Literature screening report

COVID-19 vaccines in the WHO's Emergency Use Listing (EUL): report (4)

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Abstract

This report focuses on the World Health Organization's (WHO) Emergency Use Listing (EUL) of authorized vaccines as of 13 September 2021. Currently six vaccines are authorised for emergency use: BNT162b2/COMIRNATY (Pfizer-BioNTech, USA), Spikevax/Moderna COVID-19 Vaccine/ mRNA-1273 (Moderna, USA), Vaxzevria/ChAdOx1 nCoV-19/AZD1222/Covishield (AstraZeneca/Oxford, UK, India), Janssen Covid-19 vaccine/Johnson & Johnson (Janssen, USA), Sinopharm/BBIBP-CorV (China), and Sinovac/CoronaVac (China). This report provides a condensed summary concerning vaccine efficacy, safety, protection against variants, and further important information for each vaccine, in the form of a synoptic table. Additionally, information regarding the yet-to-be-approved[1] Novavax vaccine NVX-COV2373 was added to the table, upon request of the Federal Office of Public Health (FOPH). Novavax is currently awaiting FDA and WHO EUL approval after assessing safety and immunogenicity in Phase 1/2 clinical trials. NVX-CoV2373 is currently in two pivotal Phase 3 studies to

[1] Currently undergoing Phase III clinical trials. WHO and EMA are reviewing Novavax's rolling application.

evaluate vaccine efficacy, safety, and immunogenicity[2]. The information and data in this synoptic table was extracted from phase III clinical trials and from observational studies. This report particularly focuses on vaccine efficacy and effectiveness, including variants, booster doses, and safety concerns such as myocarditis cases reported after COVID-19 vaccination in adults and children.

Content

Preamble

A large number of scientific publications become available on a daily basis, reflecting the rapid development of knowledge and progress of science on COVID-19 related issues. Leading authorities should base decisions or policies on this knowledge; hence they need to master the actual state of this knowledge. Due to the large number of publications shared daily, decision makers heavily depend on accurate summaries of these publications, in the different public health domains. Therefore, the authors of this report were mandated by the Swiss School of Public Health plus (SSPH+), upon request of the Federal Office of Public Health (FOPH), to inform the FOPH on recent findings from the literature.

[2] All Updates On Our COVID-19 Vaccine Efforts. *NOVAVAX*. https://www.novavax.com/covid-19-coronavirus-vaccine-candidate-updates

Background

According to the current global data on vaccinations, only 41.8% of the world populations, of which only 1.9% of people in low-income countries, have received at least one dose of a marketed COVID-19 vaccine as of 13 September, 2021[3]. Currently, six vaccines [namely, Pfizer-BioNTech, USA), Spikevax/Moderna COVID-19 Vaccine/ mRNA-1273 (Moderna, USA), Vaxzevria/ChAdOx1 nCoV-19/AZD1222/Covishield (AstraZeneca/Oxford, UK, India), Janssen Covid-19 vaccine/Johnson & Johnson (Janssen, USA), Sinopharm/BBIBP- CorV (China), and Sinovac/CoronaVac (China)] were assessed and granted an authorization by WHO as of 19 August 2021. Articles regarding vaccine effectiveness, vaccine efficacy and effectiveness against variants of concern (VOC), myocarditis data, booster doses, and information on the vaccine candidate Novavax were prioritized during the literature search and are the latest additions to the table. Data from clinical trials and observational studies for the six EUL-accepted vaccines and the vaccine candidate Novavax regarding these highlighted topics was summarized and can be found in the synoptic table below.

Methodology

We screened the data for the EUL-accepted vaccines and the vaccine candidate Novavax as of 13 September 2021 from PubMed, Embase, medRxiv, bioRxiv, Cochrane, and clinical trials databases such as ClinicalTrials and WHO Trial Registry. The methods used were reported previously and can be found in prior reports.

[3] https://ourworldindata.org/covid-vaccinations (accessed on 13.09.2021).

Results

As phase III COVID-19 vaccine trials confirmed vaccine efficacy and safety for all six WHO EUL authorized vaccines, and as the share of fully vaccinated people begin to slowly increase across countries, it is important to assess vaccine effectiveness in real-world conditions, especially in relation to evolving variants of concern (VOC).

With the global spread of VOCs[4] and enquiries surrounding vaccine duration of protection, it is important to track vaccine effectiveness over time. Data from observational studies have demonstrated reduced effectiveness against the Delta (B.1.617.2) for all six WHO EUL approved vaccines when compared to prior viral strains. Effectiveness studies in Canada[5], Scotland[6], and England[7] demonstrated Pfizer-BioNTech's BNT162b2 vaccine effectiveness against the Delta variant to be similar across populations, ranging from 79-88%. Israel, however, reports the BNT162b2 vaccine to have an effectiveness of only 39% against SARS-CoV-2 infection[8]. It is still uncertain why Israel demonstrates lower BNT126b2 effectiveness compared to other countries; vaccine effectiveness is regulated by a variety of factors, including demographic, host, and viral variant, at the individual and population level, which could explain effectiveness differences[9]. A recently published study that was conducted in five U.S. states over the month of July (period of high Delta variant prevalence) corroborated the Israeli data: the BNT162b2 vaccine had an effectiveness of 42% against the Delta variant[10]. The authors concluded that the reduced effectiveness could be due to "waning immunity over time" or the "dynamic landscape of SARS-CoV-2 variants". The same study reported Moderna's mRNA-1273 vaccine to have an effectiveness of 76% against the B.1.617.2 strain. Few observational studies have thus far been published on Moderna's mRNA-1273 vaccine effectiveness against the Delta variant; additional studies are needed to corroborate the vaccine's effectiveness in other populations. Astra-Zeneca's ChAdOx1 nCoV-19 and

[4] Effectiveness data against the latest emerging variant of interest (Mu) will be included in the upcoming reports based on data availability.
[5] Effectiveness of COVID-19 vaccines against variants of concern in Ontario, Canada. *medRxiv.* https://www.medrxiv.org/content/10.1101/2021.06.28.21259420v2
[6] SARS-CoV-2 Delta VOC in Scotland: demographics, risk of hospital admission, and vaccine effectiveness. *The Lancet.* https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01358-1/fulltext
[7] Effectiveness of Covid-19 Vaccines against the B.1.617.2 (Delta) Variant. *The New England Journal of Medicine.* https://www.nejm.org/doi/10.1056/NEJMoa2108891
[8] Vaccine efficacy among those first vaccinated. *State of Ministry of Health.* https://www.gov.il/BlobFolder/reports/vaccine-efficacy-safety-follow-up-committee/he/files_publications_corona_two-dose-vaccination-data.pdf
[9] Progress of the COVID-19 vaccine effort: viruses, vaccines and variants versus efficacy, effectiveness and escape. *Nature Reviews Immunology.* https://www.nature.com/articles/s41577-021-00592-1
[10] Comparison of two highly-effective mRNA vaccines for COVID-19 during periods of Alpha and Delta variant prevalence. *medRxiv.* https://www.medrxiv.org/content/10.1101/2021.08.06.21261707v3.full-text

Janssen's Johnson & Johnson vaccine demonstrates 60-67%[11,12] and 78%[13] effectiveness against the Delta variant, respectively. Sinovac's Coronavac demonstrates better vaccine effectiveness against the Delta variant (59%)[14] than the Gamma variant (50.7%)[15]. Despite reduced effectiveness against SARS-CoV-2 infection, vaccine effectiveness against hospitalization remains high for all vaccines after their recommended full-dose schedule (see synoptic table below). Little data has been released on Sinopharm's BBIBP-CorV vaccine effectiveness thus far, particularly against VOCs. On 30 August 2021, a new variant, the Mu variant (B.1.621), was added to the WHO's list of variants of interest. Published vaccine effectiveness data against the Mu variant has until now been sparse and will be included in upcoming reports based on data availability.

With approval of the administration of COVID-19 mRNA vaccines in children aged 12 years and older, some concerns regarding the safety of those vaccines, especially after the observation of myocarditis and pericarditis in adolescents and young adults, rose among the community. The majority of the reported cases were observed in young males following the second dose of the two mRNA vaccines (BNT162b2 and mRNA-1273), developed symptoms most commonly within 3 days of vaccination, and documented complete clinical recovery in 1-3 weeks post symptoms with no readmission or deaths[16,17,18]. As the risk of myocarditis among mRNA COVID-19 vaccinees became a possibility, the United States Advisory Committee for Immunization Practices (ACIP) assessed the benefit-risk balance of mRNA vaccines in adolescents and young adults using individual-level assessments that compared the benefits (i.e., COVID-19 infections and severe disease prevented) to the risks (i.e., number of myocarditis) of vaccination[19]. The results ended up demonstrating that the benefits of preventing

[11] SARS-CoV-2 Delta VOC in Scotland: demongraphics, risk of hospital admission, and vaccine effectiveness. *The Lancet.* https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)01358-1/fulltext

[12] Effectiveness of Covid-19 Vaccines against the B.1.617.2 (Delta) Variant. *The New England Journal of Medicine.* https://www.nejm.org/doi/10.1056/NEJMoa2108891

[13] Effectiveness of the Single-Dose Ad26.COV2.S COVID Vaccine. *medRxiv.* https://www.medrxiv.org/content/10.1101/2021.09.10.21263385v1

[14] Effectiveness of inactivated SARS-CoV-2 vaccines against the Delta variant infection in Guangzhou: a test-negative case–control real-world study. *Emerging Microbes & Infections.* https://www.tandfonline.com/doi/full/10.1080/22221751.2021.1969291

[15] The Sinovac-CoronaVac COVID-19 vaccine: What you need to know. *World Health Organization*. https://www.who.int/news-room/feature-stories/detail/the-sinovac-covid-19-vaccine-what-you-need-to-know?gclid=Cj0KCQjw4eaJBhDMARIsANhrQADBYtFm2zMvzbfjthveE2gmCJTRI_jPc4HPlIFSwdZpzTix45gmEM0aAml9EALw_wcB

[16] Myocarditis and Pricarditis Following mRNA COVID-19 Vaccination: What Do We Know So Far? *Children – MDPI.* https://www.mdpi.com/2227-9067/8/7/607/htm

[17] Myocarditis and Pericarditis After Vaccination for COVID-19. *JAMA.* https://jamanetwork.com/journals/jama/fullarticle/2782900

[18] Myocarditis After BNT162b2 and mRNA-1273 Vaccination. *Circulation – AHA.* https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.121.055913

[19] Use of mRNA COVID-19 Vaccine After Reports of Myocarditis Among Vaccine Recipients: Update from the Advisory Committee on Immunization Practices – United States, June 2021. *CDC Morbidity and Mortality Weekly Report (MMWR).* https://www.cdc.gov/mmwr/volumes/70/wr/mm7027e2.htm?s_cid=mm7027e2_w

COVID-19 disease and associated hospitalization, ICU admissions, and deaths outweighed the risks of expected myocarditis cases after vaccination. Among males aged 12-29 years old, 11000 COVID-19 cases, 560 hospitalizations, 138 ICU admissions, and six deaths due to COVID-19 could be prevented per million second dose of mRNA COVID-19 vaccine compared to 39-47 expected myocarditis cases after COVID-19 vaccination. As for males aged ≥30 years old, 15300 COVID-19 cases, 4598 hospitalizations, 1242 ICU admissions, and 700 deaths could be prevented compared with three to four expected myocarditis cases after COVID-19 vaccination.

As more countries have started the administration of booster doses to immunocompromised, older population, healthcare workers, or the general population, the safety, immunogenicity, and ethical concerns regarding booster doses have become important topics of discussion. ECDC and EMA have stated that booster doses should already be considered for immunocompromised as part of their primary vaccination. Additionally, they are currently considering the administration of booster doses to the general population as there is no urgent need for its administration to fully vaccinated individuals[20]. Most of the vaccine schedules for booster doses are homologous (administering a booster dose from the same vaccine type as the primary immunization), however some countries and ongoing clinical trials are offering and testing heterologous vaccine schedules. Booster doses have been recommended and tested for administration 6 to 8 months after initial vaccination regimen, except for Israel who is currently offering COVID-19 booster shots as soon as 5 months after full jab administration[21]. Overall, the booster dose for the Comirnaty, Spikevax, Covishield, Janssen, CoronaVac, and Novavax COVID-19 vaccines have demonstrated to elicit higher levels of neutralizing antibodies against the wild-type and even variants of concerns including Delta (B.1.671.2) compared to the initial full jab. In terms of reactogenicity and safety of the booster doses, preliminary results have demonstrated tolerability and similar safety compared to the full jab.

Novavax's recombinant protein vaccine (NVX-CoV2373) has not yet been authorised by WHO EUL or other authorising countries. Initial phase I and II trials have demonstrated that a two-dose regimen of the vaccine (5 ug of a recombinant nanoparticle spike protein plus 50 ug of Matrix M adjuvant), administered 21 days apart, is safe and generates robust immune response in healthy adult participants[22,23]. A randomised, placebo-controlled phase III trial demonstrated the vaccine to be highly

[20] ECDC and EMA highlight considerations for additional and booster doses of COVID-19 vaccines. *EMA.* https://www.ema.europa.eu/en/news/ecdc-ema-highlight-considerations-additional-booster-doses-covid-19-vaccines

[21] Israel offers COVID-19 booster to all vaccinated people. *Reuters* [press release]. https://www.reuters.com/world/middle-east/israel-offers-covid-19-booster-shots-all-vaccinated-people-2021-08-29/

[22] Phase 1–2 Trial of a SARS-CoV-2 Recombinant Spike Protein Nanoparticle Vaccine. *The New England Journal of Medicine*. https://www.nejm.org/doi/full/10.1056/NEJMoa2026920

[23] Evaluation of a SARS-CoV-2 Vaccine NVX-CoV2373 in Younger and Older Adults. *medRxiv.* https://www.medrxiv.org/content/10.1101/2021.02.26.21252482v1

effective against symptomatic SARS-CoV-2 infection caused by both B.1.1.7 variants and non-B.1.1.7 variants in both young (18-65 years) and older (≥65 years) participants[24]. Vaccine efficacy starting 7 days after the administration of the second dose was 89.7% (95% CI, 80.2-94.6) among all participants and was 88.9% for (95% CI, 12.8-98.6) individuals aged 65 and above[25]. No hospitalizations or deaths from COVID-19 occurred in the vaccinated recipients thus far. Furthermore, data from an ongoing phase II trial demonstrated a 4.6-fold increase in functional antibody titres following a 6-month booster dose[26]. Following the status of COVID-19 vaccines within WHO EUL/ PQ evaluation process, Novavax's rolling application has been accepted for review as of 19 August by the WHO[27]. The European Medicines Agency (EMA) is also reviewing Novavax's rolling application[28]. Novavax is currently conducting further clinical trials, focusing on the vaccine's efficacy against variants of concerns[29].

