

Incidence of Respiratory Infections after the COVID-19 Pandemic (2023–2024) and Its Association of Vaccination Among Entire Populations in Korea

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1 **Highlights**

- 2 • Patterns of respiratory infection shifted in the post-COVID era.
- 3 • Influenza-like illness (ILI) decreased substantially during the pandemic (2020–2022).
- 4 • Incidence of upper respiratory infections (URI) and the common colds resurged (2023).
- 5 • COVID-19 vaccination ( $\geq 4$ -dose) was associated with lower risks of ILI and pertussis.
- 6 • But the vaccination was associated with increased risks of URI and the common cold.

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**Incidence of Respiratory Infections after the COVID-19 Pandemic (2023–2024)  
and Its Association of Vaccination Among Entire Populations in Korea**

**Running title:** Respiratory Infections in Post-Pandemic

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- 33 1 Figure and 2 Tables.
- 34 6 supplementary materials

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35 **ABSTRACT**

36 **Objectives** We aimed to investigate nationwide trends in respiratory infections during and after  
37 the COVID-19 pandemic and to evaluate the risk according to the COVID-19 vaccine dose.

38 **Methods** Using the database, which integrates the insurance claims and vaccination records for  
39 the entire Korean population (N=51,645,564), trends were assessed using SARIMAX models.  
40 We assessed associations between the doses that have been received until June 1, 2023, and the  
41 onset of respiratory infections, using Cox hazard and Fine-Gray models.

42 **Results** Compared with pre-pandemic levels (2017–2019), influenza like illness (ILI) and  
43 pneumonia incidences dropped by over 90% during 2020–2021, followed by a resurgence of  
44 upper respiratory tract infection (URI) and common cold in 2023–2024. Pertussis incidence  
45 rose 46-fold above expected levels in late 2023. Individuals ( $\geq 4^{\text{th}}$  dose) had lower risks of ILI  
46 (adjusted hazard ratio: 0.55 [95% CI: 0.54–0.57]) and pertussis (0.06 [0.04–0.08]), but higher  
47 risks of URI (1.32 [1.32–1.33]) and common cold (1.63 [1.62–1.64]), compared with  
48 unvaccinated or partially vaccinated.

49 **Conclusion** With changes in respiratory infection patterns, COVID-19 vaccination may be  
50 differentially associated with respiratory infections in the post-pandemic era, reflecting shifts  
51 in population-level immunity and highlighting the need for adaptive public health strategies.

52 **Keywords:** *Post-COVID, COVID-19 vaccine, respiratory infectious diseases*

53 **INTRODUCTION**

54           Since the COVID-19 pandemic waves (2020–2022), numerous countries have  
55 witnessed substantial alterations of public health infrastructure, individual hygiene practices,  
56 healthcare accessibility, and patterns of diseases [1-4]. As our society has gradually transitioned  
57 into the end of the pandemic, often referred to as the ‘Post-COVID’, ‘New Normal’, or ‘With-  
58 COVID’ (2023–2024), total change has lasting implications not only on the healthcare system  
59 but also on the epidemiology of respiratory infectious diseases.

60           During the start and height of the pandemic, non-pharmaceutical interventions (NPIs)  
61 such as mask-wearing, social distancing, remote work, and school closures may reduce the  
62 transmission of various respiratory pathogens such as *influenza virus*, *human rhinovirus*,  
63 *human adenovirus*, *human respiratory syncytial virus*, and *SARS-CoV-2* [5-7]. Additionally,  
64 restrictions on healthcare services and reduced diagnostic tests for non-SARS-CoV-2  
65 respiratory infections [8] contributed to an underreporting of cases, resulting in an  
66 unprecedented decline in the incidence of flu, *etc.* during 2020 and 2021 [9-11]. Nevertheless,  
67 as public vigilance against several infections waned in Mid-2022, a notable resurgence of  
68 respiratory infections was expected. For instance, the re-emergence of non-SARS-CoV-2  
69 respiratory infections after Mid-2022 has alarmed potential rebound effects following  
70 prolonged suppression of pathogen circulation [12, 13]. Immune responses and pulmonary  
71 tissue damage following SARS-CoV-2 infection may render individuals more susceptible to  
72 other respiratory infections [14]. Furthermore, structural and behavioral changes in the Post-  
73 COVID era, including improved indoor ventilation standards, early surveillance systems,  
74 adjustments in border controls, and updated governmental policies for infectious disease  
75 preparedness, have continued to change the pattern and seasonal trend of respiratory diseases

