

## Appendix

**Appendix Table 1:** Data dictionary.

Variable	Variable type	Definition
master_hcu_id	Character	Character variable indicating unique identifier for observation (i.e., primary NHI [Master HCU ID])
gender_code	Character	Character variable denoting gender (M=male or F=female)
date_of_birth	Date	Date variable indicating date of birth
date_of_death	Date	Date variable indicating date of death (where applicable)
age	Numeric	Numeric variable indicating age
ethnicity_priority_l1	Character	Character variable indicating priority 1 ethnicity
ethnicity_priority_l2	Character	Character variable indicating priority 2 ethnicity
ethnicity_is_euro	Numeric	Binary variable indicating whether the observation ethnicity is European
ethnicity_is_maori	Numeric	Binary variable indicating whether the observation ethnicity is Māori
ethnicity_is_pacific	Numeric	Binary variable indicating whether the observation ethnicity is Pacific
ethnicity_is_asian	Numeric	Binary variable indicating whether the observation ethnicity is Asian
ethnicity_is_melaa	Numeric	Binary variable indicating whether the observation ethnicity is MELAA
ethnicity_is_other	Numeric	Binary variable indicating whether the observation ethnicity is Other
dhb_domicile_name	Character	Character variable indicating DHB name
date_last_infected	Date	Date variable indicating date of last infection
dose_1	Date	Date variable indicating date of first dose
dose_2	Date	Date variable indicating date of second dose
booster_1	Date	Date variable indicating date of booster 1 dose
booster_2	Date	Date variable indicating date of booster 2 dose
first_infection	Date	Date variable indicating date of first infection
second_infection	Date	Date variable indicating date of second infection
third_infection	Date	Date variable indicating date of third infection
fourth_infection	Date	Date variable indicating date of fourth infection
most_recent_hospitalisation	Date	Date variable indicating date of most recent hospitalisation

**Appendix Table 1 (continued):** Data dictionary.

primary_clinical_code	Character	Character variable indicating primary_clinical as at code
primary_category_short_description	Character	Character variable indicating primary_category_short as at description
primary_category_long_description	Character	Character variable indicating primary_category_long as at description
vaccination_status	Character	Character variable indicating the number of doses and boosters received (i.e., dose 1, dose 2 etc.)
date_last_vaccinated	Date	Date variable indicating date of the last vaccination
age_group	Character	Character variable indicating age group (5-year age bands)
number_of_infections	Numeric	Numeric variable indicating number of infections
m3score	Numeric	Numeric variable indicating m3 score—indices for adjusting for comorbidity and multimorbidity
p3score	Numeric	Numeric variable indicating p3 score—indices for adjusting for comorbidity and multimorbidity
infectious	Numeric	Binary variable indicating whether the observation is infected or not (1=yes, 0=no)
immunity_hybrid	Numeric	Numeric variable derived from an ABM (agent-based model) indicating level of hybrid immunity (greater the number i.e., closer 1, the more hybrid immunity)
immunity_infection_induced	Numeric	Numeric variable derived from an ABM indicating level of infection-induced immunity (greater the number i.e., closer 1, the more infection-induced immunity)
immunity_vaccine_induced	Numeric	Numeric variable derived from an ABM indicating level of vaccine-induced immunity (greater the number i.e., closer 1, the more vaccine-induced immunity)
susceptible	Numeric	Numeric variable derived from an ABM indicating level of susceptibility to infection (greater the number i.e., closer 1, the more susceptible)

**Appendix Table 2:** Uptake of COVID-19 vaccines.

Cohorts	Received dose	Total number	Percentage	Cumulative percentage
<b>Vaccinated cohort</b>				
First dose	160,197	4,318,211	3.0%	82.0%
Second dose	1,420,124	4,158,014	27.0%	78.9%
First booster	1,982,783	2,737,890	37.6%	52.0%
Second booster	755,107	755,107	14.3%	14.3%
<b>Unvaccinated cohort</b>				
Unvaccinated	N/A	950,804	18.0%	

NB: This table represents the vaccine uptake for everyone in Aotearoa New Zealand across all age groups, ranging from 0–113 years.

