

150+ studier om naturlig immunitet och varför det är överlägset bättre än vaccination.
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Study/report title, author, and year published and interactive url link

1) [Necessity of COVID-19 vaccination in previously infected individuals](#), Shrestha, 2021

2) [SARS-CoV-2-specific T cell immunity in cases of COVID-19 and SARS, and uninfected controls](#), Le Bert, 2020

3) [Comparing SARS-CoV-2 natural immunity to vaccine-induced immunity: reinfections versus breakthrough infections](#), Gazit, 2021

Predominant finding on natural immunity

“Cumulative incidence of COVID-19 was examined among 52,238 employees in an American healthcare system. The cumulative incidence of SARS-CoV-2 infection remained almost zero among previously infected unvaccinated subjects, previously infected subjects who were vaccinated, and previously uninfected subjects who were vaccinated, compared with a steady increase in cumulative incidence among previously uninfected subjects who remained unvaccinated. Not one of the 1359 previously infected subjects who remained unvaccinated had a SARS-CoV-2 infection over the duration of the study. Individuals who have had SARS-CoV-2 infection are unlikely to benefit from COVID-19 vaccination...”

“Studied T cell responses against the structural (nucleocapsid (N) protein) and non-structural (NSP7 and NSP13 of *ORF1*) regions of SARS-CoV-2 in individuals convalescing from coronavirus disease 2019 (COVID-19) ($n = 36$). In all of these individuals, we found CD4 and CD8 T cells that recognized multiple regions of the N protein... showed that patients ($n = 23$) who recovered from SARS possess long-lasting memory T cells that are reactive to the N protein of SARS-CoV 17 years after the outbreak of SARS in 2003; these T cells displayed robust cross-reactivity to the N protein of SARS-CoV-2.”

“A retrospective observational study comparing three groups: (1) SARS-CoV-2-naïve individuals who received a two-dose regimen of the BioNTech/Pfizer mRNA BNT162b2 vaccine, (2) previously infected individuals who have not been vaccinated, and (3) previously infected *and* single dose vaccinated individuals found para a 13 fold increased risk of breakthrough Delta infections in double vaccinated persons, and a 27 fold increased risk for symptomatic breakthrough infection in the double vaccinated relative to the natural immunity recovered persons... the risk of hospitalization was 8 times higher in the double vaccinated (para)...this analysis demonstrated that natural immunity affords longer lasting and stronger protection against infection, symptomatic disease and hospitalization due to the Delta variant of SARS-CoV-2, compared to the BNT162b2 two-dose

4) [Highly functional virus-specific cellular immune response in asymptomatic SARS-CoV-2 infection](#), Le Bert, 2021

5) [Large-scale study of antibody titer decay following BNT162b2 mRNA vaccine or SARS-CoV-2 infection](#), Israel, 2021

6) [SARS-CoV-2 re-infection risk in Austria](#), Pilz, 2021

7) [mRNA vaccine-induced SARS-CoV-2-specific T cells recognize B.1.1.7 and B.1.351 variants but differ in longevity and homing properties depending on prior infection status](#), Neidleman, 2021

8) [Good news: Mild COVID-19 induces lasting antibody protection](#), Bhandari, 2021

vaccine-induced immunity.”

“Studied SARS-CoV-2-specific T cells in a cohort of asymptomatic ($n = 85$) and symptomatic ($n = 75$) COVID-19 patients after seroconversion...thus, asymptomatic SARS-CoV-2-infected individuals are not characterized by weak antiviral immunity; on the contrary, they mount a highly functional virus-specific cellular immune response.”

“A total of 2,653 individuals fully vaccinated by two doses of vaccine during the study period and 4,361 convalescent patients were included. Higher SARS-CoV-2 IgG antibody titers were observed in vaccinated individuals (median 1581 AU/mL IQR [533.8-5644.6]) after the second vaccination, than in convalescent individuals (median 355.3 AU/mL IQR [141.2-998.7]; $p < 0.001$). In vaccinated subjects, antibody titers decreased by up to 40% each subsequent month while in convalescents they decreased by less than 5% per month...this study demonstrates individuals who received the Pfizer-BioNTech mRNA vaccine have different kinetics of antibody levels compared to patients who had been infected with the SARS-CoV-2 virus, with higher initial levels but a much faster exponential decrease in the first group”.

Researchers recorded “40 tentative re-infections in 14, 840 COVID-19 survivors of the first wave (0.27%) and 253 581 infections in 8, 885, 640 individuals of the remaining general population (2.85%) translating into an odds ratio (95% confidence interval) of 0.09 (0.07 to 0.13)...relatively low re-infection rate of SARS-CoV-2 in Austria. Protection against SARS-CoV-2 after natural infection is comparable with the highest available estimates on vaccine efficacies.” Additionally, hospitalization in only five out of 14,840 (0.03%) people and death in one out of 14,840 (0.01%) (tentative re-infection).

“Spike-specific T cells from convalescent vaccinees differed strikingly from those of infection-naïve vaccinees, with phenotypic features suggesting superior long-term persistence and ability to home to the respiratory tract including the nasopharynx. These results provide reassurance that vaccine-elicited T cells respond robustly to the B.1.1.7 and B.1.351 variants, confirm that convalescents may not need a second vaccine dose.”

“Months after recovering from mild cases of COVID-19, people still have immune cells in their body pumping out antibodies against the virus that causes COVID-19, according to a study from researchers at

Washington University School of Medicine in St. Louis. Such cells could persist for a lifetime, churning out antibodies all the while. The findings, published May 24 in the journal Nature, suggest that mild cases of COVID-19 leave those infected with lasting antibody protection and that repeated bouts of illness are likely to be uncommon.”

9) [Robust neutralizing antibodies to SARS-CoV-2 infection persist for months](#), Wajnberg, 2021

“Neutralizing antibody titers against the SARS-CoV-2 spike protein persisted for at least 5 months after infection. Although continued monitoring of this cohort will be needed to confirm the longevity and potency of this response, these preliminary results suggest that the chance of reinfection may be lower than is currently feared.”

10) [Evolution of Antibody Immunity to SARS-CoV-2](#), Gaebler, 2020

“Concurrently, neutralizing activity in plasma decreases by five-fold in pseudo-type virus assays. In contrast, the number of RBD-specific memory B cells is unchanged. Memory B cells display clonal turnover after 6.2 months, and the antibodies they express have greater somatic hypermutation, increased potency and resistance to RBD mutations, indicative of continued evolution of the humoral response...we conclude that the memory B cell response to SARS-CoV-2 evolves between 1.3 and 6.2 months after infection in a manner that is consistent with antigen persistence.”

11) [Persistence of neutralizing antibodies a year after SARS-CoV-2 infection in humans](#), Haveri, 2021

“Assessed the persistence of serum antibodies following WT SARS-CoV-2 infection at 8 and 13 months after diagnosis in 367 individuals...found that NAb against the WT virus persisted in 89% and S-IgG in 97% of subjects for at least 13 months after infection.”

12) [Quantifying the risk of SARS-CoV-2 reinfection over time](#), Murchu, 2021

“Eleven large cohort studies were identified that estimated the risk of SARS-CoV-2 reinfection over time, including three that enrolled healthcare workers and two that enrolled residents and staff of elderly care homes. Across studies, the total number of PCR-positive or antibody-positive participants at baseline was 615,777, and the maximum duration of follow-up was more than 10 months in three studies. Reinfection was an uncommon event (absolute rate 0%–1.1%), with no study reporting an increase in the risk of reinfection over time.”

13) [Natural immunity to covid is powerful. Policymakers seem afraid to say so](#), Makary, 2021

Makary writes “it’s okay to have an incorrect scientific hypothesis. But when new data proves it wrong, you have to adapt. Unfortunately, many elected leaders and public health officials have held on far too long to the hypothesis that natural immunity offers unreliable protection against covid-19 — a contention that is being rapidly debunked by science. More than 15 studies have demonstrated the [power of immunity](#) acquired by previously having

[The Western Journal-Makary](#)

14) [SARS-CoV-2 elicits robust adaptive immune responses regardless of disease severity](#), Nielsen, 2021

15) [Protection of previous SARS-CoV-2 infection is similar to that of BNT162b2 vaccine protection: A three-month nationwide experience from Israel](#), Goldberg, 2021

16) [Incidence of Severe Acute Respiratory Syndrome Coronavirus-2 infection among previously infected or vaccinated](#)

the virus. A 700,000-person [study](#) from Israel two weeks ago found that those who had experienced prior infections were 27 times less likely to get a second symptomatic covid infection than those who were vaccinated. This affirmed a June Cleveland Clinic [study](#) of health-care workers (who are often exposed to the virus), in which none who had previously tested positive for the [coronavirus](#) got reinfected. The study authors concluded that “individuals who have had SARS-CoV-2 infection are unlikely to benefit from covid-19 vaccination.” And in May, a Washington University [study](#) found that even a mild covid infection resulted in long-lasting immunity.”

“The data on natural immunity are now overwhelming,” Makary told the Morning Wire. “It turns out the hypothesis that our public health leaders had that vaccinated immunity is better and stronger than natural immunity was wrong. They got it backwards. And now we’ve got data from Israel showing that natural immunity is 27 times more effective than vaccinated immunity.”

“203 recovered SARS-CoV-2 infected patients in Denmark between April 3rd and July 9th 2020, at least 14 days after COVID-19 symptom recovery... report broad serological profiles within the cohort, detecting antibody binding to other human coronaviruses... the viral surface spike protein was identified as the dominant target for both neutralizing antibodies and CD8⁺ T-cell responses. Overall, the majority of patients had robust adaptive immune responses, regardless of their disease severity.”

“Analyze an updated individual-level database of the entire population of Israel to assess the protection efficacy of both prior infection and vaccination in preventing subsequent SARS-CoV-2 infection, hospitalization with COVID-19, severe disease, and death due to COVID-19... vaccination was highly effective with overall estimated efficacy for documented infection of 92·8% (CI:[92·6, 93·0]); hospitalization 94·2% (CI:[93·6, 94·7]); severe illness 94·4% (CI:[93·6, 95·0]); and death 93·7% (CI:[92·5, 94·7]). Similarly, the overall estimated level of protection from prior SARS-CoV-2 infection for documented infection is 94·8% (CI: [94·4, 95·1]); hospitalization 94·1% (CI: [91·9, 95·7]); and severe illness 96·4% (CI: [92·5, 98·3])...results question the need to vaccinate previously-infected individuals.”

“Employees were divided into three groups: (1) SARS-CoV-2 naïve and unvaccinated, (2) previous SARS-CoV-2 infection, and (3) vaccinated. Person-

[employees](#), Kojima, 2021

days were measured from the date of the employee first test and truncated at the end of the observation period. SARS-CoV-2 infection was defined as two positive SARS-CoV-2 PCR tests in a 30-day period... 4313, 254 and 739 employee records for groups 1, 2, and 3...previous SARS-CoV-2 infection and vaccination for SARS-CoV-2 were associated with decreased risk for infection or re-infection with SARS-CoV-2 in a routinely screened workforce. There was no difference in the infection incidence between vaccinated individuals and individuals with previous infection.”

17) [Having SARS-CoV-2 once confers much greater immunity than a vaccine—but vaccination remains vital](#), Wadman, 2021

“Israelis who had an infection were more protected against the Delta coronavirus variant than those who had an already highly effective COVID-19 vaccine... the newly released data show people who once had a SARS-CoV-2 infection were much less likely than never-infected, vaccinated people to get Delta, develop symptoms from it, or become hospitalized with serious COVID-19.”

18) [One-year sustained cellular and humoral immunities of COVID-19 convalescents](#), Zhang, 2021

“A systematic antigen-specific immune evaluation in 101 COVID-19 convalescents; SARS-CoV-2-specific IgG antibodies, and also NAb can persist among over 95% COVID-19 convalescents from 6 months to 12 months after disease onset. At least 19/71 (26%) of COVID-19 convalescents (double positive in ELISA and MCLIA) had detectable circulating IgM antibody against SARS-CoV-2 at 12m post-disease onset. Notably, the percentages of convalescents with positive SARS-CoV-2-specific T-cell responses (at least one of the SARS-CoV-2 antigen S1, S2, M and N protein) were 71/76 (93%) and 67/73 (92%) at 6m and 12m, respectively.”

19) [Functional SARS-CoV-2-Specific Immune Memory Persists after Mild COVID-19](#), Rodda, 2021

“Recovered individuals developed SARS-CoV-2-specific immunoglobulin (IgG) antibodies, neutralizing plasma, and memory B and memory T cells that persisted for at least 3 months. Our data further reveal that SARS-CoV-2-specific IgG memory B cells increased over time. Additionally, SARS-CoV-2-specific memory lymphocytes exhibited characteristics associated with potent antiviral function: memory T cells secreted cytokines and expanded upon antigen re-encounter, whereas memory B cells expressed receptors capable of neutralizing virus when expressed as monoclonal antibodies. Therefore, mild COVID-19 elicits memory lymphocytes that persist and display functional hallmarks of antiviral immunity.”

