1 nCoV-19 (also known as ChAdOx1-S or AZD1222) a replication-deficient adenoviral vector vaccine developed by AstraZeneca.[12,13] The Moderna vaccine mRNA-1273 which is a lipid nanoparticle-encapsulated mRNA vaccine[14] was investigated by 2 papers. Gam-COVID-Vac and the two sinopharm vaccines - BBIBP-CorV and WIBP-CorV which are both inactivated virus vaccines were also investigated by 2 papers each. The CoronaVac vaccine developed by the Chinese company Sinovac was investigated in 1 paper.

Discussion

Efficacy of COVID-19 vaccines

The efficacy of vaccines can be measured by their ability to reduce hospitalizations, prevent infections or re-infections, and reduce the mortality rate of the disease.

Reduction of COVID-19 mortality rate

The mortality rate due to COVID-19 is 1.1% in the United States.[29] Abdel Qader *et al*.[7] reported that the overall mortality rate for people without pre-existing conditions after vaccination with BNT16b2, BBIBP CorV, and ChAdOx1 reduced to 0.002% (<0.1%), while for the four vaccines, the mortality rate for people with preexisting conditions was 0.009% (<0.1%) [Table 1],[7] which is a significant reduction although it is more than 4 times higher than the mortality rate for people without preexisting conditions. Contrarily, other findings show up to 12 times higher mortality among people with preexisting conditions.[30] A study published in the China CDC Weekly revealed that the mortality rate for people with cardiovascular disease was 10.5% as against 0.9% for those without comorbidities.[31] However, Saadh and Jaber[19] studied the relative effectiveness of 3 vaccines including BNT162b2, BBIBP-CorV, and ChAdOx1 nCoV-19 vaccines for 6,132 adults with diabetes, and chronic cardiovascular and respiratory conditions; the death rate in patients was 7.9%–25.1% after the first dose, with a reduction 0.175% (~0.2%) to 2.7% after the

