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EVIDENCE BRIEF

COVID-19 Variant of Concern Omicron (B.1.1.529): Risk Assessment, January 19, 2022

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Key Messages

- Current reporting of confirmed SARS-CoV-2 cases in some jurisdictions, including Ontario, is an underestimate of the true epidemiology of infections due to changes to testing strategies. As a result, it is challenging to make an accurate and timely identification of the peak of the Omicron wave. Given distinct features of the South Africa context (e.g., prevalence of previous infections, age distribution), it is unknown if Omicron will follow a similar steep rise and fall in cases in other jurisdictions. Predicting the trajectory of ongoing Omicron waves is further complicated by reports of increasing prevalence of the BA.2 Omicron sublineage and displacement of the original BA.1 strain in jurisdictions such as the United Kingdom (UK) and Denmark.

- The evidence continues to demonstrate that three doses of a Coronavirus Disease 2019 (COVID-19) vaccine provides greater protection against severe outcomes of Omicron variant infection compared to two doses. There is additional evidence of stronger antibody responses in vaccinated, previously SARS-CoV-2-infected individuals compared to vaccinated individuals without previous infection, or individuals with previous infection and no vaccination. The duration of protection from a third dose or recent infection remains unclear, but early reports suggest third dose effectiveness against symptomatic infection wanes at ten weeks.

- The bulk of the evidence continues to demonstrate that Omicron causes less severe disease compared to Delta infections, but hospitalization data has many limitations, in particular differences in metrics across jurisdictions. Nonetheless, due to increased transmissibility of Omicron, the absolute number of severe cases poses a significant threat to health system capacity in many jurisdictions. At this time, there is insufficient data to comment on hospitalization outcomes, mortality, or long-term COVID outcomes.

- The current risk of Omicron transmission in Ontario is high, with a low degree of uncertainty. The risk of reinfection and breakthrough infection (after two doses of Pfizer, Moderna, AstraZeneca, or a heterologous combination) in Ontario is high with a low degree of uncertainty. The risk of severe disease, particularly amongst unvaccinated individuals, is moderate with a moderate degree of uncertainty. The overall risk assessment may change as new evidence emerges.

- Based on what is known about Omicron and its high transmissibility and high absolute number of severe cases in Ontario, increased or maintained community-based public health measures and accelerated vaccination efforts targeting those most at-risk of severe outcomes and onward transmission (e.g., those in congregate living settings and schools/daycares) can help protect Ontarians, ensure health system capacity to safely and optimally care for Ontarians, and limit disruption of critical infrastructure and in-person learning.

Issue and Research Question

Since its identification on November 8, 2021 in South Africa,[1] Omicron has become the dominant severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) variant in many countries. Since the last report on January 12, 2022[2] more evidence has emerged of Omicron's transmissibility, potential immune evasion, and disease severity. This brief updates the evidence since the previous Public Health Ontario (PHO) risk assessments,[3-8] and summarizes available information and evidence on the Omicron variant of concern (VOC) relevant to the risk of transmission in Ontario up to January 18, 2022.

Methods

PHO Library Services conducted daily searches of primary and preprint literature using the MEDLINE database (search strategies available upon request). In addition, PHO performed grey literature searches daily using various news feeds and custom search engines. English-language peer-reviewed and non-peer-reviewed (preprint) records that described COVID-19 variants were included.

Main Findings

Genomics

To determine the evolutionary relationships between Omicron and other SARS-CoV-2 variants, the mutational profiles, including the per-site mutation rates were analyzed.[9] Omicron has a unique mutation profile compared to other VOCs. The identification of five mouse-adapted mutation sites in the Omicron variant suggests it may have evolved in a mouse host.

Epidemiology

The early waves of the SARS-CoV-2 pandemic were highly irregular across settings and across dominant SARS-CoV-2 lineages, in part due to levels of immunity, human behavioral patterns, climate, and irregularly timed interventions. Waning population immunity and immune evasion due to Omicron's numerous mutations, make it uncertain whether Omicron outbreak trajectories outside of South Africa will follow the steep rise and fall experienced in that country. Recent analyses of SARS-CoV-2 waves, however, reveal some insights.

- Washburne et al. observed that Omicron outbreaks across South African provinces exhibited a comparable pattern to earlier Delta outbreaks, but on a shorter timescale, with an onset to peak time of approximately 30 days, in contrast to 75 to 90 days observed for Delta peaks.[10] As of January 10, 2022 the first US Omicron outbreaks appear to be exhibiting transmission trajectories similar to the early Omicron outbreaks across South Africa. **The authors hypothesize that in the absence of highly effective mitigation measures, the select Omicron outbreaks they describe have peaked roughly one month after they started, despite differences in testing, reporting, vaccination/infections**; however, it remains unclear if this trajectory will be seen in all settings.

- To visualize the dynamics of cases and deaths, Arnaout and Arnaout plotted the cases and deaths for COVID-19 waves from 16 countries, with time being implicit (and not its usual placement on the X-axis).[11] The plots suggest that in most settings, the Omicron wave is very different from previous waves. The combined plot of many countries to represent the world showed the Omicron wave as having a very steep rise in cases but not in deaths, at least at the time of analyses. The authors also note that the world wide plot shows that new waves have hit every three to five months.

- Schlickeiser and Kroger recently predicted the temporal evolution of the Omicron wave in different countries based on the susceptible-infectious-recovered/removed (SIR) epidemic compartment model, with a constant stationary ratio k=mu(t)/a(t) between the infection (a(t)) and recovery (mu(t)) rate and using a doubling time of three days for the rate of new infections.[12] They proposed three scenarios (optimistic, pessimistic, intermediate) for each country considered. The model estimated Denmark as having the smallest Omicron peak time, which agrees with the recently observed saturation of the 7-day incidence value at 2478. For Germany, the authors predicted the Omicron wave peaks ranging from 32 to 38 and 45 days after the start of the Omicron wave in the optimistic, intermediate and pessimistic scenario, respectively. If using January 1, 2022 as the starting date, the authors analyses suggest that the maximum of the Omicron wave is reached between Feb 1 and Feb 15, 2022, with similar values estimated for Switzerland. **Based on 15 countries, the range of time to Omicron peak was 15 to 67 days, but the vast majority of countries were below 39 days**. The authors go on to make estimates for the Omicron trajectory and health system impact in Germany.

The Omicron lineage BA.2 does not contain the Spike deletion at position 69-70 and therefore is S-gene positive (SGTP).[13] On January 1, 2022, the Omicron lineage BA.2 accounted for 5% of UK SGTP specimens i.e. non-Omicron, in the UK, and the UK Health Security Agency (UKHSA) reports that the proportion is increasing.[14] Therefore, S-Gene Target Failure (SGTF) is no longer considered sufficient to assess the spread of Omicron as a whole in the UK and current comparative analyses which use S-gene target results as the determinant of Omicron and Delta should be interpreted with caution. **As of January 10, 2022, 2,093 sequences on GISAID meet the Omicron BA.2 Pangolin definition, from 22 countries.** From mid-December 2021 to the week of January 1, 2022, an increasing number of BA.2 sequences were reported on GSAID, many from Denmark.

In Ontario, Canada:

- As of January 19, 2022, whole genome sequencing (WGS) from surveillance testing across Canada reported that of SARS-CoV-2 samples collected the week of December 26, 2021, 92.6% were Omicron, but data were still accumulating.[15] On January 19, 2022, Canada reported 21,163 new cases, 148 deaths, 323,113 active cases, and the daily percent positivity (over the previous 7 days) was 22.3%. The Public Health Agency of Canada (PHAC) notes that due to changes in COVID-19 testing policies in many jurisdictions starting in late December 2021, case counts will under estimate the total burden of disease.

