NH Science Brief: Safety and Effectiveness of COVID-19 mRNA Vaccines in Adults, Adolescents, & Children

September 2022

INTRODUCTION

The Pfizer-BioNTech and Moderna mRNA COVID-19 vaccines have been the primary vaccines available and used during the COVID-19 pandemic to protect against infection, symptomatic disease, severe outcomes and long-term consequences of COVID-19. These vaccines first became available to persons 16 years of age and older in December 2020, and availability subsequently expanded to adolescents 12-15 years old in May 2021, children 5-11 years old in November 2021, and infants and young children 6 months – 4 years old in June 2022. As vaccine expanded to younger age groups, the NH Division of Public Health Services (NH DPHS) has monitored and reviewed the developing global scientific and medical data from study of these vaccines, and has continually updated healthcare providers and other partners about COVID-19 vaccines.[1] This scientific brief summarizes key findings from the large number of studies on COVID-19 mRNA vaccine safety and effectiveness that has been generated from one of the largest vaccination efforts in history.

VACCINES PROTECT AGAINST INFECTION, SYMPTOMATIC DISEASE, & SEVERE DISEASE

Data on protection provided by COVID-19 vaccines comes from multiple sources, including pharmaceutical clinical trials, real-world use vaccine effectiveness studies, and studies that evaluate a person's immune response to vaccination. Because COVID-19 vaccines have become available to different age groups at different times during the pandemic, interpretation of vaccine effectiveness studies must take into account the changes in the circulating COVID-19 variants at the time of study. Study of COVID-19 mRNA vaccines in adults, adolescents, and children have shown the following important findings:

1. A 2-dose primary series with either the Pfizer-BioNTech or Moderna vaccine is highly effective against early COVID-19 variants at preventing COVID-19 and severe disease (e.g., hospitalization and death). Pharmaceutical clinical trials for adults, adolescents, and children 5 years of age or older show that both the Pfizer-BioNTech and Moderna vaccines were 90% effective or greater at preventing symptomatic disease with equal or greater protection against severe disease, and protection lasted for many months after the second vaccine dose.[2-9]

2. Vaccine effectiveness studies from real-world use in the U.S. and multiple other countries have confirmed the pharmaceutical clinical trial findings and have also shown very high 2-dose vaccine effectiveness during the early pandemic until the Delta variant began circulating (summer 2021) in both adults[10-25] and adolescents.[26-30]

3. Vaccine effectiveness studies from real-world use in children 5-11 years old did not become available until 2022, and at this point the genetically divergent Omicron (BA.1) variant was widely circulating (see findings below). COVID-19 vaccines for infants and younger children down to 6 months of age only recently became available in June 2022 during a period when additional Omicron variants (BA.2, BA.4, and BA.5) were circulating. Therefore, real-world effectiveness studies for this youngest age group are forthcoming. However, results from pharmaceutical trials and study of antibody response to vaccination in infants and younger children have shown a comparable or higher level of protection after vaccination compared to what has been seen in older children, adolescents, and adults.[31-33]

4. As time since primary series vaccination increased and the Delta variant emerged, vaccine effectiveness at preventing COVID-19 began to decrease, but vaccines remained very effective at preventing severe disease. With emergence of the Omicron variant, however, there was a notable decrease in the 2-dose vaccine effectiveness even against severe disease. Trends were consistently seen in both adults,[6,22-24,34-45] and in children and adolescents.[30,46-54]

5. Administration of a booster dose (i.e., 3rd mRNA vaccine dose), was found to be important for increasing protection against COVID-19 and severe disease, especially after Omicron emerged. A booster dose has been shown to significantly increase antibody protection against Omicron variants[55-60] and is important for expanding a person's immune response to provide better protection against a range of past and likely future variants.[61-62] Booster doses have also been shown to provide greater and longer-lasting protection against COVID-19 and severe outcomes from both Delta and Omicron variants. Findings are consistent in both adults[45,63-81] and children and adolescents.[46,49,52] One recent study showed that hospitalizations from COVID-19 were 10 times higher in people who were unvaccinated compared with people who had received both a primary series and booster dose when Omicron was the predominant circulating variant.[81]

6. Even after a single vaccine booster, however, antibody protection against the genetically divergent Omicron variants (BA.1, BA.2, BA.4, and BA.5) has been found to decrease over the course of 4-6 months, and a second booster dose (i.e., 4th mRNA vaccine dose) results in substantially increased antibody levels.[56,62,82] Real-world use vaccine effectiveness studies have similarly shown a decrease in vaccine effectiveness against Omicron variants which can be increased with a second booster dose.[68,71,73,76-77,79,83-87]