76 after the pandemic. Amid these changes, concerns regarding unidentified viral interference and  
77 increased population susceptibility emerged. An immunity debt, referring to reduced  
78 population immunity due to decreased exposure to common pathogens during the pandemic, is  
79 especially relevant to children and older adults who may face increased risk of infection or  
80 more severe clinical outcomes [15]. Moreover, the administration of COVID-19 vaccines may  
81 also have altered the seasonality of infection outbreaks and modulated population-level  
82 susceptibility to other pathogens than *SARS-CoV-2*. Therefore, it is time for studies to be carried  
83 out to analyze new trends and evaluate the impact of vaccines on other respiratory diseases.  
84 Understanding this new epidemiology of respiratory infectious diseases is essential for  
85 informing future public health strategies, resource allocation, and clinical preparedness against  
86 ongoing respiratory disease threats.

87 Here, with the entire national cohort (N = 51,645,564), our study aims to analyze the  
88 trends and characteristics of major respiratory infections in the Republic of Korea during the  
89 Pandemic (2020–2022) and the Post-pandemic (2023–2024) and to assess the association  
90 between the dose of the COVID-19 vaccine and the onset of major respiratory infections.

91 **METHODS**92 ***Data source and study population***

93 This retrospective cohort study included the entire Korean population, utilizing  
94 national health insurance data provided by the National Health Insurance Service (NHIS;  
95 database number: NHIS-2024-10-1-045). To facilitate COVID-19 research, the Korea Disease  
96 Control and Prevention Agency (KDCA), in collaboration with the NHIS, developed the K-  
97 CoV-N database. Nationwide polymerase chain reaction testing for *SARS-CoV-2* was  
98 conducted across hospitals and medical centers under KDCA supervision between January  
99 2020 and May 2023, establishing comprehensive epidemiological data, including daily SARS-  
100 CoV-2-infected cases [16]. The K-CoV-N database integrates epidemiological surveillance  
101 data, complete vaccination records, and health insurance claims data, enabling longitudinal  
102 monitoring of clinical outcomes, including respiratory infections, alongside detailed  
103 sociodemographic information such as age, sex, and household income [17].

104 To investigate the incidence of seven major respiratory infections, this study analyzed  
105 insurance claims for the entire Korean population ( $N = 51,645,564$ ) from the K-CoV-N  
106 database, with approval from the Institutional Review Board (IRB exemption number: E-2405-  
107 013-1534). Additionally, to assess the association between total received dose of COVID-19  
108 vaccine and respiratory infectious diseases, an analytic cohort ( $N = 39,447,030$ ) was  
109 constructed, excluding individuals with events of infection within three months prior to the  
110 start of observation (June 1, 2023).

111

112 ***COVID-19 pandemic and inoculation of COVID-19 vaccine (exposure)***

113 The COVID-19 pandemic was categorized into distinct phases based on dominant  
114 SARS-CoV-2 variants and corresponding epidemic waves: Origin (January 2020 – December  
115 2020), Alpha/Beta (January 2020 – June 2021), Delta (July 2021 – December 2021), and  
116 Omicron and Sub-variant (January 2022 – December 2022) [18, 19]. The Post-pandemic phase  
117 was defined as the years of 2023 and 2024, coinciding with the termination of national  
118 quarantine policies and formal COVID-19 patient management programs (June 2023; Post-  
119 COVID). Severity of COVID-19 was operationally defined by incorporating indicators such as  
120 admission to the intensive care unit, oxygen supplementation, cardiopulmonary resuscitation,  
121 and use of extracorporeal membrane oxygenation, based on the World Health Organization  
122 (WHO) criteria [20, 21]. The prescription of COVID-19-specific therapeutics, including  
123 regdanvimab, nirmatrelvir, and Paxlovid, along with comorbidities known to impact disease  
124 severity, was also considered to determine the severity.

125 COVID-19 Vaccines included ChAdOx1 nCov-19, BNT162b2, mRNA-1273,  
126 Ad26.COV2.S, Novavax, and SKYCOVIONE, as well as updated formulations (BNT162b2-  
127 BA.1, BNT162b5, and mRNA-1273.214). Based on the history of the vaccine in the K-COV-  
128 N database, all participants were classified by the final received dose of COVID-19 vaccine  
129 status on June 1, 2023: no and first dose, second dose, third dose (first boost shot), and  $\geq$  fourth  
130 dose. Participants were followed up from June 1, 2023, to the end of observation (September  
131 30, 2024) or the date of death or events.