- In Ontario, on December 28, 2021, 80.4% of samples tested at the PHO laboratory exhibited SGTF, indicating that Omicron is the dominant circulating variant.[16] The PHO laboratory discontinued SGTF testing on December 30, 2021. Due to changes in the eligibility criteria for PCR testing in Ontario effective December 31, 2021, reported confirmed case counts are an underestimate of the true number of individuals with SARS-CoV-2 infection.

    - The Ontario 7-day confirmed case average increased from 838 on December 1, 2021 to 4,592 on December 23, 2021, 14,162 on January 6, 2022, and was 11,338 on January 11, 2022.[17]

    - On December 31, 2021 (i.e., the day on which changes to the eligibility criteria for PCR testing took effect), the percent positivity was 34.3%.[18] On January 8, 2022 (i.e., just over a week since the testing eligibility update), the percent positivity was 27.7%, and on January 16, 2022 the percent positivity was 24.2%.

    - As of January 18, 2022 there were 422 ongoing outbreaks in long-term care homes, 318 in retirement homes, 595 in congregate living settings, 241 in hospitals, and 28 workplace outbreaks.[19]

Notable epidemiological trends from select countries are:

- During the week of January 10 to January 16, 2022, the World Health Organization (WHO) reported over 18 million new COVID-19 cases, which is a 20% increase compared to the previous week.[20] Only the African Region reported a decrease in incidence of weekly cases. The South-East Asia Region reported the largest increase in new cases (145%), followed by the Eastern Mediterranean Region (68%), the Western Pacific Region (38%), the Region of the Americas (17%) and the European Region (10%). New weekly deaths increased in the South-East Asia Region (12%) and Region of the Americas (7%), but remained similar to the previous week in the other Regions.

- According to modelling projections, the United States (US) Centers for Disease Control and Prevention (CDC) estimated that for the week ending January 15, 2022, 99.5% (90% Confidence Interval [CI]: 99.3-99.7)[21] of SARS-CoV-2 cases were Omicron.

    - As of January 12, 2022, the current 7-day moving average of daily new cases (782,766) increased 33.2% compared with the previous 7-day moving average (587,723).[22]

    - The 7-day daily average hospitalizations for the week ending January 11, 2022, was 20,637, which is a 24.5% increase from the prior 7-day average (16,571) for the week ending January 4, 2022.[22]

- The United Kingdom (UK) Health Security Agency (UKHSA) reported >90% of a representative sample of specimens were Omicron based on SGTF in the last week of December 2021.[23] In the UK, 108,069 new cases were reported on January 18, 2022.[24]

    - Between January 13 to January 19, 2022, 652,469 people had a confirmed positive test, which is a decrease of 37.2% compared to the previous 7 days. Between January 6 to January 12, 2022, there were 1,038,500 confirmed positive tests, which was a decrease of 19.0% compared to the previous 7 days.

    - Between January 9 to January 15, 2022, 14,927 went into hospital with coronavirus, which is a decrease of -4.9% compared to the previous 7 days. Between January 2 and January 8, 2022, there were 15,591 new COVID-19 hospitalizations, an increase of 5.2% compared to the previous 7 days.

- In Denmark, the Omicron variant represented >90% of the confirmed SARS-CoV-2 cases based on analysis of data extracted January 7, 2022.[25]

    - The 7-day rolling average of new cases per million people increased from 722 on November 30, 2021 to 4,327 on January 17, 2022.[26] On January 19, 2022, Denmark reported 38,759 new COVID-19 cases in the previous 24 hours.[27]

- **On January 20, 2022, Denmark reported that the BA.2 Omicron substrain now accounts for nearly half of their cases, and is rapidly displacing the BA.1 Omicron strain.**[28,29] In a two week period from late December to mid-January, BA.2 prevalence increased from 20% to 45% of Denmark's COVID-19 cases. During this time, Denmark's COVID-19 infections reached record highs. The week of January 17, 2022, Denmark reported over 30,000 new cases per day, which is ten times more cases than at the peaks in their previous waves.

- On January 19, 2022, South Africa reported 4,322 new COVID-19 cases and a 10.6% positivity rate.[30]

Transmissibility

Modelling, *in vitro* and *in-silico* analyses support current epidemiological findings of Omicron having higher transmissibility and suggest potential mechanisms. It remains unclear to what extent the increased transmission of Omicron is due to inherent characteristics of the virus (i.e., enhanced ability to infect cells) or due to immune evasion.

Epidemiological Evidence

- The UKHSA estimated the Omicron and Delta serial interval distributions using UK contact tracing data.[31] They reported Omicron (n=11,240) and Delta (12,353) to have similar mean serial intervals, with 3.64 days (95% CI: 3.6, 3.68) for Omicron, and 3.87 days (95% CI: 3.84, 3.9) for Delta. The Omicron serial interval had higher variance and a shorter median interval.

- An analysis of daily growth rates for the Omicron and Delta variants in the UK from November to December 2021 estimated a shorter generation time distribution for Omicron with a mean of 1.5-3.2 days and a standard deviation of 1.3-4.6 days, assuming a generation time distribution for Delta with a mean of 2.5-4 days (90% credible interval) and a standard deviation of 1.9-3 days.[32] The authors estimate this equals a **160%-210% transmission advantage for Omicron compared to Delta** in this setting, which could explain the observed variation over time in the transmission advantage of the Omicron variant. The authors note that other factors, including differences in immune escape between could play a role.

- Using genome surveillance data of Gauteng province as registered to Global Initiative on Sharing Avian Influenza Data (GISAID) to compare the predicted and observed fractions of Omicron, Delta, and other variants from September 16 to November 30, 2021, **a model estimated the effective reproduction number of Omicron to be 4.2 times (95% confidence interval [CI]: 2.1, 9.1) greater than that of the Delta variant.**[33] For the period October 18 to November 30, 2021, the authors estimated the Omicron variant was 3.3 times (95% CI: 2.0, 7.8) more transmissible than the Delta variant. The time-dependent relative risk reduction due to acquired immunity was estimated to be very small, e.g., in the order of 10–20%.

In-vivo, In-vitro and Modelling Evidence

The human ACE2 (hACE2) receptor is used by SARS-CoV-2 to enter host cells; therefore, mutations that alter binding affinity or stability or tissue tropism (e.g., faster replication in human bronchi as opposed to lungs) could impact infectivity and transmission. Since the last PHO Risk Assessment,[2] more *in vitro* studies have reported evidence of Omicron exhibiting different tissue tropism,[34,35] and new *in silico* and electron micrograph studies have analyzed Omicron binding to the hACE2 receptor, with varied findings regarding binding affinity and proteolytic cleavage.[36-39] In addition, an animal model of Omicron has reported evidence that Omicron is less pathogenic than previous SARS-CoV-2 strains, but highly transmissible.[40] A few studies are highlighted below.

- Reidiker et al investigated the distribution of airborne viral emissions for Delta and Omicron, and assessed the risk estimates for public settings given reports of higher viral load and infectivity for these variants.[41] The study simulated indoor airborne transmission of SARS-CoV-2 by including a CO_2 calculator and recirculating air cleaning devices. The authors assessed the consequences of the lower critical dose of more infectious VOCs on the infection risk in public settings with different protection strategies. Monte Carlo modelling revealed that one in 1,000 wild-type infected was a super-emitter, one in 30 for Delta; and one in 20 or 10 for Omicron (depending on the viral load estimate).**The authors conclude that surgical masks are no longer sufficient in most public settings, and correctly fitted FFP2 (European equivalent of KN95 or N95) respirators provide sufficient protection, except in high aerosol producing situations such as singing or shouting.** The authors note that altered mucous viscosity from infection and tissue tropism also play a role in transmissibility, and merits further consideration.