Further (biweekly) updated data on the six WHO EUL vaccines and the vaccine candidate Novavax are synthesized in the synoptic table.

[24] Safety and Efficacy of NVX-CoV2373 Covid-19 Vaccine. *The New England Journal of Medicine*. https://www.nejm.org/doi/10.1056/NEJMoa2107659
[25] Safety and Efficacy of NVX-CoV2373 Covid-19 Vaccine. *The New England Journal of Medicine*. https://www.nejm.org/doi/10.1056/NEJMoa2107659
[26] Novavax COVID-19 Vaccine Booster Provides 6-Fold Delta Variant Antibodies. *ContagionLive.* https://www.contagionlive.com/view/novavax-covid-19-vaccine-booster-provides-6-fold-delta-variant-antibodies
[27] Status of COVID-19 Vaccines within WHO EUL/PQ evaluation process. *World Health Organization.* https://extranet.who.int/pqweb/sites/default/files/documents/Status_COVID_VAX_19August2021.pdf
[28] EMA starts rolling review of Novavax's COVID-19 vaccine (NVX-CoV2373). *European Medicines Agency.* https://www.ema.europa.eu/en/news/ema-starts-rolling-review-novavaxs-covid-19-vaccine-nvx-cov2373
[29] Novavax Press releases & statements. *Novavax.* https://ir.novavax.com/press-releases?o=10

Synoptic table about SARS-CoV-2 vaccines accepted in the WHO's Emergency Use Listing and Novavax Vaccine (as of 13 September 2021)

							AWAITING APPROVAL FROM WHO EUL
	BNT162b2/ COMIRNATY (Pfizer-BioNTech, USA)	**Spikevax/ Moderna COVID-19 Vaccine/ mRNA-1273 (Moderna, USA)**	**Vaxzevria/ ChAdOx1 nCoV-19/ AZD1222/ Covishield (AstraZeneca/Oxford, UK, India)**	**Janssen COVID-19 vaccine/Johnson & Johnson (Janssen, USA)**	**Sinopharm/BBIBP-CorV, China**	**Sinovac CoronaVac, China**	**Novavax/ NVX-CoV2373**
GENERAL VACCINE INFORMATION							
Platform	mRNA-based vaccine	mRNA-based vaccine	Non-replicating vector-based vaccine	Non-replicating vector-based vaccine	Inactivated virus (Vero cell)	Inactivated virus (Vero cell)	Recombinant protein (nanoparticle) vaccine with Matrix-M adjuvant
Dose and frequency	2 doses, 21 days apart	2 doses, 28 days apart	2 doses, 4-12 weeks apart	1 dose, once	2 doses, 21 days apart	2 doses, 14 days apart	2 doses, 21 days apart
Target population	12 years old and over	12 years old and over	18 years old and over	18 years old and over	18 years old and over	18 years old and over	18 years old and over
Storage conditions	2°C to 8 °C (for 1 month)	2°C to 8 °C (for 1 month)	2°C until 8 °C	2°C to 8 °C (for 3 months)	2°C until 8 °C	2°C until 8 °C	2°C to 8 °C

Approving authorities	FDA (11.12.20)[i]; EMA (21.12.20); WHO EUL (31.12.20); and list of countries (including Switzerland – approved on 20.12.20)	FDA (18.12.20); EMA (06.01.21); WHO EUL (30.04.21); and list of 51 countries (including Switzerland – approved 12.01.21)	FDA (awaiting on approval); EMA (29.01.21); WHO EUL (15.02.21); and list of 121 countries (Switzerland awaiting on approval)	FDA (27.02.21); EMA (11.03.21), WHO EUL (12.03.21), and list of 59 countries (including Switzerland – approved 22.03.21)	WHO EUL (07.05.21); and list of 55 countries (e.g., Argentina, Bahrain, Brazil, China, Indonesia, United Arab Emirates, Zimbabwe)	WHO EUL (01.06.21), and list of 33 countries (e.g., Albania, Chile, Egypt, Hong Kong, Malaysia, Tunisia, Turkey, Ukraine)	Waiting on approval (Not-yet-approved by countries or WHO for emergency use)
EFFICACY							
Single dose[ii]	**52%** (95% CI, 29.5 to 68.4; starting at 12 days) or 82.2% (75.1 to 87.3; starting at ≥14 days)[1]. **91%** (95% CI, 85-94)[2].	**95.2%** (95% CI, 91.2.8 to 97.4; starting at >14 days)[3].	**72.8%** (starting at 22 days up to 60 days)[4]. **88%** (95% CI, 75-94)[2].[iii]	Single dose vaccine	Unknown	**35.1%** (95% CI, -6.6 to -60.5) [conducted in a setting with high P.1 transmission][5].	**83.4%** (95% CI, 73.6-89.5) starting at ≥14 days[6]

[i] Pfizer-BioNTech's Comirnaty Vaccine received full FDA approval on 23 August 2021 for people age 16 and above, moving it beyond emergency use status. https://www.fda.gov/news-events/press-announcements/fda-approves-first-covid-19-vaccine

[ii] Against SARS-COV-2 infection

[iii] Conducted between 8 December 2020 and 8 February 2021. Study sample = ≤1 million participants.

Two doses[iv]	**95.0%** (95% CI, 90.3-97.6) starting at ≥7 days in population without prior SARS-CoV-2 infection[7] **94.6%** (95% CI, 89.9-97.3) starting at ≥7 days in population with or without prior infection[7]	**94.1%** (95% CI, 89.3-96.8) after median follow-up of less than 63 days[3]	**63.1% (**95% CI, 51.8-71.7) starting at ≥14 days for two standard doses[4] **80.7%** (95% CI, 62.1-90.2) starting at ≥14 days for first low dose and standard second dose[4] **66.7%** (95% CI, 57.4-74.0) starting at ≥14 days for pooled analysis efficacy[4]	**66.9%** (95% CI 59.0-73.4) after 14 days and **66.1%** (95% CI 55.0-89.1) after 28 days for VE against moderate-severe-critical COVID-19[8] **76.7%** (95% CI 54.6 to 89.1) after 14 days and **85.4%** (95% CI 54.2 to 96.9) after 28 days for VE against severe-critical COVID-19[8]	After 14 days, efficacy against symptomatic cases was **72.8%** (95% CI 58.1-82.4; in WIV04 vaccine) or **78.1%** (95% CI 64.8 to 86.3; in HBO2 vaccine).[9]	After 14 days, efficacy against symptomatic cases was **50.7%** (95% CI 35.9 to 0-62.0).[10] 99.17% of NAb titres were above or equal to the Nab positivity cut-off (20 units) against wild-type[11].	**89.7%** (95% CI, 80.2-94.6) starting at ≥7 days[6]
Against asymptomatic infection	**90%** (starting at 14 days) regardless of symptom status[12]	**90%** (starting at 14 days)	Statistically non-significant **reduction of 22.2%** (95% CI -9.9 to 45.0) for asymptomatic cases	At day 71, vaccine efficacy against asymptomatic infections was **65.5%** (95% CI 39.9 to 81.1)[8].	Efficacy against symptomatic and asymptomatic cases was **64%** (95% CI 48.8 to 74.7; in WIV04 vaccine) or 73.5% (95% CI 60.6 to 82.2; in HBO2 vaccine)[9].	Unknown	Unknown
EFFICACY AGAINST VARIANTS							

[iv] Against SARS-CoV-2 infection.

Alpha (B.1.1.7)	Two doses of the vaccine **effectively neutralize** the B.1.1.7 variant and the D614G substitution[13].	**NAbs remained high** and consistent with titres of the wildtype for the B.1.1.7 variant[14].	**70.4%** (95% CI, 43.6-84.5) against symptomatic infection with alpha variant (B.1.1.7); **28.9%** (95% CI, -77.1 to 71.4) against asymptomatic infection with B.1.1.7[15].	**3.6-fold** reduction in neutralization capacity when compared to wild-type.	Demonstrated reduced neutralizing capacity. However, there were no differences in the NAbs titres against B.1.351 in vaccinated individuals vs. those naturally infected, suggesting the vaccine has a similar level of protection against infection as natural infections[16].	**10.4-fold** reduction in neutralization capacity when compared to natural infection sera[11]. **85.83%** of NAb titres were above or equal to the Nab positivity cut-off (20 units) against wild-type[11]. Neutralization decreased by **4.1-fold** when compared to wild-type[17].	Two dose efficacy against the B.1.1.7 variant **86.3%** (95% CI, 71.3-93.5)[6]
Beta (B.1.351)	Neutralization was **diminished by a factor of 5**. Despite this, the BNT162b2 mRNA vaccine still provides some protection against B.1.351[18] **100%** (95% CI, 53.5-100)[19].	NAbs were **6-fold** lower. Nevertheless, NAbs were still found to be protective[14].	Two doses of the vaccine had no efficacy against the B.1.351 (VE = **21.9%;** 95% CI, -49.9 to 59.8)[20].	Efficacy against moderate-severe-critical Covid-19 due to the variant was **52.0%** (>14 days) and **64.0%** (>28 days). Efficacy against severe-critical COVID-19 was **73.1%** (>14 days)	No published data	NT_{GM} **35.03 (95% CI, 27.46-44.68**); **8.75-fold** reduction in neutralization capacity when compared to natural infection sera[11]. **82.5%** of NAb titres were above	**51.0%** (95% CI, -0.6-76.2) efficacy against B.1.351 variant[23]

				and **81.7%** (>28 days)[8]. Demonstrated **3.6-fold** reduction in neutralization sensitivity[21]. Neutralization titres were decreased by **6.7-fold**[22].		or equal to the Nab positivity cut-off (20 units) against wild-type[11].	
Gamma (P.1)	*Single dose:* *≥21 days*: **83%** against hospitalization and death[24]. *Two doses*: *≥14 days*: **98%** against hospitalization and death[24].	**3.2-fold** reduction in neutralization capacity when compared to wild-type[25].	*Single dose:* *≥21 days*: **94%** against hospitalization and death[24].	Demonstrated **3.4-fold** reduction in neutralization sensitivity[21].	No published data	**49.6%** against P.1 (>14 days after 1st dose)[5]. Neutralization decreased by **7.5-fold** when compared to wild-type[17].	No available data
Delta (1.671.2)	**Reduced NAb activity** relative to B.1.1.7 strain[26].	**2.1-fold** reduction in neutralization capacity when compared to wild-type[25].	*Single dose:* *≥21 days*: **90%** against hospitalization and death[24].	Demonstrated **1.6-fold** reduction in neutralization sensitivity[21]. Neutralization titres were	Demonstrated **reduced neutralizing capacity**. However, there were no differences in the NAbs titres	NT_{GM} **24.48** (95% CI,19.2-31.2)[11]. **69.17%** of NAb titres were above or equal to the Nab positivity cut-off (20 units)	No available data

				decreased by **5.4-fold**[22].	against B.1.617.2 in vaccinated individuals vs. those naturally infected, suggesting the vaccine has a similar level of protection against infection as natural infections[16].	against wild-type[11].	
EFFECTIVENESS							
Effectiveness single dose	*General population:* Against infection: **70%**[27]. *Individuals ≥70:* Symptomatic disease: **58%**[28]. Hospitalization risk reduced by 35-**45%**[28].	*General population:* Symptomatic disease: **60%** (95% CI, 57-64; >2 weeks after dose)[29].[v] *Individuals ≥70:* Symptomatic disease: **64%** (95% CI, 46-78; >2 weeks after dose)[29].[vi]	*General population:* Asymptomatic or symptomatic disease: **64%;** Symptomatic disease: **67%**[30]. *Individuals ≥70:* Symptomatic disease: **58%**[28].	**50.6%** (95% CI, 14.0-74.0) in preventing SARS-CoV-2 infection (<2 weeks after dose); **76.7%** (95% CI, 30.3-95.3) in preventing SARS-CoV-2 infection (>2 weeks after dose)[31].	Partial protection[33].[vii]	**15.5%** for preventing COVID-19; **37.4%** for preventing hospitalization; **44.7%** for preventing admission to the ICU; and **45.7%** for preventing of COVID-19 related death[34].	Ongoing studies in South Africa[35] and United Kingdom[36]

[v] mRNA-aggregated data (results do not disaggregate between BNT162b2 and mRNA-1273).
[vi] mRNA-aggregated data (results do not disaggregate between BNT162b2 and mRNA-1273).
[vii] Study did not report numerical data on vaccine effectiveness. Further studies are required to validate results.