7. Omicron-targeted booster vaccines have now been developed by Pfizer-BioNTech and Moderna which have been shown to provider higher levels of antibody protection against Omicron variants. Early data show that these updated vaccine boosters increase a person's antibody protection, provide better protection across a range of different variants, and may provide longer lasting protection.[88-90]

VACCINES PROTECT AGAINST OTHER COVID-19 COMPLICATIONS

COVID-19 vaccines protect against longer-term complications that can be caused by COVID-19, sometimes called "Post-COVID Conditions" (PCC), or long-COVID. People can experience a wide range of different symptoms and complications after COVID-19; studies in adults have estimated that 10-20% of adults who develop COVID-19 may experience long-term symptoms or complications.[91-92] COVID-19 vaccines have been found to protect against long-COVID symptoms if a person develops infection after vaccination.[93-97] Evidence for occurrence of long-COVID in children and adolescents is more limited; however, it appears that children and adolescents are also at risk for long-COVID symptoms, although the risk appears to be lower than compared with adults.[98-102]

Development of myocarditis (heart inflammation) after COVID-19 is one significant risk for all ages, including children and adolescents.[102-104] One study estimated that about 150 cases of myocarditis occur for every 100,000 persons who develop COVID-19, and the risk of COVID-19 associated myocarditis was highest in young children and older adults.[104] Another example of a post-COVID condition which has potentially life-long consequences is development of diabetes. Multiple studies, including in children, have shown an increased risk of new-onset diabetes after COVID-19.[105-111] One study estimated that the increased risk of new diabetes in adults was one person for every 100 infected; however, the risk increased for people with baseline pre-diabetes, and for people with more severe disease who required hospitalization.[111] Therefore, COVID-19 has both short-term and long-term health implications which can be prevented with vaccination.

Multisystem inflammatory syndrome in children (MIS-C) is another COVID-19 syndrome that results in severe body inflammation, multiple organ system dysfunction, and hospitalization. Since the beginning of the pandemic, more than 8,800 children have been diagnosed with MIS-C resulting in 72 deaths; the most common age group to experience MIS-C after COVID-19 is children 5-11 years of age.[112] COVID-19 vaccination has been shown to be highly effective at preventing MIS-C, and the vast majority of children hospitalized with MIS-C are unvaccinated.[113-114]

VACCINES ARE SAFE

More than 610 million doses of COVID-19 vaccines have been administered in the United States since December 2020.[115] The pharmaceutical clinical trials have shown that the mRNA COVID-19 vaccines are safe to use in adults, adolescents, and children with very few serious side effects or adverse reactions.[2-9] Real-world safety monitoring has also shown the COVID-19 vaccines to be safe. Two primary monitoring systems have been implemented and used nationally to monitor the safety of vaccines – the Vaccine Adverse Event Reporting System (VAERS) and v-safe.[116-118] VAERS requires providers to report all serious adverse events that occur after vaccination, regardless of whether or not the event is associated with vaccination so further investigation can occur; VAERS was designed as an early warning system to detect potential safety signals with vaccines.[116-117] V-safe is a voluntary smartphone-based system that uses text messaging and web-based surveys to monitor occurrence of common local and systemic side effects that occur after COVID-19 vaccination.[116,118] Since COVID-19 vaccines have been rolled out to adults, adolescents, and children, these safety monitoring systems have consistently shown that the Pfizer-BioNTech and Moderna COVID-19 vaccines are safe, even in young children and infants.[119-123] VAERS has found a very small risk of myocarditis after mRNA vaccination, especially in male adolescents and young adults after the second dose.[124] However, the risk of myocarditis from COVID-19 is estimated to be substantially higher than the risk from vaccination in all age groups, even in young male adolescents and adults who have 2-8 times higher risk of myocarditis from COVID-19 than from vaccination.[125]

CONCLUSION

COVID-19 vaccines are safe and effective, and they can help prevent life-long complications from COVID-19. Everyone 6 months of age or older should be vaccinated, including with an updated Omicron booster, if eligible.