- Using longitudinal, quantitative RT-qPCR test results (n=10,324) from the National Basketball Association's (NBA) occupational health program, a study quantified the fraction of tests with PCR cycle threshold (Ct) values <30 (as a proxy for potential infectivity), duration of viral proliferation, clearance rate, and peak viral concentration for individuals with acute Omicron and Delta variant SARS-CoV-2 infections.[42] Most of the study participants were vaccinated, but details were not reported. Of 27 Omicron cases testing positive ≤ 1 day after a previous negative or inconclusive test, 52.0% (13/25) were PCR positive with Ct values <30 at day 5, 25.0% (6/24) at day 6, and 13.0% (3/23) on day 7 post detection. **Of 70 Omicron cases detected ≥ 2 days after a previous negative or inconclusive test, 39.1% (25/64) were PCR positive with Ct values <30 at day 5, 33.3% (21/63) at day 6, and 22.2% (14/63) on day 7 post detection.** Omicron infections exhibited a mean duration of 9.87 days (95% CI 8.83-10.9) relative to 10.9 days (95% CI 9.41-12.4) for Delta infections. Using PCR Ct values, the authors **estimate the peak viral RNA to be lower for Omicron infections than for Delta infections (Ct 23.3, 95% CI 22.4-24.3 for Omicron; Ct 20.5, 95% CI 19.2-21.8 for Delta) and a shorter clearance phase for Omicron infections (5.35 days, 95% CI 4.78-6.00 for Omicron; 6.23 days, 95% CI 5.43-7.17 for Delta), though the rate of clearance was similar (3.13 Ct/day, 95% CI 2.75-3.54 for Omicron; 3.15 Ct/day, 95% CI 2.69-3.64 for Delta).**

- To determine the viral load in vaccine breakthrough infections (diagnosed positive at least 14 days after second dose) from pre-VOC, Delta and Omicron, infectious virus and RNA were measured from nasopharyngeal specimens.[43] The infectious viral titres during the first five symptomatic days were assessed in vaccine breakthrough infections with Delta (n= 121) or Omicron (n=18). The median time between second dose and breakthrough infection was 79.5 (IQR 40.5-139 days) for Delta infections and 136 (IQR 85-176) for Omicron infections, but these results may be influenced by the timing of mass vaccination programs and when these VOCs emerged. Vaccine breakthrough infection with Omicron (n=18) or Delta (n=17) resulted in comparable SARS-CoV-2 genome copies (p= 0.3345). The Omicron patients had lower infectious viral titres compared to Delta patients, but the difference was not statistically significant (0.69 log difference, p= 0.1033). Of note, **the study reported a very low correlation (R2 = 0.119, p=0.0001) between viral genome copies and infectious virus particles for pre-VOC samples, and low correlation using samples from unvaccinated and vaccinated Delta patients (R2 = 0·312, p <0·0001 and R2 = 0·3962, p <0·0001, respectively).** There was no correlation between the age and infectious viral load.

- An investigation of early cases of Omicron in Japan sought to determine the duration of infectious virus shedding.[44] Using the date of specimen collection for diagnosis or symptom onset as day 0, the quantitative RT- PCR of 83 respiratory specimens from 21 cases (19 vaccinated and 2 unvaccinated cases; 4 asymptomatic and 17 mild cases) showed that **the amount of viral RNA was highest 3-6 days after diagnosis/symptom onset, and then slowly decreased over time, with a marked decrease after 10 days** since diagnosis or symptom onset. Virus isolation tests showed a similar trend as the quantitative RT-PCR. No infectious virus was detected in the respiratory samples after 10 days since diagnosis or symptom onset. For **symptomatic cases, viable virus was detected in 12.5% (2/16) of cases at 0–2 days PSO, 50.0% (4/8) at 3–6 PSO, 18.8% (3/16) at 7–9 days PSO, 0% (0/12) 10–13 days PSO, and 0% (0/10) at >14 days PSO.** The authors conclude that vaccinated Omicron cases are unlikely to shed infectious virus 10 days after diagnosis or symptom onset.

- Molecular docking analysis revealed that the Omicron Spike (S) protein has higher affinity with neuropilin1 (NRP1) than ACE2, which may explain Omicron's increased infectivity.[35] The free binding energies between NRP1 and Omicron S -protein (-332.71 kcal/mol) were significantly higher than free binding energies between NRP1 and S protein of wild-type (-312.61 kcal/mol). Similar to Omicron, wild-type S-protein (-312.61 kcal/mol) exhibited higher free binding energies with NRP1 compared to the free binding energies between ACE2.

Diagnostics

Although most current molecular tests for SARS-CoV-2 are expected to be able to detect Omicron,[8] there is increasing evidence of limited sensitivity, optimal detection windows and specimen site for rapid antigen tests, as previously described.[2]

- Given the broad use of rapid antigen tests (RATs), the sensitivity of eight RATs to Omicron was investigated using analytical sensitivity testing with cultured virus and retrospective testing in duplicates was performed with clinical samples from vaccinated individuals with Omicron (n=18) or Delta (n=17) breakthrough infection using seven RATs.[45] **The authors report high heterogeneity between RAT ability to detect Omicron. Based on cultured virus, there was a trend towards lower sensitivity for Omicron detection compared to wild-type and other VOCs.** A comparison of performance for Delta and Omicron in a comparable set of clinical samples in seven RATs, revealed that 124/252 (49.2%) of all tests performed showed a positive result for Omicron compared to 156/238 (65.6%) for Delta samples. Sensitivity for both Omicron and Delta between RATs was highly variable. **Four out of seven RATs showed significantly lower sensitivity ($p<0.001$) to detect Omicron compared to Delta, while three had comparable sensitivity to Delta.**

Clinical Presentation

Information continues to emerge regarding the signs and symptoms of Omicron and how they may differ from infection with other SARS-CoV-2 variants.

- A UKHSA analysis of NHS Test and Trace data found that loss of smell or taste was reported less often by Omicron cases than Delta cases (13% of Omicron cases, 34% of Delta cases, adjusted odds ratio [aOR]: 0.22, 95% CI: 0.21-0.23), but sore throat was reported more often by Omicron cases (53% of Omicron cases, 34% of Delta cases, aOR: 1.93, 95% CI: 1.88-1.98).[14] The UKHSA notes, however, that increases in sore throat reporting is also observed in those who test negative for SARS-CoV-2, suggesting sore throat could be an incidental finding, though sore throat is also being reported by others as a reported Omicron symptom.[2,7,8]

Disease Severity

There remain limitations with the Omicron severity literature; however, the bulk of early evidence suggests Omicron causes less severe disease than Delta, and this is supported by several new studies that have emerged since the last Risk Assessment;[46] however, there remains a moderate degree of uncertainty regarding disease severity. There is insufficient data to comment on hospitalization outcomes including progression of severity of illness, complications, and mortality. Select studies are highlighted below.