Table 1: Data chart for papers on safety/efficacy

Study	Primary aim	Population	Vaccine studied	Result
[7]	Aimed at investigating and comparing the nature and severity of AEFIs with COVID-19 vaccines Safety and efficacy	658,428 participants in Jordan (610,591, 279,606, 140,843 and 1390 received BNT16, BBIBP-CorV, ChAdOx1 nCoV-19 and Sputnik V vaccines, respectively) Between 1 January and 21 September 2021 Jordan	BNT162b2 (Pfizer) BBIBP-CorV (Sinopharm) ChAdOx1 nCoV-19 (AstraZeneca) Gam-COVID-Vac (Sputnik V)	Overall incidence of adverse effects: 28.8% Hospitalization rate following vaccination: 20 in 10,000 Mortality rate following vaccination: 1 in 10,000 Side effects identified for BNT162b2, BBIBP-CorV, ChAdOx1 nCoV-19 and Gam-COVID-Vac respectively Pain at site of injection (24.1%, 8.4%, 19.9%, 28.2%), fatigue (14.4%, 7.4%, 30.3%, 34.1%), fever (10.3%, 4.3%, 28.5%, 27.3%), headache (9.9%, 5.7%, 20.6%, 11.4%) Vaccine prompting most severe AEFIs: ChAdOx1 nCoV-19 (1st dose), BNT162b2 (2nd dose)
[19]	Aimed at evaluating the relative effectiveness of 3 vaccines for adults with chronic cardiovascular and respiratory conditions and diabetes Efficacy	6132 adult participants in Jordan (mean age 52±17 years, grouped into 1 dose and 2 doses recipient) Between July 2021 and 2022 Jordan	BNT162b2 (Pfizer) BBIBP-CorV (Sinopharm) ChAdOx1 nCoV-19 (AstraZeneca)	For any vaccine The death rate in patients: 0.175%–2.77% (2 doses); 7.98%–25.13% (1 dose) Hospitalization: 6%–7.97% (2 doses); 7.98%–25.13% (1 dose) Infection without hospitalization: 6%–25.1% (2 doses); 0.69%–10.61% (1 dose)
[20]	Investigating the efficacy of mRNA-1273 SARS-CoV-2 vaccine Efficacy	30,415 high-risk participants (15,209 received mRNA-1273 vaccine, 15,206 received placebo Data cutoff date: 26 March 2021 United States	mRNA-1273 (Moderna)	Efficacy in preventing COVID-19: 93.2%: 55 cases in the mRNA-1273 group, 744 in the placebo group (median follow-up: 5.3 months) Efficacy in the prevention of severe disease: 98.2% (2 cases in an mRNA-1273 group, 106 in placebo) Efficacy in preventing asymptomatic infection 14 days after the second dose: 63 (214 cases in the mRNA-1273 group; 498 in the placebo group)
[21]	To evaluate the efficacy of COVID-19 vaccines in Iraqi peoples Efficacy	250 Iraqi patients who recovered from COVID-19 (228 vaccinated, 22 not vaccinated) From June 1 to August 30, 2021 Iraq	BNT162b2 (Pfizer) WIBP-CorV (Sinopharm) ChAdOx1 nCoV-19 (AstraZeneca)	Prevention efficacy Pfizer efficacy: 93.75% AstraZeneca efficacy: 89% Sinopharm efficacy: 73.5% Re-infection rate after 1 dose: AstraZeneca (43%), Pfizer (16.6%), Sinopharm (5.5%) Reinfection after 2 doses: Sinopharm (94.5%), Pfizer (83.5%), AstraZeneca (43%) Postvaccination symptoms are lower than prevaccination symptoms Asymptomatic cases postvaccination is higher than prevaccination for all vaccines
[22]	To compare the immune response and safety of inactivated COVID-19 vaccine between PLWH and HNC Safety and efficacy	84 Chinese adult participants (46 PLWH, 38 HNC, all double vaccinated with WIBP-CorV 28 days apart) 70 days follow-up From March to June 2021 China	WIBP-CorV (Sinopharm)	Frequency of adverse reactions for 1st dose: PLWH=30%; HNC=32%. 2nd dose: PLWH=11%, HNC=24%) Weaker and delayed humoral immune response for PLWH
[23]	Evaluation of the safety and efficacy of ChAdOx1 nCoV-19 Efficacy	11,636 adults from Brazil, the UK, South Africa Data gathered between April 23 and November 4, 2020 Brazil, the UK, South Africa	ChAdOx1 nCoV-19 (AstraZeneca)	Vaccine efficacy for 2 standard doses=62.1% Efficacy for low dose followed by standard dose: 90% Overall vaccine efficacy: 70.4% Serious adverse events following infection: 79 severe in the vaccinated group; 89 in the control group

Contd...

Table 1: Contd...