	Risk of death reduced by **54%**[28].		Hospitalization risk reduced by **35-45%**[28].	**79%** (95% CI, 77-80) (when corrected for under-recording, VE was estimated to be **69%** (95% CI, 67-71)[32]. **81%** (95% CI, 79-84) for preventing hospitalization when corrected for under-recording, VE was estimated to be **73%** (95% CI, 69-76)[32].			
Effectiveness of two doses	*General population (against SARS-Cov-2 infection – asymptomatic or symptomatic):* **85%**[27]. **94.6%**[37]. **94.5%**[38].	*General population:* **100%**[37]. Symptomatic disease: **91%** (95% CI, 89-93; >2 weeks after dose)[29].[ix] Asymptomatic SARS-CoV-2 infection:	*General population:* Asymptomatic or symptomatic disease: **85%**; Symptomatic disease: **90%**[30].	Not Applicable (one dose schedule)	Partial protection[33].[xi]	**65.9%** for preventing COVID-19; **87.5%** for preventing hospitalization; **90.3%** for preventing ICU admission; and **86.3%** for preventing	Ongoing studies in South Africa[35] and United Kingdom[36]

[ix] Results do not disaggregate between BNT162b2 and mRNA-1273.

[xi] Study did not report numerical data on vaccine effectiveness. Further studies are required to validate results.

	Asymptomatic SARS-CoV-2 infection: **90.6%**[39].[viii]	**90.6%**[39].[x]				COVID-19 related death[34].[xii]	
EFFECTIVENESS AGAINST VARIANTS[xiii]							
Alpha (B.1.1.7)	*Single dose:* **48.7%** (95% CI, 45.5 to 51.7)[40] **66%** (95% CI,64-68)[41]. *Two doses:* **93.7%** (95% CI, 91.6 to 95.3)[40] **92%** (95% CI, 90-93)[42]. **89%** (95% CI, 86-91)[41].	*Single dose:* **88.1%** (95% CI, 83.7 to 91.5)[43] **83%** (95% CI, 80-86)[41]. *Two doses:* **100%** (95% CI, 91.8 to 100)[43] **92%** (95% CI, 86-96)[41].	*Single dose:* **48.7%** (95% CI 45.5 to 51.7)[40] 6**4%** (95% CI, 60-68)[41]. *Two doses:* **74.5%** (95% CI, 68.4 to 79.4)[40] 7**3%** (95% CI, 66-78)[42].	-	No published data	*Two doses:* Equally effective **(~76%)** in neutralizing D614G, B.1.1.7 and B.1.429 as the wild-type strain.	Ongoing studies in South Africa[35] and United Kingdom[36]
Beta (1.351)	*Single dose:* **60%** (95% CI, 52-67)[41].	*Single dose:*	*Single dose:* **48%** (95% CI, 28-63)[41].	-	No published data	Neutralization capacity was	No available data

[viii] Results do not disaggregate between BNT162b2 and mRNA-1273

[x] Results do not disaggregate between BNT162b2 and mRNA-1273

[xii] Death reports on fully vaccinated doctors (10 cases during June 2021 in Indonesia). It may be related to new variants [media report]. Indonesian Covid deaths add to questions over Sinovac vaccine. *The Guardian* [press release]. https://www.theguardian.com/world/2021/jun/28/indonesian-covid-deaths-add-to-questions-over-sinovac-vaccine

[xiii] Effectiveness data against the latest variant of interest (Mu) will be included in upcoming reports based on data availability.

	Two doses: **84%** (95% CI, 69-92)[41].	**61.3%** (95% CI, 56.5 to 65.5)[43] **77%** (95% CI, 69-92)[41]. *Two doses:* **96.4%** (95% CI, 91.9 to 98.7)[43]				decreased by factor **5.27**[44].	
Gamma (P.1)	Neutralization activity reduced by **3.3-fold**[45].	-	-	-	No published data	Demonstrated **42%** vaccine effectiveness in a setting with high P.1 transmission, in individuals aged 70 and above[46]. **50.2%** against P.1 (>14 days after 2nd dose)[47]. Neutralization was decreased by factor **3.92**[44].	No available data
Delta (1.617.2)	*Single dose:* **30.7%** (95% CI, 25.2 to 35.7)[40]; 5**7%** (95% CI, 50-63)[48] *Two doses:*	*Single dose:* **72%** effective against symptomatic SARS-Cov-2 infection[51]. *14 days after second dose:*	*Single dose:* **30.7%** (95% CI 25.2 to 35.7)[40] *Two doses:* **67.0%** (95% CI, 61.3 to 71.8)[40] **60%** (95% CI, 53-66)[42].	**78%** (95% CI, 73-82) against SARS-CoV-2 infection[32]. *Individuals ≥50:* **83% (**95% CI, 81-85)[32]	No published data	*Single dose:* **13.8%** (95% CI, -60.2-54.8) *Two doses:* **59%** (95% CI, 16-81.6) against SARS-CoV-2	No available data

	88.0% (95% CI, 85.3 to 90.1)[40]; **80%** (95% CI, 77-83)[48] **79%** (95% CI,75-82)[42]. **40.5%** (95% CI, 8.7-61.2)[49]. **42%** (95% CI, 13-62)[50].	**76%** (95% CI, 58-87)[50].	Odds ratio of **5.45** (95% CI, 1.39-21.4) to become infected with B.1.167.2 compared to non-B.1.167.2 [52].			infection and **70.2%** (95% CI, 29.6-89.3) against moderate COVID-19 infection[53].	
Effectiveness against hospitalization and death	***Alpha*** *Against hospitalization:* Single dose: **83%** (95% CI, 62-93) Two doses: **95%** (95% CI, 78-99)[54]. ***Delta*** *Against hospitalization:* Single dose: **94%** (95% CI, 46-99) Two doses: **96%** (95% CI, 86-99)[54]. **88%** (95% CI, 78.9-93.2)[49]. *Against severe COVID-19*: **91.4%** (95% CI, 82.5-95.7)[49].	***Delta*** 96% against severe COVID-19 infection[51].	***Alpha*** *Against hospitalization:* Single dose: **76%** (95% CI, 61-85) Two doses: **86%** (95% CI, 53-96)[54]. ***Delta*** *Against hospitalization:* Single dose: **71%** (95% CI, 51-83) Two doses: **92%** (95% CI, 75-97)[54].	***Beta*** **67%** effective at preventing hospitalizations[55]. ***Delta*** **71%** effective at preventing hospitalizations and 96% effective at preventing death[55]. **85%** effective at preventing severe disease and hospitalization[56]. **85%** (95% CI, 73-91) effective at	No published data	***Delta*** **94%** (95% CI, 79-99) significant decreased risk of severe illness in fully vaccinated group compared to unvaccinated group[57]	No available data

				preventing hospitalizations[32]. *<u>Individuals ≥50:</u>* **84% (**95% CI, 81-85)[32]			
SAFETY AND ADVERSE EVENTS							
Common side effects	Pain at the injection site, fatigue, headache, myalgia, chills and fever.[58] Optimal safety for asthma patients[59].	Pain at injection site, headache, fatigue, myalgia, arthralgia[3], Covid arm (cutaneous hypersensitivity)[60].	Fatigue, myalgia, arthralgia, headache[61], lethargy, fever, & nausea[62].	Headache, fever, chills, fatigue, myalgia, and nausea[63].	Pain at the injection site, dizziness, fever, headache, fatigue, nausea, vomiting, & allergic dermatitis[62,64].	Pain at injection site, headache, fatigue, tremors, & flushing[10], inflammatory reaction, urticaria[65].	Pain at injection-site, headache, muscle pain, fatigue[6]
Phase III clinical trial serious adverse events	Serious adverse events were observed in a similar proportion of vaccine (0.6%) and placebo (0.5%) recipients. These events also occur at a similar frequency within the general population[58,66].	The frequency of grade 3 adverse events was similar in both the vaccine (1.5%) and placebo groups (1.3). Serious adverse events were observed in a similar proportion in both groups (0.6%). 3 Bell's Palsy cases	Serious adverse events were balanced across the study arms. 79 cases occurred in the vaccine group and 89 cases in the placebo group – 3 cases were considered related to the experimental or control vaccine (out of 11 636	Serious adverse events were reported in 0.4% of vaccine recipients and 0.4% of placebo recipients. Seven of the serious adverse events were considered to be related to the vaccine: Guillain-Barré syndrome (1),	A cross-sectional survey collected data on adverse events following vaccination in the UAE - none of the symptoms were of serious nature or required hospitalization[64].	Overall incidence of serious adverse events was 0.5% (31 in placebo group and 33 in vaccine group). All adverse events were determined to be unrelated to the vaccine[10].	<u>Phase II:</u> Nine serious adverse events were reported, only one of which was assessed as related to the vaccine: acute colitis[67].

		occurred in the vaccine group and one Bell's Palsy case occurred in the placebo group[3].	vaccine recipients): transverse myelitis, haemolytic anaemia and a case of fever higher than 40°C [61].	pericarditis (1), brachial radiculitis (1), hypersensitivity (1), Bell's Palsy (2), & severe generalized weakness, fever & headache (1)[8].			
Rare adverse events	Axillary lymphadenopathy, paroxysmal ventricular arrhythmia, leg paresthesia[7]. Myocarditis[68,69], anaphylaxis and swelling of the lips, face, and tongue related to anaphylaxis[70] (11 anaphylaxis cases per million doses administered)[71], pityriasis rosea (lesions improved completely after ~8 weeks)[72], lymphocytic vasculitis[73], reactivation of varicella-zoter virus after second	Myocarditis[68,69], orofacial swelling & anaphylaxis[70]. Potential risk factor for Bell's palsy (most improve upon follow-up)[76], herpes zoster reactivation (very rare)[77] One case developed IgA Nephropathy after receiving the second dose of mRNA-1273 (causal link not yet proven)[78]	Transverse myelitis, high fever[61,79], cutaneous hypersensitivity[79], vasculitis[80], cerebral venous sinus thrombosis[81] (higher risk for women)[82], thromboembolism[83], vaccine induced immune thrombotic thrombocytopenia[84], small vessel vasculitis[80]. Vaccination in individuals with adrenal insufficiency can lead to adrenal crises[85].	Thrombosis, thrombocytopenia, cerebral venous sinus thrombosis[86], increased risk of developing Guillain-Barré syndrome post vaccination[87]. 97% of reported reactions after vaccine administration were non-serious[63].	Similar among the vaccine groups and control group within 7 days[9].	Myalgia, fever[10], pityriasis rosea (lesions improved completely after ~8 weeks)[72], reactivation of herpes zoster and herpes simplex[65]. Most reactions improved without treatment within a few weeks[65].	Myocarditis was reported in one vaccine recipient, occurring 3 days after second dose[6]

	dose (typically occur in individuals with pre-existing conditions)[74], Kikuchi-Fujimoto disease[75].						
Potential associated adverse events (warrants further analysis)	Cerebral venous sinus thrombosis and intracranial haemorrhage (causal link not yet proven)[88], aseptic meningitis (causal link not yet proven)[89]. Autoimmune hepatitis[90]	Autoimmune hepatitis[90].	Autoimmune hepatitis[90]. Acute hyperglycaemic crisis[91].	-	-	-	No available data
Myocarditis data	Mainly reported in young adults and adolescents Refer to children vaccination section for more details	Mainly reported in young adults and adolescents Refer to children vaccination section for more details	No available data	No available data	No available data	No available data	Myocarditis was reported as viral myocarditis. Participant fully recovered after 2 days of hospitalisation. No episode of anaphylaxis or vaccine-associated

							enhanced COVID-19 was reported[6]
TRANSMISSION, PREVENTION & PROTECTION							
Immunogenicity	*7-14 days after second dose:* *18-55 years*: GMT ranged from **1.7 to 4.6** times the GMT of the convalescent serum[92]. *65-85 years*: GMT ranged from **1.1 to 2.2** times the GMT of the convalescent serum[92].	*14 days after second dose:* *18-55 years*: $PRNT_{80}$ GMT **654.3 (95% CI, 460.1-930.5)**[93]. *56-70 years:* $PRNT_{80}$ GMT **878 (95% CI, 516-1494)**[94]. *≥71 years*: $PRNT_{80}$ GMT **317 (95% CI, 181-557)**[94].	*28 days after second dose median antibody titres:* *18–55 years*: **20,713 AU/mL [IQR 13,898 - 33,550]**[95] *56–69 years*: **16,170 AU/mL [IQR 10,233 - 40,353]**[95]. *≥70 years*: **17,561 AU/mL [IQR 9,705 - 37,796]**[95].	*29 days after vaccination:* *18-55 years:* GMC **586 (95% CI, 445-771)**; GMT **224 (95% CI, 168-298)**[96]. *≥65 years*: GMC **312 (95% CI, 246-396);** GMT **212 (95% CI, 163-266)**[96]. *57 days after vaccination:* *18-55 years*: **754 (95% CI, 592-961)**; GMT **288**	*14 days after second dose:* *18-55 years:* GMT ***211.2*** **(95% CI, 158.9-280.6)**[97]. *≥60 years: GMT* ***131.5*** **(95% CI, 108.2-159.7)**[97].	*Single dose (≥4 weeks)*: **37.7±57.08 IU/ml (min: 0, max: 317.25);** 57.02% of participants did not develop sufficient antibody titres (<25.6 IU ml) *Two doses (≥4 weeks)*: **194.61±174.88 IU/ml (min: 0, max: 677.82);** 11.48% of participants did not develop sufficient antibody	*14 days after second dose (18-84 years):* 5-ug: IgG GMT **44,421 EU/ ml (95% CI, 37,929-52,024)**[67]. 25-ug: IgG GMT **46,459 EU/ml (95% CI, 40,839-52,853)**[67].