- The UKHSA reported that the number of pediatric admissions with any COVID-19 infection (>90% of UK samples were Omicron at end of November 2021) began increasing from December 26, 2021, from an average of 40 admissions per day to 120 per day, which is a 3-fold rise in 2 weeks.[14] The increase was most rapid among children under 5 years, and highest in infants aged under 1 year. The most common three symptoms (not specified) were consistent with respiratory infection. However, **The Royal College of Pediatrics and Child Health has issued a statement that pediatricians are not reporting Omicron to be a more serious or severe disease in children and young people in the UK.**

- A prospective cohort study conducted in California compared the risk of severe clinical outcomes among Omicron patients and patients infected with other SARS-CoV-2 VOCs.[47] Over 288,534 person-days of follow-up after an outpatient positive test, 88 patients with Omicron variant infections were admitted to hospital, and 189 patients with Delta variant infections over 264,408 person-days of follow-up. Similar to earlier studies, risk of hospital admission was lower in Omicron cases compared to Delta cases. Compared to cases with a Delta infection, the unadjusted hazard ratios of ICU admission and mortality associated with Omicron variant infection were 0.26 (95% CI: 0.10-0.73) and 0.09 (95% CI: 0.01-0.75), respectively, among cases with infections first ascertained in outpatient settings. **The daily risk of mechanical ventilation among Delta patients was significantly higher compared to Omicron variant infections (0.04 vs 0 per 1000 person days at risk following a positive outpatient test; p<0.001).** The estimated median duration of stay for patients with Omicron variant infections with symptomatic hospitalizations was 1.5 (1.3-1.6) days, with 90% of patients expected to complete hospitalizations within 3.1 (2.7-3.6) days. Among symptomatic hospitalized patients with Delta variant infections, the estimated median duration of stay was 4.9 (4.3-5.6) days. This difference corresponded to a **69.6% (64.0-74.5%) shorter median length of hospital stay among patients with Omicron variant infections as compared to patients with Delta variant infections.** In terms of age, **Omicron patients had higher adjusted odds of being aged 20-29 and 30-39 years, and had lowest odds of being young children and older adults, compared to Delta patients.**

- Although South Africa's progress through its Omicron wave is ahead of the rest of the world, data from South Africa may not be generalizable to the Ontario context due to differences in history of previous SARS-CoV-2 infection and vaccination status, as well as age distribution of the population. Nevertheless, two studies are highlighted below, the first of which adjusts their model for previous infection and vaccination.

    - A cohort study in South Africa of 5,144 patients from wave four and 11,609 from prior waves used Cox regression analysis to compare the risk between waves for death, severe outcomes ≤14 days after diagnosis.[48] Adjustments were made for age, sex, comorbidities, geography, vaccination and prior infection. After adjusting for age, sex, comorbidities and sub-district **there was a substantially reduced hazard of death in wave four compared to wave three (adjusted Hazard Ratio [aHR] 0.27; 95% CI: 0.19; 0.38), which was attenuated (0.41; 95% CI 0.29; 0.59) when adjusted for prior infections and vaccination.** The hazard of reduced severity showed a similar pattern to severe hospitalization and death. Of note, **for all outcomes, the reduced risk during the Omicron wave was attenuated with adjustment for prior diagnosed infection and vaccination.** Protection by vaccination against outcomes was similar in wave four compared to wave three: protection against

death from full vaccination aHR (95% CI) was 0.24 (0.10; 0.58) in wave four and 0.35 (0.22; 0.54) in late wave three. Protection by prior infection against hospitalization or death was aHR (95%CI) of 0.32 (0.20; 0.52) in late wave three and 0.13 (0.06; 0.27) during wave four. **Even after accounting for previous infections, there was a 25% reduction in severe hospitalization or death in wave four (Omicron) compared to wave three (Delta).**

- Using SARS-CoV-2 cases from November 1 to December 14, 2021 in South Africa, a study reported that Omicron cases (using lack of RdRp target delay [a cycle threshold in the PCR platform used] as a proxy for the Omicron variant)(n=1,486) had a lower hazard of hospital admission (adjusted Hazard Ratio [aHR] of 0.56, 95% confidence interval [CI] 0.34-0.91), than Delta cases (n=150).[49] Complete vaccination was protective of admission with an aHR of 0.45 (95%CI 0.26-0.77). Adjustments were made for vaccination status, prior infection, and comorbidities.

Vaccine Effectiveness (VE)

Since the last PHO Risk Assessment,[2] more evidence has emerged demonstrating that two doses of COVID-19 vaccines are less effective at preventing Omicron breakthrough infections compared to other VOCs and 'wild-type' SARS-CoV-2. A third COVID-19 vaccine dose increases short-term protection against symptomatic Omicron infection.

- A test negative case control study using UK data estimated the VE against symptomatic infection in 236,023 Delta cases and 760,647 Omicron cases.[14] In individuals who received two doses of AstraZeneca, VE decreased from 45 to 50% at two to four weeks after dose two to almost no effect against Omicron from 20 weeks after the second dose. In individuals who received two doses of Pfizer or Moderna, VE decreased from around 65 to 70% down to around 10% by 20 weeks after the second dose. **Two to four weeks after a third dose, VE ranged from around 65 to 75%, then dropped to 55 to 65% at 5 to 9 weeks, and 45 to 50% from 10+ weeks after the booster.** One dose of vaccine was associated with a 43% reduced risk of hospitalization among symptomatic cases with the Omicron variant, two doses with a 55% reduction up to 24 weeks after the second dose and a 40% reduced risk 25 or more weeks after the second dose, and **a third dose was associated with a 74% reduced risk of hospitalization in the first two to four weeks after vaccination, but dropped slightly to a 66% reduction by 10+ weeks after the booster dose.** Combined with VE against symptomatic disease, this results in a VE against hospitalisation of 58% after one dose, 64% 2 to 24 weeks after two doses, 44% 25+ weeks after two doses, and 92% dropping to 83% 10+ weeks after a third dose. Combining the periods for the third dose, overall VE against hospitalization 2+ weeks after the third dose was 89% (95% CI 86-91%).

In-Vitro and Modelling Evidence of Vaccine Efficacy

Since the previous PHO Risk Assessment,[2] additional studies have reported reduced antibody levels and function against Omicron compared to wild-type SARS-CoV-2 and other VOCs in two-dose vaccinated and/or previously infected individuals,[34,50-52] with some evidence of relatively well-preserved Fc effector function and neutralization against Omicron.[53,54] There is additional evidence to support previous reports that despite the numerous mutations in Omicron, T cell recognition of Omicron is largely preserved.[55,56] There is additional evidence to support the benefit of a longer interval between vaccinations to improve antibody boosting, benefit of heterologous vaccine platform prime-boost compared to homologous adenoviral prime-boost regimens and evidence of stronger antibody responses in vaccinated, previously infected individuals compared to vaccinated individuals without previous infection, or individuals with previous infection and no vaccination.[52,57,58] Select reports are highlighted below.

- AstraZeneca has reported that when their vaccine was given as a third dose booster to individuals previously vaccinated with the AstraZeneca or an mRNA vaccine, it increased the immune response to Beta, Delta, Alpha and Gamma SARS-CoV-2 variants, and increased the antibody response to Omicron.[51,59] The exact results were not reported, but the company indicated data will be submitted to regulators given the demand for boosters. The results build on a recent pre-print reporting that a dose of AstraZeneca COVID-19 vaccine substantially increased antibody levels following a primary vaccine series with CoronaVac (Sinovac Biotech).[60]

- Burns et al quantified antibody responses immediately after a Pfizer vaccination and six months post-inoculation against the wild-type SARS-CoV-2 Spike and RBD, as well as Omicron RBD.[61] A subgroup of adolescents showed decreased Omicron sensitivity compared to wild-type in the weeks following the second vaccine, but most exhibited equal sensitivity for Omicron and wild-type RBD after the second vaccine. **At six-months, adolescents showed a trend towards increased immune responses against Omicron, despite an overall trend towards lower total antibody titers.** There was a strong correlation in declining anti-Spike and anti-RBD titers for both wild-type and Omicron.