REFERENCES

1. New Hampshire Department of Health and Human Services (DHHS). General provider COVID-19 resources and information. NH COVID-19 response website: https://www.covid19.nh.gov/resources/general-provider-covid-19-resources-and-information. Accessed 9/14/2022.
2. Polack FP, et al. Safety and efficacy of the BNT162b2 mRNA COVID-19 vaccine. N Engl J Med. 2020 Dec;383(27):2603-15.
3. Baden LR, et al. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. N Engl J Med. 2021 Feb;384(5):403-16.
4. Frenck RW, et al. Safety, immunogenicity, and efficacy of the BNT162b2 COVID-19 vaccine in adolescents. N Engl J Med. 2021 Jul;385(3):239-50.
5. El Sahly HM, et al. Efficacy of the mRNA-1273 SARS-CoV-2 vaccine at completion of blinded phase. N Engl J Med. 2021 Nov;385(19):1774-85.
6. Thomas SJ, et al. Safety and efficacy of the BNT162b2 mRNA COVID-19 vaccine through 6 months. N Engl J Med. 2021 Nov;385(19):1761-1773.
7. Kashif A, et al. Evaluation of mRNA-1273 SARS-CoV-2 vaccine in adolescents. N Engl J Med. 2021 Dec;385(24):2241-51.
8. Walter EB, et al. Evaluation of the BNT162b2 COVID-19 vaccine in children 5 to 11 years of age. N Engl J Med. 2022 Jan;386(1):35-46.
9. Creech CB, et al. Evaluation of mRNA-1273 COVID-19 vaccine in children 6 to 11 years of age. N Engl J Med. 2022 May;386(21):2011-23.
10. Thompson MG, 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 Morb Mortal Wkly Rep. 2021 Apr;70(13):495-500.
11. Dagan N, et al. BNT162b2 mRNA COVID-19 vaccine in a nationwide mass vaccination setting. N Engl J Med. 2021 Apr;384(15):1412-23.
12. Tenforde MW, et al. Effectiveness of Pfizer-BioNTech and Moderna vaccines against COVID-19 among hospitalized adults aged ≥65 years – United States, January-March 2021. MMWR Morb Mortal Wkly Rep. 2021 May;70(18):674-9.
13. Hall VJ, et al. COVID-19 vaccine coverage in health-care workers in England and effectiveness of BNT162b2 mRNA vaccine against infection (SIREN): a prospective, multicenter, cohort study. Lancet. 2021 May;397(10286):1725-35.

14. Pilishvili T, et al. Interim estimates of vaccine effectiveness of Pfizer-BioNTech and Moderna COVID-19 vaccines among health care personnel – 33 U.S. sites, January-March2021. MMWR Morb Mortal Wkly Rep. 2021 May;70(20):753-8.

15. Haas EJ, et al. Impact and effectiveness of mRNA BNT162b2 vaccine against SARS-CoV-2 infections and COVID-19 cases, hospitalizations, and deaths following a nationwide vaccination campaign in Israel: an observation study using national surveillance data. Lancet. 2021 May;397(10287):1819-29.

16. Angel Y, et al. Association between vaccination with BNT162b2 and incidence of symptomatic and asymptomatic SARS-CoV-2 infections among healthcare workers. JAMA. 2021 Jun;325(24):2457-65.

17. Abu-Raddad LJ, Chemaitelly H, and Butt AA. Effectiveness of the BNT162b2 COVID-19 vaccine against the B.1.1.7 and B.1.351 variants. N Engl J Med. 2021 Jul;385(2):187-9.

18. Thompson MG, et al. Prevention and attenuation of COVID-19 with the BNT162b2 and mRNA-1273 vaccines. N Engl J Med. 2021 Jul;385(4):320-29.

19. Moline HL, et al. Effectiveness of COVID-19 vaccines in preventing hospitalization among adults aged ≥65 years – COVID-Net, 13 states, February-April 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(32):1088-93.

20. Self WH, et al. Comparative effectiveness of Moderna, Pfizer-BioNTech, and Janssen (Johnson & Johnson) vaccines in preventing COVID-19 hospitalizations among adults without immunocompromising conditions – United States, March-August 2021. MMWR Morb Mortal Wkly Rep. 2021 Sept;70(38):1337-43.

21. Butt AA, et al. SARS-CoV-2 vaccine effectiveness in a high-risk national population in a real-world setting. Ann Intern Med. 2021 Oct;174(10):1404-8.

22. Tenforde MW, et al. Association between mRNA vaccination and COVID-19 hospitalization and disease severity. JAMA. 2021 Nov;326(20):2043-54.

23. Pilishvili T, et al. Effectiveness of mRNA COVID-19 vaccine among U.S. health care personnel. N Engl J Med. 2021 Dec;385(25):e90.

24. Rosenberg ES, et al. COVID-19 vaccine effectiveness in New York State. N Engl J Med. 2022 Jan;386(2):116-27.

25. Chodick G, et al. The effectiveness of the two-dose BNT162b2 vaccine: Analysis of real-world data. Clin Infect Dis. 2022 Feb;74(3):472-8.

26. Delahoy MJ, et al. Hospitalizations associated with COVID-19 among children and adolescents – COVID-NET, 14 states, March 1, 2020 – August 14, 2021. MMWR Morb Mortal Wkly Rep. 2021 Sep;70(36):1255-60.