**Appendix Table 3:** Vaccine effectiveness as a function of time elapsed since the second booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% CI)	
	Hospitalisation	Infections (PCR+RAT)*
<b>Age (10–49 years)</b>		
1	89.4% (71.6–96.0)	53.2% (31.8–68.3)
2	47.9% (5.3–71.3)	23.4% (-43.5–59.1)
3		-23.2% (-117.30–30.2)
4		-7.1% (-119.2–47.6)
5		34.0% (-9.9–60.4)
6		
<b>Age (50–69 years)</b>		
1	85.9% (75.1–92.2)	61.8% (49.4–71.2)
2	81.0% (58.1–91.4)	35.1% (3.9–56.2)
3	77.6% (59.3–89.7)	-4.4% (-66.0–34.4)
4	79.2% (60.7–89.7)	18.1% (-20.7–44.4)
5	62.0% (34.8–76.7)	-22.0% (-87.6–20.6)
6		12.5% (-42.2–46.1)
<b>Age (≥70 years)</b>		
1	73.9% (54.2–85.2)	61.0% (43.3–73.1)
2	79.0% (58.8–89.3)	48.8% (18.3–67.9)
3	78.3% (55.8–89.6)	25.6% (-28.1–56.8)
4	34.3% (56.4–86.4)	17.2% (-12.1–38.8)
5		
6		-9.1% (-79.2–33.6)
<b>Sex (female)</b>		
1	72.0% (54.3–82.8)	51.5% (35.6–63.4)
2	82.3% (65.8–90.9)	29.1% (0.2–49.6)
3	64.8% (37.7–80.1)	-5.8% (-60.0–30.0)
4	74.5% (58.7–84.6)	20.0% (-15.7–44.7)
5	53.7% (25.6–71.2)	-0.6% (-40.7–28.1)
6		26.2% (-14.5–52.4)

**Appendix Table 3 (continued):** Vaccine effectiveness as a function of time elapsed since the second booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% CI)	
	Hospitalisation	Infections (PCR+RAT)*
<b>Sex (male)</b>		
1	89.0% (80.3–93.9)	62.0% (50.4–70.8)
2	75.5% (50.6–90.8)	38.2% (5.2–59.7)
3	77.6% (60.3–89.3)	12.1% (-39.2–44.5)
4	41.9% (16.6–59.5)	30.4% (-0.4–51.8)
5		-29.5% (-89.5–11.5)
6		-10.3% (-67.8–27.5)
<b>Ethnicity (Māori)</b>		
1	81.1% (46.0–93.4)	55.4% (21.4–74.7)
2	51.9% (7.6–74.9)	65.0% (21.7–84.4)
3		10.9% (-84.4–56.9)
4	36.6% (-16.8–63.4)	37.8% (0.4–61.2)
5		
6		
<b>Ethnicity (Pacific peoples)</b>		
1	92.2% (37.6–98.9)	75.8% (43.5–89.6)
2	80.2% (23.8–95.2)	64.9% (1.0–87.5)
3		24.5% (-59.6–64.3)
4	56.7% (-0.7–81.3)	-55.6% (-148.6–50.7)
5		
6		
<b>Ethnicity (European)</b>		
1	79.8% (69.2–87.7)	56.9% (45.6–65.9)
2	84.0% (71.7–92.6)	33.5% (8.0–52.0)
3	73.8% (57.2–83.6)	-6.6% (-58.3–28.2)
4	75.7% (62.0–84.5)	12.0% (-6.1–27.0)
5	40.8% (01.2–64.5)	
6	45.9% (-7.5–29.3)	

**Appendix Table 3 (continued):** Vaccine effectiveness as a function of time elapsed since the second booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% CI)	
	Hospitalisation	Infections (PCR+RAT)*
<b>Ethnicity (Asian and MELAA)</b>		
1	83.4% (54.5–93.9)	42.2% (7.0–64.1)
2	61.6% (12.9–73.0)	9.3% (-93.2–57.4)
3		26.2% (-58.0–65.6)
4		24.4% (-12.9–49.5)
5	17.0% (-136.6–70.9)	
6		

\*Rapid antigen tests (RATs) were introduced on 16 February 2022.