Study	Primary aim	Population	Vaccine studied	Result
[8]	Exploring the safety and immunogenicity of ChADOx1 nCoV-19 in PLWH in London, UK Safety	54 males HIV patients aged 18–55 on ART (given 2 doses about 5 weeks apart, compared with HIV-uninfected group with the same demographics and dosing strategy) November 5–24, 2020 United Kingdom	ChAdOx1 nCoV-19 (AstraZeneca)	No SAEs Local and systemic reactions occurred including: Nausea (8%), joint pain (9%), muscle aches (36%), chills (23%), malaise (34%), headache (47%), fatigue (47%), pain at the injection site (49%)
[24]	Investigation of safety of two immunization schedules of Corona Vac Safety	2212 healthy adults (receiving 2 doses 14 or 28 days apart) Chile Data cutoff: October 2021	CoronaVac (Sinovac)	No SAEs Mild local and systemic adverse effects were reported by 31.2% and 32.9% with 14 days and 28 days of vaccination respectively Adverse effects after at least 1 dose included pain at the injection site (26.6%), headache (20%–26%), myalgia (11%–14%) and fatigue (12%–17%) Minor allergic reactions (2%), fever (1%)
[25]	Aimed at describing the safety and efficacy of the Gam-COVID-Vac vaccine in people with active GU malignancies Safety	122 participants with GU malignancies were surveyed anonymously online (average age: 66, all received 2 doses within 21 days) Russia February 11–August 31, 2021	Gam-COVID-Vac (Sputnik V)	No severe adverse effects 81% experienced mild adverse effects including injection site reactions (76%), flu-like illness (68%), asthenia (49%), chills (4.5%), fever (2.7%)
[26]	Investigating significant health events in pregnant women after mRNA vaccination with COVID-19 Safety	9044 pregnant women aged 15–49 years (unvaccinated: 339, vaccinated: 5597 (1 dose), 3108 (2 doses) Data cutoff: November 4, 2021 Canada	BNT162b2 (Pfizer) mRNA-1273 (Moderna)	Overall reported significant health event: 1 dose: 4% 2 doses: 7.3% Unvaccinated: 3.2% For mRNA-1273, significant health event: 12.1% after 2 doses
[27]	Investigation of the side effects of the BNT162b2 vaccine Safety	1245 vaccinated HCWs participants (803 vaccinated with BNT162b2; 442 vaccinated with mRNA-1273; average age: 43; 86.55% females) January 24–March 10, 2021 United States	BNT162b2 (Pfizer)	After the second dose, participants reported experiencing Localized symptoms (89.54%) Reaction at the injection site (88.04%), itching (5.35%) Generalized symptoms (75.97%) Fatigue (58.89%), headache (45.48%), chills (36.6%), fever (21.99%), sweating (9.64%), dizziness, 9.04%), flushing (8.13%) As a result of symptoms, 79.7% were unable to continue ADL
[28]	Investigation of the adverse effects of vaccines in the short term Safety	398 adult participants (56.3% vaccinated with Pfizer, 43.7% vaccinated with AstraZeneca; 22.6% received 2 doses) July–December 2021 Saudi Arabia	BNT162b2 (Pfizer) ChAdOx1 nCoV-19 (AstraZeneca)	Average side effects: 3.4±2.2 More side effects with ChAdOx1 nCoV-19 Side effects include: Pain at the injection site (85.2%), joint or bone pain (54%), fatigue (61.8%) and fever (42.5%) More risk of side effects for females, young people

DM=Diabetes mellitus, AEFIs=adverse events following immunization, PLWH=People living with HIV, HNC=HIV negative controls, HCWs: Healthcare workers, HNC=HIV negative controls, ADL=Activities of daily living, ART=Antiretroviral therapy, GU=Genitourinary, SAEs=Serious adverse effects

second dose. These show that the vaccines reduced mortality even in people with preexisting conditions.

Preventing COVID-19 hospitalizations

The hospitalization rate after vaccination was reported to be 0.002% (<0.1%) after 2 doses of BNT162b2, BBIBP-CorV, or ChAdOx1 nCoV-19 vaccines.[7] For people living with diabetes, and chronic cardiovascular and respiratory conditions, Saadh and Jaber[19] showed that hospitalizations also reduced with a range of 7.9%–25.1% with one dose to 6.0%–7.9% after a second dose of BNT162b2, BBIBP-CorV, and ChAdOx1 nCoV-19 vaccines after two doses. In addition, they also showed that infections without the need for hospitalization increased between 0.7% AND 10.6% after one dose of vaccine to 6.0% to 25.1% after two doses. These may be attributed to the possibility of adherence to precautions and increased movements among vaccinated people. Regardless, the studies showed reduced hospitalization rates following a COVID-19 vaccination, especially for people with preexisting conditions such as cardiovascular disease, diabetes, and chronic lung