Breakthrough Infections and Reinfections

As more individuals in a population become vaccinated, a greater proportion of SARS-CoV-2 infections will occur in vaccinated individuals. However, this does not mean that vaccinated individuals are more likely to get infected. Since the last PHO Risk Assessment,[2] more evidence has emerged characterizing breakthrough infections caused by Omicron.[14,62,63] One study is highlighted below.

- An update to the UK SIREN study (data from June 15, 2020 to January 9, 2022),[14] which is a cohort of over 44,000 National Health Service healthcare workers that undergo asymptomatic testing every two weeks, reported that since mid-December 2021, there has been a steep increase in the PCR positivity. A preliminary assessment of protection from Omicron infections (including symptomatic and asymptomatic individuals), provided by vaccination, prior SARS-CoV-2 infection, or a combination, in a subset (18,464) of the SIREN cohort between December 1, 2021 and January 4, 2022 reported increased protective effect of a third vaccine dose, even in individuals with prior infection, compared to uninfected and unvaccinated participants. **There was additional incremental benefit from each vaccine exposure, even in individuals who have had prior infection.** These results were unadjusted and will be refined in future analyses. Of note, reinfections were defined as new PCR positive infections 90 days after a previous PCR positive date or 28 days after antibody positivity consistent with prior infection.

Measures in Response to Omicron

This section was informed by scanning government websites and searches in the Google search engine for literature related to Omicron, public health measures, and vaccination programming; thus, some relevant articles may not be included. The following jurisdictions were searched on January 18, 2022: Denmark, England, Finland, France, Germany, Ireland, Israel, Italy, Netherlands, Norway, Portugal, New York State, and California.

Changes to Public Health Measures

All included jurisdictions have implemented public health measures in response to the emergence of Omicron. However, some jurisdictions are shifting focus to emphasize vaccination and are expressing interest in or have already started removing restrictions. Since the last Risk Assessment, the following changes to public health measures were identified in select jurisdictions:

- Some jurisdictions eased measures including reopening public venues (e.g., Denmark, Portugal, Netherlands),[64-66] increasing capacity limits (e.g., Norway),[67] or lifting alcohol sales curfews (e.g., Norway).[67] Additionally, some jurisdictions are expressing interest in easing measures in the near future (e.g., England, Finland, Ireland).[68-70]

- Finland limited hours for food and drink establishments and extended public health measures currently in place for another month.[71]

- Some jurisdictions tightened public health measures including vaccine pass eligibility (e.g., France)[72] and validity (e.g., France, Germany).[73,74]

- New York State updated its school attendance policy to allow students a remote option.[75]

Changes to Vaccination Programming

On January 18, 2022, the WHO stated that although there is evidence of some waning of vaccine immunity against Omicron in children and adolescents, more research is needed to ascertain which children and adolescents need booster doses.[76] Since the last Risk Assessment, the following changes to vaccination programming were identified in select jurisdictions:

- Some jurisdictions increased vaccinations either through a fourth dose (e.g., Denmark),[77] second and booster doses for children ages 12 – 17 years (e.g., Germany, Norway),[78,79] first doses for children ages 5 – 11 years (e.g., Norway)[79] or a booster dose for adults (e.g., Portugal).[80]

Ontario Risk Assessment

- The current risk of Omicron transmission in Ontario is high, with a low degree of uncertainty. The risk of reinfection and breakthrough infection in Ontario is high with a low degree of uncertainty, while the risk of severe disease, particularly amongst unvaccinated individuals, is moderate, with a moderate degree of uncertainty. The volume of cases due to the increased transmission of Omicron presents risks to testing capacity and as a result, risks to surveillance quality. The incidence of severe cases due to increased transmission is a threat to health system capacity.
- The overall risk assessment may change as new evidence emerges (see Table 1).

Table 1. Risk Assessment for Omicron B.1.1.529

Issues	Risk Level	Degree of Uncertainty
Increased Transmissibility	**High**	**Low**
Disease Severity	**Moderate**	**Moderate**
COVID-19 Re-infection	**High**	**Low**
Lowered Vaccine Effectiveness/Breakthrough Infections	**High**	**Low**
Impacts on Testing/Surveillance	**Moderate**	**Low**

Implications for Practice

The epidemiology of Omicron in Ontario has become more challenging to interpret due to the rapid increase in Omicron cases and changes in eligibility for PCR testing, which makes metrics such as the reproduction number and confirmed case rate an underestimate. As a result, it is difficult to identify when an Omicron wave has peaked in Ontario and some other jurisdictions.

The evidence for three vaccine doses providing additional protection against symptomatic infection and good protection from hospitalization is strong, making three dose vaccinations (and four doses, in those eligible) a key public health tool in the current Omicron context. There is also growing evidence of similarly high immunity in individuals with a combination of previous infection and vaccination. There is strong evidence to inform an update to the definition of fully vaccinated from two doses to three doses in the context of vaccine certificates and their intended use to lift public health measures while minimizing potential infections. To retain the purpose and effectiveness of vaccine certificates, they should indicate the bearer has the optimal vaccine effectiveness available to them. To prevent inequities, all eligible individuals require support to access third doses. Evidence of what combination of infection(s) and vaccination(s) provide comparable immunity to three doses of vaccine is building, but is less consistent than the evidence that three doses of vaccine provides greater protection against severe outcomes of Omicron variant infection compared to two doses.

Public health measures (e.g., masking, capacity limits) and accelerated booster vaccinations are important to mitigate the surge in Omicron cases, reduce population morbidity and mortality, and address impacts to the health system.

References

1. Network for Genomic Surveillance in South Africa; National Health Laboratory National Institute for Communicable Diseases. SARS-CoV-2 sequencing update: 1 December 2021 [Internet]. Durban: Network for Genomic Surveillance in South Africa; 2021 [cited 2021 Dec 31]. Available from: https://www.nicd.ac.za/wp-content/uploads/2021/12/Update-of-SA-sequencing-data-from-GISAID-1-Dec-Final.pdf

2. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, January 12, 2022 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2022 [cited 2022 Jan 18]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2022/01/covid-19-omicron-b11529-risk-assessment-jan-12.pdf?sc_lang=en

3. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 06]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2021/11/covid-19-omicron-b11529-risk-assessment.pdf?sc_lang=en

4. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, December 7, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 04]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2021/12/covid-19-omicron-b11529-risk-assessment-dec-7.pdf?sc_lang=en

5. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, December 13, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 04]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2021/12/covid-19-omicron-b11529-risk-assessment-dec-13.pdf?sc_lang=en

6. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, December 21, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2021 Dec 26]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2021/12/covid-19-omicron-b11529-risk-assessment.pdf?sc_lang=en

7. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, December 29, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 06]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2022/01/covid-19-omicron-b11529-risk-assessment-dec-29.pdf?sc_lang=en

8. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 variant of concern Omicron (B.1.1.529): risk assessment, January 6, 2022 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2022 [cited 2022 Jan 11]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2022/01/covid-19-omicron-b11529-risk-assessment-jan-6.pdf?sc_lang=en