NB: Deaths were not considered as there was no COVID-19-related death in the vaccinated cohort (second booster dose) during the follow-up period.

**Appendix Table 4:** Vaccine effectiveness as a function of time elapsed since first booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)			
	Hospitalisation	Death	Infection (PCR)	Infection (PCR+RAT)*
<b>Age (10–49 years)</b>				
1	86.8% (72.2–93.4)	-	42.8% (21.5–58.2)	30.6% (25.4–35.5)
2	83.7% (72.6–90.3)	-		19.9% (15.0–24.4)
3	59.8% (22.9–79.0)	-		-11.4% (-19.9--3.6)
4	47.5% (18.5–66.2)	-	-	-28.9% (-40.1--18.5)
5		-	-	-48.7% (-72.0--28.6)
6		-	-	-41.6% (-76.0--24.0)
<b>Age (50–69 years)</b>				
1	79.3% (61.5–88.8)	-	68.9% (50.6–80.4)	32.7% (26.3–38.5)
2	81.6% (72.5–92.5)	83.8% (60.2–93.4)		28.0% (23.3–32.3)
3	80.5% (71.2–86.7)			9.1% (2.9–14.8)
4	75.3% (61.4–84.2)	92.8% (67.1–98.4)	-	-12.4% (-20.8--4.5)
5	61.8% (38.6–76.3)		-	-38.7% (-53.8--25.0)
6	66.9% (50.8–77.8)		-	-11.3% (-29.8–4.6)
<b>Age (≥70 years)</b>				
1	92.4% (79.6–97.2)	-	40.0% (-90.8–81.1)	46.4% (27.4–60.4)
2	89.2% (80.7–93.9)	92.0% (83.3–96.2)		27.6% (14.2–38.9)
3	86.2% (77.0–91.7)			17.9% (5.5–28.6)

**Appendix Table 4 (continued):** Vaccine effectiveness as a function of time elapsed since first booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)			
	Hospitalisation	Death	Infection (PCR)	Infection (PCR+RAT)*
4	68.6% (50.6–80.1)	85.8% (73.7–92.3)	-	-24.2% (-43.9--7.3)
5	64.0% (44.6–76.7)		-	-65.2% (-96.6--38.0)
6	54.7% (32.9–69.4)		-	-13.1% (-41.6--9.6)
<b>Female</b>				
1	81.7% (73.7–87.7)	-	56.4% (37.4–69.6)	19.2% (15.7–22.6)
2	79.9% (73.1–85.1)	96.9% (77.7–99.6)		20.7% (17.8–23.5)
3	74.6% (65.4–81.4)	91.1% (73.7–97.0)		-6.5% (-11.1--2.0)
4	61.3% (46.8–71.4)	92.1% (73.3–97.7)	-	-22.1% (-28.3--16.2)
5	59.0% (41.9–71.1)	92.2% (65.5–98.2)	-	-44.1% (-56.1--33.0)
6	53.8% (34.6–67.4)		-	-28.3% (-44.0--14.3)
<b>Male</b>				
1	81.3% (70.6–88.8)	-	45.1% (21.1–61.8)	21.4% (17.8–24.8)
2	82.2% (75.0–88.0)	89.0% (67.2–96.3)		16.6% (13.3–19.9)
3	74.8% (64.6–82.1)	87.7% (67.8–95.3)		-16.2% (-21.8--10.9)
4	70.4% (56.7–79.8)	87.0% (63.2–94.7)	-	-39.1% (-47.3--31.3)
5	62.2% (45.9–73.8)	80.3% (25.0–94.8)	-	-53.8% (-68.7--40.2)
6	59.7% (43.5–71.2)		-	-33.4% (-52.7--16.5)