Table 2: Data chart for papers on attitudes/factors

Study	Aim	Population	Data/attitude/perceptions	Factors
[5]	Investigation of COVID-19 vaccine hesitancy by parents in Saudi Arabia	500 parents with children<12 (average age: 37.31, 78.6% mothers) August 2021–February 2022 Saudi Arabia	38.6% hesitancy 18.4%: Vaccines will not strengthen the immune system 23%: Risks are greater than benefits 26.4% of vaccines are not safe for children 10.4%: Vaccines will cause SAEs in children	Parents who opted for vaccination were mothers, older, married and employed, not being aware of a child who has suffered a serious reaction from the COVID-19 vaccines Predictors of vaccination: Age of parents, educational level, children's age, belief in the safety of COVID-19 vaccines for children, acceptance of the vaccine
[10]	Assessment of COVID-19 vaccine hesitancy among people with DM	73 adults with DM (65.8% males, 72.6% married 19.2% confirmed positive for COVID-19, 6.8% vaccinated) March–May 2021 11 SSA countries (82.2% from South Africa, Nigeria and Ghana)	91.8% hesitancy 35.7%: Do not perceive themselves as being at risk	Unwilling people were advised by religious leaders (36%); distrusts of the vaccine country of origin, the medical process of its development, the pharmaceutical company or the health system in one's country (35%); concerned about vaccine safety (21%); has personal beliefs/past experiences (8%) People significantly less likely to receive the vaccine include those who: Have safety concerns and have performed a COVID-19 test in the past
[9]	Evaluation of the factors for parent's hesitation to child's COVID-19 vaccination	11478 parents with children 5–11 or 12–17 (57.7% children and 25.2% adolescents unvaccinated) December 29, 2021–January 10, 2022 USA	19% of parents are hesitant about vaccinating their children 12.6% are hesitant about vaccinating their adolescents	Unvaccinated parents were less likely than vaccinated parents to vaccinate their children (54.8% against 10.8%) or adolescents (59% against 3.9%) respectively Reason for hesitancy: Concern about adverse effects (63.6% and 62.4%), desire to "wait and see" (45.5% and 32.9%), distrust of the vaccines (41.1% and 11.9%), distrust of government (31.3% and 14.5%) and belief vaccine is unnecessary for a child (28% and 18%)
[15]	Assessment of vaccine acceptance among HCWs	171 dental teaching staff (84.8% female, 76% frontline HCWs) August 2021–October 2021 Egypt	46.7% oppose vaccination 7.6% hesitant 9.4% reported not ever following COVID-19 guidelines	Participants that were less likely to accept vaccination: Females (40.7%), people who did not promptly receive other recommended vaccines (82.7%) The refusal group also believed that trials were too short, desired to wait for more public acceptance, did not trust the manufacturers, and do not intend to travel abroad
[16]	Investigation of public misperceptions of COVID-19 Vaccine in Ireland	1821 Irish participants May 31–June 21, 2022 Ireland	57% of participants believe the COVID-19 vaccine to be 49% effective on average	Older participants had higher opinions on vaccine effectiveness Participants aged 60 and above believed the vaccine will save more lives (72.1 lives out of 100) as opposed to those aged 18–39 (64.7 lives out of 100)
[17]	Evaluating the factors affecting vaccine hesitancy	801 participants (average age: 37.92, 53.3% male) Iran	43.7% say adverse effects outweigh benefits 40.4% are not sure of vaccine efficacy 32.8% distrust vaccine manufacturers	People more likely to be vaccine hesitant: Low socioeconomic status, people who strongly believe they are immune, people unsure of efficacy, people who distrust vaccines and the manufacturers
[18]	Investigating the relationship between misinformation about COVID-19 vaccines and vaccine hesitancy in the US	3597 participants April 2021–January 2022 United States	40% of participants with the highest misinformation accepted vaccination	Worrying about infection led to an increase in the vaccination rate Increased vaccination was linked to less misinformation, increased age, more education and more income

DM=Diabetes mellitus, HCW=Healthcare worker, SAEs=Serious adverse effects

disease.[30] For people who got infected with the COVID-19 vaccine after receiving the mRNA-1273 vaccine, its efficacy in preventing severe disease was recorded at 98.2%. They found that 2 persons who had received the vaccine got severely sick with the disease as opposed to 106 persons who had received a placebo.[20] Post-vaccination COVID-19 symptoms were shown to be lower than pre-vaccination symptoms for BNT162b2, ChAdOx1 nCoV-19, and WIBP-CorV vaccines.[21] Voysey *et al*.[23] reported that the number of persons who experienced serious symptoms after getting infected with the COVID-19 virus was fewer (79) in the vaccinated group than those (89) in the control/unvaccinated group.