132

### 133 ***Outcome: major respiratory infectious diseases***

134 Outcome was operationally defined with the International Classification of Diseases,  
135 Tenth Revision (ICD-10) codes: I. upper respiratory tract infection (URI, 'J00–J06') [22], II.

136 hospitalized pneumonia ('J10–J18', requiring more than two days of hospitalization;  
137 accuracy= $\sim$ 96%) [23], III. influenza like illness (ILI, 'J09–J11') [24], IV. acute nasopharyngitis  
138 (common cold, 'J00') [25], V. scarlet fever ('A38') [26], VI. pertussis ('A37') [27], VII.  
139 tuberculosis ('A15-A19', 'B90', 'U84.3', and 'U88') [28], and VIII. COVID-19 ('U07.1' and  
140 'U07.2' with the KDCA's reports) [29]. Based on the operational definition, claims for the  
141 above infection from hospitals were extracted from insurance claim data between January 2016  
142 and September 2024. If 91 days had elapsed from the previous infection (URI, pneumonia, ILI,  
143 common cold, scarlet fever, pertussis, and COVID-19), it was determined as the new infection  
144 (re-infection), and if not, the existing infection would continue. The time gap to determine a  
145 new onset of tuberculosis was used as a standard of 182 days.

146

#### 147 *Statistical analysis*

148 Variables that were considered and included in the regression models were selected  
149 based on their clinical relevance and statistical significance: age (continuous), sex (male or  
150 female), income level (quartiles), Charlson comorbidity index (continuous), severity of  
151 COVID-19 (mild or severe among patients with COVID-19), phase of initial SARS-CoV-2  
152 infection (origin, alpha/beta, delta, or omicron), and intervals between date of last inoculation  
153 and start date of observation (year, continuous). All citizens in Korea were stratified into four  
154 age groups for subgroup analyses: children and adolescents (0–19 years), young adults (20–39  
155 years), middle-aged adults (40–64 years), and older adults ( $\geq$ 65 years).

156 All statistical analyses were performed using SAS software, version 9.4 (SAS Institute  
157 Inc., Cary, NC, USA). Statistics were reported as frequencies with percentages for categorical  
158 variables and means with standard deviations for continuous variables. The chi-square test and  
159 one-way analysis of variance (ANOVA) were employed to evaluate differences between groups

160 for categorical and continuous variables, respectively. To estimate the pattern or seasonal trend  
161 during the Pandemic or Post-pandemic, autoregressive integrated moving average exogenous  
162 (ARIMAX) models for pertussis and tuberculosis or seasonal ARIMAX (SARIMAX) models  
163 for URI, pneumonia, ILI, common cold, and scarlet fever calculated an estimated or expected  
164 monthly incidence of each infectious diseases, based on the previous incidence (2017–2019)  
165 and inputs (age, sex, income level, and Charlson comorbidity index). Then, comparisons  
166 between the monthly observed and estimated incidence during the periods or phases were  
167 performed. Furthermore, multivariable Cox proportional hazard regression or Fine-Gray sub-  
168 distribution hazards model (competing events: all-cause mortality) was used to estimate  
169 adjusted hazard ratio (aHR) or adjusted sub-distribution hazard ratio (aSHR) with  
170 corresponding 95% confidence intervals (CIs) and to evaluate the association between the dose  
171 of vaccine and major respiratory infectious diseases. Statistical significance thresholds ( $p$ -value,  
172 two-tailed) were set at  $* < 0.05$ ,  $** < 0.01$ , and  $\# < 0.001$ . As one of the solutions for the error of  
173 multiple comparisons, the Benjamini-Hochberg method was used to calculate the adjusted  $p$ -  
174 value.