				(95% CI, 221-376)[96].		titres (<25.6 IU ml)[98].	
Transmission prevention	*Prior Delta Variant:* Vaccine effectiveness against infectiousness given infections **41.3%**[99] Vaccine effectiveness against transmission **88.5%**[99] *During Delta Variant:* Similar Ct values (<25) were found in both vaccinated and unvaccinated groups[100] Studies from Scotland and England demonstrated reductions in secondary infections among	Limited data	**48%** (limited data) May not be able to block the transmission of the alpha variant as efficiently as the wild type[15].	Limited data	Unknown	Unknown	Unknown

	families of vaccinated individuals compared to families of unvaccinated individuals[101,102].						
Duration of protection	Limited data[103] Median time between second dose and infection: **146 days (IQR, 121-167)**[104] *Anti-SARS-CoV-2 Antibodies:* 1 month after 2nd dose: **1762 KU/L (IQR: 933-3761)** 3 months after 2nd dose: **1086 KU/L (IQR: 629-2155)** 6 months after 2nd dose: **802 KU/L (IQR, 447-1487)**[105] No health worker had antibodies	Limited data[103] *Preliminary phase I results:* Antibody activity remained high in all age groups at **day 209** (approximately 6 months) GMT were lower in ≥56 years old[106]	*Antibody Response:* After single dose, antibody response declined within one year, but remained above baseline levels. Antibody levels after **day 180**: 0.54 GMR (CI, 0.47-0.61). Antibody levels after **day 320**: 0.30 GMR (CI, 0.24-0.39)[107] *Cellular Immune Response:* **Day 182** after first dose: median of **237 SFUx10^6**	*Neutralizing antibodies:* Remained largely stable for **8-9 months**[108] *Binding antibodies:* Remained stable **6 months** irrespective of age group[108] *Humoral & Cellular Immune Response:* Antibody responses were detected in all vaccine recipients on **day 239** (stable response	Limited data[103]	A phase I/II clinical trial found that NAbs titres dropped below the seropositive cut-off of 8, **6 months** after the administration of the first dose[110]. **80-90%** of anti-S IgG and Nab titers against wild type waned **6 months** after second vaccination[111]	Unknown

	BELOW method-dependent cut-off (0.8 KU/L)		**PBMC (IQR, 109-520)**[107] **6 months** after second dose: **(median 1240, IQR 432-2002**) in groups with 15-25 week interval between doses[107]	for at least 8 months)[109] A study observed sustained and stable vaccine effectiveness starting 14 days post vaccination to a maximum of 152 days after vaccination[32].			
CHILDREN VACCINATION							
Efficacy	*Adolescents (12-15):* After one dose had efficacy of **75% (CI, 7.6-95.5)** After second dose efficacy of **100% (CI, 78.1-100)**[112]. *Children (6months-11):* Ongoing trials[113]	*Adolescents (12-17):* After one dose had efficacy of **92.7% (CI, 67.8-99.2)** After second dose efficacy of **93.3% (CI, 47.9-99.9)**[114]. *Children (6month-11):* Ongoing trials[115]	No available data Paused ongoing trials in children aged 6-17 due to concerns over rare blood clots reported in adult population[116].	No available data Announced at begging of April ongoing study in adolescents but paused to investigate blood clots in adult population[116].	*Children (3-17):* Ongoing clinical trial[117]. Countries such as China and UAE have approved its use in children[118].	*Children (3-17):* Unknown. Clinical trial only looked at safety, tolerability and immunogenicity[119].	*Adolescents (16-17):* PREVENT-19 clinical trial[xiv] expanded to assess efficacy, safety, and immunogenicity in 12–17-year-old adolescents[120]

[xiv] A Study to Evaluate the Efficacy, Immune Response, and Safety of a COVID-19 Vaccine in Adults ≥18 Years With a Pediatric Expansion in Adolescents (12 to <18 Years) at Risk for SARS-CoV-2. *ClinicalTrials.gov*. ClinicalTrials.gov Identifier: NCT04611802. https://clinicaltrials.gov/ct2/show/NCT04611802?term=Novavax&cond=Covid19&draw=2

Immunogenicity	*Adolescents (12-15) serum-neutralizing titer:* 1 month after 2nd dose had **1283.0 GMN_{50} (CI, 1095.5-1402.5)**[112]. *Adolescents/young adult (16-25) serum-neutralizing titer:* 1 month after 2nd dose had **705.1 GMN_{50} (CI, 621.4-800.2)**[112]. *Children (6months-11):* Ongoing trials[113]	*Adolescents (12-17):* Neutralizing antibody titer after 2nd dose was **1401.7 GMN_{50} (CI, 1276.3-1539.4)** Serological response was **98.8% (CI, 97.0-99.7)** *Children (6month-11):* Ongoing trials[115]	No available data	No available data	Ongoing clinical trial[117].	*Children (3-17):* Neutralizing antibody response after 2nd dose **(100%)** with GMT ranging from **45.9-212.6**[119]	Ongoing clinical trial[121]
Safety and Adverse events	*Adolescents (12-15):* Local and systemic events were generally mild to moderate Severe injection-site pain **(1.5%)** Fever **(20%)** High Fever **(0.1%)** Adverse events **(6%)**	*Adolescents (12-17):* Solicited local reactions after 2nd dose **(93.4%)** Most common solicited adverse reactions were Injection-site pain **(92.7%)** Headache **(70.2%)** Fatigue **(67.8%)**	No available data	No available data	Ongoing clinical trial[117]	*Children (3-17):* Adverse reactions in 12–17 year group **(35%)**, 3-5 year group **(26%)**, and 6-11 year group **(18%)** Reported at least one adverse event **(27%)** Most reported events were mild and moderate and	Ongoing clinical trial[121]

	Severe adverse events **(0.6%)**[112]. *Adolescent/young adults (16-25):* Local and systemic events were generally mild to moderate Severe injection-site pain **(3.4%)** Fever **(17%)** Adverse events **(6%)** Severe adverse events **(1.7%)**[112]. *Children (6months-11):* Ongoing trials[113]	Grade 3 adverse events **(6.8%)** Few reported cases of acute myocarditis and pericarditis (mainly in males)[122] *Children (6month-11):* Ongoing trials[115]				only **(<1%)** grade 3 events Injection-site pain **(13%)** Fever **(25%)**[119]	
Myocarditis Data	Few reported cases of acute myocarditis and pericarditis in 16-25 year olds (mainly in males)[122]	Few reported cases of acute myocarditis in adolescents and young adults	No available data	No available data	No available data	No available data	No available data

HETEROLOGOUS VACCINATION							
Vaccine Schedule	**BNT162b2/ChAdOx1** Administration of ChAdOx1 as second/booster dose	**ChAdOx1/mRNA-1273** Administration of mRNA-1273 as second/booster dose	**ChAdOx1/BNT162b2** Administration of BNT162b2 as second/booster dose	Not Applicable (one dose schedule) For more information refer to booster section	**BBIBP/BNT162b2**	**CoronaVac/ChAdOx1** Press releases have confirmed that Thailand will use the AstraZeneca vaccine as the second dose for individuals whose first dose was Sinovac[xv] **CoronaVac/Convidecia**	Ongoing trial[123] (Com-Cov2)[xvi]
Vaccine Immunogenicity	*GMCs of SARS-CoV-2 anti-spike IgG at 28 days post booster:* Heterologous **(7133 ELU/mL, CI 6415-7932)** vs. Homologous **(14080 ELU/mL,**	***Spike-specific IgG antibodies:* Heterologous **(3602 BAU/mL)** vs. Homologous **(4189 BAU/mL)**[48]	*RBD antibody titres:* Heterologous **(7756.68 BAU/mL, CI 7371.53-8161.96)** vs. Homologous **(99.84 BAU/mL,**	Not Applicable (one dose schedule) For more information refer to booster section	Unknown (on-going clinical trial)[49]	**CoronaVac/ChAdOx1 :** *Anti-S Antibodies:* Heterologous **(797 U/mL; 95% CI, 598.7-1062)** vs. Homologous CoronaVac **(94.4**	No available data Ongoing trial[123]

[xv] Malaysia to stop using Sinovac vaccine after supply ends - minister. *Reuters* [press release]. https://www.reuters.com/world/asia-pacific/malaysia-stop-using-sinovac-vaccine-after-supply-ends-minister-2021-07-15/

[xvi] Comparing COVID-19 Vaccine Schedule Combinations. *University of Oxford.* https://comcovstudy.org.uk/about-com-cov2

	CI 12491-15871)[124]. *SFC frequency (T0cell ELISpot):* Heterologous **(99 SFC/10^6 PBMCs)** vs. Homologous **(80 SFC/10^6 PBMCs)**[124]**.**	**Neutralizing antibodies:* Heterlogous **(100%)** vs. Homologous **(100%)**[125]. *Results based on immunosuppressed population	**CI 76.93-129.59)** at day 14[126]. *IgG antibody titres:* Heterologous **(3684 BAU/mL)** vs. Homologous **(101.2 BAU/mL)** at day 14[126]. *Neutralizing antibodies:* Heterologous **(100%)** at day 14 vs. Homologous **(30%)** at day 14[126].			**U/mL; 95% CI : 76.1-122.1)** vs. Homologous ChAdOx1 **(818 U/mL; 95% CI: 662.5-1010)**[127] **CoronaVac/Convidecia** *Neutralizing antibodies :* Heterologous **54.4 GMT** (95% CI, 37.9-78) vs. Homologous CoronaVac **12.8 GMT** (95% CI, 9.3-17.5)[128]	
Vaccines Reactogenicity	Observed increase in systemic reactogenicity after boost in heterologous schedules in comparison with homologous schedules[124] *Adverse events in heterologous:*	*Adverse events in heterologous and homologous vaccination groups were very similar[125]. *Majority of adverse events self-reported were Pain at injection site, Swelling at injection site,	*Adverse events in heterologous:* Headache **(44%)**, Myalgia **(43%)**, Malaise **(42%)**, Fever **(2%)**, Injection site pain **(88%)**, Induration **(35%)**, Erythema **(31%)**[126].	Not Applicable (one dose schedule) For more information refer to booster section	Unknown (on-going clinical trial)[129]	**CoronaVac/ChAdOx1:** Unknown **CoronaVac/Convidecia:** Convidecia recipients reported more adverse reactions and reported higher occurrence of	No available data Ongoing trial[123]

	Adverse events **(90)** Grade 1 **(54.4%)** Grade 2 **(37.8%)** Grade 3 **(7.8%)** Grade 4 **(0%)** Arthralgia, Migraine, Back Pain[124]. *Adverse events in homologous:* Adverse events **(81)** Grade 1 **(59.3%)** Grade 2 **(39.5%)** Grade 3 **(1.2%)** Grade 4 **(0%)**[124].	Fever, Headaches, Fatigue, Chills, GI effects, Myalgia, Arthralgia[125]. *Results based on immunosuppressed population	*Severity of adverse events in heterologous:* Mild **(68%)**, Moderate **(30%)**, Severe **(2%)**[126].			solicited injection-site pain)[128]	
BOOSTER DOSES							
Vaccine Schedule	*Homologous:* **BNT162b2/BNT162b2**	*Homologous:* **mRNA-1273/mRNA-1273**	*Homologous:* **ChAdOx1/ChAdOX1**	*Homologous:* **Ad26.CoV.2.S/ Ad26.CoV.2.S** *Heterologous:* **BNT162b2/Ad26.CoV.2.S**	*Homologous:* **SinoPharm/SinoPharm** *Heterologous:* **SinoPharm/BNT162b2**	*Homologous:* **CoronaVac/CoronaVac**	*Homologous:* **NVX-CoV2373/NVX-CoV2373** *Heterologous:* Ongoing trial of heterologous booster shot

							using NVX-CoV2373[xvii]
Approved Administration	*Israel:* 12-year-old and over can received homologous booster shot 5 months after full jab[xviii] *United States:* Starting September, adults who received mRNA vaccine 8 months ago are eligible for booster *Europe:* Starting in fall, most European countries are	Phase II booster trial of three booster doses are ongoing[130] Moderna sought FDA approval of its COVID-19 vaccine booster[xx] *United States:* Starting September, adults who received mRNA vaccine 8 months ago are eligible for booster.	Preliminary results on tolerability and immunogenicity of third dose of ChAdOx1 vaccines showed strong boost to the immune response[131]	Janssen/ Johnson & Johnson are testing a 2-dose version of their vaccine that provides stronger immunogenicity and duration of protection[132]	*UAE:* Offering booster doses of Pfizer and Sinopharm to people who received full Sinopharm jab ≥6 months ago	**Turkey** and the **United Arab Emirates** began homologous booster shots **Indonesia** and **Thailand** are considering giving homologous booster shot to HCW[xxi]	Ongoing phase II trials[133] Results below are based on ongoing phase II trial

[xvii] COV-Boost Evaluating COVID-19 Vaccine Boosters. *University of Southampton & NHS.* https://www.covboost.org.uk/home

[xviii] Israel offers COVID-19 booster to all vaccinated people. *Reuters* [press release]. https://www.reuters.com/world/middle-east/israel-offers-covid-19-booster-shots-all-vaccinated-people-2021-08-29/

[xx] Moderna seeks U.S. authorization for COVID-19 vaccine booster. *Reuters* [press release]. https://www.reuters.com/business/healthcare-pharmaceuticals/moderna-submits-initial-data-covid-19-vaccine-booster-us-fda-2021-09-01/