9. Sun Y, Lin W, Dong W, Xu J. Origin and evolutionary analysis of the SARS-CoV-2 Omicron variant. J Biosaf Biosecur. 2022;4(1):33-7. Available from: https://doi.org/10.1016/j.jobb.2021.12.001

10. Washburne AD, Hupert N, Kogan N, Hanage W, Santillana M. Characterizing features of outbreak duration for novel SARS-CoV-2 variants of concern. medRxiv 22269288 [Preprint]. 2022 Jan 14 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.14.22269288

11. Arnaout R, Arnaout R. Visualizing Omicron: COVID-19 deaths vs. cases over time. Res Sq 1257935 [Preprint]. 2022 Jan 14 [cited 2022 Jan 16]. Available from: https://doi.org/10.21203/rs.3.rs-1257935/v1

12. Schlickeiser R, Kröger M. Forecast of omicron wave time evolution. medRxiv 22269161 [Preprint]. 2022 Jan 16 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.16.22269161

13. World Health Organization. Enhancing response to Omicron SARS-CoV-2 variant [Internet]. Geneva: World Health Organization; 2022 [cited 2022 Jan 20]. Available from: https://www.who.int/publications/m/item/enhancing-readiness-for-omicron-(b.1.1.529)-technical-brief-and-priority-actions-for-member-states

14. UK Health Security Agency. SARS-CoV-2 variants of concern and variants under investigation in England: technical briefing 34 [Internet]. London: Crown Copyright; 2022 [cited 2022 Jan 18]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1048395/technical-briefing-34-14-january-2022.pdf

15. Government of Canada. COVID-19 daily epidemiology update [Internet]. Ottawa, ON: Government of Canada; 2022 [cited 2022 Jan 19]. Available from: https://health-infobase.canada.ca/covid-19/epidemiological-summary-covid-19-cases.html#a1

16. Ontario Agency for Health Protection and Promotion (Public Health Ontario). SARS-CoV-2 (COVID-19 virus) variant of concern (VoC) screening and genomic sequencing for surveillance [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 19]. Available from: https://www.publichealthontario.ca/en/laboratory-services/test-information-index/covid-19-voc

17. Ontario Agency for Health Protection and Promotion (Public Health Ontario). Ontario COVID-19 data tool: case trends [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2022 Jan 18]. Available from: https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool?tab=trends

18. Ontario Agency for Health Protection and Promotion (Public Health Ontario). Ontario COVID-19 data tool: lab tests [Internet]. Toronto, ON: Queen's Printer for Ontario; 2022 [cited 2022 Jan 19]. Available from: https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool?tab=labTests

19. Ontario Agency for Health Protection and Promotion (Public Health Ontario). Ontario COVID-19 data tool: outbreaks [Internet]. Toronto, ON: Queen's Printer for Ontario; 2022 [cited 2022 Jan 19]. Available from: https://www.publichealthontario.ca/en/data-and-analysis/infectious-disease/covid-19-data-surveillance/covid-19-data-tool?tab=outbreaks

20. World Health Organization. Weekly epidemiological update on COVID-19 - 18 January 2022 [Internet]. Geneva: World Health Organization; 2022 [cited 2022 Jan 18]. Available from: https://www.who.int/publications/m/item/weekly-epidemiological-update-on-covid-19---18-january-2022

21. Centers for Disease Control and and Prevention. COVID data tracker: monitoring variant proportions [Internet]. Atlanta, GA: Centers for Disease Control and and Prevention; 2021 [cited 2022 Jan 19]. Available from: https://covid.cdc.gov/covid-data-tracker/#variant-proportions

22. Centers for Disease Control and and Prevention. COVID data tracker weekly review [Internet]. Atlanta, GA: Centers for Disease Control and Prevention; 2022 [cited 2022 Jan 19]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/index.html

23. Thomas T, Duncan P. If Omicron is the dominant variant in UK, why is the number of confirmed cases so low? Guardian [Internet], 2021 Dec 23 [cited 2022 Jan 18]; Omicron variant. Available from: https://www.theguardian.com/world/2021/dec/23/if-omicron-is-the-dominant-variant-in-uk-why-is-the-number-of-confirmed-cases-so-low

24. UK. Health Security Agency. Coronavirus (COVID-19) in the UK: simple summary for United Kingdom [Internet]. London: Crown Copyright; 2022 [cited 2022 Jan 18]. Available from: https://coronavirus.data.gov.uk/easy_read

25. Statens Serum Institut. Status of the SARS-CoV-2 variant Omicron in Denmark [Internet]. Copenhagen: Statens Serum Institut; 2022 [cited 2022 Jan 20]. Available from: https://files.ssi.dk/covid19/omikron/statusrapport/rapport-omikronvarianten-07012022-27nk

26. Our World in Data. Daily new confirmed COVID-19 cases per million people [Internet]. Oxford: Global Change Data Lab; 2022 [cited 2022 Jan 12]. Available from: https://ourworldindata.org/covid-cases

27. Danish Health Authority. Covid-19 surveillance: current data on the development of coronavirus in Denmark [Internet]. Copenhagen: Danish Health Authority; 2022 [cited 2022 Jan 18]. Available from: https://www.sst.dk/en/English/Corona-eng/Status-of-the-epidemic/COVID-19-updates-Statistics-and-charts

28. Statens Serum Institut. Now, an Omicron variant, BA.2, accounts for almost half of all Danish Omicron-cases [Internet]. Copenhagen: Staten Serum Institut; 2022 [updated 2022 Jan 20; cited 2022 Jan 20]. Available from: https://en.ssi.dk/news/news/2022/omicron-variant-ba2-accounts-for-almost-half-of-all-danish-omicron-cases

29. McGregor G. What is 'stealth Omicron'? The rise of the subvariant is alarming some scientists who say it needs its own Greek letter. Fortune [Internet], 2022 Jan 21 [cited 2022 Jan 21]; Coronavirus. Available from: https://fortune.com/2022/01/21/what-is-stealth-omicron-new-covid-variant-substrain-denmark/

30. National Institute for Communicable Diseases. Latest confirmed cases of COVID-19 in South Africa (19 January 2022) [Internet]. Cape Town: National Institute for Communicable Diseases; 2022 [cited 2022 Jan 21]. Available from: https://www.nicd.ac.za/latest-confirmed-cases-of-covid-19-in-south-africa-19-january-2022/

31. UK. Health Security Agency. Infectious disease modelling team: Omicron and Delta serial interval distributions from UK contact tracing data [Internet]. London: Crown Copyright; 2021 [cited 2022 Jan 18]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1046481/S1480_UKHSA_Omicron_serial_intervals.pdf

32. Abbott S, Sherratt K, Gerstung M, Funk S. Estimation of the test to test distribution as a proxy for generation interval distribution for the Omicron variant in England. medRxiv 22268920 [Preprint]. 2022 Jan 10 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.08.22268920

33. Nishiura H, Ito K, Anzai A, Kobayashi T, Piantham C, Rodríguez-Morales AJ. Relative reproduction number of SARS-CoV-2 Omicron (B.1.1.529) compared with Delta variant in South Africa. J Clin Med. 2022;11(1):30. Available from: https://doi.org/10.3390/jcm11010030

34. Aggarwal A, Stella A, Akerman A, Walker G, Milogiannakis V, McAllery S, et al. Rapid isolation and resolution immune evasion and viral fitness across contemporary SARS-CoV-2 variants. Res Sq 1210846 [Preprint]. 2022 Jan 13 [cited 022 Jan 18]. Available from: https://doi.org/10.21203/rs.3.rs-1210846/v1