175 **RESULTS**176 *New trends of respiratory infectious diseases during and after the COVID-19 Pandemic*

177 **Figure 1** illustrates the monthly observed (black solid line) and estimated (blue dashed  
178 line) incidence of major respiratory infectious diseases during the Pandemic (2020–2022) and  
179 Post-pandemic periods (2023–2024). During the early COVID-19 pandemic (2020–2021), the  
180 monthly incidence of pneumonia, ILI, and scarlet fever markedly declined compared to the  
181 pre-pandemic periods (2017–2019). Especially, the monthly incidence of ILI decreased by  
182 more than 90% during the winter season of 2020–2021, relative to the expected level that was  
183 estimated from SARIMAX models (**Table 1**). During the Post-pandemic period, a resurgence  
184 of respiratory infections was observed. Notably, infectious cases of URI and common cold  
185 increased during the winter season of 2023 and 2024; the ratio of observed and estimated values  
186 of common cold between January 2023 and September 2024 was approximately 2.2-fold.  
187 While tuberculosis incidence remained stably decreasing throughout the overall period, that of  
188 pertussis, initially low (N of monthly cases < 100), began rising notably after mid-2023.  
189 ARIMAX models estimated a 46.1-fold (95% CIs, 2.04–90.2) increase in the incidence of  
190 pertussis, compared to the expected values. Similarly, stratified time series by age groups show  
191 that the dynamics and seasonality of major respiratory infections such as URI, hospitalized  
192 pneumonia, and common cold in Korea have substantially changed, with lower incidence and  
193 re-emerging (**Supplementary Figure 1**). Notably, the proportion of the middle-aged (orange)  
194 and older (red) adults increased in pneumonia and ILI during the Pandemic (**Supplementary**  
195 **Figure 2**). Conversely, the proportion of children (sky blue) and adolescents (blue) in the ILI  
196 increased after the COVID-19 pandemic (2023–2024). **Supplementary Figure 3** illustrates the  
197 monthly sex ratio of infected cases.

198

199 *Association of the dose of the vaccine and major respiratory infections after the Pandemic*

200 Among 39,447,030 individuals included in the analytic cohort, the association between  
201 the total dose of COVID-19 vaccine on June 1, 2023, and the onset of subsequent major  
202 respiratory infections was evaluated. The mean of age  $\pm$  SD in those who were unvaccinated  
203 or received only the first dose (No and 1<sup>st</sup> dose; N = 7,933,859), those who have received with  
204 two doses (2<sup>nd</sup> dose; N = 7,551,773), those who have inoculated with the first boost shoot (3<sup>rd</sup>  
205 dose; N = 16,662,259), and those who have received four and more doses ( $\geq$  4<sup>th</sup> dose; N =  
206 7,299,139) were  $37.0 \pm 24.2$ ,  $38.0 \pm 15.0$ ,  $47.3 \pm 15.9$ , and  $67.1 \pm 13.2$  years, respectively, with  
207 substantial differences in age distribution across the groups (**Supplementary Table 1**). The  
208 number (%) of patients with COVID-19 was 3,824,829 (48.2%) in No and 1<sup>st</sup>, 4,423,939  
209 (58.6%) in 2<sup>nd</sup> dose, 8,723,256 (52.4%) in 3<sup>rd</sup> dose, and 3,169,059 (43.4%) in 4<sup>th</sup> dose. Sex  
210 ratio (male to female) in No and 1<sup>st</sup>, 2<sup>nd</sup> dose, 3<sup>rd</sup> dose, and  $\geq$  4<sup>th</sup> dose was 1.18, 1.13, 0.99, and  
211 0.99, in order. Individuals who received the four or more doses of COVID-19 vaccine ( $\geq$  4<sup>th</sup>  
212 dose) showed a significantly lower risk of ILI, compared to those who were unvaccinated or  
213 only partially vaccinated (no and 1<sup>st</sup>): the aHR in Model 3 = 0.55 (0.54–0.57, adjusted  $p < 0.001$ )  
214 and aSHR for ILI was 0.56 (0.54–0.97,  $p < 0.001$ ). Similarly, an inverse association was  
215 observed for pertussis. Participants in  $\geq$  4<sup>th</sup> dose had a 94% lower risk of pertussis (aHR in  
216 Model 3 = 0.06 (0.04–0.08, adjusted  $p < 0.001$ ) and aSHR = 0.06 (0.04–0.08,  $p < 0.001$ ) compared  
217 to those in No and 1<sup>st</sup> dose. Conversely, the aHRs for URI and common cold in the  $\geq$  4<sup>th</sup> dose  
218 were higher than those in the 2<sup>nd</sup> dose; after adjustment (Model 3), the aHRs for URI and  
219 common cold were 1.32 (1.32–1.33,  $p < 0.001$ ) and 1.63 (1.62–1.64,  $p < 0.001$ ) in the  $\geq$  4<sup>th</sup> group,  
220 respectively. The aHRs for pneumonia among children and adolescents (0–19 years) and older