[xxi] Indonesia and Thailand consider booster shots amid doubts over Sinovac vaccine. *Reuters* [press release]. https://www.reuters.com/world/china/indonesia-thailand-consider-booster-shots-amid-doubts-over-sinovac-vaccine-2021-07-08/

	planning on rolling out booster shots to immunocompromised and elder populations[xix]						
Time-to-booster dose	**6 months to 8 months** after initial two-dose regimen Israel offers up to **5 months** after initial two-dose regimen	**6 months to 8 months** after initial two-dose regimen	**6-9 months** after initial two-dose regimen	*Homologous:* **6 months** after one dose regimen[108] *Heterologous:* **4 months** after initial two-dose BNT162b2 regimen[134]	**6 months** after initial two-dose regimen	**6 months to 12 months** After primary vaccination **8 months** after the primary vaccination to healthy adults ≥60 years	**6 months** after initial two-dose regimen (**189 days**)[133]
Immunogenicity	*Neutralizing titers:* Elicits **>5-8 more** for wild type after 6 months after 2nd dose[135]	Booster doses (mRNA1273 or mRNA1273.351) increased neutralizing antibody titers against wild-type[136]	*Antibody Levels:* Higher levels after third dose (tIgG EU **3746**; IQR: 2047-6420) [131] *Spike Cellular Immune Response:* Increased from **200 SFUx10^6**	*Homologous:* 5X10^{10} vp booster dose elicited **9-fold** increase at day 7 compared to first dose after 29 days in 18-55-year-olds[108] 1.25X10^{10} vp booster dose	Ongoing trial[129]	*Neutralizing Antibodies:* **60%** higher NAbs activity against wild-type compared to 2-doses[111] *Anti-S IgG and NAbs:*	*Anti-spike IgG:* Increase of **4.6-fold** compared to peak response after 2nd dose (**Day 217 GMEU = 200408**; 95% CI: 159796-251342)[133]

[xix] A country-by-country guide to coronavirus vaccine booster plans. *POLITICO* [press reléase]. https://www.politico.eu/article/vaccine-booster-coronavirus-covid-19-europe-delta-varian-who/

			PBMC (IQR, 127-389) after the second dose to **399 SFUx10^6 PBMC (IQR, 314-662)** after the third one[131]	elicited **6-7.7-fold** increase at day 28 compared to first dose after 29 days in 18-55 and ≥65-year-old[108] *Heterologous:* **14.8 to 32.4-fold** increase in neutralization titers against wild-type virus[134]		**20-fold** increase 4 weeks post booster vaccination NAbs were maintained **60** to **180 days** post booster[111]	*Wild-type Neutralizing Response:* Increase of **4.3-fold** compared to peak response after 2nd dose **(IC50 = 6231; 95% CI: 4738-8195)** [133] *Older Participants (60-84):* **5.4-fold** increase in antibody response[133] *Younger Participants (18-59):* **3.7-fold** increase in antibody response[133]
Immunogenicity against variants	*Beta (B.1.351):* Elicits **15-21** more neutralizing titers for Beta variant after 6 months after 2nd dose[135]	Preliminary results of booster doses of mRNA-1273 vaccine show robust antibody response against Delta variant[130]	Third dose provided higher antibody titters against Alpha, Beta, and Delta variants[131]	*Homologous:* No available data *Heterologous:* **10.9 to 21.2-fold** increase in pseudovirus	Ongoing trial[129]	*Beta (B.1.351):* **3.0-fold** decrease in neutralizing antibodies compared to wild type[111]	High levels of functional antibodies against Alpha (B.1.1.7), Beta (B.1.351), and

	Delta (B.1.671.2): **>5-fold** increase in neutralizing titers against Delta compared to dose 2 titers in 18–55-year-olds **>11-fold** increase in neutralizing titers against Delta compared to dose 2 titers in 65–85-year-olds[135]			neutralization assay (one volunteer did not have any against fB.1.351) [134]		*Gamma (P.1):* **3.1-fold** decrease in neutralizing antibodies compared to wild type[111] *Delta (B.1.671.2):* **2.3-fold** decrease in neutralizing antibodies compared to wild type **2.5-fold** higher neutralizing potency than 2-dose vaccination[111]	Delta (B.1.671.2)[133] *Delta (B.1.671.2):* Increase of **6.6-fold** in antibody response compared to Delta response observed with primary vaccination[133]
Reactogenicity	Preliminary results show consistent tolerability[135]	Similar safety and tolerability compared to second dose[130] *Common solicited local adverse events:* Injection-site pain **(68.4% for mRNA-1273.351, 90% for mRNA-1273)** fatigue **(36.8% for mRNA-1273.351,**	Lower reactogenicity after third dose compared to first dose[107]	No available data	Ongoing trial[129]	The third shot is considered to be safe[110]. *Common side effects:* Pain at the injection site. *Adverse events:* Unrelated to the vaccination	Booster dose was **well tolerated** Local and systemic **reactogenicity increased** between Dose 1, Dose 2, and Dose 3 **90%** of symptoms were

		70% for mRNA-1273) headache **(36.8% for mRNA1273.351, 55.0% for mRNA-1273)** myalgia **(31.6% for mRNA-1273.351, 45.0% for mRNA-1273)** arthralgia **(21.1% for mRNA-1273, 50.0% for mRNA-1273)**[136]					rated as mild or moderate[133]
Other	**11.4-fold** decrease (95% CI; 10.0-12.9) in relative risk of confirmed infection 12 days after booster dose[137] **>10-fold** decrease in relative risk of severe illness[137]					For more detailed information regarding immunogenicity of third dose refer to study[xxii]	

[xxii] A third dose of inactivated vaccine augments the potency, breadth, and duration of anamnestic responses against SARS-CoV-2. *medRxiv.* https://www.medrxiv.org/content/10.1101/2021.09.02.21261735v1

	~5-fold protection against confirmed infection[137] 14-20 days after booster, marginal effectiveness increases to **70-84%**[138]						

VACCINE PRODUCTION SITES							
	BNT162b2/ COMIRNATY (Pfizer-BioNTech, USA)[xxiii]	**Spikevax/ Moderna COVID-19 Vaccine/ mRNA-1273 (Moderna, USA)[xxiv]**	**Vaxzevria/ ChAdOx1 nCoV-19/ AZD1222/ Covishield**	**Janssen COVID-19 vaccine/Johnson & Johnson**	**Sinopharm/BBIBP-CorV, China[xxvii]**	**Sinovac CoronaVac, China[xxviii]**	**Novavax/ NVX-CoV2373**

[xxiii] WHO recommendation BioNTech Tozinameran – COVID-19 mRNA vaccine (nucleoside modified) – COMIRNATY. *WHO.* https://extranet.who.int/pqweb/vaccines/who-recommendation-covid-19-mrna-vaccine-nucleoside-modified-comirnaty

[xxiv] 1. WHO recommendation ModernaTX, Inc/USFDA COVID-19 mRNA vaccine (nucleoside modified). *WHO*. https://extranet.who.int/pqweb/vaccines/who-recommendation-modernatx-incusfda-covid-19-mrna-vaccine-nucleoside-modified

2. WHO recommendation Moderna COVID-19 mRNA Vaccine (nucleoside modified). *WHO*. https://extranet.who.int/pqweb/vaccines/covid-19-mrna-vaccine-nucleoside-modified

[xxvii] WHO recommendation COVID-19 vaccine BIBP/Sinopharm. *WHO.* https://extranet.who.int/pqweb/vaccines/who-recommendation-covid-19-vaccine-bibp

[xxviii] WHO recommendation of Sinovac COVID-19 vaccine (Vero Cell [Inactivated]) – CoronaVac. *WHO*. https://extranet.who.int/pqweb/vaccines/who-recommendation-sinovac-covid-19-vaccine-vero-cell-inactivated-coronavac

			(AstraZeneca/Oxford, UK, India)[xxv]	(Janssen, USA)[xxvi]			
EUL holder	BioNTech Manufacturing GmbH (Germany)	ModernaTX, Inc. (USA)[1] Moderna Biotech (Spain)[2]	AstraZeneca AB (Sweden)	Janssen-Cilag International NV (Belgium)	Beijing Institute of Biological Products Co., Ltd. (BIBP) (China)	Sinovac Life Sciences Co., Ltd. (China)	Novavax (USA)
Production sites (Drug substance)	BioNTech Manufacturing GmbH (Mainz, Germany) BioNTech Manufacturing Marburg (Marburg, Germany) Rentschler Biopharma SE	Lonza Biologics, Inc., (USA)[1] Moderna TX, Inc. (USA)[1] Lonza AG (Switzerland)[2]	Henogen S.A (Belgium) Catalent Maryland, Inc. (USA) Oxford Biomedica (UK) Ltd. (United Kingdom) SK Bioscience (Republic of Korea)	Janssen Vaccines & Prevention B.V. (The Netherlands) Janssen Biologics B.V. (The Netherlands) Emergent Manufacturing Operations Baltimore LLC (USA)	Beijing Institute of Biological Products Co., Ltd. (China)	Sinovac Life Sciences Co., Ltd. (China)	Novavax (Bohumil, Czech Republic)

[xxv] WHO recommendation AstraZeneca/ EU approved sites COVID-19 vaccine (ChAdOx1-S) [recombinant]. *WHO.* https://extranet.who.int/pqweb/vaccines/covid-19-vaccine-chadox1-s-recombinant-0

[xxvi] WHO recommendation Janssen-Cilag International NV (Belgium) COVID-19 Vaccine (Ad26.COV2-S [recombinant]). *WHO*. https://extranet.who.int/pqweb/vaccines/who-recommendation-janssen-cilag-international-nv-belgium-covid-19-vaccine-ad26cov2-s

	(Laupheim, Germany) Wyeth BioPharma Division of Wyeth Pharmaceuticals (USA)		Halix B.V (Netherlands) WuXi Biologics (China)				
Production sites (Drug product)	Baxter Oncology GmbH (Halle/ Westfallen, Germany) BioNTech Manufacturing GmbH (Mainz, Germany) Pfizer Manufacturing Belgium NV (Belgium) Novartis Pharma Stein AG (Switzerland) Mibe GmbH Arzneimittel (Brehna, Germany)	Baxter Pharmaceutical Solutions, LLC. (USA)[1] Catalent Indiana, LLC. (USA)[1] Rovi Pharma Industrial Services, S.A. (Spain)[2]	Catalent Anagni (Italy) CP Pharmaceuticals (United Kingdom) IDT Biologika (Germany) SK Bioscience (Republic of Korea) Universal Farma, S.L. ("Chemo") (Spain) Amylin Ohio LLC (USA)	Janssen Biologics B.V. (The Netherlands) Janssen Pharmaceutica NV (Belgium) Aspen SVP. (South Africa) Catalent Indiana LLC. (USA) Grand River Aseptic Manufacturing Inc. (USA) Catalent Anagni S.R.L. (Italy)	Beijing Institute of Biological Products Co., Ltd. (China)	Sinovac Life Sciences Co., Ltd. (China)	Novavax (Bohumil, Czech Republic)
Diluent suppliers	Pfizer Perth, Australia	-	-	-	-	-	-

	Fresenius Kabi, USA						

PHASE III TRIALS RESULTS[xxix]							
	BNT162b2/ COMIRNATY (Pfizer-BioNTech, USA)	**Spikevax/ Moderna COVID-19 Vaccine/ mRNA-1273 (Moderna, USA)**	**Vaxzevria/ ChAdOx1 nCoV-19/ AZD1222/ Covishield (AstraZeneca/Oxford, UK, India)**	**Janssen COVID-19 vaccine/Johnson & Johnson (Janssen, USA)**	**Sinopharm/BBIBP-CorV, China**	**Sinovac CoronaVac, China**	**Novavax/ NVX-CoV2373**
Number of participants (vaccine/ placebo)	43,448 (21,720/ 21,728)[7]	30,420 (15,210/15,210)[3]	17,178 (8597/8581)[4]	39,321 (19,630/19,691)[8]	26,917 (13,459/13458); or 26,914 (13,465/13,458)[9]	9,823 (4,953/4,870)[10]	14,039 (7,020/7,019)[6]
Total COVID-19 cases (vaccine/ control)	170(8/162)[7]	196 (11/185)[3]	332 (84/248)[4]	464 (116/348)[8]	121(26/95) or 116(21/95)[9]	253(85/168)[10]	106(10/96)[6]

[xxix] Phase III trials were conducted between 27 July and 14 November 2020 for BNT162b2/ COMIRNATY, 27 July and 23 October 2020 for Spikevax/ Moderna, 23 April and 6 December 2020 for Vaxzevria/ ChAdOx1 nCoV-19/ AZD1222/ Covishield, 21 September 2020 and 22 January 2021 for Janssen Covid-19 vaccine/ Johnson & Johnson, 16 July and 20 December 2020 for Sinopharm/ BBIB-CorV, 21 July and 16 December 2020 for the Sinovac/ CoronaVac vaccine, and 28 September 2020 and 28 November 2020 for the Novavax vaccine. All trials were conducted prior to the transmission of the more contagious variant strains, particularly the delta variant (B.1.617.2). Studies are currently ongoing to determine the effectiveness of the vaccines against the delta variant.