Reduction of COVID-19 cases

The first task of an efficacious vaccine is to prevent the establishment of infection by the virus. A study of the mRNA-1237 (Moderna) vaccine among 30,415 participants found a 93.2% efficacy in preventing infection with only 55 vaccine recipients getting infected compared with 744 unvaccinated individuals.[20] Furthermore, Jawad *et al*.[21] reported overall prevention efficacy of 93.75% for BNT162b2 vaccine, 89.0% for ChAdOx1 nCoV-19, and 73.5% for WIBP-CorV among the Iraqi population, respectively. These demonstrated the high protection provided by the three vaccines. Similarly, Voysey *et al*.[23] further tested the prevention efficacy of ChAdOx1 nCoV-19 and reported overall vaccine efficacy of 70.4%. Although this was lower, their study reported a peculiar pattern of a dose-response relationship; a low dose followed by a standard dose led to an efficacy of 90.0%, while receiving two standard doses led to an efficacy of 62.1% with an average of 71.0% efficacy. The difference was later attributed to dose measurement errors due to ancillary vaccine materials (excipients); this was then corrected and utilized by the researchers to better determine the minimum effective (immunogenicity) dose of the product.

Some viral infections stimulate a sufficient immune response against the virus, thereby preventing reinfection, but this was less observed with the COVID-19 virus, making vaccinations a necessity. Jawad *et al*.[21] tested the abilities of BNT162b2, ChAdOx1 nCoV-19, and WIBP-CorV vaccines to inhibit reinfection. They found that the reinfection rate increased with increased dosage of the BNT162b2 vaccine which showed 16.6% after 1 dose, to 83.5% after 2 doses; and WIBP-CorV vaccine which showed 5.5% after 1 dose, to 94.5% after 2 doses. For ChAdOx1 nCoV-19, the reinfection rate stays constant at 43.0% after 1 and 2 doses. Zou *et al*.[22] showed that for PLWH/AIDS, the humoral immune response following vaccination by WIBP-CorV was lower than for HIV-negative controls. In addition, the number of asymptomatic cases after vaccination was reported to be higher than before vaccination for BNT162b2, ChAdOx1 nCoV-19, and WIBP-CorV vaccines.[21] These statistics follow the general pattern of vaccine effectiveness in reducing rates of infections or reducing associated morbidity.

Safety of COVID-19 vaccines

How the body reacts to a vaccine is a very important factor to consider when tackling vaccine hesitancy. Many people have refused the available vaccines because they had concerns over the potential negative effects associated with them.[5,9,10] No serious adverse effects following COVID-19 vaccination. None were reported for ChAdOX1 nCoV-19 vaccine,[8] CoronaVac,[24] Gam-COVID-Vac.[25] For the mild events, Abdel-Qader *et al*.[7] studied 4 COVID-19 vaccines including BNT162b2, BBIBP-CorV, and ChAdOx1 nCoV-19, and reported an overall adverse effects incidence of 28.8%. The side effects mostly reported were lymphadenopathy (0.2%), anxiety disorders (0.1%), and lower respiratory tract infections 0.1%). The first dose of ChAdOx1 nCoV-19 and the second dose of BN5162b2 prompted the most severe adverse events following immunization.

According to Zou *et al*.,[22] the adverse effects following immunization with WIBP-CorV reached 32.0% after the first dose and 24.0% after the second dose. For PLWH, the statistics were better at 30.0% after the first dose and 11.0% after the second dose due to a weaker humoral immune response.[22] Several pieces of evidence support that the COVID-19 vaccines are safe for use by PLWH, more especially those receiving antiretroviral therapy.[32,33]

Meanwhile, Frater *et al*.[8] reported certain systemic and local reactions following immunization with the ChAdOx1 nCoV-19 vaccine. The experience by more than a third of their population include headache, fatigue, pain at the injection site, muscle ache, and malaise. Abarca *et al*.[24] also reported pain at the injection site, headache, and fatigue as common adverse effects following vaccination with CoronaVac, but also included myalgia. Another study reported chills, fever, injection site reactions, and flu-like illness after 6.2 months of follow-up.[25]

Among pregnant women, Sadarangani *et al*.[26] found that following vaccination with an mRNA vaccine, including BNT162b2 and mRNA-1273, significant health occurred among the participant (4.0% after 1 dose, 7.3% after 2 doses) while unvaccinated counterparts had 3.2% of such events. Nevertheless, this did not translate into increased doctor consultations for vaccinated pregnant women and nor to more negative birth outcomes.