**Appendix Table 4 (continued):** Vaccine effectiveness as a function of time elapsed since first booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)			
	Hospitalisation	Death	Infection (PCR)	Infection (PCR+RAT)*
<b>Māori</b>				
1	77.5% (62.4–86.5)	-		22.8% (18.0–27.2)
2	84.0% (75.4–89.6)	95.6% (66.1–99.4)	75.1% (52.0–87.1)	21.5% (17.2–26.6)
3	70.2% (52.0–80.5)			-11.2% (-19.2--3.7)
4	61.6% (38.3–76.1)	93.5% (44.1–99.3)	-	-29.1% (-41.0--18.3)
5	53.0% (30.2–68.4)		-	-55.6% (-81.2--33.5)
6		-	-	-47.8% (-86.2--17.4)
<b>Pacific peoples</b>				
1	83.5% (71.3–90.4)	-		15.9% (9.1–22.2)
2	91.0% (83.8–95.0)	95.5% (83.0–98.8)	37.8% (5.2–59.2)	2.0% (-6.8–10.1)
3	76.7% (56.1–76.7)	94.4% (47.4–99.4)		-19.4% (-34.5--6.0)
4	80.6% (60.7–80.6)	85.4% (44.3–96.2)	-	-68.0% (-97.9--42.5)
5	61.6% (7.8–77.0)		-	-84.8% (-145.2--58.6)
6	61.6% (5.0–75.0)		-	-41.1% (-105.2--70.0)
<b>European</b>				
1	84.4% (76.0–89.9)	-		26.5% (23.5–29.5)
2	77.7% (70.1–83.3)	89.6% (53.0–97.7)	68.6% (51.2–79.8)	24.0% (21.5–26.4)
3	78.2% (70.8–82.2)	83.8% (64.0–92.7)		-5.8% (-9.7--1.9)
4	66.3% (54.4–73.1)	89.1% (70.9–95.9)	-	-27.7% (-33.4--22.3)

**Appendix Table 4 (continued):** Vaccine effectiveness as a function of time elapsed since first booster dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)			
	Hospitalisation	Death	Infection (PCR)	Infection (PCR+RAT)*
5	63.4% (50.4–72.9)	90.5% (66.9–97.3)	-	-47.5% (-58.2--37.5)
6	52.8% (36.9–64.7)		-	-33.6% (-48.3--20.4)
<b>Asian and MELAA</b>				
1	80.5% (56.6–91.3)	-	37.4% (-18.9–62.6)	-18.2% (-32.9--5.2)
2	72.5% (43.2–86.6)	92.3% (62.0–98.4)		-22.1% (-35.1--10.3)
3	61.6% (10.5–83.5)	93.4% (63.8–98.8)		-54.0% (-74.0--36.3)
4	61.5% (9.4–90.6)		-	-26.2% (-43.4--11.0)
5	54.3% (5.4–80.0)	-	-	-41.9% (-72.0--17.1)
6	69.1% (36.1–85.0)	-	-	-10.6% (-41.1--58.9)

\*Rapid antigen tests (RATs) were introduced on 16 February 2022.