Efficacy estimates in Phase III trials	Starting from 7 days after 2nd dose: **95.0%** (95% CI, 90.3 to 97.6) in population without prior SARS-CoV-2 infection. Efficacy of **94.6%** (95% CI, 89.9 to 97.3) in population with or without prior infection. **100%** among adolescents (12-15 years old)[7].	After a median follow-up of less than 63 days: Efficacy of **94.1%** (95% CI, 89.3 to 96.8; P<0.001). **100%** among adolescents (12 to <18 years old)[3].	Two standard doses: efficacy was **63·1%** (95% CI 51.8 to 71.7; ≥14 days) while those with first low dose and standard 2nd dose the efficacy was **80.7%** (95% CI 62.1 to 90.2). Pooled analysis efficacy was **66.7%** (95% CI 57.4 to 74.0). For any nucleic acid amplification test-positive swab: efficacy was 54.1% (95% CI 44.7 to 61.9)[4].	VE against moderate-severe-critical Covid-19 was **66.9%** (95% CI 59.0 to 73.4) after 14 days post vaccine administration, and **66.1%** (95% CI 55.0 to 89.1) after 28 days. VE against severe-critical COVID-19 cases was **76.7%** (95% CI 54.6 to 89.1) after 14 days and **85.4%** (95% CI 54.2 to 96.9) after 28 days[8].	After 14 days, efficacy against symptomatic cases was **72.8%** (95% CI 58.1 to 82.4; in WIV04 vaccine) or **78.1%** (95% CI 64.8 to 86.3; in HBO2 vaccine)[9].	After 14 days, efficacy against symptomatic cases was **50.7%** (95% CI 35.9 to 0-62.0).[10]	**83.4%** (95% CI, 73.6-89.5) starting at ≥14 days after first dose[6] **89.7%** (95% CI, 80.2-94.6) starting at ≥7 days after second dose[6]
Efficacy against hospitalization and death	**100%** (after 7 days)[7]	**100%** (≥14 days)[3]	**100%** (after 21 days)[4]	**76.7%** (≥14 days) or **85.4%** (≥28 days)[8]	**100%** (>14 days)[9]	**100%** (>14 days)[10]	**100%** (after 7 days)[6].
PHASE III TRIAL OTHER							
Comments	Specific populations were excluded (HIV and	Calculation of efficacy were not based on the total number of			Only 2 severe cases occurred in the control group and none in the		Novavax is currently awaiting FDA, EMA, and WHO EUL approval.

	immunocompromised patients, and pregnant women).	confirmed Covid-19 cases.			vaccine group (very few cases to get a reliable estimate).			Upcoming information regarding results of clinical trials or approval will be updated in upcoming reports

References

1. Pilishvili T, Fleming-Dutra KE, Farrar JL, et al. Interim Estimates of Vaccine Effectiveness of Pfizer-BioNTech and Moderna COVID-19 Vaccines Among Health Care Personnel — 33 U.S. Sites, January–March 2021. *MMWR Morbidity and mortality weekly report.* 2021;70(20):753–758. https://doi.org/http://dx.doi.org/10.15585/mmwr.mm7020e2external
2. Vasileiou E, Simpson CR, Shi T, et al. Interim findings from first-dose mass COVID-19 vaccination roll-out and COVID-19 hospital admissions in Scotland: a national prospective cohort study. *The Lancet.* 2021;397(10285):1646-1657. https://doi.org/10.1016/S0140-6736(21)00677-2
3. Baden LR, El Sahly HM, Essink B, et al. Efficacy and Safety of the mRNA-1273 SARS-CoV-2 Vaccine. *New England Journal of Medicine.* 2020;384(5):403-416. https://doi.org/10.1056/NEJMoa2035389
4. Voysey M, Costa Clemens SA, Madhi SA, et al. Single-dose administration and the influence of the timing of the booster dose on immunogenicity and efficacy of ChAdOx1 nCoV-19 (AZD1222) vaccine: a pooled analysis of four randomised trials. *The Lancet.* 2021;397(10277):881-891. https://doi.org/10.1016/S0140-6736(21)00432-3
5. Hitchings MDT, Ranzani OT, Scaramuzzini Torres MS, et al. Effectiveness of CoronaVac in the setting of high SARS-CoV-2 P.1 variant transmission in Brazil: A test-negative case-control study. *medRxiv.* 2021:2021.2004.2007.21255081. https://doi.org/10.1101/2021.04.07.21255081
6. Heath PT, Galiza EP, Baxter DN, et al. Safety and Efficacy of NVX-CoV2373 Covid-19 Vaccine. *New England Journal of Medicine.* 2021. https://doi.org/10.1056/NEJMoa2107659
7. Polack FP, Thomas SJ, Kitchin N, et al. Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine. *New England Journal of Medicine.* 2020;383(27):2603-2615. https://doi.org/10.1056/NEJMoa2034577
8. Sadoff J, Gray G, Vandebosch A, et al. Safety and Efficacy of Single-Dose Ad26.COV2.S Vaccine against Covid-19. *N Engl J Med.* 2021;384(23):2187-2201. https://doi.org/10.1056/NEJMoa2101544
9. Al Kaabi N, Zhang Y, Xia S, et al. Effect of 2 Inactivated SARS-CoV-2 Vaccines on Symptomatic COVID-19 Infection in Adults: A Randomized Clinical Trial. *JAMA.* 2021;326(1):35-45. https://doi.org/10.1001/jama.2021.8565
10. Palacios R, Batista AP, Santos Nascimento Albuquerque C, et al. Efficacy and Safety of a COVID-19 Inactivated Vaccine in Healthcare Professionals in Brazil: The PROFISCOV Study. *SSRN - Preprint.* 2021. https://doi.org/http://dx.doi.org/10.2139/ssrn.3822780
11. Vacharathit V, Aiewsakun P, Manopwisedjaroen S, et al. SARS-CoV-2 variants of concern exhibit reduced sensitivity to live-virus neutralization in sera from CoronaVac vaccinees and naturally infected COVID-19 patients. *medRxiv.* 2021:2021.2007.2010.21260232. https://doi.org/10.1101/2021.07.10.21260232
12. Thompson MG, Burgess JL, Naleway AL, et al. Interim Estimates of Vaccine Effectiveness of BNT162b2 and mRNA-1273 COVID-19 Vaccines in Preventing SARS-CoV-2 Infection Among Health Care Personnel, First Responders, and Other Essential and Frontline Workers — Eight U.S. Locations, December 2020–March

2021. *MMWR Morbidity and mortality weekly report.* 2021;70(13):495-500. https://doi.org/http://dx.doi.org/10.15585/mmwr.mm7013e3external icon.
13. Jalkanen P, Kolehmainen P, Häkkinen HK, et al. COVID-19 mRNA vaccine induced antibody responses against three SARS-CoV-2 variants. *Nat Commun.* 2021;12(1):3991. https://doi.org/10.1038/s41467-021-24285-4
14. Moderna. *Moderna COVID-19 Vaccine Retains Neutralizing Activity Against Emerging Variants First Identified in the U.K. and the Republic of South Africa.* 2021. https://investors.modernatx.com/node/10841/pdf.
15. Emary KRW, Golubchik T, Aley PK, et al. Efficacy of ChAdOx1 nCoV-19 (AZD1222) vaccine against SARS-CoV-2 variant of concern 202012/01 (B.1.1.7): an exploratory analysis of a randomised controlled trial. *Lancet.* 2021;397(10282):1351-1362. https://doi.org/10.1016/s0140-6736(21)00628-0
16. Jeewandara C, Aberathna IS, Pushpakumara PD, et al. Antibody and T cell responses to Sinopharm/BBIBP-CorV in naïve and previously infected individuals in Sri Lanka. *medRxiv.* 2021:2021.2007.2015.21260621. https://doi.org/10.1101/2021.07.15.21260621
17. Fernández J, Bruneau N, Fasce R, et al. Neutralization of alpha, gamma, and D614G SARS-CoV-2 variants by CoronaVac vaccine-induced antibodies. *Journal of Medical Virology.* 2021. https://doi.org/10.1002/jmv.27310
18. Jalkanen P, Kolehmainen P, Häkkinen HK, et al. COVID-19 mRNA vaccine induced antibody responses against three SARS-CoV-2 variants. *Nature Communications.* 2021;12(1). https://doi.org/10.1038/s41467-021-24285-4
19. Thomas SJ, Moreira ED, Kitchin N, et al. Six Month Safety and Efficacy of the BNT162b2 mRNA COVID-19 Vaccine. *medRxiv.* 2021:2021.2007.2028.21261159. https://doi.org/10.1101/2021.07.28.21261159
20. Madhi SA, Baillie V, Cutland CL, et al. Efficacy of the ChAdOx1 nCoV-19 Covid-19 Vaccine against the B.1.351 Variant. *New England Journal of Medicine.* 2021;384(20):1885-1898. https://doi.org/10.1056/NEJMoa2102214
21. Jongeneelen M, Kaszas K, Veldman D, et al. Ad26.COV2.S elicited neutralizing activity against Delta and other SARS-CoV-2 variants of concern. *bioRxiv.* 2021:2021.2007.2001.450707. https://doi.org/10.1101/2021.07.01.450707
22. Tada T, Zhou H, Samanovic MI, et al. Comparison of Neutralizing Antibody Titers Elicited by mRNA and Adenoviral Vector Vaccine against SARS-CoV-2 Variants. *bioRxiv.* 2021:2021.2007.2019.452771. https://doi.org/10.1101/2021.07.19.452771
23. Shinde V, Bhikha S, Hoosain Z, et al. Efficacy of NVX-CoV2373 Covid-19 Vaccine against the B.1.351 Variant. *New England Journal of Medicine.* 2021;384(20):1899-1909. https://doi.org/10.1056/NEJMoa2103055
24. Buntz B. AstraZeneca, Pfizer Moderna vaccines fare well against Beta, Gamma and Delta variants in study. Drug Discovery & Development. https://www.drugdiscoverytrends.com/astrazeneca-pfizer-moderna-vaccines-fare-well-against-beta-gamma-and-delta-variants-in-study/. Published 2021. Updated 23 July 2021. Accessed 9 September 2021.
25. Choi A, Koch M, Wu K, et al. Serum Neutralizing Activity of mRNA-1273 against SARS-CoV-2 Variants. *bioRxiv.* 2021:2021.2006.2028.449914. https://doi.org/10.1101/2021.06.28.449914
26. Wall EC, Wu M, Harvey R, et al. Neutralising antibody activity against SARS-CoV-2 VOCs B.1.617.2 and B.1.351 by BNT162b2 vaccination. *The Lancet.* 2021;397(10292):2331-2333. https://doi.org/10.1016/S0140-6736(21)01290-3

27. Hall VJ, Foulkes S, Saei A, et al. Effectiveness of BNT162b2 mRNA Vaccine Against Infection and COVID-19 Vaccine Coverage in Healthcare Workers in England, Multicentre Prospective Cohort Study (the SIREN Study). *SSRN - Preprint.* 2021. https://doi.org/10.2139/ssrn.3790399
28. Public Health England. *Public Health England vaccine effectiveness report.* 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/989360/PHE_COVID-19_vaccine_effectiveness_report_March_2021_v2.pdf.
29. Chung H, He S, Nasreen S, et al. Effectiveness of BNT162b2 and mRNA-1273 covid-19 vaccines against symptomatic SARS-CoV-2 infection and severe covid-19 outcomes in Ontario, Canada: test negative design study. *BMJ.* 2021;374:n1943. https://doi.org/10.1136/bmj.n1943
30. Lumley SF, Rodger G, Constantinides B, et al. An observational cohort study on the incidence of SARS-CoV-2 infection and B.1.1.7 variant infection in healthcare workers by antibody and vaccination status. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America.* 2021. https://doi.org/10.1093/cid/ciab608
31. Corchado-Garcia J, Puyraimond-Zemmour D, Hughes T, et al. Real-World Effectiveness of Ad26.COV2.S Adenoviral Vector Vaccine for COVID-19. *SSRN - Preprint.* 2021. https://doi.org/10.2139/ssrn.3835737
32. Polinski JM, Weckstein AR, Batech M, et al. Effectiveness of the Single-Dose Ad26.COV2.S COVID Vaccine. *medRxiv.* 2021:2021.2009.2010.21263385. https://doi.org/10.1101/2021.09.10.21263385
33. Jahromi M, Al Sheikh MH. Partial protection of Sinopharm vaccine against SARS COV2 during recent outbreak in Bahrain. *Microb Pathog.* 2021;158:105086. https://doi.org/10.1016/j.micpath.2021.105086
34. Jara A, Undurraga EA, González C, et al. Effectiveness of an Inactivated SARS-CoV-2 Vaccine in Chile. *New England Journal of Medicine.* 2021. https://doi.org/10.1056/NEJMoa2107715
35. A Study Looking at the Effectiveness and Safety of a COVID-19 Vaccine in South African Adults. In. ClinicalTrials.gov2021. https://clinicaltrials.gov/ct2/show/NCT04533399?term=Novavax&cond=Covid19&draw=2.
36. A Study Looking at the Effectiveness, Immune Response, and Safety of a COVID-19 Vaccine in Adults in the United Kingdom. In. ClinicalTrials.gov2021. https://clinicaltrials.gov/ct2/show/NCT04583995?term=Novavax&cond=Covid19&draw=2&rank=2.
37. Paris C, Perrin S, Hamonic S, et al. Effectiveness of mRNA-BNT162b2, mRNA-1273, and ChAdOx1 nCoV-19 vaccines against COVID-19 in healthcare workers: an observational study using surveillance data. *Clinical Microbiology and Infection.* 2021. https://doi.org/10.1016/j.cmi.2021.06.043
38. Katz MA, Bron Harlev E, Chazan B, et al. Covid-19 Vaccine Effectiveness in Healthcare Personnel in six Israeli Hospitals (CoVEHPI). *medRxiv.* 2021:2021.2008.2030.21262465. https://doi.org/10.1101/2021.08.30.21262465
39. Knobel P, Serra C, Grau S, et al. Coronavirus disease 2019 (COVID-19) mRNA vaccine effectiveness in asymptomatic healthcare workers. *Infect Control Hosp Epidemiol.* 2021:1-2. https://doi.org/10.1017/ice.2021.287