Kadali *et al*.[27] tested for the side effects of BNT162b2 among 1245 vaccinated HCWs and reported that 89.5% had localized symptoms including reaction at the injection site and itching. Furthermore, 75.9% reported generalized symptoms including fatigue (58.9%), headache (45.4%), chills, (36.6%), fever (21.9%), and sweating (9.6%). The symptoms were severe enough to hinder 79.7% from performing activities of daily living. According to Alzarea *et al*.,[28] the average number of reported side effects by the 398 participants who had at least 1 dose of BNT162b2 or ChAdOx1 nCoV-19 vaccine was 3.4 ± 2.2. The side effects reported included pain at the injection site (85.2%), joint or bone pain (54.0%), fatigue (61.0%), and fever (42.5%). They also reported that females and young people were more at risk of experiencing side effects from the vaccines. The study also reported that participants who had received the ChAdOx1 nCoV-19 vaccine experienced more side effects than those who had received BNT162b2. In general, the studies showed that the vaccines were safe for use with only mild side effects as shown in Table 3.

Attitudes toward COVID-19 vaccination

Vaccine hesitancy is observed to be high across the studies. Almansour *et al*.[5] investigated vaccine hesitancy among 500 parents, mostly mothers, in Saudi Arabia and found hesitancy among 38.6% of the study population. A study of

people living with DM in SSA reported a vaccine hesitancy of 91.8%.[10] Opposition to vaccination among HCWs in Egypt was reported as 46.7% and hesitancy was 7.6%;[15] while 9.4% of the respondents from that study reported not obeying COVID-19 guidelines. Some of the negative attitudes and misconceptions surrounding the vaccine include disbelief in the efficacy of vaccines (18.4%), safety concerns (26.4%), and fear of adverse effects in children (10.4%). Similarly, 23.0% of the population believes that COVID-19 vaccines pose greater risks than benefits.[5]

In Ireland, 57.0% of the perceived effectiveness of the COVID-19 vaccine averaged about 49.0%.[16] This is a significant deviation from the average efficacy of 82.1% [Table 4] previously calculated and reveals a lack of awareness about the actual efficacy of the vaccines.

Table 3: Major reported side effects and average prevalence

Side effect	Vaccine	Average percentage prevalence (count)
Reaction/ pain at the injection site	BNT162b2	65.8 (3)
	BBIBP-CorV	8.4 (1)
	ChAdOx1 nCoV-19	51.7 (3)
	Gam-COVID-Vac	52.1 (2)
	CoronaVac	26.1 (1)
Joint or bone pain	BNT162b2	54.0 (1)
	ChAdOx1 nCoV-19	31.5 (2)
Fatigue	BNT162b2	45.0 (3)
	BBIBP-CorV	7.4 (1)
	ChAdOx1 nCoV-19	46.4 (3)
	Gam-COVID-Vac	34.1 (1)
	CoronaVac	14.5 (1)
Fever	BNT162b2	26.4 (2)
	BBIBP-CorV	4.3 (1)
	ChAdOx1 nCoV-19	35.5 (2)
	Gam-COVID-Vac	15.0 (2)
	CoronaVac	1.0 (1)
Itching	BNT162b2	5.4 (2)
Headache	BNT162b2	27.7 (2)
	BBIBP-CorV	5.7 (1)
	CoronaVac	23.0 (1)
	ChAdOx1 nCoV-19	33.8 (2)
	Gam-COVID-Vac	11.4 (1)
Chills	BNT162b2	36.6 (1)
	Gam-COVID-Vac	4.5 (1)
	ChAdOx1 nCoV-19	23.0 (1)

Table 4: Reported prevention efficacy of vaccines

Vaccine	Average prevention efficacy (%)
mRNA-1273 (Moderna)	93.2
BNT162b2 (Pfizer)	93.8
WIBP-CorV (Sinopharm)	73.5
ChAdOx1 nCoV-19 (AstraZeneca)	79.7
Total average	82.1

Meanwhile, 38.6% of parents in Saudi Arabia refused to vaccinate their children.[5] In the US, a survey showed that some parents refused to vaccinate their younger children and adolescents (19%) and adolescents (12.6%)[9], and several persons do not perceive themselves as being at risk, including 35.7% of participants suffering from DM in SSA.[10]