221 adults ( $\geq 65$  years) were 0.46 (0.44–0.49,  $p < 0.001$ ) and 0.75 (0.73–0.76,  $p < 0.001$ ) in  $\geq 4^{\text{th}}$  dose,  
222 respectively, compared to those in 2<sup>nd</sup> dose (**Supplementary Table 3**) Additionally, the risk of  
223 tuberculosis was reduced by 12% in  $\geq 4^{\text{th}}$  dose; the aHR was 0.88 (0.79–0.98,  $p < 0.05$ )  
224 compared in 2<sup>nd</sup> dose. Among patients with COVID-19, the risk of common cold gradually  
225 increased according to more dose of vaccine; the aHRs in 2<sup>nd</sup>, 3<sup>rd</sup>, and  $\geq 4^{\text{th}}$  dose were 1.05  
226 (1.03–1.06,  $p < 0.001$ ), 1.12 (1.10–1.14,  $p < 0.001$ ), and 1.36 (1.34–1.39,  $p < 0.001$ ), in order,  
227 compared to that in No and 1<sup>st</sup> (**Supplementary Table 2**). Notably, regardless of the history of  
228 SARS-CoV-2 infection, the risk of ILI and pertussis gradually reduced when individuals  
229 received more doses of the vaccine.

230 **DISCUSSION**

231 Through the retrospective cohort study, a temporary decline followed by a resurgence  
232 of URI and common cold was observed during and after the COVID-19 pandemic. In the Post-  
233 pandemic period (January 2023–September 2024), the risk of URI and common cold increased  
234 with higher COVID-19 vaccine doses, while ILI and pertussis showed an inverse association,  
235 indicating a protective effect. These key findings highlight the divergent trajectories of  
236 respiratory infections and their varying associations with vaccination status.

237 Our findings reveal the distinct pattern of respiratory infection incidence, including the  
238 short-term suppression of URI, pneumonia, ILI, and pertussis (2020–2022) and the following  
239 rise of URI, common cold, pertussis, and tuberculosis (2023–2024). The initial sharp decline  
240 in respiratory infections observed during the early phase of the COVID-19 pandemic is  
241 consistent with previous international reports [30, 31]. Previous studies documented significant  
242 reductions in *influenza virus* and other common respiratory viruses during the Pandemic, due  
243 to strict NPIs and an abnormal monitoring system [32, 33]. Hidden and undetected infection  
244 cases may be one of the reasons to decline due to the restrictions on hospital visits and the  
245 allocation of medical resources for COVID-19 management [34]. Another important  
246 distinction lies in the timing and magnitude of resurgence after the Pandemic. While some  
247 countries would experience immediate rebounds of respiratory infections following the  
248 relaxation (early 2022), our study shows a more gradual increase, with pronounced peaks  
249 emerging during late 2023 and early 2024, potentially reflecting differences in public health  
250 policies, healthcare access, population immunity, and spread of SARS-CoV-2 infection. This  
251 difference could be partially explained by Korea's own national health programs, including  
252 mandatory reporting and a national-level vaccination system, which persisted despite pandemic  
253 disruptions. The relaxation of NPIs and immunity debt (reduced population immunity) has

254 created conditions favorable for other respiratory infections [35, 36], such as damage to mucous  
255 membranes and lung tissues caused by SARS-CoV-2 infection, the prognosis of excess  
256 antibiotic prescription to prevent other infections during treatment for COVID-19, and  
257 disturbance of or exhaustion of the immune system. Especially, disruption of immune  
258 homeostasis due to prior SARS-CoV-2 infection may increase vulnerability to secondary  
259 infections [37, 38]. Thus, these socio- and biological factors together contribute to altered  
260 transmission dynamics of the pathogens and heightened infection risk during the Post-  
261 pandemic era.