20) [Discrete Immune Response Signature to SARS-CoV-2 mRNA Vaccination Versus Infection](#), Ivanova, 2021

“Performed multimodal single-cell sequencing on peripheral blood of patients with acute COVID-19 and healthy volunteers before and after receiving the

SARS-CoV-2 BNT162b2 mRNA vaccine to compare the immune responses elicited by the virus and by this vaccine...both infection and vaccination induced robust innate and adaptive immune responses, our analysis revealed significant qualitative differences between the two types of immune challenges. In COVID-19 patients, immune responses were characterized by a highly augmented interferon response which was largely absent in vaccine recipients. Increased interferon signaling likely contributed to the observed dramatic upregulation of cytotoxic genes in the peripheral T cells and innate-like lymphocytes in patients but not in immunized subjects. Analysis of B and T cell receptor repertoires revealed that while the majority of clonal B and T cells in COVID-19 patients were effector cells, in vaccine recipients clonally expanded cells were primarily circulating memory cells...we observed the presence of cytotoxic CD4 T cells in COVID-19 patients that were largely absent in healthy volunteers following immunization. While hyper-activation of inflammatory responses and cytotoxic cells may contribute to immunopathology in severe illness, in mild and moderate disease, these features are indicative of protective immune responses and resolution of infection.”

21) [SARS-CoV-2 infection induces long-lived bone marrow plasma cells in humans](#), Turner, 2021

“Bone marrow plasma cells (BMPCs) are a persistent and essential source of protective antibodies... durable serum antibody titres are maintained by long-lived plasma cells—non-replicating, antigen-specific plasma cells that are detected in the bone marrow long after the clearance of the antigen ... S-binding BMPCs are quiescent, which suggests that they are part of a stable compartment. Consistently, circulating resting memory B cells directed against SARS-CoV-2 S were detected in the convalescent individuals. Overall, our results indicate that mild infection with SARS-CoV-2 induces robust antigen-specific, long-lived humoral immune memory in humans...overall, our data provide strong evidence that SARS-CoV-2 infection in humans robustly establishes the two arms of humoral immune memory: long-lived bone marrow plasma cells (BMPCs) and memory B-cells.”

22) [SARS-CoV-2 infection rates of antibody-positive compared with antibody-negative health-care workers in England: a large, multicentre, prospective cohort study \(SIREN\)](#), Jane Hall, 2021

“The SARS-CoV-2 Immunity and Reinfection Evaluation study... 30 625 participants were enrolled into the study... a previous history of SARS-CoV-2 infection was associated with an 84% lower risk of infection, with median protective effect observed 7 months following primary infection. This time period is the minimum probable effect because seroconversions were not included. This study shows that previous infection with SARS-CoV-2 induces

23) [Pandemic peak SARS-CoV-2 infection and seroconversion rates in London frontline health-care workers](#), Houlihan, 2020

24) [Antibodies to SARS-CoV-2 are associated with protection against reinfection](#), Lumley, 2021

25) [Longitudinal analysis shows durable and broad immune memory after SARS-CoV-2 infection with persisting antibody responses and memory B and T cells](#), Cohen, 2021

26) [Single cell profiling of T and B cell repertoires following SARS-CoV-2 mRNA vaccine](#), Sureshchandra, 2021

27) [SARS-CoV-2 antibody-positivity protects against reinfection for at least seven months with 95% efficacy](#), Abu-Raddad, 2021

28) [Orthogonal SARS-CoV-2 Serological Assays Enable Surveillance of Low-Prevalence Communities and Reveal](#)

effective immunity to future infections in most individuals.”

“Enrolled 200 patient-facing HCWs between March 26 and April 8, 2020...represents a 13% infection rate (i.e. 14 of 112 HCWs) within the 1 month of follow-up in those with no evidence of antibodies or viral shedding at enrolment. By contrast, of 33 HCWs who tested positive by serology but tested negative by RT-PCR at enrolment, 32 remained negative by RT-PCR through follow-up, and one tested positive by RT-PCR on days 8 and 13 after enrolment.”

“Critical to understand whether infection with Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) protects from subsequent reinfection... 12219 HCWs participated...prior SARS-CoV-2 infection that generated antibody responses offered protection from reinfection for most people in the six months following infection.”

“Evaluate 254 COVID-19 patients longitudinally up to 8 months and find durable broad-based immune responses. SARS-CoV-2 spike binding and neutralizing antibodies exhibit a bi-phasic decay with an extended half-life of >200 days suggesting the generation of longer-lived plasma cells... most recovered COVID-19 patients mount broad, durable immunity after infection, spike IgG+ memory B cells increase and persist post-infection, durable polyfunctional CD4 and CD8 T cells recognize distinct viral epitope regions.”

“Used single-cell RNA sequencing and functional assays to compare humoral and cellular responses to two doses of mRNA vaccine with responses observed in convalescent individuals with asymptomatic disease... natural infection induced expansion of larger CD8 T cell clones occupied distinct clusters, likely due to the recognition of a broader set of viral epitopes presented by the virus not seen in the mRNA vaccine.”

“SARS-CoV-2 antibody-positive persons from April 16 to December 31, 2020 with a PCR-positive swab \geq 14 days after the first-positive antibody test were investigated for evidence of reinfection, 43,044 antibody-positive persons who were followed for a median of 16.3 weeks...reinfection is rare in the young and international population of Qatar. Natural infection appears to elicit strong protection against reinfection with an efficacy \sim 95% for at least seven months.”

“Conducted a serological study to define correlates of immunity against SARS-CoV-2. Compared to those with mild coronavirus disease 2019 (COVID-19)

[Durable Humoral Immunity](#), Ripperger, 2020

29) [Anti-spike antibody response to natural SARS-CoV-2 infection in the general population](#), Wei, 2021

30) [Researchers find long-lived immunity to 1918 pandemic virus](#), CIDRAP, 2008

and the actual [2008 NATURE journal publication](#) by Yu

31) [Live virus neutralisation testing in convalescent patients and subjects vaccinated against 19A, 20B, 20I/501Y.V1 and 20H/501Y.V2 isolates of SARS-CoV-2](#),

cases, individuals with severe disease exhibited elevated virus-neutralizing titers and antibodies against the nucleocapsid (N) and the receptor binding domain (RBD) of the spike protein...neutralizing and spike-specific antibody production persists for at least 5–7 months... nucleocapsid antibodies frequently become undetectable by 5–7 months.”

“In the general population using representative data from 7,256 United Kingdom COVID-19 infection survey participants who had positive swab SARS-CoV-2 PCR tests from 26-April-2020 to 14-June-2021...we estimated antibody levels associated with protection against reinfection likely last 1.5-2 years on average, with levels associated with protection from severe infection present for several years. These estimates could inform planning for vaccination booster strategies.”

“A study of the blood of older people who survived the 1918 influenza pandemic reveals that antibodies to the strain have lasted a lifetime and can perhaps be engineered to protect future generations against similar strains...the group collected blood samples from 32 pandemic survivors aged 91 to 101..the people recruited for the study were 2 to 12 years old in 1918 and many recalled sick family members in their households, which suggests they were directly exposed to the virus, the authors report. The group found that 100% of the subjects had serum-neutralizing activity against the 1918 virus and 94% showed serologic reactivity to the 1918 hemagglutinin. The investigators generated B lymphoblastic cell lines from the peripheral blood mononuclear cells of eight subjects. Transformed cells from the blood of 7 of the 8 donors yielded secreting antibodies that bound the 1918 hemagglutinin.” Yu: “here we show that of the 32 individuals tested that were born in or before 1915, each showed sero-reactivity with the 1918 virus, nearly 90 years after the pandemic. Seven of the eight donor samples tested had circulating B cells that secreted antibodies that bound the 1918 HA. We isolated B cells from subjects and generated five monoclonal antibodies that showed potent neutralizing activity against 1918 virus from three separate donors. These antibodies also cross-reacted with the genetically similar HA of a 1930 swine H1N1 influenza strain.”

“No significant difference was observed between the 20B and 19A isolates for HCWs with mild COVID-19 and critical patients. However, a significant decrease in neutralisation ability was found for 20I/501Y.V1 in

Gonzalez, 2021

comparison with 19A isolate for critical patients and HCWs 6-months post infection. Concerning 20H/501Y.V2, all populations had a significant reduction in neutralising antibody titres in comparison with the 19A isolate. Interestingly, a significant difference in neutralisation capacity was observed for vaccinated HCWs between the two variants whereas it was not significant for the convalescent groups... the reduced neutralising response observed towards the 20H/501Y.V2 in comparison with the 19A and 20I/501Y.V1 isolates in fully immunized subjects with the BNT162b2 vaccine is a striking finding of the study.”

32) [Differential effects of the second SARS-CoV-2 mRNA vaccine dose on T cell immunity in naïve and COVID-19 recovered individuals](#), Camara, 2021

“Characterized SARS-CoV-2 spike-specific humoral and cellular immunity in naïve and previously infected individuals during full BNT162b2 vaccination...results demonstrate that the second dose increases both the humoral and cellular immunity in naïve individuals. On the contrary, the second BNT162b2 vaccine dose results in a reduction of cellular immunity in COVID-19 recovered individuals.”

33) [Op-Ed: Quit Ignoring Natural COVID Immunity](#), Klausner, 2021

“Epidemiologists estimate over [160 million people worldwide](#) have recovered from COVID-19. Those who have recovered have an astonishingly low frequency of repeat infection, disease, or death.”

34) [Association of SARS-CoV-2 Seropositive Antibody Test With Risk of Future Infection](#), Harvey, 2021

“To evaluate evidence of SARS-CoV-2 infection based on diagnostic nucleic acid amplification test (NAAT) among patients with positive vs negative test results for antibodies in an observational descriptive cohort study of clinical laboratory and linked claims data...the cohort included 3 257 478 unique patients with an index antibody test...patients with positive antibody test results were initially more likely to have positive NAAT results, consistent with prolonged RNA shedding, but became markedly less likely to have positive NAAT results over time, suggesting that seropositivity is associated with protection from infection.”

35) [SARS-CoV-2 seropositivity and subsequent infection risk in healthy young adults: a prospective cohort study](#), Letizia, 2021

“Investigated the risk of subsequent SARS-CoV-2 infection among young adults (CHARM marine study) seropositive for a previous infection...enrolled 3249 participants, of whom 3168 (98%) continued into the 2-week quarantine period. 3076 (95%) participants...Among 189 seropositive participants, 19 (10%) had at least one positive PCR test for SARS-CoV-2 during the 6-week follow-up (1·1 cases per person-year). In contrast, 1079 (48%) of 2247 seronegative participants tested positive (6·2 cases per person-year). The incidence rate ratio was 0·18 (95% CI 0·11–0·28; p<0·001)...infected seropositive

participants had viral loads that were about 10-times lower than those of infected seronegative participants (ORF1ab gene cycle threshold difference 3.95 [95% CI 1.23–6.67]; $p=0.004$).”

“Of 9,180 individuals with no record of vaccination but with a record of prior infection at least 90 days before the PCR test (group 3), 7694 could be matched to individuals with no record of vaccination or prior infection (group 2), among whom PCR positivity was 1.01% (95% CI, 0.80%-1.26%) and 3.81% (95% CI, 3.39%-4.26%), respectively. The relative risk for PCR positivity was 0.22 (95% CI, 0.17-0.28) for vaccinated individuals and 0.26 (95% CI, 0.21-0.34) for individuals with prior infection compared with no record of vaccination or prior infection.”

“Followed up with a subsample of our previous sero-survey participants to assess whether natural immunity against SARS-CoV-2 was associated with a reduced risk of re-infection (India)... out of the 2238 participants, 1170 were sero-positive and 1068 were sero-negative for antibody against COVID-19. Our survey found that only 3 individuals in the sero-positive group got infected with COVID-19 whereas 127 individuals reported contracting the infection the sero-negative group...from the 3 sero-positives re-infected with COVID-19, one had hospitalization, but did not require oxygen support or critical care... development of antibody following natural infection not only protects against re-infection by the virus to a great extent, but also safeguards against progression to severe COVID-19 disease.”

“The researchers found durable immune responses in the majority of people studied. Antibodies against the spike protein of SARS-CoV-2, which the virus uses to get inside cells, were found in 98% of participants one month after symptom onset. As seen in previous studies, the number of antibodies ranged widely between individuals. But, promisingly, their levels remained fairly stable over time, declining only modestly at 6 to 8 months after infection... virus-specific B cells increased over time. People had more memory B cells six months after symptom onset than at one month afterwards... levels of T cells for the virus also remained high after infection. Six months after symptom onset, 92% of participants had CD4+ T cells that recognized the virus... 95% of the people had at least 3 out of 5 immune-system components that could recognize SARS-CoV-2 up to 8 months after infection.”