Factors contributing to vaccine hesitancy

General perception

Perceptions about vaccine efficacy and safety are major reasons for vaccine hesitancy for many participants; many of whom are hesitant about the vaccine because they are unsure about its efficacy.[17] People refused to receive the vaccine or let their children have it because they have safety concerns,[5,10] ranging up to 63.6% of parents among some populations.[9,15]

Lack of trust

Distrust toward the vaccine's manufacturers, the medical process that produced it, the vaccine's safety, and even the government is a major influence on choices.[10,15,17] Nguyen *et al*.[9] reported that 41.1% refused the vaccine for their children for lack of trust. About a third (31.3%) of study participants reported that they will not take the vaccines because they do not trust their government.[9] Other people would not receive the vaccine because they had no trust in their country's health system.[10]

History of hesitancy

Results from this review showed that people who had rejected vaccines in the past were more reluctant to get the COVID-19 vaccine, for themselves and/or their offspring.[5,9] One study reported that 82.7% of people who had refused to accept other recommended vaccines were hesitant to accept the COVID-19 vaccine.[15] This was partly due to perceived or actual negative experiences with either the COVID-19 vaccine or other vaccines in the past; or even because they believe they might have these negative experiences.[10] Certain parents would not even vaccinate their children because they have seen other children manifest adverse effects of the vaccine in the past.[5]

Personal feelings/beliefs

Participants in one study stated that their personal beliefs were the reason they were hesitant about vaccination;[10] others believed they were immune to the virus and therefore do not need the vaccine.[17] People who were worried about getting infected with the virus were more likely to get vaccinated.[18] More than a third of people in a study were less likely to receive the vaccine if they have been advised to the contrary by their religious leaders.[10,34]

Socioeconomic and employment

People who earn more were shown to be more likely to accept vaccination.[18] Maharlouei *et al*.[17] reported that among the 801 Iranian participants, those with low economic status were more likely to be vaccine-hesitant. In addition, people who were employed were more likely to choose vaccination for their children.[5]

Education and proper information

People with more education were shown to be more likely to accept vaccination with COVID-19 vaccines than those with less education.[5,18] Also, Romer *et al*.[18] checked for the role of misinformation and found that less misinformation meant an increased vaccination rate in their population.[18] This is like reports from Papua New Guinea where the vaccination rate was as low as 1.7% due to major misinformation.[35] Meanwhile, some people believe they do not need the vaccine unless they desire to travel abroad.[15]

Age, marital status, and gender

Lunn and Timmons[16] reported that participants who are 60 years and above believe the vaccine will save more lives and that generally, older participants had more positive opinions and receptiveness toward the vaccines.[5,18] Almansour *et al*.[5] further reported that married participants were also more likely to choose vaccination for their children, while Sharaf *et al*.[15] shows that fathers of females were generally less likely to accept vaccination than of males.

Conclusion and Recommendations

Conclusion

This review of COVID-19, as it relates to safety, efficacy, and the behavior towards 7 COVID-19 vaccines, shows that all the vaccines were efficacious in the reduction of COVID-19 incidence, reducing morbidity, prevention of hospitalization after infection, and reduction in the mortality rate of COVID 19 patients. The safety margins and minimum effective dose of the vaccines were determined in the clinical trials to ensure their safety for use. Although some studies revealed that the perceived efficacy and safety of the vaccines were higher than those recorded in the earlier analyses, there were misconceptions, mixed attitudes, and high hesitancy toward the COVID-19 vaccine from most studies reviewed. Several factors were identified for this, including distrust of the vaccines, the manufacturers, the governments, and different institutions, as well as personal beliefs and feelings, age, gender, education, and socioeconomic status.

Recommendations

- Publicity of the vaccines should be structured around communicating data about their efficacy and safety, as these are the major factors influencing vaccination hesitancy, especially for parents
- Clinical research data on COVID-19 and subsequent vaccines should be made readily available to enhance informed decision-making
- The communication about COVID-19 and other vaccines should put people's sociodemographics into consideration to effect meaningful information to disparate groups or populations
- Biotechnological advancements in drugs and vaccine development should consider creating transparent public awareness and sensitization
- COVID-19 vaccine safety in pregnancy and children should be further and carefully studied especially in phase 4 of clinical trials.

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Conflicts of interest

There are no conflicts of interest.

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