27. Olson SM, et al. Effectiveness of Pfizer-BioNTech mRNA vaccination against COVID-19 hospitalization among persons aged 12-18 years – United States, June-September 2021. MMWR Morb Mortal Wkly Rep. 2021 Oct;70(42):1483-8.

28. Reis BY, et al. Effectiveness of BNT162b2 vaccine against Delta variant in adolescents. N Engl J Med. 2021 Nov;385(22):2101-3.

29. Olson SM, et al. Effectiveness of BNT162b2 vaccine against critical COVID-19 in adolescents. N Engl J Med. 2022 Feb;386(8):713-23.

30. Price AM, et al. BNT162b2 protection against the Omicron variant in children and adolescents. N Engl J Med. 2022 May;386(20):1899-1909.

31. U.S. Food and Drug Administration (FDA), Vaccines and Related Biological Products Advisory Committee (VRBPAC). FDA briefing document: EUA amendment request for Pfizer-BioNTech COVID-19 vaccine for use in children 6 months through 4 years of age. VRBPAC meeting. 2022 Jun;Online: https://www.fda.gov/media/159195/download.

32. U.S. Food and Drug Administration (FDA), Vaccines and Related Biological Products Advisory Committee (VRBPAC). FDA briefing document: EUA amendment request for use of the Moderna COVID-19 vaccine in children 6 months through 17 years of age. VRBPAC meeting. 2022 Jun;Online: https://www.fda.gov/media/159189/download.

33. Fleming-Dutra KE, et al. Interim recommendations of the Advisory Committee on Immunization Practices for use of Moderna and Pfizer-BioNTech COVID-19 vaccines in children age 6 months – 5 years – United States, June 2022. MMWR Morb Mortal Wkly Rep. 2022 Jul;71(26):859-68.

34. Bernal JL, et al. Effectiveness of COVID-19 vaccines against the B.1.617.2 (Delta) variant. N Engl J Med. 2021 Aug;385(7):585-94.

35. Rosenberg ES, et al. New COVID-19 cases and hospitalizations among adults, by vaccination status – New York, May 3 – July 25, 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(34):1150-5.

36. Tenforde MW, et al. Sustained effectiveness of Pfizer-BioNTech and Moderna vaccines against COVID-19 associated hospitalizations among adults – United States, March-July 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(34):1156-62.

37. Fowlkes A, et al. Effectiveness of COVID-19 vaccines in preventing SARS-CoV-2 infection among frontline workers before and during B.1.617.2 (Delta) variant predominance – Eight U.S. locations, December 2020-August 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(34):1167-9.

38. Nanduri S, et al. Effectiveness of Pfizer-BioNTech and Moderna vaccines in preventing SARS-CoV-2 infection among nursing home residents before and during widespread circulation of the SARS-CoV-2 B.1.617.2 (Delta) variant – National healthcare safety network, March 1-August 1, 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(34):1163-6.

39. Bajema KL, et al. Effectiveness of COVID-19 mRNA vaccines against COVID-19 – associated hospitalizations – Five Veterans Affairs medical centers, United States, February 1 – August 6, 2021. MMWR Morb Mortal Wkly Rep. 2021 Sept;70(37):1294-99.

40. Scobie HM, et al. Monitoring incidence of COVID-19 cases, hospitalizations, and deaths, by vaccination status – 13 U.S. jurisdictions, April 4 – July 17, 2021. MMWR Morb Mortal Wkly Rep. 2021 Sept;70(37):1284-90.

41. Tartof SY, et al. Effectiveness of mRNA BNT162b2 COVID-19 vaccine up to 6 months in a large integrated health system in the USA: a retrospective cohort study. Lancet. 2021 Oct;398(10309):1407-16.

42. Chemaitelly H, et al. Waning of BNT162b2 vaccine protection against SARS-CoV-2 infection in Qatar. N Engl J Med. 2021 Dec;385(24):e83.

43. Hall V, et al. Protection against SARS-CoV-2 after COVID-19 vaccination and previous infection. N Engl J Med. 2022 Mar;386(13):1207-20.

44. Ssentongo P, et al. SARS-CoV-2 vaccine effectiveness against infection, symptomatic and severe COVID-19: a systematic review and meta-analysis. BMC Infect Dis. 2022 May;22(1):439.

45. Altarawneh HN, et al. Effects of previous infection and vaccination on symptomatic Omicron infections. N Engl J Med. 2022 Jul.387(1):21-34.

46. Klein NP, et al. Effectiveness of COVID-19 Pfizer-BioNTech BNT162b2 mRNA vaccination in preventing COVID-19 – associated emergency department and urgent care encounters and hospitalizations among nonimmunocompromised children and adolescents aged 5 – 17 years – VISION Network, 10 states, April 2021 – January 2022. MMWR Morb Mortal Wkly Rep. 2022 Mar;71(9):352-8.