**Appendix Table 5:** Vaccine effectiveness as a function of time elapsed since the second dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)		
	Hospitalisation	Infection (PCR)	Infection (PCR+RAT)*
<b>Age (10–49 years)</b>			
1	91.2% (82.6–95.6)	87.55% (84.31–89.88)	75.56% (65.64–82.62)
2	88.9% (77.4–94.6)	89.65% (86.94–91.80)	60.20% (48.22–69.40)
3	71.0% (55.6–81.0)	77.07% (71.35–81.65)	22.44% (6.56–35.62)
4	73.2% (61.4–81.4)	43.39% (30.72–53.64)	22.87% (13.30–31.29)
5	72.6% (62.6–79.9)	34.45% (15.68–49.05)	48.03% (43.50–52.30)
6	67.3% (54.8–76.3)	-	71.26% (68.81–73.52)
<b>Age (50–69 years)</b>			
1	98.8% (90.8–99.8)	92.35% (87.73–95.23)	77.04% (69.71–82.59)
2		92.83% (86.37–96.22)	77.25% (68.95–84.86)
3	92.9% (78.2–97.7)	88.75% (79.93–93.69)	46.40% (32.46–57.45)
4	71.5% (34.9–87.5)	75.17% (59.13–85.31)	19.13% (5.33–30.92)
5	75.9% (58.1–86.2)	67.61% (44.65–81.04)	54.71% (49.65–59.65)
6	79.9% (67.2–87.6)	-	76.80% (74.44–79.45)
<b>Age (≥70 years)</b>			
1	86.0% (23.8–97.4)	84.95% (25.34–96.70)	75.64% (-12.20–87.80)
2			-0.60% (-233.90–69.71)
3	60.0% (10.7–82.1)	78.76% (-17.00–96.15)	51.68% (-11.90–88.10)
4			30.01% (-24.60–60.68)
5	61.5% (35.5–77.1)	-69.70% (-4663.00–49.12)	36.62% (7.94–56.37)
6			69.89% (57.35–78.74)
<b>Female</b>			
1	91.7% (79.5–96.7)	85.45% (80.53–89.13)	61.51% (58.15–64.61)
2	86.8% (68.6–94.5)	88.26% (84.26–91.24)	40.98% (35.68–46.84)
3	70.9% (51.8–82.5)	77.34% (70.94–82.68)	11.60% (5.17–17.60)
4	68.3% (52.9–78.6)	52.47% (38.88–63.80)	2.97% (-2.10–7.90)
5	69.1% (56.8–77.8)	44.63% (23.03–60.17)	29.85% (27.58–32.58)
6	69.9% (58.8–78.1)	-	51.44% (49.43–53.37)

**Appendix Table 5 (continued):** Vaccine effectiveness as a function of time elapsed since the second dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)		
	Hospitalisation	Infection (PCR)	Infection (PCR+RAT)*
<b>Male</b>			
1	93.9% (84.5–97.6)	90.82% (87.10–92.90)	57.82% (54.23–60.12)
2	94.0% (84.4–97.0)	91.56% (88.30–93.92)	43.01% (38.09–47.53)
3	78.6% (62.5–87.7)	81.07% (74.24–84.92)	10.74% (4.15–16.88)
4	78.9% (63.6–87.7)	45.70% (28.79–58.60)	2.56% (-2.80–7.60)
5	77.0% (64.9–84.9)	36.32% (13.43–53.17)	23.56% (20.43–26.56)
6	76.2% (64.6–84.0)	-	45.3% (43.0–47.5)
<b>Māori</b>			
1	90.0% (69.9–96.7)	83.7% (78.1–87.9)	50.9% (44.6–56.4)
2	86.1% (65.0–94.6)	93.4% (90.3–95.5)	42.7% (36.3–48.4)
3	65.2% (37.8–80.5)	85.4% (78.1–89.1)	4.3% (-3.4–9.6)
4	79.2% (63.0–88.3)	75.6% (64.1–83.3)	0.0% (-6.1–6.4)
5	70.9% (49.2–82.5)	67.7% (44.9–75.9)	23.4% (19.2–27.3)
6	73.1% (56.4–83.5)	-	41.3% (37.8–44.6)
<b>Pacific peoples</b>			
1	91.2% (72.7–97.2)	86.5% (79.0–91.3)	54.6% (46.8–62.0)
2	95.8% (79.6–99.1)	84.6% (78.1–89.1)	46.6% (37.5–54.3)
3	75.6% (50.0–88.1)	68.3% (56.2–77.0)	0.83% (-11.5–8.8)
4	60.7% (23.1–79.9)	30.6% (3.2–50.3)	-11.4% (-21.9--1.8)
5	73.5% (56.3–84.0)	22.4% (-10.6–37.6)	13.4% (6.9–19.3)
6	79.2% (61.6–88.8)	-	34.3% (28.1–40.9)
<b>European</b>			
1	94.6% (84.2–98.1)	93.4% (90.1–95.5)	60.0% (57.1–62.7)
2	90.5% (76.6–96.1)	92.7% (89.1–95.1)	36.7% (31.6–41.5)
3	87.2% (74.8–93.5)	87.2% (80.7–91.5)	18.4% (12.6–23.9)
4	73.3% (56.3–83.7)	53.7% (36.5–64.6)	8.1% (3.4–13.6)
5	62.7% (46.2–74.1)	53.4% (30.0–69.9)	32.7% (30.2–35.0)
6	75.1% (65.4–82.0)	-	51.9% (50.2–53.6)

**Appendix Table 5 (continued):** Vaccine effectiveness as a function of time elapsed since the second dose (sub-group analysis).