40. Lopez Bernal J, Andrews N, Gower C, et al. Effectiveness of Covid-19 Vaccines against the B.1.617.2 (Delta) Variant. *New England Journal of Medicine.* 2021;385(7):585-594. https://doi.org/10.1056/NEJMoa2108891
41. Nasreen S, Chung H, He S, et al. Effectiveness of COVID-19 vaccines against variants of concern in Ontario, Canada. *medRxiv.* 2021:2021.2006.2028.21259420. https://doi.org/10.1101/2021.06.28.21259420
42. Sheikh A, McMenamin J, Taylor B, Robertson C. SARS-CoV-2 Delta VOC in Scotland: demographics, risk of hospital admission, and vaccine effectiveness. *The Lancet.* 2021;397(10293):2461-2462. https://doi.org/10.1016/S0140-6736(21)01358-1
43. Chemaitelly H, Yassine HM, Benslimane FM, et al. mRNA-1273 COVID-19 vaccine effectiveness against the B.1.1.7 and B.1.351 variants and severe COVID-19 disease in Qatar. *Nature Medicine.* 2021. https://doi.org/10.1038/s41591-021-01446-y
44. Chen Y, Shen H, Huang R, Tong X, Wu C. Serum neutralising activity against SARS-CoV-2 variants elicited by CoronaVac. *The Lancet Infectious Diseases.* 2021;21(8):1071-1072. https://doi.org/10.1016/S1473-3099(21)00287-5
45. Gidari A, Sabbatini S, Bastianelli S, et al. Cross-neutralization of SARS-CoV-2 B.1.1.7 and P.1 variants in vaccinated, convalescent and P.1 infected. *Journal of Infection.* 2021. https://doi.org/10.1016/j.jinf.2021.07.019
46. Ranzani O, Hitchings M, Neto M, et al. Effectiveness of the CoronaVac vaccine in the elderly population during a P.1 variant-associated epidemic of COVID-19 in Brazil: A test-negative case-control study. *medRxiv preprint.* 2021. https://doi.org/10.1101/2021.05.19.21257472
47. World Health Organization. The Sinovac-CoronaVac COVID-19 vaccine: What you need to know. World Health Organization. https://www.who.int/news-room/feature-stories/detail/the-sinovac-covid-19-vaccine-what-you-need-to-know?gclid=Cj0KCQjw4eaJBhDMARIsANhrQADBYtFm2zMvzbfjthveE2gmCJTRl_jPc4HPlIFSwdZpzTix45gmEM0aAml9EALw_wcB. Published 2021. Updated 2 September 2021. Accessed 8 September, 2021.
48. Pouwels KB, Pritchard E, Matthews P, et al. Impact of Delta on viral burden and vaccine effectiveness against new SARS-CoV-2 infections in the UK. *medRxiv.* 2021:2021.2008.2018.21262237. https://doi.org/10.1101/2021.08.18.21262237
49. State of Israel Ministry of Health. Vaccine efficacy among those first vaccinated. https://www.gov.il/BlobFolder/reports/vaccine-efficacy-safety-follow-up-committee/he/files_publications_corona_two-dose-vaccination-data.pdf Published 2021. Accessed 25 August, 2021.
50. Puranik A, Lenehan PJ, Silvert E, et al. Comparison of two highly-effective mRNA vaccines for COVID-19 during periods of Alpha and Delta variant prevalence. *medRxiv.* 2021:2021.2008.2006.21261707. https://doi.org/10.1101/2021.08.06.21261707
51. Mayo Foundation for Medical Education and Research (MFMER). Do COVID-19 vaccines protect against the variants? Mayo Clinic. Published 2021. Updated 24 August 2021. Accessed 8 September, 2021.
52. Mlcochova P, Kemp SA, Shanker Dhar M, et al. SARS-CoV-2 B.1.617.2 Delta variant replication, sensitivity to neutralising antibodies and vaccine breakthrough. *bioRxiv.* 2021:2021.2005.2008.443253. https://doi.org/10.1101/2021.05.08.443253
53. Li X-n, Huang Y, Wang W, et al. Efficacy of inactivated SARS-CoV-2 vaccines against the Delta variant infection in Guangzhou: A test-negative case-control real-world study. *Emerging Microbes & Infections.* 2021:1-32. https://doi.org/10.1080/22221751.2021.1969291

54. Stowe J, Andrews N, Gower C, et al. Effectiveness of COVID-19 vaccines against hospital admission with the delta (B.1.617.2) variant *Public Health Enland Publishing - Preprint.* 2021. https://khub.net/web/phe-national/public-library/-/document_library/v2WsRK3ZlEig/view_file/479607329?_com_liferay_document_library_web_portlet_DLPortlet_INSTANCE_v2WsRK3ZlEig_redirect=https%3A%2F%2Fkhub.net%3A443%2Fweb%2Fphe-national%2Fpublic-library%2F-%2Fdocument_library%2Fv2WsRK3ZlEig%2Fview%2F479607266.
55. Foley KE. J&J shot effective against Delta variant in large South Africa study. Politico. https://www.politico.eu/article/johnson-johnson-coronavirus-vaccine-delta-variant/. Published 2021. Updated 6 August 2021. Accessed 7 September, 2021.
56. Johnson & Johnson. Positive New Data for Johnson & Johnson Single-Shot COVID-19 Vaccine on Activity Against Delta Variant and Long-lasting Durability of Response. Johnson & Johnson. https://www.jnj.com/positive-new-data-for-johnson-johnson-single-shot-covid-19-vaccine-on-activity-against-delta-variant-and-long-lasting-durability-of-response. Published 2021. Updated 1 July 2021. Accessed 8 September, 2021.
57. Wang J, Huang P, Yi Y, et al. Effectiveness of inactive COVID-19 vaccines against severe illness in B.1.617.2 (Delta) variant-infected patients in Jiangsu, China. *medRxiv.* 2021:2021.2009.2002.21263010. https://doi.org/10.1101/2021.09.02.21263010
58. Oliver SE, Gargano JW, Marin M, et al. The Advisory Committee on Immunization Practices' Interim Recommendation for Use of Pfizer-BioNTech COVID-19 Vaccine - United States, December 2020. *MMWR Morbidity and mortality weekly report.* 2020;69(50):1922-1924. https://doi.org/10.15585/mmwr.mm6950e2
59. Caminati M, Guarnieri G, Batani V, et al. Covid-19 vaccination in patients with severe asthma on biologic treatment: Safety, tolerability, and impact on disease control. *Vaccines.* 2021;9(8). https://doi.org/10.3390/vaccines9080853
60. Wei N, Fishman M, Wattenberg D, Gordon M, Lebwohl M. "COVID arm": A reaction to the Moderna vaccine. *JAAD case reports.* 2021;10:92-95. https://doi.org/10.1016/j.jdcr.2021.02.014
61. Voysey M, Costa Clemens SA, Madhi SA, et al. Safety and efficacy of the ChAdOx1 nCoV-19 vaccine (AZD1222) against SARS-CoV-2: an interim analysis of four randomised controlled trials in Brazil, South Africa, and the UK. *The Lancet.* 2021;397(10269):99-111. https://doi.org/10.1016/S0140-6736(20)32661-1
62. Ghiasi N, Valizadeh R, Arabsorkhi M, et al. Efficacy and side effects of Sputnik V, Sinopharm and AstraZeneca vaccines to stop COVID-19; a review and discussion. 2021. https://doi.org/http://immunopathol.com/PDF/ipp-7-e31.pdf
63. Shay DK, Gee J, Su JR, et al. Safety Monitoring of the Janssen (Johnson & Johnson) COVID-19 Vaccine - United States, March–April 2021. *Morbidity and Mortality Weekly Report.* 2021;70(18):680–684. https://doi.org/http://dx.doi.org/10.15585/mmwr.mm7018e2external
64. Saeed BQ, Al-Shahrabi R, Alhaj SS, Alkokhardi ZM, Adrees AO. Side Effects and Perceptions Following Sinopharm COVID-19 Vaccination. *Int J Infect Dis.* 2021. https://doi.org/10.1016/j.ijid.2021.08.013
65. Durmaz K, Temiz SA, Zuhal K, Dursun R, Abdelmaksoud A. Allergic and Cutaneous reactions following Inactivated SARS-CoV-2 vaccine (CoronaVac®) in Healthcare workers. *Clin Exp Dermatol.* 2021. https://doi.org/10.1111/ced.14896

66. Chagla Z. The BNT162b2 (BioNTech/Pfizer) vaccine had 95% efficacy against COVID-19 ≥7 days after the 2nd dose. *Annals of Internal Medicine.* 2021;174(2):JC15. https://doi.org/10.7326/ACPJ202102160-015
67. Formica N, Mallory R, Albert G, et al. Evaluation of a SARS-CoV-2 Vaccine NVX-CoV2373 in Younger and Older Adults. *medRxiv.* 2021:2021.2002.2026.21252482. https://doi.org/10.1101/2021.02.26.21252482
68. Kim HW, Jenista ER, Wendell DC, et al. Patients With Acute Myocarditis Following mRNA COVID-19 Vaccination. *JAMA Cardiology.* 2021. https://doi.org/10.1001/jamacardio.2021.2828
69. Bozkurt B, Kamat I, Hotez PJ. Myocarditis With COVID-19 mRNA Vaccines. *Circulation.* 2021;144(6):471-484. https://doi.org/doi:10.1161/CIRCULATIONAHA.121.056135
70. Cirillo N. Reported orofacial adverse effects of COVID-19 vaccines: The knowns and the unknowns. *Journal of Oral Pathology & Medicine.* 2021;50(4):424-427. https://doi.org/10.1111/jop.13165
71. Shimabukuro T. Allergic reactions including anaphylaxis after receipt of the first dose of Pfizer-BioNTech COVID-19 vaccine - United States, December 14-23, 2020. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* 2021;21(3):1332-1337. https://doi.org/10.1111/ajt.16516
72. Temiz SA, Abdelmaksoud A, Dursun R, Durmaz K, Sadoughifar R, Hasan A. Pityriasis rosea following SARS-CoV-2 vaccination: A case series. *Journal of Cosmetic Dermatology.* 2021. https://doi.org/10.1111/jocd.14372
73. Vassallo C, Boveri E, Brazzelli V, et al. Cutaneous lymphocytic vasculitis after administration of COVID-19 mRNA vaccine. *Dermatol Ther.* 2021:e15076. https://doi.org/10.1111/dth.15076
74. Santovito LS, Pinna G. A case of reactivation of varicella-zoster virus after BNT162b2 vaccine second dose? *Inflamm Res.* 2021:1-3. https://doi.org/10.1007/s00011-021-01491-w
75. Soub HA, Ibrahim W, Maslamani MA, A. Ali G, Ummer W, Abu-Dayeh A. Kikuchi-Fujimoto disease following SARS CoV2 vaccination: Case report. *IDCases.* 2021;25. https://doi.org/10.1016/j.idcr.2021.e01253
76. Iftikhar H, Noor SMU, Masood M, Bashir K. Bell's Palsy After 24 Hours of mRNA-1273 SARS-CoV-2 Vaccine. *Cureus.* 2021;13(6):e15935-e15935. https://doi.org/10.7759/cureus.15935
77. Channa L, Torre K, Rothe M. Herpes zoster reactivation after mRNA-1273 (Moderna) SARS-CoV-2 vaccination. *JAAD Case Reports.* 2021;15:60-61. https://doi.org/10.1016/j.jdcr.2021.05.042
78. Abramson M, Mon-Wei Yu S, Campbell KN, Chung M, Salem F. IgA Nephropathy After SARS-CoV-2 Vaccination. *Kidney Medicine.* 2021. https://doi.org/10.1016/j.xkme.2021.05.002
79. Català A, Muñoz-Santos C, Galván-Casas C, et al. Cutaneous reactions after SARS-COV-2 vaccination: A cross-sectional Spanish nationwide study of 405 cases. *The British journal of dermatology.* 2021. https://doi.org/10.1111/bjd.20639
80. Guzmán-Pérez L, Puerta-Peña M, Falkenhain-López D, et al. Small-vessel vasculitis following Oxford-AstraZeneca vaccination against SARS-CoV-2. *Journal of the European Academy of Dermatology and Venereology.* 2021. https://doi.org/10.1111/jdv.17547

81. Wolf ME, Luz B, Niehaus L, Bhogal P, Bäzner H, Henkes H. Thrombocytopenia and Intracranial Venous Sinus Thrombosis after "COVID-19 Vaccine AstraZeneca" Exposure. *Journal of Clinical Medicine.* 2021;10(8):1599. https://www.mdpi.com/2077-0383/10/8/1599.
82. Schulz JB, Berlit P, Diener HC, et al. COVID-19 vaccine-associated cerebral venous thrombosis in Germany. *Annals of neurology.* 2021. https://doi.org/10.1002/ana.26172
83. Perera R, Fletcher J. Thromboembolism and the Oxford-AstraZeneca vaccine. *BMJ.* 2021;373:n1159. https://doi.org/10.1136/bmj.n1159
84. Althaus K, Möller P, Uzun G, et al. Antibody-mediated procoagulant platelets in SARS-CoV-2-vaccination associated immune thrombotic thrombocytopenia. *Haematologica.* 2021;106(8):2170-2179. https://doi.org/10.3324/haematol.2021.279000
85. Maguire D, McLaren DS, Rasool I, Shah PM, Lynch J, Murray RD. ChAdOx1 SARS-CoV-2 vaccination: A putative precipitant of adrenal crises. *Clinical Endocrinology.* 2021. https://doi.org/10.1111/cen.14566
86. MacNeil JR, Su JR, Broder KR, et al. Updated Recommendations from the Advisory Committee on Immunization Practices for Use of the Janssen (Johnson & Johnson) COVID-19 Vaccine After Reports of Thrombosis with Thrombocytopenia Syndrome Among Vaccine Recipients - United States, April 2021. *MMWR Morbidity and mortality weekly report.* 2021;70(17):651-656. https://doi.org/10.15585/mmwr.mm7017e4
87. U.S. Food & Drug Administration. Coronavirus (COVID-19) Update: July 13, 2021. U.S Food & Drug Administration. Published 2021. Updated 13 July 2021. Accessed 18 August, 2021.
88. Shimazawa R, Ikeda M. Potential adverse events in Japanese women who received tozinameran (BNT162b2, Pfizer-BioNTech). *Journal of Pharmaceutical Policy and Practice.* 2021;14(1):46. https://doi.org/10.1186/s40545-021-00326-7
89. Saito K, Shimizu T, Suzuki-Inoue K, Ishida T, Wada Y. Aseptic meningitis after vaccination of the BNT162b2 mRNA COVID-19 vaccine. *Neurol Sci.* 2021:1-3. https://doi.org/10.1007/s10072-021-05543-1
90. Bril F, Fettig DM. Reply to: "Comment on "Autoimmune hepatitis developing after coronavirus disease 2019 (COVID-19) vaccine: Causality or casualty?"". *Journal of Hepatology.* 2021. https://doi.org/10.1016/j.jhep.2021.06.008
91. Edwards AE, Vathenen R, Henson SM, Finer S, Gunganah K. Acute hyperglycaemic crisis after vaccination against COVID-19: A case series. *Diabet Med.* 2021:e14631. https://doi.org/10.1111/dme.14631
92. Walsh EE, Frenck RW, Falsey AR, et al. Safety and Immunogenicity of Two RNA-Based Covid-19 Vaccine Candidates. *New England Journal of Medicine.* 2020;383(25):2439-2450. https://doi.org/10.1056/NEJMoa2027906
93. Jackson LA, Anderson EJ, Rouphael NG, et al. An mRNA vaccine against SARS-CoV-2—preliminary report. *New England Journal of Medicine.* 2020.
94. Anderson EJ, Rouphael NG, Widge AT, et al. Safety and Immunogenicity of SARS-CoV-2 mRNA-1273 Vaccine in Older Adults. *New England Journal of Medicine.* 2020;383(25):2427-2438. https://doi.org/10.1056/NEJMoa2028436
95. Ramasamy MN, Minassian AM, Ewer KJ, et al. Safety and immunogenicity of ChAdOx1 nCoV-19 vaccine administered in a prime-boost regimen in young and old adults (COV002): a single-blind, randomised, controlled, phase 2/3 trial. *The Lancet.* 2020;396(10267):1979-1993. https://doi.org/10.1016/S0140-6736(20)32466-1