35. Baindara P, Roy D, Mandal SM. Omicron favors neuropilin1 binding over ACE2: increased infectivity and available drugs. Res Sq 1247982 [Preprint]. 2022 Jan 12 [cited 2022 Jan 18]. Available from: https://doi.org/10.21203/rs.3.rs-1247982/v1

36. Wu L, Zhou L, Mo M, Liu T, Wu C, Gong C, et al. SARS-CoV-2 Omicron RBD shows weaker binding affinity than the currently dominant Delta variant to human ACE2. Signal Transduct Target Ther. 2022;7(1):8. Available from: https://doi.org/10.1038/s41392-021-00863-2

37. Rath SL, Padhi AK, Mandal N. Scanning the RBD-ACE2 molecular interactions in Omicron variant. Biochem Biophys Res Commun. 2022;592:18-23. Available from: https://doi.org/https://doi.org/10.1016/j.bbrc.2022.01.006

38. Hong Q, Han W, Li J, Xu S, Wang Y, Li Z, et al. Molecular basis of SARS-CoV-2 Omicron variant receptor engagement and antibody evasion and neutralization. bioRxiv 475532 [Preprint]. 2022 Jan 10 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.10.475532

39. Eileen S, Lukas H, Friedrich P, Friederike Z, Philipp A. Molecular dynamics simulations of the delta and omicron SARS-CoV-2 spike – ACE2 complexes reveal distinct changes between both variants. Res Sq 1228784 [Preprint]. 2022 Jan 12 [cited 2022 Jan 18]. Available from: https://doi.org/10.21203/rs.3.rs-1228784/v1

40. Yuan S, Ye Z-W, Liang R, Tang K, Zhang AJ, Lu G, et al. The SARS-CoV-2 Omicron (B.1.1.529) variant exhibits altered pathogenicity, transmissibility, and fitness in the golden Syrian hamster model. bioRxiv 476031 [Preprint]. 2022 Jan 13 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.12.476031

41. Riediker M, Briceno-Ayala L, Ichihara G, Albani D, Poffet D, Tsai DH, et al. Higher viral load and infectivity increase risk of aerosol transmission for Delta and Omicron variants of SARS-CoV-2. Swiss Med Wkly. 2022;152:w30133. Available from: https://doi.org/10.4414/smw.2022.w30133

42. Hay JA, Kissler SM, Fauver JR, Mack C, Tai CG, Samant RM, et al. Viral dynamics and duration of PCR positivity of the SARS-CoV-2 Omicron variant. medRxiv 22269257 [Preprint]. 2022 Jan 14 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.13.22269257

43. Puhach O, Adea K, Hulo N, Sattonnet-Roche P, Genecand C, Iten A, et al. Infectious viral load in unvaccinated and vaccinated patients infected with SARS-CoV-2 WT, Delta and Omicron. medRxiv 22269010 [Preprint]. 2022 Jan 18 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.10.22269010

44. Japan. National Institute of Infectious Diseases. Active epidemiological investigation on SARS-CoV-2 infection caused by Omicron variant (Pango lineage B.1.1.529) in Japan: preliminary report on infectious period [Internet]. Tokyo: National Institute of Infectious Diseases; 2022 [cited 2022 Jan 18]. Available from: https://www.niid.go.jp/niid/en/2019-ncov-e/10884-covid19-66-en.html

45. Bekliz M, Perez-Rodriguez F, Puhach O, Adea K, Melancia SM, Baggio S, et al. Sensitivity of SARS-CoV-2 antigen-detecting rapid tests for Omicron variant. medRxiv 21268018 [Preprint]. 2022 Jan 17 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2021.12.18.21268018

46. Garg R, Gautam P, Suroliya V, Agarwal R, Bhugra A, Kaur US, et al. Evidence of early community transmission of Omicron (B1.1.529) in Delhi- A city with very high seropositivity and past-exposure! medRxiv 22269041 [Preprint]. 2022 Jan 13 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.10.22269041

47. Lewnard JA, Hong VX, Patel MM, Kahn R, Lipsitch M, Tartof SY. Clinical outcomes among patients infected with Omicron (B.1.1.529) SARS-CoV-2 variant in southern California. medRxiv 22269045 [Preprint]. 2022 Jan 11 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.11.22269045

48. Davies M-A, Kassanjee R, Rosseau P, Morden E, Johnson L, Solomon W, et al. Outcomes of laboratory-confirmed SARS-CoV-2 infection in the Omicron-driven fourth wave compared with previous waves in the Western Cape Province, South Africa. medRxiv 22269148 [Preprint]. 2022 Jan 12 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.12.22269148

49. Hussey H, Davies M-A, Heekes A, Williamson C, Valley-Omar Z, Hardie D, et al. Assessing the clinical severity of the Omicron variant in the Western Cape Province, South Africa, using the diagnostic PCR proxy marker of RdRp target delay to distinguish between Omicron and Delta infections – a survival analysis. medRxiv 22269211 [Preprint]. 2022 Jan 14 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.13.22269211

50. Zhang J, Cai Y, Lavine CL, Peng H, Zhu H, Anand K, et al. Structural and functional impact by SARS-CoV-2 Omicron spike mutations. bioRxiv 475922 [Preprint]. 2022 Jan 12 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.11.475922

51. Banerjee A, Lew J, Kroeker A, Baid K, Aftanas P, Nirmalarajah K, et al. Immunogenicity of convalescent and vaccinated sera against clinical isolates of ancestral SARS-CoV-2, beta, delta, and omicron variants. bioRxiv 475409 [Preprint]. 2022 Jan 13 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.13.475409

52. Rössler A, Riepler L, Bante D, von Laer D, Kimpel J. SARS-CoV-2 Omicron variant neutralization in serum from vaccinated and convalescent persons. N Eng J Med. 2022 Jan 12 [Epub ahead of print]. Available from: https://doi.org/10.1056/NEJMc2119236

53. Kitchin D, Richardson SI, van der Mescht MA, Motlou T, Mzindle N, Moyo-Gwete T, et al. Ad26.COV2.S breakthrough infections induce high titers of neutralizing antibodies against Omicron and other SARS-CoV-2 variants of concern. medRxiv 21266049 [Preprint]. 2022 Jan 04 [cited 2022 Jan 11]. Available from: https://doi.org/10.1101/2021.11.08.21266049

54. Bartsch Y, Tong X, Kang J, Avendaño MJ, Serrano EF, García-Salum T, et al. Preserved Omicron spike specific antibody binding and Fc-recognition across COVID-19 vaccine platforms. medRxiv 21268378 [Preprint]. 2021 Dec 27 [cited 2022 Jan 11]. Available from: https://doi.org/10.1101/2021.12.24.21268378

55. Nguyen AT, Szeto C, Chatzileontiadou DSM, Tong ZWM, Dewar-Oldis MJ, Cooper L, et al. COVID-19 vaccine booster induces a strong CD+ T cell response against Omicron variant epitopes in HLA-A*02:01+ individuals. bioRxiv 473243 [Preprint]. 2022 Jan 13 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.12.473243

56. Jergovic M, Coplen CP, Uhrlaub JL, Beitel SC, Burgess JL, Lutrick K, et al. Resilient T cell responses to B.1.1.529 (Omicron) SARS-CoV-2 variant. medRxiv 22269361 [Preprint]. 2022 Jan 16 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.16.22269361

57. Aggarwal A, Stella A, Walker G, Akerman A, Milogiannakis V, Brilot F, et al. SARS-CoV-2 Omicron: evasion of potent humoral responses and resistance to clinical immunotherapeutics relative to viral variants of concern. Res Sq 1207364 [Preprint]. 2022 Jan 11 [cited 2022 Jan 18]. Available from: https://doi.org/10.21203/rs.3.rs-1207364/v1