“The seropositive rate in the convalescent individuals was above 95% at all sampling time points for both

36) [Associations of Vaccination and of Prior Infection With Positive PCR Test Results for SARS-CoV-2 in Airline Passengers Arriving in Qatar](#), Bertollini, 2021

37) [Natural immunity against COVID-19 significantly reduces the risk of reinfection: findings from a cohort of sero-survey participants](#), Mishra, 2021

38) [Lasting immunity found after recovery from COVID-19](#), NIH, 2021

39) [SARS-CoV-2 Natural Antibody Response Persists for at Least 12 Months in](#)

[a Nationwide Study From the Faroe Islands](#), Petersen, 2021

40) [SARS-CoV-2-specific T cell memory is sustained in COVID-19 convalescent patients for 10 months with successful development of stem cell-like memory T cells](#), Jung, 2021

41) [Immune Memory in Mild COVID-19 Patients and Unexposed Donors Reveals Persistent T Cell Responses After SARS-CoV-2 Infection](#), Ansari, 2021

42) [COVID-19 natural immunity](#), WHO, 2021

43) [Antibody Evolution after SARS-CoV-2](#)

assays and remained stable over time; that is, almost all convalescent individuals developed antibodies... results show that SARS-CoV-2 antibodies persisted at least 12 months after symptom onset and maybe even longer, indicating that COVID-19-convalescent individuals may be protected from reinfection.”

“ex vivo assays to evaluate SARS-CoV-2-specific CD4⁺ and CD8⁺ T cell responses in COVID-19 convalescent patients up to 317 days post-symptom onset (DPSO), and find that memory T cell responses are maintained during the study period regardless of the severity of COVID-19. In particular, we observe sustained polyfunctionality and proliferation capacity of SARS-CoV-2-specific T cells. Among SARS-CoV-2-specific CD4⁺ and CD8⁺ T cells detected by activation-induced markers, the proportion of stem cell-like memory T (T_{SCM}) cells is increased, peaking at approximately 120 DPSO.”

“Analyzed 42 unexposed healthy donors and 28 mild COVID-19 subjects up to 5 months from the recovery for SARS-CoV-2 specific immunological memory. Using HLA class II predicted peptide megapools, we identified SARS-CoV-2 cross-reactive CD4⁺ T cells in around 66% of the unexposed individuals. Moreover, we found detectable immune memory in mild COVID-19 patients several months after recovery in the crucial arms of protective adaptive immunity; CD4⁺ T cells and B cells, with a minimal contribution from CD8⁺ T cells. Interestingly, the persistent immune memory in COVID-19 patients is predominantly targeted towards the Spike glycoprotein of the SARS-CoV-2. This study provides the evidence of both high magnitude pre-existing and persistent immune memory in Indian population.”

“Current evidence points to most individuals developing strong protective immune responses following natural infection with SARSCoV-2. Within 4 weeks following infection, 90-99% of individuals infected with the SARS-CoV-2 virus develop detectable neutralizing antibodies. The strength and duration of the immune responses to SARS-CoV-2 are not completely understood and currently available data suggests that it varies by age and the severity of symptoms. Available scientific data suggests that in most people immune responses remain robust and protective against reinfection for at least 6-8 months after infection (the longest follow up with strong scientific evidence is currently approximately 8 months).”

“We conclude that memory antibodies selected over

[mRNA Vaccination](#), Cho, 2021

44) [Humoral Immune Response to SARS-CoV-2 in Iceland](#), Gudbjartsson, 2020

45) [Immunological memory to SARS-CoV-2 assessed for up to 8 months after infection](#), Dan, 2021

46) [The prevalence of adaptive immunity to COVID-19 and reinfection after recovery – a comprehensive systematic review and meta-analysis of 12 011 447 individuals](#), Chivese, 2021

47) [Reinfection Rates among Patients who Previously Tested Positive for COVID-19: a Retrospective Cohort Study](#), Sheehan, 2021

48) [Assessment of SARS-CoV-2 Reinfection 1 Year After Primary Infection in a Population in Lombardy, Italy](#), Vitale, 2020

49) [Prior SARS-CoV-2 infection is associated with protection against symptomatic reinfection](#), Hanrath, 2021

time by natural infection have greater potency and breadth than antibodies elicited by vaccination... boosting vaccinated individuals with currently available mRNA vaccines would produce a quantitative increase in plasma neutralizing activity but not the qualitative advantage against variants obtained by vaccinating convalescent individuals.”

“Measured antibodies in serum samples from 30,576 persons in Iceland...of the 1797 persons who had recovered from SARS-CoV-2 infection, 1107 of the 1215 who were tested (91.1%) were seropositive... results indicate risk of death from infection was 0.3% and that antiviral antibodies against SARS-CoV-2 did not decline within 4 months after diagnosis (para).”

“Analyzed multiple compartments of circulating immune memory to SARS-CoV-2 in 254 samples from 188 COVID-19 cases, including 43 samples at \geq 6 months post-infection...IgG to the Spike protein was relatively stable over 6+ months. Spike-specific memory B cells were more abundant at 6 months than at 1 month post symptom onset.”

“Fifty-four studies, from 18 countries, with a total of 12 011 447 individuals, followed up to 8 months after recovery, were included. At 6-8 months after recovery, the prevalence of detectable SARS-CoV-2 specific immunological memory remained high; IgG – 90.4%... pooled prevalence of reinfection was 0.2% (95%CI 0.0 – 0.7, $I^2 = 98.8$, 9 studies). Individuals who recovered from COVID-19 had an 81% reduction in odds of a reinfection (OR 0.19, 95% CI 0.1 – 0.3, $I^2 = 90.5\%$, 5 studies).”

“Retrospective cohort study of one multi-hospital health system included 150,325 patients tested for COVID-19 infection...prior infection in patients with COVID-19 was highly protective against reinfection and symptomatic disease. This protection increased over time, suggesting that viral shedding or ongoing immune response may persist beyond 90 days and may not represent true reinfection.”

“The study results suggest that reinfections are rare events and patients who have recovered from COVID-19 have a lower risk of reinfection. Natural immunity to SARS-CoV-2 appears to confer a protective effect for at least a year, which is similar to the protection reported in recent vaccine studies.”

“We observed no symptomatic reinfections in a cohort of healthcare workers...this apparent immunity to reinfection was maintained for at least 6 months...test positivity rates were 0% (0/128 [95% CI: 0–2.9]) in those with previous infection compared to 13.7% (290/2115 [95% CI: 12.3–15.2]) in those without

50) [Targets of T Cell Responses to SARS-CoV-2 Coronavirus in Humans with COVID-19 Disease and Unexposed Individuals](#), Grifoni, 2020

51) [NIH Director's Blog: Immune T Cells May Offer Lasting Protection Against COVID-19](#), Collins, 2021

52) [Ultrapotent antibodies against diverse and highly transmissible SARS-CoV-2 variants](#), Wang, 2021

53) [Why COVID-19 Vaccines Should Not Be Required for All Americans](#), Makary, 2021

54) [Protracted yet coordinated differentiation of long-lived SARS-CoV-2-specific CD8+ T cells during COVID-19 convalescence](#), Ma, 2021

($P < 0.0001$ χ^2 test).”

“Using HLA class I and II predicted peptide “megapools,” circulating SARS-CoV-2-specific CD8⁺ and CD4⁺ T cells were identified in ~70% and 100% of COVID-19 convalescent patients, respectively. CD4⁺ T cell responses to spike, the main target of most vaccine efforts, were robust and correlated with the magnitude of the anti-SARS-CoV-2 IgG and IgA titers. The M, spike, and N proteins each accounted for 11%–27% of the total CD4⁺ response, with additional responses commonly targeting nsp3, nsp4, ORF3a, and ORF8, among others. For CD8⁺ T cells, spike and M were recognized, with at least eight SARS-CoV-2 ORFs targeted.”

“Much of the study on the immune response to SARS-CoV-2, the novel coronavirus that causes COVID-19, has focused on the production of [antibodies](#). But, in fact, immune cells known as memory T cells also play an important role in the ability of our immune systems to protect us against many viral infections, including—it now appears—COVID-19. An intriguing new study of these memory T cells suggests they might protect some people newly infected with SARS-CoV-2 by remembering past encounters with other [human coronaviruses](#). This might potentially explain why some people seem to fend off the virus and may be less susceptible to becoming severely ill with COVID-19.”

“Our study demonstrates that convalescent subjects previously infected with ancestral variant SARS-CoV-2 produce antibodies that cross-neutralize emerging VOCs with high potency...potent against 23 variants, including variants of concern.”

“Requiring the vaccine in people who are already immune with natural immunity has no scientific support. While vaccinating those people may be beneficial – and it’s a reasonable hypothesis that vaccination may bolster the longevity of their immunity – to argue dogmatically that they *must* get vaccinated has zero clinical outcome data to back it. As a matter of fact, we have data to the contrary: A Cleveland Clinic [study](#) found that vaccinating people with natural immunity did not add to their level of protection.”

“Screened 21 well-characterized, longitudinally-sampled convalescent donors that recovered from mild COVID-19...following a typical case of mild COVID-19, SARS-CoV-2-specific CD8⁺ T cells not only persist but continuously differentiate in a

coordinated fashion well into convalescence, into a state characteristic of long-lived, self-renewing memory.”

“Characterized the profiles of measles vaccine (MV) vaccine-induced antigen-specific T cells over time since vaccination. In a cross-sectional study of healthy subjects with a history of MV vaccination, we found that MV-specific CD4 and CD8 T cells could be detected up to 34 years after vaccination. The levels of MV-specific CD8 T cells and MV-specific IgG remained stable, whereas the level of MV-specific CD4 T cells decreased significantly in subjects who had been vaccinated >21 years earlier.”

“The success of vaccines is dependent on the generation and maintenance of immunological memory. The immune system can remember previously encountered pathogens, and memory B and T cells are critical in secondary responses to infection. Studies in mice have helped to understand how different memory B cell populations are generated following antigen exposure and how affinity for the antigen is determinant to B cell fate... upon re-exposure to an antigen the memory recall response will be faster, stronger, and more specific than a naïve response. Protective memory depends first on circulating antibodies secreted by LLPCs. When these are not sufficient for immediate pathogen neutralization and elimination, memory B cells are recalled.”

“Examined the magnitude, breadth, and durability of SARS-CoV-2 specific antibodies in two distinct B-cell compartments: long-lived plasma cell-derived antibodies in the plasma, and peripheral memory B-cells along with their associated antibody profiles elicited after *in vitro* stimulation. We found that magnitude varied amongst individuals, but was the highest in hospitalized subjects. Variants of concern (VoC) -RBD-reactive antibodies were found in the plasma of 72% of samples in this investigation, and VoC-RBD-reactive memory B-cells were found in all but 1 subject at a single time-point. This finding, that VoC-RBD-reactive MBCs are present in the peripheral blood of all subjects including those that experienced asymptomatic or mild disease, provides a reason for optimism regarding the capacity of vaccination, prior infection, and/or both, to limit disease severity and transmission of variants of concern as they continue to arise and circulate.”

“T-cell immunity is important for recovery from COVID-19 and provides heightened immunity for re-infection. However, little is known about the SARS-

55) [Decrease in Measles Virus-Specific CD4 T Cell Memory in Vaccinated Subjects](#), Naniche, 2004

56) [Remembrance of Things Past: Long-Term B Cell Memory After Infection and Vaccination](#), Palm, 2019

57) [SARS-CoV-2 specific memory B-cells from individuals with diverse disease severities recognize SARS-CoV-2 variants of concern](#), Lyski, 2021

58) [Exposure to SARS-CoV-2 generates T-cell memory in the absence of a detectable viral infection](#), Wang, 2021

59) [CD8+ T-Cell Responses in COVID-19 Convalescent Individuals Target Conserved Epitopes From Multiple Prominent SARS-CoV-2 Circulating Variants](#), Redd, 2021 and Lee, 2021

CoV-2-specific T-cell immunity in virus-exposed individuals...report virus-specific CD4⁺ and CD8⁺ T-cell memory in recovered COVID-19 patients and close contacts...close contacts are able to gain T-cell immunity against SARS-CoV-2 despite lacking a detectable infection.”

“The CD4 and CD8 responses generated after natural infection are equally robust, showing activity against multiple “epitopes” (little segments) of the spike protein of the virus. For instance, CD8 cells responds to [52 epitopes](#) and CD4 cells respond to [57 epitopes](#) across the spike protein, so that a few mutations in the variants cannot knock out such a robust and in-breadth T cell response...only 1 mutation found in Beta variant-spike overlapped with a previously identified epitope (1/52), suggesting that virtually all anti-SARS-CoV-2 CD8+ T-cell responses should recognize these newly described variants.”

60) [Exposure to common cold coronaviruses can teach the immune system to recognize SARS-CoV-2](#), La Jolla, Crotty and Sette, 2020

“Exposure to common cold coronaviruses can teach the immune system to recognize SARS-CoV-2”

61) [Selective and cross-reactive SARS-CoV-2 T cell epitopes in unexposed humans](#), Mateus, 2020

“Found that the pre-existing reactivity against SARS-CoV-2 comes from memory T cells and that cross-reactive T cells can specifically recognize a SARS-CoV-2 epitope as well as the homologous epitope from a common cold coronavirus. These findings underline the importance of determining the impacts of pre-existing immune memory in COVID-19 disease severity.”