47. Shi DS, et al. Hospitalizations of children aged 5-11 years with laboratory-confirmed COVID-19 – COVID-NET, 14 states, March 2020 – February 2022. MMWR Morb Mortal Wkly Rep. 2022 Apr;71(16):574-81.

48. Dorabawila V, et al. Risk of infection and hospitalization among vaccinated and unvaccinated children and adolescents in New York after the emergence of the Omicron variant. JAMA. 2022 Jun;327(22):2242-4.

49. Fleming-Dutra KE, et al. Association of prior BNT162b2 COVID-19 vaccination with symptomatic SARS-CoV-2 infection in children and adolescents during Omicron predominance. JAMA. 2022 Jun;327(22):2210-9.

50. Cohen-Stavi CJ, et al. BNT162b2 vaccine effectiveness against Omicron in children 5 to 11 years of age. N Engl J Med. 2022 Jul;387(3):227-36.

51. Florentino PTV, et al. Vaccine effectiveness of two-dose BNT162b2 against symptomatic and severe COVID-19 among adolescents in Brazil and Scotland over time: a test-negative case-control study. Lancet Infect dis. 2022 Aug;S1473-3099(22):Online ahead of print: https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(22)00451-0/fulltext.

52. Tartof SY, et al. Effectiveness associated with BNT162b2 vaccine against emergency department and urgent care encounters for Delta and Omicron SARS-CoV-2 infection among adolescents aged 12 to 17 years. JAMA Netw Open. 2022 Aug;5(8):e2225162.

53. Tan SHX, et al. Effectiveness of BNT162b2 vaccine against Omicron in children 5 to 11 years of age. N Engl J Med. 2022 Aug;387(6):525-32.

54. Lin D-Y, et al. Effects of vaccination and previous infection on Omicron infections in children. N Engl J Med. 2022 Sept;Online ahead of print: https://www.nejm.org/doi/full/10.1056/NEJMc2209371.

55. Falsey AR, et al. SARS-CoV-2 neutralization with BNT162b2 vaccine dose 3. N Engl J Med. 2021 Oct.385(17):1627-9.

56. Pajon R, et al. SARS-Cov-2 Omicron variant neutralization after mRNA-1273 booster vaccination. N Engl J Med. 2022 Mar;386(11):1088-91.

57. Yu J, et al. Neutralization of the SARS-Cov-2 Omicron BA.1 and BA.2 variants. N Engl J Med. 2022 Apr;386(16):1579-80.

58. Qu P, et al. Neutralization of the SARS-CoV-2 Omicron BA.4/5 and BA.2.12.1 subvariants. N Engl J Med. 2022 Jun;386(26):2526-8.

59. Wang L, et al. Differential neutralization and inhibition of SARS-CoV-2 variants by antibodies elicited by COVID-19 mRNA vaccines. Nat Commun. 2022 Jul;13(1):4350.

60. Hachmann NP, et al. Neutralization escape by SARS-CoV-2 Omicron subvariants BA.2.12.1, BA.4, and BA.5. N Engl J Med. 2022 Jul;387(1):86-8.

61. Muecksch F, et al. Increased memory B cell potency and breadth after a SARS-CoV-2 mRNA boost. Nature. 2022 Jul;607(7917):128-34.

62. Munro APS, et al. Safety, immunogenicity, and reactogenicity of BNT162b2 and mRNA-1273 COVID-19 vaccines given as fourth-dose boosters following two doses of ChAdOx1 nCoV-19 or BNT162b2 and a third dose of BNT162b2 (COV-BOOST): a multicenter, blinded, phase 2, randomised trial. Lancet Infect Dis. 2022 Aug;22(8):1131-41.

63. Yinon MB, et al. Protection of BNT162b2 vaccine booster against COVID-19 in Israel. N Engl J Med. 2021 Oct;385(15):1393-1400.

64. Yinon MB, et al. Protection against COVID-19 by BNT162b2 booster across age groups. N Engl J Med. 2021 Dec;385(26):2421-30.

65. Arbel R, et al. BNT162b2 vaccine booster and mortality due to COVID-19. N Engl J Med. 2021 Dec;385(26):2413-20.

66. Barda N, et al. Effectiveness of a third dose of the BNT162b2 mRNA COVID-19 vaccine for preventing severe outcomes in Israel: an observational study. Lancet. 2021 Dec;398(10316):2093-2100.

67. Yaki S, et al. Effectiveness of a third dose of BNT162b2 mRNA vaccine. J Infect dis. 2022 Jan;225(1)1:30-3.

68. Thompson MG, et al. Effectiveness of a third dose of mRNA vaccines against COVID-19 – associated emergency department and urgent care encounters and hospitalizations among adults during periods of Delta and Omicron variant predominance – VISION Network, 10 states, August 2021 – January 2022. MMWR Morb Mortal Wkly Rep. 2022 Jan;71(4):139-45.