58. Lyke KE, Atmar RL, Islas CD, Posavad CM, Szydlo D, PaulChourdhury R, et al. SARS-CoV-2 Omicron neutralization after heterologous vaccine boosting. medRxiv 22268861 [Preprint]. 2022 Jan 14 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.13.22268861

59. AstraZeneca. New Vaxzevria data further support its use as third dose booster [Internet]. Wilmington, DE: AstraZeneca; 2022 [cited 2022 Jan 18]. Available from: https://www.astrazeneca.com/media-centre/press-releases/2022/new-vaxzevria-data-further-support-its-use-as-third-dose-booster.html

60. Costa Clemens SA, Weckx LY, Clemens R, Almeida Mendes AV, Ramos Souza A, Silveira MV, et al. Randomized immunogenicity and safety study of heterologous versus homologous COVID-19 booster vaccination in previous recipients of two doses of Coronavac COVID-19 vaccine. Lancet. 2021;398(10318):P2258-76. Available from: https://doi.org/10.2139/ssrn.3989848

61. Burns MD, Bartsch YC, Boribong BP, Loiselle M, Davis JP, Lima R, et al. Durability and cross-reactivity of SARS-CoV-2 mRNA vaccine in adolescent children. medRxiv 22268617 [Preprint]. 2022 Jan 10 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.05.22268617

62. Georgii AB, Daria MD, Andrey BK, Nikita Y, Olga VS, Elena N, et al. SARS-CoV-2 Omicron outbreak in a dormitory in Saint-Petersburg, Russia. Res Sq 1243723 [Preprint]. 2022 Jan 11 [cited 2022 Jan 18]. Available from: https://doi.org/10.21203/rs.3.rs-1243723/v1

63. Kared H, Wolf A-S, Alirezaylavasani A, Ravussin A, Solum G, Tran TT, et al. Immunity in Omicron SARS-CoV-2 breakthrough COVID-19 in vaccinated adults. medRxiv 22269213 [Preprint]. 2022 Jan 13 [cited 2022 Jan 18]. Available from: https://doi.org/10.1101/2022.01.13.22269213

64. ABC 8 News. Denmark lifts COVID restrictions, opens many public venues. ABC 8 News [Internet], 2022 Jan 16 [cited 2022 Jan 19]; U.S. and world business news. Available from: https://www.wric.com/business/us-world-business/denmark-lifts-covid-restrictions-opens-many-public-venues/

65. LUSA. Portugal: bars, nightclubs can re-open on Friday from 10pm. Macau Business [Internet], 2022 Jan 14 [cited 2022 Jan 18]; MNA international. Available from: https://www.macaubusiness.com/portugal-bars-nightclubs-can-re-open-on-friday-from-10pm/

66. Government of the Netherlands. Shops, gyms and hairdressers to reopen on Saturday 15 January [Internet]. Amsterdam: Government of the Netherlands; 2022 [cited 2022 Jan 18]. Available from: https://www.government.nl/topics/coronavirus-covid-19/news/2022/01/14/press-conference-14-january-2022

67. Nikel D. Norway lifts alcohol ban, relaxes some Covid restrictions. Forbes [Internet], 2022 Jan 13 [cited 2022 Jan 18]; Travel. Available from: https://www.forbes.com/sites/davidnikel/2022/01/13/norway-lifts-alcohol-ban-relaxes-some-covid-restrictions/?sh=29e18a72dd68

68. Gregory A. 'Encouraging signs' plan B Covid measures may soon be lifted in England. Guardian [Internet], 2022 Jan 16 [cited 2022 Jan 18]; Coronavirus. Available from: https://www.theguardian.com/world/2022/jan/16/encouraging-signs-plan-b-covid-measures-may-soon-be-lifted-in-england

69. YLE News. Current coronavirus restrictions to be extended till mid-February. YLE News [Internet], 2022 Jan 18 [cited 2022 Jan 18]. Available from: https://yle.fi/news/3-12276258

70. Higgins A. Passed the Peak: Covid-19 Ireland – all restrictions including masks and vaccine passes could be axed by end of March. Irish Sun [Internet], 2022 Jan 18 [cited 2022 Jan 18]; Irish News. Available from: https://www.thesun.ie/news/8225398/covid-ireland-restrictions-axed-masks-vaccine-passes-stephen-donnelly/

71. Finland. Government Communications Department. Changes to opening hours of food and beverage service businesses and to use of COVID-19 passport [Internet]. Helsinki: Finnish Government; 2022 [cited 2022 Jan 18]. Available from: https://valtioneuvosto.fi/en/-/1271139/changes-to-opening-hours-of-food-and-beverage-service-businesses-and-to-use-of-covid-19-passport

72. France 24. Health pass becomes 'vaccine pass': details of France's tough new anti-pandemic bill. France 24 [Internet], 2022 Jan 17 [cited 2022 Jan 18]. Available from: https://www.msn.com/en-gb/news/world/health-pass-becomes-vaccine-pass-details-of-france-e2-80-99s-tough-new-anti-pandemic-bill/ar-AASQV2M?ocid=BingNewsSearch

73. Government of France. Coronavirus information: situation update [Internet]. Paris: Government of France; 2022 [cited 2022 Jan 18]. Available from: https://www.gouvernement.fr/info-coronavirus

74. The Local. Covid 'recovered' status only valid for three months, says German Health Ministry. The Local [Internet], 2022 Jan 17 [cited 2022 Jan 18]; COVID-19. Available from: https://www.thelocal.de/20220117/covid-recovered-status-only-valid-for-three-months-says-german-health-ministry/

75. Chang S. NYC Education Department quietly opens door for teachers to allow more remote learning. Gothamist [Internet], 2022 Jan 14 [cited 2022 Jan 18]. Available from: https://gothamist.com/news/nyc-education-department-quietly-opens-door-teachers-allow-more-remote-learning

76. Reuters. WHO says no evidence healthy children, adolecents need COVID-19 boosters. National Post [Internet], 2022 Jan 18 [cited 2022 Jan 18]. Available from: https://nationalpost.com/pmn/health-pmn/who-says-no-evidence-healthy-children-adolecents-need-covid-19-boosters

77. Reuters. Denmark to offer fourth coronavirus jab while easing curbs. Yahoo News [Internet], 2022 Jan 12 [cited 2022 Jan 18]. Available from: https://news.yahoo.com/denmark-ease-coronavirus-restrictions-despite-151750433.html

78. Alkousaa R, Murray M. Germany among first to recommend COVID-19 booster for 12 to 17-year-olds. Reuters [Internet], 2022 Jan 13 [cited 2022 Jan 18]; World. Available from: https://torontosun.com/news/world/germany-among-first-to-recommend-covid-19-booster-for-12-to-17-year-olds

79. Norwegian Institute of Public Health. Offer of coronavirus immunisation for children and adolescents expanded [Internet]. Oslo: Norwegian Institute of Public Health; 2022 [cited 2022 Jan 18]. Available from: https://www.fhi.no/en/news/2022/offer-of-coronavirus-immunisation-for-children-and-adolescents-expanded/

80. TPN/Lusa. Booster jabs now available for over 40's. Portugal News [Internet], 2022 Jan 18 [cited 2022 Jan 18]; COVID-19. Available from: https://www.theportugalnews.com/news/2022-01-17/booster-jabs-now-available-for-over-40s/64673

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