62) [Longitudinal observation of antibody responses for 14 months after SARS-CoV-2 infection](#), Dehgani-Mobaraki, 2021

“Better understanding of [antibody responses](#) against SARS-CoV-2 after natural infection might provide valuable insights into the future implementation of [vaccination policies](#). Longitudinal analysis of [IgG antibody titers](#) was carried out in 32 recovered COVID-19 patients based in the [Umbria](#) region of Italy for 14 months after Mild and Moderately-Severe infection...study findings are consistent with recent studies reporting antibody persistency suggesting that induced SARS-CoV-2 immunity through natural infection, might be very efficacious against re-infection (>90%) and could persist for more than six months. Our study followed up patients up to 14 months demonstrating the presence of anti-S-RBD IgG in 96.8% of recovered COVID-19 subjects.”

63) [Humoral and circulating follicular helper T cell responses in recovered patients with COVID-19](#), Juno, 2020

“Characterized humoral and circulating follicular helper T cell (cTFH) immunity against spike in recovered patients with coronavirus disease 2019 (COVID-19). We found that S-specific antibodies, memory B cells and cTFH are consistently elicited after SARS-CoV-2 infection, demarking robust

- 64) [Convergent antibody responses to SARS-CoV-2 in convalescent individuals](#), Robbiani, 2020
- 65) [Rapid generation of durable B cell memory to SARS-CoV-2 spike and nucleocapsid proteins in COVID-19 and convalescence](#), Hartley, 2020
- 66) [Had COVID? You'll probably make antibodies for a lifetime](#), Callaway, 2021
- 67) [A majority of uninfected adults show preexisting antibody reactivity against SARS-CoV-2](#), Majdoubi, 2021
- 68) [SARS-CoV-2-reactive T cells in healthy donors and patients with COVID-19](#), Braun, 2020
[Presence of SARS-CoV-2-reactive T cells in COVID-19 patients and healthy donors](#), Braun, 2020
- 69) [Naturally enhanced neutralizing breadth against SARS-CoV-2 one year after infection](#), Wang, 2021
- 70) [One Year after Mild COVID-19: The Majority of Patients Maintain Specific Immunity, But One in Four Still Suffer from Long-Term Symptoms](#), Rank, 2021
- 71) [IDSA](#), 2021
- humoral immunity and positively associated with plasma neutralizing activity.”
- “149 COVID-19-convalescent individuals...antibody sequencing revealed the expansion of clones of RBD-specific memory B cells that expressed closely related antibodies in different individuals. Despite low plasma titres, antibodies to three distinct epitopes on the RBD neutralized the virus with half-maximal inhibitory concentrations (IC₅₀ values) as low as 2 ng ml⁻¹.”
- “COVID-19 patients rapidly generate B cell memory to both the spike and nucleocapsid antigens following SARS-CoV-2 infection...RBD- and NCP-specific IgG and Bmem cells were detected in all 25 patients with a history of COVID-19.”
- “People who recover from mild COVID-19 have bone-marrow cells that can churn out antibodies for decades...the study provides evidence that immunity triggered by SARS-CoV-2 infection will be extraordinarily long-lasting.”
- In greater Vancouver Canada, “using a highly sensitive multiplex assay and positive/negative thresholds established in infants in whom maternal antibodies have waned, we determined that more than 90% of uninfected adults showed antibody reactivity against the spike protein, receptor-binding domain (RBD), N-terminal domain (NTD), or the nucleocapsid (N) protein from SARS-CoV-2.”
- “The results indicate that spike-protein cross-reactive T cells are present, which were probably generated during previous encounters with endemic coronaviruses.”
- “The presence of pre-existing SARS-CoV-2-reactive T cells in a subset of SARS-CoV-2 naïve HD is of high interest.”
- “A cohort of 63 individuals who have recovered from COVID-19 assessed at 1.3, 6.2 and 12 months after SARS-CoV-2 infection...the data suggest that immunity in convalescent individuals will be very long lasting.”
- “Long-lasting immunological memory against SARS-CoV-2 after mild COVID-19... activation-induced marker assays identified specific T-helper cells and central memory T-cells in 80% of participants at a 12-month follow-up.”
- “Immune responses to SARS-CoV-2 following natural infection can persist for at least 11 months... natural infection (as determined by a prior positive antibody or PCR-test result) can confer protection

72) [Assessment of protection against reinfection with SARS-CoV-2 among 4 million PCR-tested individuals in Denmark in 2020: a population-level observational study](#), Holm Hansen, 2021

73) [Antigen-Specific Adaptive Immunity to SARS-CoV-2 in Acute COVID-19 and Associations with Age and Disease Severity](#), Moderbacher, 2020

74) [Detection of SARS-CoV-2-Specific Humoral and Cellular Immunity in COVID-19 Convalescent Individuals](#), Ni, 2020

75) [Robust SARS-CoV-2-specific T-cell immunity is maintained at 6 months following primary infection](#), Zuo, 2020

76) [Negligible impact of SARS-CoV-2 variants on CD4⁺ and CD8⁺ T cell reactivity](#)

against SARS-CoV-2 infection.”

Denmark, “during the first surge (ie, before June, 2020), 533 381 people were tested, of whom 11 727 (2·20%) were PCR positive, and 525 339 were eligible for follow-up in the second surge, of whom 11 068 (2·11%) had tested positive during the first surge. Among eligible PCR-positive individuals from the first surge of the epidemic, 72 (0·65% [95% CI 0·51–0·82]) tested positive again during the second surge compared with 16 819 (3·27% [3·22–3·32]) of 514 271 who tested negative during the first surge (adjusted RR 0·195 [95% CI 0·155–0·246]).”

“Adaptive immune responses limit COVID-19 disease severity...multiple coordinated arms of adaptive immunity control better than partial responses...completed a combined examination of all three branches of adaptive immunity at the level of SARS-CoV-2-specific CD4⁺ and CD8⁺ T cell and neutralizing antibody responses in acute and convalescent subjects. SARS-CoV-2-specific CD4⁺ and CD8⁺ T cells were each associated with milder disease. Coordinated SARS-CoV-2-specific adaptive immune responses were associated with milder disease, suggesting roles for both CD4⁺ and CD8⁺ T cells in protective immunity in COVID-19.”

“Collected blood from COVID-19 patients who have recently become virus-free, and therefore were discharged, and detected SARS-CoV-2-specific humoral and cellular immunity in eight newly discharged patients. Follow-up analysis on another cohort of six patients 2 weeks post discharge also revealed high titers of immunoglobulin G (IgG) antibodies. In all 14 patients tested, 13 displayed serum-neutralizing activities in a pseudotype entry assay. Notably, there was a strong correlation between neutralization antibody titers and the numbers of virus-specific T cells.”

“Analysed the magnitude and phenotype of the SARS-CoV-2 cellular immune response in 100 donors at six months following primary infection and related this to the profile of antibody level against spike, nucleoprotein and RBD over the previous six months. T-cell immune responses to SARS-CoV-2 were present by ELISPOT and/or ICS analysis in all donors and are characterised by predominant CD4⁺ T cell responses with strong IL-2 cytokine expression... functional SARS-CoV-2-specific T-cell responses are retained at six months following infection.”

“Performed a comprehensive analysis of SARS-CoV-2-specific CD4⁺ and CD8⁺ T cell responses from

[in COVID-19 exposed donors and vaccinees](#), Tarke, 2021

COVID-19 convalescent subjects recognizing the ancestral strain, compared to variant lineages B.1.1.7, B.1.351, P.1, and CAL.20C as well as recipients of the Moderna (mRNA-1273) or Pfizer/BioNTech (BNT162b2) COVID-19 vaccines... the sequences of the vast majority of SARS-CoV-2 T cell epitopes are not affected by the mutations found in the variants analyzed. Overall, the results demonstrate that CD4+ and CD8+ T cell responses in convalescent COVID-19 subjects or COVID-19 mRNA vaccinees are not substantially affected by mutations.”

77) [A 1 to 1000 SARS-CoV-2 reinfection proportion in members of a large healthcare provider in Israel: a preliminary report](#), Perez, 2021

Israel, “out of 149,735 individuals with a documented positive PCR test between March 2020 and January 2021, 154 had two positive PCR tests at least 100 days apart, reflecting a reinfection proportion of 1 per 1000.”

78) [Persistence and decay of human antibody responses to the receptor binding domain of SARS-CoV-2 spike protein in COVID-19 patients](#), Iyer, 2020

“Measured plasma and/or serum antibody responses to the receptor-binding domain (RBD) of the spike (S) protein of SARS-CoV-2 in 343 North American patients infected with SARS-CoV-2 (of which 93% required hospitalization) up to 122 days after symptom onset and compared them to responses in 1548 individuals whose blood samples were obtained prior to the pandemic...IgG antibodies persisted at detectable levels in patients beyond 90 days after symptom onset, and seroreversion was only observed in a small percentage of individuals. The concentration of these anti-RBD IgG antibodies was also highly correlated with pseudovirus NAb titers, which also demonstrated minimal decay. The observation that IgG and neutralizing antibody responses persist is encouraging, and suggests the development of robust systemic immune memory in individuals with severe infection.”

79) [A population-based analysis of the longevity of SARS-CoV-2 antibody seropositivity in the United States](#), Alfego, 2021

“To track population-based SARS-CoV-2 antibody seropositivity duration across the United States using observational data from a national clinical laboratory registry of patients tested by nucleic acid amplification (NAAT) and serologic assays... specimens from 39,086 individuals with confirmed positive COVID-19...both S and N SARS-CoV-2 antibody results offer an encouraging view of how long humans may have protective antibodies against COVID-19, with curve smoothing showing population seropositivity reaching 90% within three weeks, regardless of whether the assay detects N or S-antibodies. Most importantly, this level of seropositivity was sustained with little decay through ten months after initial positive PCR.”

80) [What are the roles of antibodies versus a durable, high- quality T-cell response in](#)

“Progress in laboratory markers for SARS-CoV2 has been made with identification of epitopes on CD4 and

[protective immunity against SARS-CoV-2?](#)
Hellerstein, 2020

CD8 T-cells in convalescent blood. These are much less dominated by spike protein than in previous coronavirus infections. Although most vaccine candidates are focusing on spike protein as antigen, natural infection by SARS-CoV-2 induces broad epitope coverage, cross-reactive with other betacoronviruses.”

81) [Broad and strong memory CD4⁺ and CD8⁺ T cells induced by SARS-CoV-2 in UK convalescent COVID-19 patients](#), Peng, 2020

“Study of 42 patients following recovery from COVID-19, including 28 mild and 14 severe cases, comparing their T cell responses to those of 16 control donors...found the breadth, magnitude and frequency of memory T cell responses from COVID-19 were significantly higher in severe compared to mild COVID-19 cases, and this effect was most marked in response to spike, membrane, and ORF3a proteins...total and spike-specific T cell responses correlated with the anti-Spike, anti-Receptor Binding Domain (RBD) as well as anti-Nucleoprotein (NP) endpoint antibody titre...furthermore showed a higher ratio of SARS-CoV-2-specific CD8⁺ to CD4⁺ T cell responses...immunodominant epitope clusters and peptides containing T cell epitopes identified in this study will provide critical tools to study the role of virus-specific T cells in control and resolution of SARS-CoV-2 infections.”

82) [Robust T Cell Immunity in Convalescent Individuals with Asymptomatic or Mild COVID-19](#), Sekine, 2020

“SARS-CoV-2-specific memory T cells will likely prove critical for long-term immune protection against COVID-19...mapped the functional and phenotypic landscape of SARS-CoV-2-specific T cell responses in unexposed individuals, exposed family members, and individuals with acute or convalescent COVID-19...collective dataset shows that SARS-CoV-2 elicits broadly directed and functionally replete memory T cell responses, suggesting that natural exposure or infection may prevent recurrent episodes of severe COVID-19.”

83) [Potent SARS-CoV-2-Specific T Cell Immunity and Low Anaphylatoxin Levels Correlate With Mild Disease Progression in COVID-19 Patients](#), Lafron, 2021

“Provide a full picture of cellular and humoral immune responses of COVID-19 patients and prove that robust polyfunctional CD8⁺ T cell responses concomitant with low anaphylatoxin levels correlate with mild infections.”