262 In terms of varying vaccine-associated outcomes, some studies have suggested that  
263 COVID-19 vaccines may exert indirect protective effects against some respiratory pathogens  
264 [39, 40] by modulating the host immune response or through behavioral changes such as  
265 refraining from outdoor activities after the inoculation. Our results align with these  
266 observations, potentially showing an inverse association between the number of COVID-19  
267 vaccine doses and the onset of ILI and pertussis. The inverse association of COVID-19  
268 vaccination with ILI and pertussis might be explained by immune system priming. COVID-19  
269 vaccines, particularly platforms of mRNA, virus-driven materials, or adjuvants, have been  
270 shown to stimulate innate immune responses, potentially enhancing antiviral and antibacterial  
271 defenses [41]. Additionally, individuals who adhere to vaccination schedules may also engage  
272 more rigorously in other protective health behaviors, such as inoculation for seasonal influenza  
273 vaccination [42-44]. Despite these similarities, however, our study also revealed notable  
274 deviations from prior findings. Interestingly, we observed that the risk of URI and common  
275 cold increased in proportion to the number of COVID-19 vaccine doses received. This finding  
276 contrasts with earlier hypotheses proposing that COVID-19 vaccination might confer broad  
277 nonspecific protection against other respiratory viruses. Since the demographic nature of

278 vaccinated individuals, such as age and the interests of individual health care, greatly differed,  
279 the positive relationship between higher vaccine doses and increased risk of URI and common  
280 cold may reflect age-related confounding. Older adults, who were more likely to receive  
281 booster doses, are inherently at higher risk for respiratory infections due to immune-senescence  
282 and underlying comorbidities. Although multivariable adjustments and stratified analysis were  
283 done, residual confounding cannot be completely solved. Nevertheless, several biological  
284 mechanisms may underlie the observed associations between COVID-19 vaccination status  
285 and respiratory infection risk. Pandemic-driven changes in pathogen circulation patterns and  
286 viral interference may have contributed. Suppression of one respiratory virus can sometimes  
287 facilitate the spread of others through the ecological niche model. For example, suppression of  
288 the *influenza virus* during the pandemic may have altered competitive dynamics among  
289 respiratory pathogens. Furthermore, alterations in mucosal immunity due to prolonged periods  
290 of reduced pathogen exposure may have rendered populations more susceptible to certain  
291 infections once public health restrictions were lifted [45]. This mechanism likely contributed  
292 to the observed rebound in URI and common cold incidence, particularly among younger  
293 individuals who had limited exposure to common pathogens during the pandemic.

294 This study has several limitations. First, although this retrospective cohort study  
295 provides novel evidence on the potential associations of COVID-19 vaccine doses with the  
296 onset of several respiratory infections, our findings should be interpreted as associative in the  
297 absence of immunologic and clinical biomarkers. Since the mechanisms underlying these  
298 heterogeneous results remain unclear, further immunologic, epidemiologic, and laboratory-  
299 based investigations are warranted to clarify and confirm these associations among different  
300 populations. Next, as we utilized a nationwide cohort encompassing all insurance claims data  
301 in Korea, diagnostic accuracy may be affected by potential miscoding or limitations inherent

302 to claims-based operational definitions. Notably, young and middle-aged adults may be less  
303 likely to visit the hospitals for mild symptoms of common cold or ILI, which could lead to an  
304 underestimation of the incidence of URI, common cold, and ILI due to unrecorded claims.  
305 Moreover, despite adjusting for multiple covariates, residual confounding effects, particularly  
306 related to age and behavioral factors, may persist. While both crude and adjusted risks were  
307 presented across population groups, further methods to solve the heterogeneity, such as  
308 matching or weighting, could not be feasibly implemented due to substantial differences in  
309 demographic and clinical characteristics between vaccination groups. Additionally, vaccination  
310 status was classified solely based on the number of doses received, without accounting for  
311 vaccine type, intervals between doses, or episodes of inoculation and SARS-CoV-2 infection,  
312 all of which may influence susceptibility to other infections. Finally, as this was an  
313 observational study, causal inferences between COVID-19 vaccination and the risk of  
314 subsequent respiratory infections cannot be definitively established.

315 In conclusion, this retrospective cohort study provides robust evidence of dynamic  
316 changes in respiratory infection patterns during and after the COVID-19 pandemic in Korea.  
317 While COVID-19 vaccination appears to confer partial protection against certain respiratory  
318 infections, such as ILI and pertussis, a paradoxical increase in the risk of URI and common  
319 cold with higher vaccine doses was noted. These findings identify the complex interplay  
320 between vaccination, immunity, and pathogen ecology in the post-COVID era and highlight  
321 the need for tailored public health strategies to manage respiratory infections in a transitioning  
322 global health landscape.