69. Johnson AG, et al. COVID-19 incidence and death rates among unvaccinated and fully vaccinated adults with and without booster doses during periods of Delta and Omicron variant emergence – 25 U.S. jurisdictions, April 4 – December 25, 2021. MMWR Morb Mortal Wkly Rep. 2022 Jan;71(4):132-8.

70. Spitzer A, et al. Association of a third dose of BNT162b2 vaccine with incidence of SARS-CoV-2 infection among health care workers in Israel. JAMA. 2022 Jan;327(4):341-9.

71. Accorsi EK, et al. Association between 3 doses of mRNA COVID-19 vaccine and symptomatic infection caused by the SARS-CoV-2 Omicron and Delta variants. JAMA. 2022 Feb;327(7):639-51.

72. Patalon T, et al. Odds of testing positive for SARS-CoV-2 following receipt of 3 vs 2 doses of the BNT162b2 mRNA vaccine. JAMA Intern Med. 2022 Feb;182(2):179-84.

73. Ferdinands JM, et al. Waning 2-dose and 3-dose effectiveness of mRNA vaccines against COVID-19 – associated emergency department and urgent care encounters and hospitalizations among adults during periods of Delta and Omicron variant predominance – VISION Network, 10 states, August 2021 – January 2022. MMWR Morb Mortal Wkly Rep. 2022 Feb;71(7):255-63.

74. Tenforde MW, et al. Effectiveness of mRNA vaccination in preventing COVID-19 – associated invasive mechanical ventilation and death – United States, March 2021 – January 2022. MMWR Morb Mortal Wkly Rep. 2022 Mar;71(12):459-65.

75. Lauring AS, et al. Clinical severity of, and effectiveness of mRNA vaccines against, COVID-19 from Omicron, delta, and alpha SARS-CoV-2 variants in the United States: prospective observational study. BMJ. 2022 Mar;376:e069761.

76. Andrews N, et al. COVID-19 vaccine effectiveness against the Omicron (BA.1.1.529) variant. N Engl J Med. 2022 Apr;386(16):1532-46.

77. Tseng HF, et al. Effectiveness of mRNA-1273 against SARS-CoV-2 Omicron and Delta variants. Nat Med. 2022 May;28(5):1063-71.

78. Björk J, et al. COVID-19 vaccine effectiveness against severe disease from SARS-CoV-2 Omicron BA.1 and BA.2 subvariants – surveillance results from southern Sweden, December 2021 to March 2022. Euro Surveill. 2022 May;27(18):2200322.

79. Tartof SY, et al. Durability of BNT162b2 vaccine against hospital and emergency department admissions due to the Omicron and Delta variants in a large health system in the USA: a test-negative case-control study. Lancet Respir Med. 2022 Jul;10(7):689-99.

80. Ng OT, et al. Analysis of COVID-19 incidence and severity among adults vaccinated with 2-dose mRNA COVID-19 or inactivated SARS-CoV-2 vaccines with and without boosters in Singapore. JAMA Netw Open. 2022 Aug;5(8):e2228900.

81. Havers FP, et al. COVID-19 – associated hospitalizations among vaccinated and unvaccinated adults 18 years or older in 13 US states, January 2021 to April 2022. JAMA Intern Med. 2022 Sep;Online ahead of print: https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2796235.

82. Regev-Yochay G, et al. Efficacy of a fourth dose of COVID-19 mRNA vaccine against Omicron. N Engl J Med. 2022 Apr;386(14):1377-80.

83. Magen O, et al. Fourth dose of BNT162b2 mRNA COVID-19 vaccine in a nationwide setting. N Engl J Med. 2022 Apr;386(17):1603-14.

84. Bar-On YM, et al. Protection by a fourth dose of BNT162b2 against Omicron in Israel. N Engl J Med. 2022 May;386(18):1712-20.

85. Gazit S, et al. Short term, relative effectiveness of four doses versus three doses of BNT162b2 vaccine in people aged 60 years and older in Israel: retrospective, test negative, case-control study. BMJ. 2022 May;377:e071113.

86. Muhsen K, et al. Association of receipt of the fourth BNT162b2 dose with Omicron infection and COVID-19 hospitalizations among residents of long-term care facilities. JAMA Intern Med. 2022 Aug;182(8):859-67.

87. Cohen MJ, et al. Association of receiving a fourth dose of the BNT162b vaccine with SARS-CoV-2 infection among health care workers in Israel. JAMA Netw Open. 2022 Aug;5(8):e2224657.