84) [SARS-CoV-2 T-cell epitopes define heterologous and COVID-19 induced T-cell recognition](#), Nelde, 2020

“The first work identifying and characterizing SARS-CoV-2-specific and cross-reactive HLA class I and HLA-DR T-cell epitopes in SARS-CoV-2 convalescents (n = 180) as well as unexposed individuals (n = 185) and confirming their relevance for immunity and COVID-19 disease course...cross-reactive SARS-CoV-2 T-cell epitopes revealed pre-existing T-cell responses in 81% of unexposed individuals, and validation of similarity to common cold human coronaviruses provided a

- 85) [Karl Friston: up to 80% not even susceptible to Covid-19](#), Sayers, 2020
- 86) [CD8⁺ T cells specific for an immunodominant SARS-CoV-2 nucleocapsid epitope cross-react with selective seasonal coronaviruses](#), Lineburg, 2021
- 87) [SARS-CoV-2 genome-wide mapping of CD8 T cell recognition reveals strong immunodominance and substantial CD8 T cell activation in COVID-19 patients](#), Saini, 2020
- 88) [Equivalency of Protection from Natural Immunity in COVID-19 Recovered Versus Fully Vaccinated Persons: A Systematic Review and Pooled Analysis](#), Shenai, 2021
- 89) [ChAdOx1nCoV-19 effectiveness during an unprecedented surge in SARS CoV-2 infections](#), Satwik, 2021
- functional basis for postulated heterologous immunity in SARS-CoV-2 infection...intensity of T-cell responses and recognition rate of T-cell epitopes was significantly higher in the convalescent donors compared to unexposed individuals, suggesting that not only expansion, but also diversity spread of SARS-CoV-2 T-cell responses occur upon active infection.”
- “Results have just been [published](#) of a study suggesting that 40%-60% of people who have not been exposed to coronavirus have resistance at the T-cell level from other similar coronaviruses like the common cold...the true portion of people who are not even susceptible to Covid-19 may be as high as 80%.”
- “Screening of SARS-CoV-2 peptide pools revealed that the nucleocapsid (N) protein induced an immunodominant response in HLA-B7⁺ COVID-19-recovered individuals that was also detectable in unexposed donors...the basis of selective T cell cross-reactivity for an immunodominant SARS-CoV-2 epitope and its homologs from seasonal coronaviruses, suggesting long-lasting protective immunity.”
- “COVID-19 patients showed strong T cell responses, with up to 25% of all CD8⁺ lymphocytes specific to SARS-CoV-2-derived immunodominant epitopes, derived from ORF1 (open reading frame 1), ORF3, and Nucleocapsid (N) protein. A strong signature of T cell activation was observed in COVID-19 patients, while no T cell activation was seen in the ‘non-exposed’ and ‘high exposure risk’ healthy donors.”
- “Systematic review and pooled analysis of clinical studies to date, that (1) specifically compare the protection of natural immunity in the COVID-recovered versus the efficacy of full vaccination in the COVID-naive, and (2) the added benefit of vaccination in the COVID-recovered, for prevention of subsequent SARS-CoV-2 infection...review demonstrates that natural immunity in COVID-recovered individuals is, at least, equivalent to the protection afforded by full vaccination of COVID-naïve populations. There is a modest and incremental relative benefit to vaccination in COVID-recovered individuals; however, the net benefit is marginal on an absolute basis.”
- “The third key finding is that previous infections with SARS-CoV-2 were significantly protective against all studied outcomes, with an effectiveness of 93% (87 to 96%) seen against symptomatic infections, 89% (57 to 97%) against moderate to severe disease and 85% (-9 to 98%) against supplemental oxygen therapy. All

- 90) [SARS-CoV-2 specific T cells and antibodies in COVID-19 protection: a prospective study](#), Molodtsov, 2021
- 91) [Anti- SARS-CoV-2 Receptor Binding Domain Antibody Evolution after mRNA Vaccination](#), Cho, 2021
- 92) [Seven-month kinetics of SARS-CoV-2 antibodies and role of pre-existing antibodies to human coronaviruses](#), Ortega, 2021
- 93) [Immunodominant T-cell epitopes from the SARS-CoV-2 spike antigen reveal robust pre-existing T-cell immunity in unexposed individuals](#), Mahajan, 2021
- 94) [Neutralizing Antibody Responses to Severe Acute Respiratory Syndrome Coronavirus 2 in Coronavirus Disease 2019 Inpatients and Convalescent Patients](#), Wang, 2020
- 95) [Not just antibodies: B cells and T cells mediate immunity to COVID-19](#), Cox, 2020
- 96) [T cell immunity to SARS-CoV-2 following natural infection and vaccination](#), DiPiazza, 2020
- deaths occurred in previously uninfected individuals. This was higher protection than that offered by single or double dose vaccine.”
- “Explore the impact of T cells and to quantify the protective levels of the immune responses...5,340 Moscow residents were evaluated for the antibody and cellular immune responses to SARS-CoV-2 and monitored for COVID-19 up to 300 days. The antibody and cellular responses were tightly interconnected, their magnitude inversely correlated with infection probability. Similar maximal level of protection was reached by individuals positive for both types of responses and by individuals with antibodies alone...T cells in the absence of antibodies provided an intermediate level of protection.”
- “SARS-CoV-2 infection produces B-cell responses that continue to evolve for at least one year. During that time, memory B cells express increasingly broad and potent antibodies that are resistant to mutations found in variants of concern.”
- “Impact of pre-existing antibodies to human coronaviruses causing common cold (HCoVs), is essential to understand protective immunity to COVID-19 and devise effective surveillance strategies...after the peak response, anti-spike antibody levels increase from ~150 days post-symptom onset in all individuals (73% for IgG), in the absence of any evidence of re-exposure. IgG and IgA to HCoV are significantly higher in asymptomatic than symptomatic seropositive individuals. Thus, pre-existing cross-reactive HCoVs antibodies could have a protective effect against SARS-CoV-2 infection and COVID-19 disease.”
- “Findings suggest that SARS-CoV-2 reactive T-cells are likely to be present in many individuals because of prior exposure to flu and CMV viruses.”
- “117 blood samples were collected from 70 COVID-19 inpatients and convalescent patients...the neutralizing antibodies were detected even at the early stage of disease, and a significant response was shown in convalescent patients.”
- “Reports that antibodies to SARS-CoV-2 are not maintained in the serum following recovery from the virus have caused alarm...the absence of specific antibodies in the serum does not necessarily mean an absence of immune memory.”
- “Although T cell durability to SARS-CoV-2 remains to be determined, current data and past experience from human infection with other CoVs demonstrate the potential for persistence and the capacity to

- control viral replication and host disease, and importance in vaccine-induced protection.”
- “Multiple studies have shown loss of severe acute respiratory syndrome coronavirus 2-specific (SARS-CoV-2-specific) antibodies over time after infection, raising concern that humoral immunity against the virus is not durable. If immunity wanes quickly, millions of people may be at risk for reinfection after recovery from coronavirus disease 2019 (COVID-19). However, memory B cells (MBCs) could provide durable humoral immunity even if serum neutralizing antibody titers decline... data indicate that most SARS-CoV-2-infected individuals develop S-RBD-specific, class-switched rMBCs that resemble germinal center-derived B cells induced by effective vaccination against other pathogens, providing evidence for durable B cell-mediated immunity against SARS-CoV-2 after mild or severe disease.”
- “All memory T cell responses detected target the SARS-CoV structural proteins... these responses were found to persist up to 11 years post-infection... knowledge of the persistence of SARS-specific cellular immunity targeting the viral structural proteins in SARS-recovered individuals is important.”
- “The adaptive immune system is important for control of most viral infections. The three fundamental components of the adaptive immune system are B cells (the source of antibodies), CD4⁺ T cells, and CD8⁺ T cells... a picture has begun to emerge that reveals that CD4⁺ T cells, CD8⁺ T cells, and neutralizing antibodies all contribute to control of SARS-CoV-2 in both non-hospitalized and hospitalized cases of COVID-19.”
- “These findings provide support for the prognostic value of early functional SARS-CoV-2-specific T cells with important implications in vaccine design and immune monitoring.”
- “A multiplexed peptide-MHC tetramer approach was used to screen 408 SARS-CoV-2 candidate epitopes for CD8⁺ T cell recognition in a cross-sectional sample of 30 coronavirus disease 2019 convalescent individuals... Modelling demonstrated a coordinated and dynamic immune response characterized by a decrease in inflammation, increase in neutralizing antibody titer, and differentiation of a specific CD8⁺ T cell response. Overall, T cells exhibited distinct differentiation into stem cell and transitional memory states (subsets), which may be key to developing durable protection.”
- “Most importantly, we demonstrate that infection generates both IgG and IgG MBCs against the novel
- 97) [Durable SARS-CoV-2 B cell immunity after mild or severe disease](#), Ogega, 2021
- 98) [Memory T cell responses targeting the SARS coronavirus persist up to 11 years post-infection.](#), Ng, 2016
- 99) [Adaptive immunity to SARS-CoV-2 and COVID-19](#), Sette, 2021
- 100) [Early induction of functional SARS-CoV-2-specific T cells associates with rapid viral clearance and mild disease in COVID-19 patients](#), Tan, 2021
- 101) [SARS-CoV-2-specific CD8⁺ T cell responses in convalescent COVID-19 individuals](#), Kared, 2021
- 102) [S Protein-Reactive IgG and Memory B Cell Production after Human SARS-CoV-2](#)

[Infection Includes Broad Reactivity to the S2 Subunit](#), Nguyen-Contant, 2021

receptor binding domain and the conserved S2 subunit of the SARS-CoV-2 spike protein. Thus, even if antibody levels wane, long-lived MBCs remain to mediate rapid antibody production. Our study results also suggest that SARS-CoV-2 infection strengthens pre-existing broad coronavirus protection through S2-reactive antibody and MBC formation.”

103) [Persistence of Antibody and Cellular Immune Responses in Coronavirus Disease 2019 Patients Over Nine Months After Infection](#), Yao, 2021

“A cross-sectional study to assess the virus-specific antibody and memory T and B cell responses in coronavirus disease 2019 (COVID-19) patients up to 343 days after infection...found that approximately 90% of patients still have detectable immunoglobulin (Ig)G antibodies against spike and nucleocapsid proteins and neutralizing antibodies against pseudovirus, whereas ~60% of patients had detectable IgG antibodies against receptor-binding domain and surrogate virus-neutralizing antibodies...SARS-CoV-2-specific IgG+ memory B cell and interferon- γ -secreting T cell responses were detectable in more than 70% of patients...coronavirus 2-specific immune memory response persists in most patients approximately 1 year after infection, which provides a promising sign for prevention from reinfection and vaccination strategy.”

104) [Naturally Acquired SARS-CoV-2 Immunity Persists for Up to 11 Months Following Infection](#), De Giorgi, 2021

“A prospective, longitudinal analysis of COVID-19 convalescent plasma donors at multiple time points over an 11-month period to determine how circulating antibody levels change over time following natural infection... data suggest that immunological memory is acquired in most individuals infected with SARS-CoV-2 and is sustained in a majority of patients.”

105) [Decreasing Seroprevalence of Measles Antibodies after Vaccination – Possible Gap in Measles Protection in Adults in the Czech Republic](#), Smetana, 2017

“A long-term high rate of seropositivity persists after natural measles infection. By contrast, it decreases over time after vaccination. Similarly, the concentrations of antibodies in persons with measles history persist for a longer time at a higher level than in vaccinated persons.”

106) [Broadly cross-reactive antibodies dominate the human B cell response against 2009 pandemic H1N1 influenza virus infection](#), Wrammert, 2011

“The expansion of these rare types of memory B cells may explain why most people did not become severely ill, even in the absence of pre-existing protective antibody titers”...found “extraordinarily” powerful antibodies in the blood of nine people who caught the swine flu naturally and recovered from it.”...unlike antibodies elicited by annual influenza vaccinations, most neutralizing antibodies induced by pandemic H1N1 infection were broadly cross-reactive against epitopes in the hemagglutinin (HA) stalk and head domain of multiple influenza strains. The antibodies were from cells that had undergone extensive affinity maturation.”

107) [Reinfection With Severe Acute](#)

“Reinfection was identified in 0.7% (n = 63, 95%

[Respiratory Syndrome Coronavirus 2 \(SARS-CoV-2\) in Patients Undergoing Serial Laboratory Testing](#), Qureshi, 2021

108) [Distinct antibody and memory B cell responses in SARS-CoV-2 naïve and recovered individuals following mRNA vaccination](#), Goel, 2021

109) [Covid-19: Do many people have pre-existing immunity?](#) Doshi, 2020

110) [Pre-existing and *de novo* humoral immunity to SARS-CoV-2 in humans](#), Ng, 2020

111) [Phenotype of SARS-CoV-2-specific T-cells in COVID-19 patients with acute respiratory distress syndrome](#), Weiskopf, 2020

112) [Pre-existing immunity to SARS-CoV-2: the knowns and unknowns](#), Sette, 2020

113) [Pre-existing immunity against swine-origin H1N1 influenza viruses in the general human population](#), Greenbaum, 2009

confidence interval [CI]: .5%–.9%) during follow-up of 9119 patients with SARS-CoV-2 infection.”

“Interrogated antibody and antigen-specific memory B cells over time in 33 SARS-CoV-2 naïve and 11 SARS-CoV-2 recovered subjects... In SARS-CoV-2 recovered individuals, antibody and memory B cell responses were significantly boosted after the first vaccine dose; however, there was no increase in circulating antibodies, neutralizing titers, or antigen-specific memory B cells after the second dose. This robust boosting after the first vaccine dose strongly correlated with levels of pre-existing memory B cells in recovered individuals, identifying a key role for memory B cells in mounting recall responses to SARS-CoV-2 antigens.”

“Six studies have reported T cell reactivity against SARS-CoV-2 in 20% to 50% of people with no known exposure to the virus... in a study of donor blood specimens obtained in the US between 2015 and 2018, 50% displayed various forms of T cell reactivity to SARS-CoV-2... Researchers are also confident that they have made solid inroads into ascertaining the origins of the immune responses. “Our hypothesis, of course, was that it’s so called ‘common cold’ coronaviruses, because they’re closely related...we have really shown that this is a true immune memory and it is derived in part from common cold viruses.”