Baseline characteristic	Vaccine effectiveness (95% confidence interval)		
	Hospitalisation	Infection (PCR)	Infection (PCR+RAT)*
<b>Asian and MELAA</b>			
1	85.4% (12.5–97.6)	77.0% (53.2–60.3)	65.4% (59.0–70.8)
2	90.5% (20.8–98.9)	87.5% (73.0–94.2)	51.6% (41.8–59.8)
3	74.5% (45.7–88.0)	74.4% (54.2–54.8)	39.4% (26.8–49.8)
4		24.7% (-27.1–75.3)	6.9% (-8.9–20.4)
5	68.1% (39.2–83.2)	34.9% (-8.4–58.4)	7.4% (-2.9–17.1)
6		-	31.3% (24.2–37.8)

\*Rapid antigen tests (RATs) were introduced on 16 February 2022.

**Appendix Table 6:** Vaccine effectiveness as a function of time elapsed since the first dose.

Months	Vaccine effectiveness (95% confidence interval)			
	Hospitalisation	Death	Infection (PCR)	Infection (PCR + RAT)*
1	69.6% (50.1–81.5)	87.6% (38.9–97.5)	63.2% (56.1–69.2)	46.4% (43.0–49.6)
2	88.5% (80.6–93.1)		-	46.5% (44.6–48.5)
3	-		-	-

Baseline characteristics	Vaccine effectiveness (95% confidence interval)		
	Hospitalisation	Infection (PCR)	Infection (PCR+RAT)*
<b>Age (10–49 years)</b>			
1	69.1% (46.6–82.1)	63.8% (56.5–69.9)	61.7% (39.4–75.7)
2	87.5% (78.4–92.8)	-	93.6% (89.2–96.2)
<b>Age (50–69 years)</b>			
1	71.0% (9.3–90.7)	65.0% (32.3–68.3)	53.2% (19.2–72.9)
2	96.4% (72.0–99.5)	-	86.7% (76.8–92.3)
<b>Age (≥70 years)</b>			
1	92.1% (22.7–99.2)	-	-
2		-	-
<b>Female</b>			
1	76.1% (50.7–88.4)	65.5% (55.5–73.2)	50.1% (45.8–54.5)
2	86.5% (72.6–93.3)	-	46.5% (43.6–49.3)

**Appendix Table 6:** Vaccine effectiveness as a function of time elapsed since the first dose.

<b>Male</b>			
1	61.3% (22.3–80.8)	60.8% (49.7–69.4)	42.5% (37.4–47.2)
2	90.1% (79.4–95.2)	-	46.2% (43.4–48.9)
<b>Māori</b>			
1	77.2% (47.0–90.2)	54.3% (41.3–64.5)	35.0% (27.4–41.8)
2	84.9% (64.9–93.5)	-	45.7% (41.2–49.8)
<b>Pacific peoples</b>			
1	54.6% (-13.9–81.7)	54.8% (38.2–66.9)	51.0% (45.3–56.4)
2	87.9% (64.9–95.9)	-	52.1% (47.0–56.7)
<b>European</b>			
1	78.7% (49.5–91.0)	67.9% (55.1–77.1)	41.5% (36.5–46.5)
2	83.9% (68.2–91.9)	-	40.4% (37.7–43.0)
<b>Asian and MELAA</b>			
1	72.4% (-6.2–93.8)	82.4% (72.2–88.9)	61.6% (55.5–66.8)
2	84.8% (41.1–96.1)	-	50.5% (45.7–54.7)

\*Rapid antigen tests (RATs) were introduced on 16 February 2022.