88. Chalkias S, et al. A bivalent Omicron-containing booster vaccine against COVID-19. N Engl J Med. 2022 Sep;Online ahead of print: https://www.nejm.org/doi/full/10.1056/NEJMoa2208343.

89. U.S. Centers for Disease Control and Prevention (CDC), Advisory Committee on Immunization Practices (ACIP). Pfizer/BioNTech COVID-19 Omicron-modified bivalent vaccine. ACIP meeting presentation. Sept 1, 2022;Online: https://www.cdc.gov/vaccines/acip/meetings/downloads/slides-2022-09-01/07-COVID-Swanson-508.pdf.

90. U.S. Centers for Disease Control and Prevention (CDC), Advisory Committee on Immunization Practices (ACIP). Booster doses of Moderna COVID-19 vaccines in adults, adolescents & children. ACIP meeting presentation. Sept 1, 2022;Online: https://www.cdc.gov/vaccines/acip/meetings/downloads/slides-2022-09-01/06-COVID-Miller-508.pdf.

91. Bull-Otterson L, et al. Post-COVID conditions among adult COVID-19 survivors aged 18-64 and ≥65 years – United States, March 2020 – November 2021. MMWR Morb Mortal Wkly Rep. 2022 May;71(21):713-7.

92. Tenforde MW, et al. Point prevalence estimates of activity-limiting long-term symptoms among United States adults ≥1 month after reported severe acute respiratory syndrome coronavirus 2 infection, 1 November 2021. J Infect Dis. 2022 Jul;Online ahead of print: https://academic.oup.com/jid/advance-article/doi/10.1093/infdis/jiac281/6625825.

93. Antonelli M, et al. Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID symptom study app: a prospective, community-based, nested, case-control study. Lancet Infect Dis. 2022 Jan;22(1):43-55.

94. UK Health Security Agency. The effectiveness of vaccination against long COVID: A rapid evidence briefing. 2022 Feb;Online: https://ukhsa.koha-ptfs.co.uk/cgi-bin/koha/opac-retrieve-file.pl?id=fe4f10cd3cd509fe045ad4f72ae0dfff.

95. Zisis SN, et al. The protective effect of coronavirus disease 2019 (COVID-19) vaccination on post-acute sequelae of COVID-19: A multicenter study from a large national health research network. Open Forum Infect Dis. 2022 May;9(7):ofac228.

96. Kuodi P, et al. Association between BNT162b2 vaccination and reported incidence of post-COVID-19 symptoms: cross-sectional study 2020-21, Israel. NPJ Vaccines. 2022 Aug;7(1):101.

97. Azzolini E, et al. Association between BNT162b2 vaccination and long COVID after infections not requiring hospitalizations in health care workers. JAMA. 2022 Aug;328(7):676-8.

98. Zimmermann P, et al. How common is long COVID in children and adolescents? Pediatr Infect dis J. 2021 Dec;40(12):e482-7.

99. Borch L, et al. Long COVID symptoms and duration in SARS-CoV-2 positive children – a nationwide cohort study. Eur J Pediatr. 2022 Apr;181(4):1597-1607.

100. Funk AL, et al. Post-COVID-19 conditions among children 90 days after SARS-CoV-2 infection. JAMA Netw Open. 2022 Jul;5(7):e2223253.

101. Taquet M, et al. Neurological and psychiatric risk trajectories after SARS-CoV-2 infection: an analysis of 2-year retrospective cohort studies including 1,284,437 patients. Lancet Psychiatry. 2022 Aug;Online ahead of print: https://www.thelancet.com/journals/lanpsy/article/PIIS2215-0366(22)00260-7/fulltext.

102. Rao S, et al. Clinical features and burden of postacute sequelae of SARS-CoV-2 infection in children and adolescents. JAMA Pediatr. 2022 Aug;e222800.

103. Pei-Ni J, et al. SARS-CoV-2 infection and associated cardiovascular manifestations and complications in children and young adults: A scientific statement from the American Heart Association. Circulation. 2022 May;145(19):e1037-52.

104. Boehmer TK, et al. Association between COVID-19 and myocarditis using hospital-based administrative data – United States, March 2020-January 2021. MMWR Morb Mortal Wkly Rep. 2021 Sept;70(35):1228-32.

105. Barrett CE, et al. Risk for newly diagnosed diabetes >30 days after SARS-CoV-2 infecitno among persons aged <18 years – United States, March 1, 2020-June 28, 2021. MMWR Morb Mortal Wkly Rep. 2022 Jan;71(2):59-65.

106. Gottesman BL, et al. Incidence of new-onset type 1 diabetes among US children during the COVID-19 global pandemic. JAMA Pediatr. 2022 Apr;176(4):414-5.