“We demonstrate the presence of pre-existing humoral immunity in uninfected and unexposed humans to the new coronavirus. SARS-CoV-2 S-reactive antibodies were readily detectable by a sensitive flow cytometry-based method in SARS-CoV-2-uninfected individuals and were particularly prevalent in children and adolescents.”

“We detected SARS-CoV-2-specific CD4⁺ and CD8⁺ T cells in 100% and 80% of COVID-19 patients, respectively. We also detected low levels of SARS-CoV-2-reactive T-cells in 20% of the healthy controls, not previously exposed to SARS-CoV-2 and indicative of cross-reactivity due to infection with ‘common cold’ coronaviruses.”

“T cell reactivity against SARS-CoV-2 was observed in unexposed people...it is speculated that this reflects T cell memory to circulating ‘common cold’ coronaviruses.”

“Memory T-cell immunity against S-OIV is present in the adult population and that such memory is of similar magnitude as the pre-existing memory against seasonal H1N1 influenza...the conservation of a large

114) [Cellular immune correlates of protection against symptomatic pandemic influenza](#), Sridhar, 2013

115) [Preexisting influenza-specific CD4+ T cells correlate with disease protection against influenza challenge in humans](#), Wilkinson, 2012

116) [Serum cross-reactive antibody response to a novel influenza A \(H1N1\) virus after vaccination with seasonal influenza vaccine](#), CDC, MMWR, 2009

117) [No one is naive: the significance of heterologous T-cell immunity](#), Welsh, 2002

118) [Intrafamilial Exposure to SARS-CoV-2 Induces Cellular Immune Response without Seroconversion](#), Gallais, 2020

fraction of T-cell epitopes suggests that the severity of an S-OIV infection, as far as it is determined by susceptibility of the virus to immune attack, would not differ much from that of seasonal flu.”

“The 2009 H1N1 pandemic (pH1N1) provided a unique natural experiment to determine whether cross-reactive cellular immunity limits symptomatic illness in antibody-naive individuals... Higher frequencies of pre-existing T cells to conserved CD8 epitopes were found in individuals who developed less severe illness, with total symptom score having the strongest inverse correlation with the frequency of interferon- γ (IFN- γ)(+) interleukin-2 (IL-2)(-) CD8(+) T cells ($r = -0.6$, $P = 0.004$)... CD8(+) T cells specific to conserved viral epitopes correlated with cross-protection against symptomatic influenza.”

“Precise role of T cells in human influenza immunity is uncertain. We conducted influenza infection studies in healthy volunteers with no detectable antibodies to the challenge viruses H3N2 or H1N1...mapped T cell responses to influenza before and during infection... found a large increase in influenza-specific T cell responses by day 7, when virus was completely cleared from nasal samples and serum antibodies were still undetectable. Pre-existing CD4+, but not CD8+, T cells responding to influenza internal proteins were associated with lower virus shedding and less severe illness. These CD4+ cells also responded to pandemic H1N1 (A/CA/07/2009) peptides and showed evidence of cytotoxic activity.”

“No increase in cross-reactive antibody response to the novel influenza A (H1N1) virus was observed among adults aged >60 years. These data suggest that receipt of recent (2005–2009) seasonal influenza vaccines is unlikely to elicit a protective antibody response to the novel influenza A (H1N1) virus.”

“Memory T cells that are specific for one virus can become activated during infection with an unrelated heterologous virus, and might have roles in protective immunity and immunopathology. The course of each infection is influenced by the T-cell memory pool that has been laid down by a host’s history of previous infections, and with each successive infection, T-cell memory to previously encountered agents is modified.”

“Individuals belonging to households with an index COVID-19 patient, reported symptoms of COVID-19 but discrepant serology results... All index patients recovered from a mild COVID-19. They all developed anti-SARS-CoV-2 antibodies and a significant T cell response detectable up to 69 days

“Individuals belonging to households with an index COVID-19 patient, reported symptoms of COVID-19 but discrepant serology results... All index patients recovered from a mild COVID-19. They all developed anti-SARS-CoV-2 antibodies and a significant T cell response detectable up to 69 days

after symptom onset. Six of the eight contacts reported COVID-19 symptoms within 1 to 7 days after the index patients but all were SARS-CoV-2 seronegative... exposure to SARS-CoV-2 can induce virus-specific T cell responses without seroconversion. T cell responses may be more sensitive indicators of SARS-CoV-2 exposure than antibodies... results indicate that epidemiological data relying only on the detection of SARS-CoV-2 antibodies may lead to a substantial underestimation of prior exposure to the virus.”

“It important to note that antibodies are incomplete predictors of protection. After vaccination or infection, many mechanisms of immunity exist within an individual not only at the antibody level, but also at the level of cellular immunity. It is known that SARS-CoV-2 infection induces specific and durable T-cell immunity, which has multiple SARS-CoV-2 spike protein targets (or epitopes) as well as other SARS-CoV-2 protein targets. The broad diversity of T-cell viral recognition serves to enhance protection to SARS-CoV-2 variants, with recognition of at least the alpha (B.1.1.7), beta (B.1.351), and gamma (P.1) variants of SARS-CoV-2. Researchers have also found that people who recovered from SARS-CoV infection in 2002–03 continue to have memory T cells that are reactive to SARS-CoV proteins 17 years after that outbreak. Additionally, a memory B-cell response to SARS-CoV-2 evolves between 1·3 and 6·2 months after infection, which is consistent with longer-term protection.”

“This ‘super antibody’ for COVID fights off multiple coronaviruses... 12 antibodies... that was involved in the study, isolated from people who had been infected with either SARS-CoV-2 or its close relative SARS-CoV.”

“Taken together, our data indicate sustained humoral immunity in recovered patients who suffer from symptomatic COVID-19, suggesting prolonged immunity.”

“Whereas anti-CoV-2 IgA antibodies rapidly decayed, IgG antibodies remained relatively stable up to 115 days PSO in both biofluids. Importantly, IgG responses in saliva and serum were correlated, suggesting that antibodies in the saliva may serve as a surrogate measure of systemic immunity.”

“Early appearance, multi-specificity and functionality of SARS-CoV-2-specific T cells are associated with accelerated viral clearance and with protection from severe COVID-19.”

“Found a significantly faster decay in naïve vaccinees

119) [Protective immunity after recovery from SARS-CoV-2 infection](#), Kojima, 2021

120) [This ‘super antibody’ for COVID fights off multiple coronaviruses](#), Kwon, 2021

121) [SARS-CoV-2 infection induces sustained humoral immune responses in convalescent patients following symptomatic COVID-19](#), Wu, 2020

122) [Evidence for sustained mucosal and systemic antibody responses to SARS-CoV-2 antigens in COVID-19 patients](#), Isho, 2020

123) [The T-cell response to SARS-CoV-2: kinetic and quantitative aspects and the case for their protective role](#), Bertoletti, 2021

124) [The longitudinal kinetics of antibodies](#)

[in COVID-19 recovered patients over 14 months](#), Eyrán, 2020

125) [Continued Effectiveness of COVID-19 Vaccination among Urban Healthcare Workers during Delta Variant Predominance](#), Lan, 2021

126) [Immunity to COVID-19 in India through vaccination and natural infection](#), Sarraf, 2021

127) [Asymptomatic or mild symptomatic SARS-CoV-2 infection elicits durable neutralizing antibody responses in children and adolescents](#), Garrido, 2021

128) [T cell response to SARS-CoV-2 infection in humans: A systematic review](#), Shrotri, 2021

compared to recovered patients suggesting that the serological memory following natural infection is more robust compared to vaccination. Our data highlights the differences between serological memory induced by natural infection vs. vaccination.”

“Followed a population of urban Massachusetts HCWs...we found no re-infection among those with prior COVID-19, contributing to 74,557 re-infection-free person-days, adding to the evidence base for the robustness of naturally acquired immunity.”

“Compared the vaccination induced immune response profile with that of natural infection, evaluating thereby if individuals infected during the first wave retained virus specific immunity...the overall immune response resulting from natural infection in and around Kolkata is not only to a certain degree better than that generated by vaccination, especially in the case of the Delta variant, but cell mediated immunity to SARS-CoV-2 also lasts for at least ten months after the viral infection.”

“Evaluated humoral immune responses in 69 children and adolescents with asymptomatic or mild symptomatic SARS-CoV-2 infection. We detected robust IgM, IgG, and IgA antibody responses to a broad array of SARS-CoV-2 antigens at the time of acute infection and 2 and 4 months after acute infection in all participants. Notably, these antibody responses were associated with virus-neutralizing activity that was still detectable 4 months after acute infection in 94% of children. Moreover, antibody responses and neutralizing activity in sera from children and adolescents were comparable or superior to those observed in sera from 24 adults with mild symptomatic infection. Taken together, these findings indicate that children and adolescents with mild or asymptomatic SARS-CoV-2 infection generate robust and durable humoral immune responses that can likely contribute to protection from reinfection.”

“Symptomatic adult COVID-19 cases consistently show peripheral T cell lymphopenia, which positively correlates with increased disease severity, duration of RNA positivity, and non-survival; while asymptomatic and paediatric cases display preserved counts. People with severe or critical disease generally develop more robust, virus-specific T cell responses. T cell memory and effector function has been demonstrated against multiple viral epitopes, and, cross-reactive T cell responses have been demonstrated in unexposed and uninfected adults, but the significance for protection and susceptibility, respectively, remains unclear.”

- 129) [Severity of SARS-CoV-2 Reinfections as Compared with Primary Infections](#), Abu-Raddad, 2021
- 130) [Assessment of the Risk of Severe Acute Respiratory Syndrome Coronavirus 2 \(SARS-CoV-2\) Reinfection in an Intense Re-exposure Setting](#), Abu-Raddad, 2021
- 131) [Increased risk of infection with SARS-CoV-2 Beta, Gamma, and Delta variant compared to Alpha variant in vaccinated individuals](#), Andeweg, 2021
- 132) [Prior COVID-19 protects against reinfection, even in the absence of detectable antibodies](#), Breathnach, 2021
- “Reinfections had 90% lower odds of resulting in hospitalization or death than primary infections. Four reinfections were severe enough to lead to acute care hospitalization. None led to hospitalization in an ICU, and none ended in death. Reinfections were rare and were generally mild, perhaps because of the primed immune system after primary infection.”
- “SARS-CoV-2 reinfection can occur but is a rare phenomenon suggestive of protective immunity against reinfection that lasts for at least a few months post primary infection.”
- “Analyzed 28,578 sequenced SARS-CoV-2 samples from individuals with known immune status obtained through national community testing in the Netherlands from March to August 2021. They found evidence for an “increased risk of infection by the Beta (B.1.351), Gamma (P.1), or Delta (B.1.617.2) variants compared to the Alpha (B.1.1.7) variant after vaccination. No clear differences were found between vaccines. However, the effect was larger in the first 14-59 days after complete vaccination compared to 60 days and longer. In contrast to vaccine-induced immunity, no increased risk for reinfection with Beta, Gamma or Delta variants relative to Alpha variant was found in individuals with infection-induced immunity.”
- “Studies did not address whether prior infection is protective in the absence of a detectable humoral immune response. Patients with primary or secondary antibody deficiency syndrome and reduced or absent B cells can recover from COVID-19...Although there have been few mechanistic studies, preliminary data show that such individuals generate striking T-cell immune responses against SARS-CoV-2 peptide pools...SARS-CoV-2 specific T cell immune responses but not neutralising antibodies are associated with reduced disease severity suggesting the immune system may have considerable redundancy or compensation following COVID-19...our results add to the emerging evidence that detectable serum antibody may be an incomplete marker of protection against reinfection. This could have implications for public health and policy-making, for example if using seroprevalence data to assess population immunity, or if serum antibody levels were to be taken as official evidence of immunity – a minority of truly immune patients have no detectable antibody and could be disadvantaged as a result. Our findings highlight the need for further studies of immune correlates of protection from infection with SARS-CoV-2, which may in turn

enhance development of effective vaccines and treatments.”

133) [Natural infection vs vaccination: Which gives more protection?](#), Rosenberg, 2021

“With a total of 835,792 Israelis known to have recovered from the virus, the 72 instances of reinfection amount to 0.0086% of people who were already infected with COVID...By contrast, Israelis who were vaccinated were 6.72 times more likely to get infected after the shot than after natural infection, with over 3,000 of the 5,193,499, or 0.0578%, of Israelis who were vaccinated getting infected in the latest wave.”

134) [Community transmission and viral load kinetics of the SARS-CoV-2 delta \(B.1.617.2\) variant in vaccinated and unvaccinated individuals in the UK: a prospective, longitudinal, cohort study](#), Singanayagam, 2021

“Nonetheless, fully vaccinated individuals with breakthrough infections have peak viral load similar to unvaccinated cases and can efficiently transmit infection in household settings, including to fully vaccinated contacts.”