96. Sadoff J, Le Gars M, Shukarev G, et al. Interim results of a phase 1–2a trial of Ad26. COV2. S Covid-19 vaccine. *New England Journal of Medicine.* 2021;384(19):1824-1835.
97. Xia S, Zhang Y, Wang Y, et al. Safety and immunogenicity of an inactivated SARS-CoV-2 vaccine, BBIBP-CorV: a randomised, double-blind, placebo-controlled, phase 1/2 trial. *The Lancet Infectious Diseases.* 2021;21(1):39-51. https://doi.org/10.1016/S1473-3099(20)30831-8
98. Karamese M, Tutuncu EE. The effectiveness of inactivated SARS-CoV-2 vaccine (CoronaVac) on antibody response in participants aged 65 years and older. *Journal of Medical Virology.* 2021. https://doi.org/10.1002/jmv.27289
99. Prunas O, Warren JL, Crawford FW, et al. Vaccination with BNT162b2 reduces transmission of SARS-CoV-2 to household contacts in Israel. *medRxiv.* 2021:2021.2007.2013.21260393. https://doi.org/10.1101/2021.07.13.21260393
100. Riemersma KK, Grogan BE, Kita-Yarbro A, et al. Shedding of Infectious SARS-CoV-2 Despite Vaccination when the Delta Variant is Prevalent - Wisconsin, July 2021. *medRxiv.* 2021:2021.2007.2031.21261387. https://doi.org/10.1101/2021.07.31.21261387
101. Harris RJ, Hall JA, Zaidi A, Andrews NJ, Dunbar JK, Dabrera G. Effect of vaccination on household transmission of sars-cov-2 in england. *New England Journal of Medicine.* 2021;385(8):759-760. https://doi.org/10.1056/NEJMc2107717
102. Shah ASV, Gribben C, Bishop J, et al. Effect of vaccination on transmission of COVID-19: an observational study in healthcare workers and their households. *medRxiv.* 2021:2021.2003.2011.21253275. https://doi.org/10.1101/2021.03.11.21253275
103. Swiss National COVID-19 Task Force. *Protection Duration After Vaccination or Infection.* Swiss National COVID-19 Task Force; 10 August 2021 2021. https://sciencetaskforce.ch/wp-content/uploads/2021/06/Protection_Duration16Jun2021_EN.pdf.
104. Israel A, Merzon E, Schäffer AA, et al. Elapsed time since BNT162b2 vaccine and risk of SARS-CoV-2 infection in a large cohort. *medRxiv.* 2021:2021.2008.2003.21261496. https://doi.org/10.1101/2021.08.03.21261496
105. Salvagno GL, Henry B, Pighi L, De Nitto S, Lippi G. Total Anti-SARS-CoV-2 Antibodies Measured 6 Months After Pfizer-BioNTech COVID-19 Vaccination in Healthcare Workers. *SSRN- Preprint.* 2021. https://doi.org/10.2139/ssrn.3915349
106. Doria-Rose N, Suthar MS, Makowski M, et al. Antibody Persistence through 6 Months after the Second Dose of mRNA-1273 Vaccine for Covid-19. *New England Journal of Medicine.* 2021;384(23):2259-2261. https://doi.org/10.1056/NEJMc2103916
107. Flaxman A, Marchevsky N, Jenkin D, et al. Tolerability and Immunogenicity After a Late Second Dose or a Third Dose of ChAdOx1 nCoV-19 (AZD1222). *SSRN - Preprint.* 2021. https://doi.org/10.2139/ssrn.3873839
108. Sadoff J, Le Gars M, Cardenas V, et al. Durability of antibody responses elicited by a single dose of Ad26.COV2.S and substantial increase following late boosting. *medRxiv.* 2021:2021.2008.2025.21262569. https://doi.org/10.1101/2021.08.25.21262569
109. Barouch DH, Stephenson KE, Sadoff J, et al. Durable Humoral and Cellular Immune Responses 8 Months after Ad26.COV2.S Vaccination. *New England Journal of Medicine.* 2021. https://doi.org/http://doi.org/10.1056/NEJMc2108829
110. Li M, Yang J, Wang L, et al. A booster dose is immunogenic and will be needed for older adults who have completed two doses vaccination with CoronaVac: a

randomised, double-blind, placebo-controlled, phase 1/2 clinical trial. *medRxiv.* 2021:2021.2008.2003.21261544. https://doi.org/10.1101/2021.08.03.21261544

111. Wang K, Cao YR, Zhou Y, et al. A third dose of inactivated vaccine augments the potency, breadth, and duration of anamnestic responses against SARS-CoV-2. *medRxiv.* 2021:2021.2009.2002.21261735. https://doi.org/10.1101/2021.09.02.21261735
112. Frenck RW, Klein NP, Kitchin N, et al. Safety, Immunogenicity, and Efficacy of the BNT162b2 Covid-19 Vaccine in Adolescents. *New England Journal of Medicine.* 2021;385(3):239-250. https://doi.org/10.1056/NEJMoa2107456
113. Study to Evaluate the Safety, Tolerability, and Immunogenicity of an RNA Vaccine Candidate Against COVID-19 in Healthy Children <12 Years of Age. In: https://ClinicalTrials.gov/show/NCT04816643;
114. Ali K, Berman G, Zhou H, et al. Evaluation of mRNA-1273 SARS-CoV-2 Vaccine in Adolescents. *N Engl J Med.* 2021. https://doi.org/10.1056/NEJMoa2109522
115. A Study to Evaluate Safety and Effectiveness of mRNA-1273 COVID-19 Vaccine in Healthy Children Between 6 Months of Age and Less Than 12 Years of Age. In: https://ClinicalTrials.gov/show/NCT04796896;
116. Ewen Callaway. COVID vaccines and kids: five questions as trials begin. https://www.nature.com/articles/d41586-021-01061-4. Published 2021. Accessed August 11, 2021, 2021.
117. Immuno-bridging Study of Inactivated SARS-CoV-2 Vaccine in Healthy Population Aged 3-17 vs Aged 18 Years Old and Above. In: https://ClinicalTrials.gov/show/NCT04917523;
118. Global Times. UAE approves use of Chinese Sinopharm COVID-19 vaccine for 3-17 age group. https://www.globaltimes.cn/page/202108/1230498.shtml. Published 2021. Accessed 16 August, 2021.
119. Han B, Song Y, Li C, et al. Safety, tolerability, and immunogenicity of an inactivated SARS-CoV-2 vaccine (CoronaVac) in healthy children and adolescents: a double-blind, randomised, controlled, phase 1/2 clinical trial. *The Lancet Infectious Diseases.* 2021. https://doi.org/10.1016/S1473-3099(21)00319-4
120. Novavax Initiates Pediatric Expansion for Phase 3 Clinical Trial of COVID-19 Vaccine [press release]. May 3, 2021 2021. https://ir.novavax.com/2021-05-03-Novavax-Initiates-Pediatric-Expansion-for-Phase-3-Clinical-Trial-of-COVID-19-Vaccine.
121. A Study to Evaluate the Efficacy, Immune Response, and Safety of a COVID-19 Vaccine in Adults ≥ 18 Years With a Pediatric Expansion in Adolescents (12 to < 18 Years) at Risk for SARS-CoV-2. In. ClinicalTrials.gov2021. https://clinicaltrials.gov/ct2/show/NCT04611802?id=NCT04917523+OR+NCT05003466+OR+NCT05003479+OR+NCT04998240+OR+NCT04611802&draw=2&rank=5&load=cart.
122. Das BB, Moskowitz WB, Taylor MB, Palmer A. Myocarditis and Pericarditis Following mRNA COVID-19 Vaccination: What Do We Know So Far? *Children.* 2021;8(7). https://doi.org/10.3390/children8070607
123. University of Oxford. Comparing COVID-19 Vaccine Schedule Combinations. https://comcovstudy.org.uk/about-com-cov2. Published 2021. Accessed September 2, 2021.
124. Liu X, Shaw RH, Stuart ASV, et al. Safety and immunogenicity of heterologous versus homologous prime-boost schedules with an adenoviral vectored and mRNA COVID-19 vaccine (Com-COV): a single-blind, randomised, non-inferiority trial. *Lancet.* 2021. https://doi.org/10.1016/S0140-6736(21)01694-9

125. Schmidt T, Klemis V, Schub D, et al. Immunogenicity and reactogenicity of a heterologous COVID-19 prime-boost vaccination compared with homologous vaccine regimens. *medRxiv.* 2021:2021.2006.2013.21258859. https://doi.org/10.1101/2021.06.13.21258859
126. Borobia AM, Carcas AJ, Pérez-Olmeda M, et al. Immunogenicity and reactogenicity of BNT162b2 booster in ChAdOx1-S-primed participants (CombiVacS): a multicentre, open-label, randomised, controlled, phase 2 trial. *The Lancet.* 2021;398(10295):121-130. https://doi.org/10.1016/S0140-6736(21)01420-3
127. Yorsaeng R, Vichaiwattana P, Klinfueng S, et al. Immune response elicited from heterologous SARS-CoV-2 vaccination: Sinovac (CoronaVac) followed by AstraZeneca (Vaxzevria). *medRxiv.* 2021:2021.2009.2001.21262955. https://doi.org/10.1101/2021.09.01.21262955
128. Li J, Hou L, Guo X, et al. Heterologous prime-boost immunization with CoronaVac and Convidecia. *medRxiv.* 2021:2021.2009.2003.21263062. https://doi.org/10.1101/2021.09.03.21263062
129. Safety and Efficacy of COVID-19 Prime-boost Vaccine in Bahrain. In: https://ClinicalTrials.gov/show/NCT04993560;
130. Moderna Announces Positive Initial Booster Data Against SARS-CoV-2 Variants of Concern [press release]. Cambridge, Massachusetts, May 5 2021. https://investors.modernatx.com/news-releases/news-release-details/moderna-announces-positive-initial-booster-data-against-sars-cov.
131. Flaxman A, Marchevsky NG, Jenkin D, et al. Reactogenicity and immunogenicity after a late second dose or a third dose of ChAdOx1 nCoV-19 in the UK: a substudy of two randomised controlled trials (COV001 and COV002). *Lancet.* 2021. https://doi.org/10.1016/s0140-6736(21)01699-8
132. A Study of Ad26.COV2.S in Adults (COVID-19). In: https://clinicaltrials.gov/ct2/show/NCT04436276?id=NCT04436276&draw=1&rank=1;
133. Novavax Announces COVID-19 Vaccine Booster Data Demonstrating Four-Fold Increase in Neutralizing Antibody Levels Versus Peak Responses After Primary Vaccination [press release]. Novavax, August 5, 2021 2021. https://ir.novavax.com/2021-08-05-Novavax-Announces-COVID-19-Vaccine-Booster-Data-Demonstrating-Four-Fold-Increase-in-Neutralizing-Antibody-Levels-Versus-Peak-Responses-After-Primary-Vaccination.
134. Iketani S, Liu L, Nair MS, et al. A third COVID-19 vaccine shot markedly boosts neutralizing antibody potency and breadth. *medRxiv.* 2021:2021.2008.2011.21261670. https://doi.org/10.1101/2021.08.11.21261670
135. PFIZER AND BIONTECH ANNOUNCE SUBMISSION OF INITIAL DATA TO U.S. FDA TO SUPPORT BOOSTER DOSE OF COVID-19 VACCINE [press release]. NEW YORK & MAINZ, Germany2021. https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-submission-initial-data-us-fda.
136. Wu K, Choi A, Koch M, et al. Preliminary Analysis of Safety and Immunogenicity of a SARS-CoV-2 Variant Vaccine Booster. *medRxiv.* 2021:2021.2005.2005.21256716. https://doi.org/10.1101/2021.05.05.21256716
137. Bar-On YM, Goldberg Y, Mandel M, et al. BNT162b2 vaccine booster dose protection: A nationwide study from Israel. *medRxiv.* 2021:2021.2008.2027.21262679. https://doi.org/10.1101/2021.08.27.21262679
138. Patalon T, Gazit S, Pitzer VE, Prunas O, Warren JL, Weinberger DM. Short Term Reduction in the Odds of Testing Positive for SARS-CoV-2; a Comparison Between

Two Doses and Three doses of the BNT162b2 Vaccine. *medRxiv.* 2021:2021.2008.2029.21262792. https://doi.org/10.1101/2021.08.29.21262792