107. Cromer SJ, et al. Newly diagnosed diabetes vs. pre-existing diabetes upon admission for COVID-19: Associated factors, short-term outcomes, and long-term glycemic phenotypes. J diabetes Complications. 2022 Apr;36(4):108145.

108. Xie Y and Al-Aly Z. Risks and burdens of incident diabetes in long COVID: a cohort study. Lancet Diabetes Endocrinol. 2022 May;10(5):311-21.

109. Rathmann W, Kuss O, and Kostev K. Incidence of newly diagnosed diabetes after COVID-19. Diabetologia. 2022 Jun;65(6):949-54.

110. Magge SN, et al. The COVID-19 pandemic is associated with a substantial rise in frequency and severity of presentation of youth-onset type 2 diabetes. J Pediatr. 2022 Aug;Online ahead of print: https://www.jpeds.com/article/S0022-3476(22)00719-3/fulltext.

111. Montori VM. Patients surviving COVID-19 had increased risk for incident diabetes vs. persons without COVID-19. Ann Intern Med. 2022 Aug;175(8):JC93.

112. U.S. Centers for Disease Control and Prevention (CDC). Health department-reported cases of multisystem inflammatory syndrome in children (MIS-C) in the United States. CDC website: https://covid.cdc.gov/covid-data-tracker/#mis-national-surveillance. Accessed 9/13/2022.

113. Zambrano LD, et al. Effectiveness of BNT162b2 (Pfizer-BioNTech) mRNA vaccination against multisystem inflammatory syndrome in children among persons 12-18 years – United States, July – December 2021. MMWR Morb Mortal Wkly Rep. 2022 Jan;71(2):52-8.

114. Zambrano LD, et al. BNT162b2 mRNA vaccination against COVID-19 is associated with decreased likelihood of multisystem inflammatory syndrome in U.S. children ages 5-18 years. Clin Infect Dis. 2022 Aug;Online ahead of print: https://academic.oup.com/cid/advance-article/doi/10.1093/cid/ciac637/6655523.

115. U.S. Centers for Disease Control and Prevention (CDC). COVID-19 Vaccinations in the United States. CDC website: https://covid.cdc.gov/covid-data-tracker/#vaccinations. Accessed 9/13/2022.

116. Rosenblum HG, et al. Safety of mRNA vaccines administered during the initial 6 months of the US COVID-19 vaccination programme: and observational study of reports to the Vaccine Adverse Event Reporting System and v-safe. Lancet Infect Dis. 2022 Jun;22(6):802-12.

117. U.S. Centers for Disease Control and Prevention (CDC). Vaccine Adverse Event Reporting System (VAERS). CDC website: https://www.cdc.gov/vaccinesafety/ensuringsafety/monitoring/vaers/index.html. Accessed 9/13/2022.

118. U.S. Centers for Disease Control and Prevention (CDC). V-safe after vaccination health checker. CDC website: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/safety/vsafe.html. Accessed 9/13/2022.

119. Hause AM, et al. COVID-19 vaccine safety in adolescents aged 12-17 years – United States, December 14, 2020 – July 16, 2021. MMWR Morb Mortal Wkly Rep. 2021 Aug;70(31):1053-8.

120. Hause AM, et al. Safety monitoring of COVID-19 vaccine booster doses among persons aged 12-17 years – United States, December 9, 2021 – February 20, 2022. MMWR Morb Mortal Wkly Rep. 2022 Mar;71(9):347-51.

121. Hause AM, et al. Safety of COVID-19 vaccination in United States children ages 5 to 11 years. Pediatrics. 2022 Aug;150(2):e2022057313.

122. Hause AM, et al. Safety monitoring of Pfizer-BioNTech COVID-19 vaccine booster among children aged 5-11 years – United States, May 17 – July 31, 2022. MMWR Morb Mortal Wkly Rep. 2022 Aug;71(33):1047-51.

123. Hause AM, et al. COVID-19 mRNA vaccine safety among children aged 6 months – 5 years – United States, June 18, 2022 – August 21, 2022. MMWR Morb Mortal Wkly Rep. 2022 Sept;71(35):1115-20.

124. Shimabukuro T. COVID-19 vaccine safety update: Primary series in young children and booster doses in older children and adults. ACIP meeting presentation. 2022 Sept;Presentation online: https://www.cdc.gov/vaccines/acip/meetings/downloads/slides-2022-09-01/05-COVID-Shimabukuro-508.pdf.

125. Block JP, et al. Cardiac complications after SARS-CoV-2 infection and mRNA COVID-19 vaccination – PCORnet, United States, January 2021-January 2022. MMWR Morb Mortal Wkly Rep. 2022 Apr;71(14):517-23.