135) [Antibodies elicited by mRNA-1273 vaccination bind more broadly to the receptor binding domain than do those from SARS-CoV-2 infection](#), Greaney, 2021

“The neutralizing activity of vaccine-elicited antibodies was more targeted to the receptor-binding domain (RBD) of the SARS-CoV-2 spike protein compared to antibodies elicited by natural infection. However, within the RBD, binding of vaccine-elicited antibodies was more broadly distributed across epitopes compared to infection-elicited antibodies. This greater binding breadth means that single RBD mutations have less impact on neutralization by vaccine sera compared to convalescent sera. Therefore, antibody immunity acquired by natural infection or different modes of vaccination may have a differing susceptibility to erosion by SARS-CoV-2 evolution.”

136) [Antigen-Specific Adaptive Immunity to SARS-CoV-2 in Acute COVID-19 and Associations with Age and Disease Severity](#), Moderbacher, 2020

“Limited knowledge is available on the relationship between antigen-specific immune responses and COVID-19 disease severity. We completed a combined examination of all three branches of adaptive immunity at the level of SARS-CoV-2-specific CD4+ and CD8+ T cell and neutralizing antibody responses in acute and convalescent subjects. SARS-CoV-2-specific CD4+ and CD8+ T cells were each associated with milder disease. Coordinated SARS-CoV-2-specific adaptive immune responses were associated with milder disease, suggesting roles for both CD4+ and CD8+ T cells in protective immunity in COVID-19. Notably, coordination of SARS-CoV-2 antigen-specific responses was disrupted in individuals \geq 65 years old. Scarcity of naive T cells was also associated with aging and poor disease outcomes. A parsimonious explanation is that coordinated CD4+ T cell, CD8+ T cell, and antibody responses are protective, but uncoordinated responses frequently

- fail to control disease, with a connection between aging and impaired adaptive immune responses to SARS-CoV-2.”
- 137) [Protection and waning of natural and hybrid COVID-19 immunity](#), Goldberg, 2021
- 138) [A Systematic Review of the Protective Effect of Prior SARS-CoV-2 Infection on Repeat Infection](#), Kojima, 202
- 139) [High-affinity memory B cells induced by SARS-CoV-2 infection produce more plasmablasts and atypical memory B cells than those primed by mRNA vaccines](#), Pape, 2021
- 140) [Differential antibody dynamics to SARS-CoV-2 infection and vaccination](#), Chen, 2021
- 141) [Children develop robust and sustained cross-reactive spike-specific immune responses to SARS-CoV-2 infection](#), Dowell, 2022
- “Protection from reinfection decreases with time since previous infection, but is, nevertheless, higher than that conferred by vaccination with two doses at a similar time since the last immunity-conferring event.”
- “The protective effect of prior SARS-CoV-2 infection on re-infection is high and similar to the protective effect of vaccination.”
- “Compare SARS-CoV-2 spike receptor binding domain (S1-RBD)-specific primary MBCs that form in response to infection or a single mRNA vaccination. Both primary MBC populations have similar frequencies in the blood and respond to a second S1-RBD exposure by rapidly producing plasmablasts with an abundant immunoglobulin (Ig)A+ subset and secondary MBCs that are mostly IgG+ and cross-react with the B.1.351 variant. However, infection-induced primary MBCs have better antigen-binding capacity and generate more plasmablasts and secondary MBCs of the classical and atypical subsets than do vaccine-induced primary MBCs. Our results suggest that infection-induced primary MBCs have undergone more affinity maturation than vaccine-induced primary MBCs and produce more robust secondary responses.”
- “Optimal immune responses furnish long-lasting (durable) antibodies protective across dynamically mutating viral variants (broad). To assess robustness of mRNA vaccine-induced immunity...compared antibody durability and breadth after SARS-CoV-2 infection and vaccination...While vaccination delivered robust initial virus-specific antibodies with some cross-variant coverage, pre-variant SARS-CoV-2 infection-induced antibodies, while modest in magnitude, showed highly stable long-term antibody dynamics...Differential antibody durability trajectories favored COVID-19-recovered subjects with dual memory B cell features of greater early antibody somatic mutation and cross-coronavirus reactivity...illuminating an infection-mediated antibody breadth advantage and an anti-SARS-CoV-2 antibody durability-enhancing function conferred by recalled immunity.”
- “Compare antibody and cellular immunity in children (aged 3-11 years) and adults. Antibody responses against spike protein were high in children and seroconversion boosted responses against seasonal Beta-coronaviruses through cross-recognition of the

S2 domain. Neutralization of viral variants was comparable between children and adults. Spike-specific T cell responses were more than twice as high in children and were also detected in many seronegative children, indicating pre-existing cross-reactive responses to seasonal coronaviruses. Importantly, children retained antibody and cellular responses 6 months after infection, whereas relative waning occurred in adults. Spike-specific responses were also broadly stable beyond 12 months. Therefore, children generate robust, cross-reactive and sustained immune responses to SARS-CoV-2 with focused specificity for the spike protein. These findings provide insight into the relative clinical protection that occurs in most children and might help to guide the design of pediatric vaccination regimens.”

142) [Severity of SARS-CoV-2 Reinfections as Compared with Primary Infections](#), Abu-Raddad, 2021

[Abu-Raddad et al.](#) has recently published on the severity of SARS-CoV-2 reinfections as compared with primary infections. They reported that in earlier studies, they assessed the efficacy of previous natural infection “as protection against reinfection with SARS-CoV-2 as being 85% or greater. Accordingly, for a person who has already had a primary infection, the risk of having a severe reinfection is only approximately 1% of the risk of a previously uninfected person having a severe primary infection...Reinfections had 90% lower odds of resulting in hospitalization or death than primary infections. Four reinfections were severe enough to lead to acute care hospitalization. None led to hospitalization in an ICU, and none ended in death. Reinfections were rare and were generally mild, perhaps because of the primed immune system after primary infection.”

143) [SARS-CoV-2 spike T cell responses induced upon vaccination or infection remain robust against Omicron](#), Keeton, 2021

“Assessed the ability of T cells to react with Omicron spike in participants who were vaccinated with Ad26.CoV2.S or BNT162b2, and in unvaccinated convalescent COVID-19 patients (n = 70). We found that 70-80% of the CD4 and CD8 T cell response to spike was maintained across study groups. Moreover, the magnitude of Omicron cross-reactive T cells was similar to that of the Beta and Delta variants, despite Omicron harbouring considerably more mutations. Additionally, in Omicron-infected hospitalized patients (n = 19), there were comparable T cell responses to ancestral spike, nucleocapsid and membrane proteins to those found in patients hospitalized in previous waves dominated by the ancestral, Beta or Delta variants (n = 49). These results demonstrate that despite Omicron’s extensive mutations and reduced susceptibility to neutralizing

antibodies, the majority of T cell response, induced by vaccination or natural infection, cross-recognises the variant. Well-preserved T cell immunity to Omicron is likely to contribute to protection from severe COVID-19, supporting early clinical observations from South Africa.”

“69% (54/78) of the epitopes recognized by CD8+ T cells are completely invariant. We further demonstrate experimentally that some memory T-cell immunity against S-OIV is present in the adult population and that such memory is of similar magnitude as the pre-existing memory against seasonal H1N1 influenza. Because protection from infection is antibody mediated, a new vaccine based on the specific S-OIV HA and NA proteins is likely to be required to prevent infection. However, T cells are known to blunt disease severity. Therefore, the conservation of a large fraction of T-cell epitopes suggests that the severity of an S-OIV infection, as far as it is determined by susceptibility of the virus to immune attack, would not differ much from that of seasonal flu. These results are consistent with reports about disease incidence, severity, and mortality rates associated with human S-OIV...overall, 49% of the epitopes reported in the literature and present in recently circulating seasonal H1N1 are also found totally conserved in S-OIV. Interestingly, the number of conserved epitopes varied greatly as a function of the class of epitopes considered. Although only 31% of the B-cell epitopes were conserved, 41% of the CD4+ and 69% of the CD8+ T-cell epitopes were conserved. It is known that cross-reactive T-cell immune responses can exist even between serologically distinct influenza A strains (14, 15). Based on this observation and the data presented above, we hypothesized that it is possible that immune memory responses against S-OIV exist in the adult population, at the level of both B and T cells.”

“*PES* against symptomatic reinfection was estimated at 90.2% (95% CI: 60.2-97.6) for Alpha, 84.8% (95% CI: 74.5-91.0) for Beta, 92.0% (95% CI: 87.9-94.7) for Delta, and 56.0% (95% CI: 50.6-60.9) for Omicron. Only 1 Alpha, 2 Beta, 0 Delta, and 2 Omicron reinfections progressed to severe COVID-19. None progressed to critical or fatal COVID-19. *PES* against hospitalization or death due to reinfection was estimated at 69.4% (95% CI: -143.6-96.2) for Alpha, 88.0% (95% CI: 50.7-97.1) for Beta, 100% (95% CI: 43.3-99.8) for Delta, and 87.8% (95% CI: 47.5-97.1) for Omicron.”

“Observe higher frequencies of cross-reactive ($p =$

144) [Pre-existing immunity against swine-origin H1N1 influenza viruses in the general human population](#), Greenbaum, 2009

145) [Protection afforded by prior infection against SARS-CoV-2 reinfection with the Omicron variant](#), Altarawneh, 2021

146) [Cross-reactive memory T cells](#)

[associate with protection against SARS-CoV-2 infection in COVID-19 contacts](#), Kundu, 2022

0.0139), and nucleocapsid-specific ($p = 0.0355$) IL-2-secreting memory T cells in contacts who remained PCR-negative despite exposure ($n = 26$), when compared with those who convert to PCR-positive ($n = 26$); no significant difference in the frequency of responses to spike is observed, hinting at a limited protective function of spike-cross-reactive T cells. Our results are thus consistent with pre-existing non-spike cross-reactive memory T cells protecting SARS-CoV-2-naïve contacts from infection, thereby supporting the inclusion of non-spike antigens in second-generation vaccines.”

“At 18 months, 97% participants tested positive for anti-NCP hinting towards the persistence of infection-induced immunity even for the vaccinated individuals.”

147) [Long-Term Persistence of IgG Antibodies in recovered COVID-19 individuals at 18 months and the impact of two-dose BNT162b2 \(Pfizer-BioNTech\) mRNA vaccination on the antibody response](#), Dehgani-Mobaraki, 2021

“Enrolled 412 adults mostly with mild or moderate disease course. At each study visit, subjects donated peripheral blood for testing of anti-SARS-CoV-2 IgG antibodies and IFN- γ release after SARS-CoV-2 S-protein stimulation. Anti-SARS-CoV-2 IgG antibodies were identified in 316/412 (76.7%) of the patients and 215/412 (52.2%) had positive neutralizing antibody levels. Likewise, in 274/412 (66.5 %) positive IFN- γ release and IgG antibodies were detected. With respect to time after infection, both IgG antibody levels and IFN- γ concentrations decreased by about half within three hundred days. Statistically, IgG and IFN- γ production were closely associated, but on an individual basis we observed patients with high antibody titres but low IFN- γ levels and vice versa. Our data suggest that immunological reaction is acquired in most individuals after infection with SARS-CoV-2 and is sustained in the majority of patients for at least 10 months after infection.”

148) [Long-term course of humoral and cellular immune responses in outpatients after SARS-CoV-2 infection](#), Schiffner, 2021

“Enrolled 412 adults mostly with mild or moderate disease course. At each study visit, subjects donated peripheral blood for testing of anti-SARS-CoV-2 IgG antibodies and IFN- γ release after SARS-CoV-2 S-protein stimulation. Anti-SARS-CoV-2 IgG antibodies were identified in 316/412 (76.7%) of the patients and 215/412 (52.2%) had positive neutralizing antibody levels. Likewise, in 274/412 (66.5 %) positive IFN- γ release and IgG antibodies were detected. With respect to time after infection, both IgG antibody levels and IFN- γ concentrations decreased by about half within three hundred days. Statistically, IgG and IFN- γ production were closely associated, but on an

individual basis we observed patients with high antibody titres but low IFN- γ levels and vice versa. Our data suggest that immunological reaction is acquired in most individuals after infection with SARS-CoV-2 and is sustained in the majority of patients for at least 10 months after infection.”

“By the week beginning October 3, compared with COVID-19 cases rates among unvaccinated persons without a previous COVID-19 diagnosis, case rates among vaccinated persons without a previous COVID-19 diagnosis were 6.2-fold (California) and 4.5-fold (New York) lower; rates were substantially lower among both groups with previous COVID-19 diagnoses, including 29.0-fold (California) and 14.7-fold lower (New York) among unvaccinated persons with a previous diagnosis, and 32.5-fold (California) and 19.8-fold lower (New York) among vaccinated persons with a previous diagnosis of COVID-19. During the same period, compared with hospitalization rates among unvaccinated persons without a previous COVID-19 diagnosis, hospitalization rates in California followed a similar pattern. These results demonstrate that vaccination protects against COVID-19 and related hospitalization, and that surviving a previous infection protects against a reinfection and related hospitalization. Importantly, infection-derived protection was higher after the Delta variant became predominant, a time when vaccine-induced immunity for many persons declined because of immune evasion and immunologic waning.”

“In this cross-sectional study of unvaccinated US adults, antibodies were detected in 99% of individuals who reported a positive COVID-19 test result, in 55% who believed they had COVID-19 but were never tested, and in 11% who believed they had never had COVID-19 infection. Anti-RBD levels were observed after a positive COVID-19 test result up to 20 months, extending previous 6-month durability data

Qatar researchers investigated SARS-CoV-2 Omicron symptomatic BA.1 infection, symptomatic BA.2 infection, BA.1 hospitalization and death, and BA.2 hospitalization and death, between December 23, 2021 and February 21, 2022. The researchers conducted 6 national, matched, test-negative case-control studies were conducted to examine effectiveness of BNT162b2 (Pfizer-BioNTech) vaccine, mRNA-1273 (Moderna) vaccine, natural immunity due to prior infection with pre-Omicron variants, and hybrid immunity from prior infection and vaccination. They found that “Effectiveness of

149) [COVID-19 Cases and Hospitalizations by COVID-19 Vaccination Status and Previous COVID-19 Diagnosis — California and New York, May–November 2021](#), Leon, 2022

150) [Prevalence and Durability of SARS-CoV-2 Antibodies Among Unvaccinated US Adults by History of COVID-19](#), Alejo, 2022

151) [Effect of prior infection, vaccination, and hybrid immunity against symptomatic BA.1 and BA.2 Omicron infections and severe COVID-19 in Qatar](#), Altarawneh, March 2022

only prior infection against symptomatic BA.2 infection was 46.1% (95% CI: 39.5-51.9%). Effectiveness of only two-dose BNT162b2 vaccination was negligible at -1.1% (95% CI: -7.1-4.6), but nearly all individuals had received their second dose several months earlier. Effectiveness of only three-dose BNT162b2 vaccination was 52.2% (95% CI: 48.1-55.9%). Effectiveness of hybrid immunity of prior infection and two-dose BNT162b2 vaccination was 55.1% (95% CI: 50.9-58.9%).” The key finding was “There are no discernable differences in the effects of prior infection, vaccination, and hybrid immunity against BA.1 versus BA.2.”

A [Swedish study by Nordström et al.](#) found that **the risk of SARS-CoV-2 reinfection and COVID-19 hospitalization in individuals who have survived and recovered from a previous infection remained suppressed for up to 20 months.** This was a retrospective cohort study using Swedish nationwide registers managed by the Public Health Agency of Sweden, the National Board of Health and Welfare, and Statistics Sweden. Three cohorts were formed: Cohort 1 included unvaccinated individuals with natural immunity matched pairwise on birth year and sex to unvaccinated individuals without natural immunity at baseline. Cohort 2 and cohort 3 included individuals vaccinated with one dose (one-dose hybrid immunity) or two doses (two-dose hybrid immunity) of a COVID-19 vaccine, respectively, after a previous infection, matched pairwise on birth year and sex to individuals with natural immunity at baseline.

Specifically, after the initial 3 months post-infection, natural immunity was associated with a 95% lower risk of SARS-CoV-2 infection (adjusted hazard ratio [aHR] 0.05 [95% CI 0.05–0.05] $p < 0.001$) and an 87% (0.13 [0.11–0.16]; $p < 0.001$) lower risk of COVID-19 hospitalization for up to 20 months of follow-up. Researchers concluded “**The risk of SARS-CoV-2 reinfection and COVID-19 hospitalization in individuals who have survived and recovered from a previous infection remained low for up to 20 months. Vaccination seemed to further decrease the risk of both outcomes for up to 9 months, although the differences in absolute numbers, especially in hospitalizations, were small.** These findings suggest that if passports are used for societal restrictions, they should acknowledge either a previous infection or vaccination as proof of immunity, as opposed to vaccination only.”

“Evaluate anti-nucleocapsid antibody (anti-N Ab) seropositivity in mRNA-1273 vaccine efficacy trial

152. [Risk of SARS-CoV-2 reinfection and COVID-19 hospitalisation in individuals with natural and hybrid immunity: a retrospective, total population cohort study in Sweden](#), Nordstrom, March 2020.

153.) [Anti-nucleocapsid antibodies following SARS-CoV-2 infection in the](#)

[blinded phase of the mRNA-1273 Covid-19 vaccine efficacy clinical trial](#), Follmann, 2022

participants after SARS-CoV-2 infection during the trial's blinded phase...nested analysis in a Phase 3 randomized, placebo-controlled vaccine efficacy trial...at 99 sites in the US...trial participants were \geq 18 years old with no known history of SARS-CoV-2 infection and at appreciable risk of SARS-CoV-2 infection and/or high risk of severe Covid-19...among participants with PCR-confirmed Covid-19 illness, seroconversion to anti-N Abs at a median follow up of 53 days post diagnosis occurred in 21/52 (40%) of the mRNA-1273 vaccine recipients vs. 605/648 (93%) of the placebo recipients ($p < 0.001$).” Substantially less N Ab (nucleocapsid antibodies are highly conserved and stable, unlike the mutable spike protein) emerged in the vaccinated than those who were unvaccinated. Prior mRNA-1273 vaccination influenced/impacted anti-nucleocapsid antibody seroconversion relative to those unvaccinated. This is a major concern if the mRNA vaccine is impacting N Ab inducement, for then the unvaccinated who are naturally exposed and infected and mount an immune response, will show a far superior and broad immune response that includes Ab to not only the mutable spike but also to other viral proteins such as the interior nucleocapsid protein (evidence of long-term acquired-adaptive natural immunity).

Setting: Nationally centralized database of Maccabi Healthcare Services, an Israeli national health fund that covers 2.5 million people.

Participants: The study population included between 293,743 and 458,959 individuals (depending on the model), 5-18 years of age, who were unvaccinated SARS-CoV-2 naive persons or unvaccinated convalescent patients.

Evaluated three SARS-CoV-2-related outcomes: (1) documented PCR confirmed infection or reinfection, (2) COVID-19 and (3) severe COVID-19.

Results: Overall, children and adolescents who were previously infected acquired durable protection against reinfection (symptomatic or not) with SARS-CoV-2 for at least 18 months. Importantly, no COVID-19 related deaths were recorded in either the SARS-CoV-2 naive group or the previously infected group. Effectiveness of naturally-acquired immunity against a recurrent infection reached 89.2% (95% CI: 84.7%-92.4%) three to six months after first infection, mildly declining to 82.5% (95% CI, 79.1%-85.3%) nine months to one year after infection, then remaining rather steady for children and adolescents for up to 18 months, with a slight non-significant waning trend. Found that ages 5-11 exhibited no significant waning of naturally acquired protection

154) [Naturally-acquired Immunity Dynamics against SARS-CoV-2 in Children and Adolescents](#), Patalon, 2022

throughout the outcome period, whereas waning protection in the 12-18 age group was more prominent, but still mild.

Conclusions: **Children and adolescents who were previously infected with SARS-CoV-2 remain protected against reinfection to a high degree and policy decision makers should consider when and if convalescent children and adolescents should be vaccinated.'**

Researchers studied the duration of protection afforded by natural infection, the effect of viral immune evasion on duration of protection, and protection against severe reinfection, in Qatar, between February 28, 2020 and June 5, 2022. They conducted and included three national, matched, retrospective cohort studies so as to compare incidence of SARS-CoV-2 infection and COVID-19 severity among unvaccinated persons with a documented SARS-CoV-2 primary infection, to incidence among those infection-naive and unvaccinated.

They found that “effectiveness of pre-Omicron primary infection against pre-Omicron reinfection was 85.5% (95% CI: 84.8-86.2%). Effectiveness peaked at 90.5% (95% CI: 88.4-92.3%) in the 7th month after the primary infection, but waned to ~70% by the 16th month. Extrapolating this waning trend using a Gompertz curve suggested an effectiveness of 50% in the 22nd month and <10% by the 32nd month. Effectiveness of pre-Omicron primary infection against Omicron reinfection was 38.1% (95% CI: 36.3-39.8%) and declined with time since primary infection. A Gompertz curve suggested an effectiveness of <10% by the 15th month. Effectiveness of primary infection against severe, critical, or fatal COVID-19 reinfection was 97.3% (95% CI: 94.9-98.6%), irrespective of the variant of primary infection or reinfection, and with no evidence for waning. Similar results were found in sub-group analyses for those ≥ 50 years of age.”

Key is that protection of natural infection against reinfection wanes and may diminish within a few years. Viral immune evasion accelerates this waning. **However, and very tantalizing is that protection against severe reinfection “remains very strong, with no evidence for waning, irrespective of variant.”**

“Estimates the effectiveness of previous infection with SARS-CoV-2 in preventing reinfection with Omicron BA.4/BA.5 subvariants using a test-

155) [Duration of immune protection of SARS-CoV-2 natural infection against reinfection in Qatar](#), Chemaitelly, 2022

156) [Protection of SARS-CoV-2 natural infection against reinfection with the Omicron BA.4 or BA.5](#)

negative, case-control study design. Cases (SARS-CoV-2-positive test results) and controls (SARS-CoV-2-negative test results) were matched according to sex, 10-year age group, nationality, comorbid condition count, calendar week of testing, method of testing, and reason for testing.

Effectiveness of a previous Omicron infection against symptomatic BA.4/BA.5 reinfection was 76.1% (95% CI: 54.9-87.3%), and against any BA.4/BA.5 reinfection was 79.7% (95% CI: 74.3-83.9%).

Results using all diagnosed infections when BA.4/BA.5 dominated incidence confirmed the same findings. Sensitivity analyses adjusting for vaccination status confirmed study results. Protection of a previous infection against BA.4/BA.5 reinfection was modest when the previous infection involved a pre-Omicron variant, but strong when the previous infection involved the Omicron BA.1 or BA.2 subvariants.”

“Six months after the initial two BNT162b2 immunizations, the median neutralizing antibody pseudovirus titer was 124 against WA1/2020 but less than 20 against all the tested omicron subvariants. Two weeks after administration of the booster dose, the median neutralizing antibody titer increased substantially, to 5783 against the WA1/2020 isolate, 900 against the BA.1 subvariant, 829 against the BA.2 subvariant, 410 against the BA.2.12.1 subvariant, and 275 against the BA.4 or BA.5 subvariant.

Among the participants with a history of Covid-19, the median neutralizing antibody titer was 11,050 against the WA1/2020 isolate, 1740 against the BA.1 subvariant, 1910 against the BA.2 subvariant, 1150 against the BA.2.12.1 subvariant, and 590 against the BA.4 or BA.5 subvariant.”

“We analyzed 28,578 sequenced SARS-CoV-2 samples from individuals with known immune status obtained through national community testing in the Netherlands from March to August 2021. We found evidence of an increased risk of infection by the Beta (B.1.351), Gamma (P.1), or Delta (B.1.617.2) variants compared to the Alpha (B.1.1.7) variant after vaccination. No clear differences were found between vaccines. However, the effect was larger in the first 14-59 days after complete vaccination compared to ≥60 days. In contrast to vaccine-induced immunity, there was no increased risk for re-infection with Beta, Gamma or Delta variants relative to Alpha variant in

[subvariants](#), Altarawneh & Abu-Raddad, 2022

157) [Neutralization Escape by SARS-CoV-2 Omicron Subvariants BA.2.12.1, BA.4, and BA.5](#), Hachmann, 2022

158) [Elevated risk of infection with SARS-CoV-2 Beta, Gamma, and Delta variant compared to Alpha variant in vaccinated individuals](#), ANDEWEG, 2022

individuals with infection-induced immunity.”

“We found no association between previous infection and a new infection with Beta, Gamma, or Delta versus Alpha, suggesting that there is no difference in protection from a previous infection between Beta, Gamma, or Delta variants compared to the Alpha variant. This is in line with the similar relative risk reductions for re-infection found for the Alpha and Delta variant (9). Early studies showed that previous infection conferred better protection than vaccination without previous infection during the Delta period.”

These researchers applied a registry-based study design that indeed lacks the level of precision of a test-negative design. Yet as they rightly argue, the very large number of cases studied that covered all the residents of Portugal over 12 years old, allowed confidence in a derived risk estimate for individuals with prior BA.1/BA.2 infection that was robust and trustworthy enough and located close to an estimate from Qatar based on a test-negative design.

Background and findings:

“Portugal was one of the first countries affected by a BA.5 predominance. We used the national coronavirus disease 2019 (Covid-19) registry (SINAVE) to calculate the risk of BA.5 infection among persons with documented infection with past variants, including BA.1 and BA.2. The registry includes all reported cases in the country, regardless of clinical presentation.”

“We found that previous SARS-CoV-2 infection had a protective effect against BA.5 infection, and this protection was maximal for previous infection with BA.1 or BA.2. These data should be considered in the context of breakthrough infections in a highly vaccinated population, given that in Portugal more than 98% of the study population completed the primary vaccination series before 2022.”

Conclusion:

“Overall, we found that breakthrough infections with the BA.5 subvariant were less likely among persons with a previous SARS-CoV-2 infection history in a highly vaccinated population, especially for previous BA.1 or BA.2 infection, than among uninfected persons.”

159.) [Risk of BA.5 Infection among Persons Exposed to Previous SARS-CoV-2 Variants](#), Graca, 2022