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445 **Table 1. Ratio of observed to estimated incidence of respiratory infections.**

	Obs.	Est.	Difference (Obs. - Est.)	Ratio (Obs. per Est.)
<b>Upper respiratory tract infection</b>				
COVID-19 pandemic (January 2020–December 2022)	28,318,005	33,243,495	-4,925,490	0.98 (0.55, 1.42)
In Delta phase (July 2021–December 2021)	1,797,941	6124,186	-4,326,245	0.41 (0.25, 0.57)
In Omicron/sub-variant phase (January–December 2022)	18,669,363	11510,037	7,159,326	1.90 (0.68, 3.11)
Post-Pandemic (January 2023–September 2024)	32,908,366	19319,903	13,588,463	1.92 (1.42, 2.43)
<b>Pneumonia</b>				
COVID-19 pandemic (January 2020–December 2022)	682,927	1730,273	-1,047,346	0.41 (0.34, 0.47)
In Delta phase (July 2021–December 2021)	92,064	280,976	-188,912	0.36 (0.26, 0.46)
In Omicron/sub-variant phase (January–December 2022)	272,136	589,805	-317,669	0.49 (0.38, 0.60)
Post-Pandemic (January 2023–September 2024)	857,140	1019,019	-161,879	0.92 (0.75, 1.08)
<b>Influenza Like Illness</b>				
COVID-19 pandemic (January 2020–December 2022)	1,692,345	9019,560	-7,327,215	0.08 (0.01, 0.15)
In Delta phase (July 2021–December 2021)	5,367	1117,027	-1,111,660	0.01 (0.00, 0.01)
In Omicron/sub-variant phase (January–December 2022)	931,294	3387,157	-2,455,863	0.15 (0.03, 0.33)
Post-Pandemic (January 2023–September 2024)	4,970,983	5928,136	-957,153	0.88 (0.36, 1.41)
<b>Common cold</b>				
COVID-19 pandemic (January 2020–December 2022)	9,778,720	9534,016	244,704	1.54 (1.03, 2.05)
In Delta phase (July 2021–December 2021)	811,241	1274,436	-463,195	1.23 (0.54, 1.92)
In Omicron/sub-variant phase (January–December 2022)	6,379,630	3531,585	2,848,045	2.68 (1.34, 4.01)
Post-Pandemic (January 2023–September 2024)	10,721,067	6327,289	4,393,778	2.24 (1.76, 2.72)
<b>Pertussis</b>				
COVID-19 pandemic (January 2020–December 2022)	227	4,835	-4,608	0.05 (0.01, 0.09)
In Delta phase (July 2021–December 2021)	23	827	-804	0.03 (0.01, 0.04)
In Omicron/sub-variant phase (January–December 2022)	45	1,847	-1,802	0.02 (0.02, 0.03)
Post-Pandemic (January 2023–September 2024)	191,591	3,847	187,744	46.1 (2.04, 90.2)
<b>Tuberculosis</b>				
COVID-19 pandemic (January 2020–December 2022)	90,843	90,744	99	1.01 (0.98, 1.04)
In Delta phase (July 2021–December 2021)	14,975	14,482	493	1.03 (0.95, 1.11)
In Omicron/sub-variant phase (January–December 2022)	26,924	25,115	1,809	1.08 (1.01, 1.14)
Post-Pandemic (January 2023–September 2024)	45,682	31,606	14,076	1.47 (1.38, 1.55)

446 Estimated (or expected) values were calculated using ARIMAX or SRIMAX models, based on monthly incidences

447 before the COVID-19 pandemic (2017-2019; 3-year

448 Ratio > 1: excess events occurred.

449 Abbreviation: Observed (Obs.); Estimate (Est.); Autoregressive integrated moving average exogenous

450 (ARIMAX); Seasonal autoregressive integrated moving average exogenous (SRIMAX)

451 **Table 2. Association of vaccine history of SARS-CoV-2 with respiratory infections during**

452 **the Post-pandemic periods (2023–2024).**

	Vaccine status on June 01, 2023, [dose]				<i>P</i> <sub>for trend</sub>
	No and 1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	≥ 4 <sup>th</sup>	
<b>Study population, N</b>	7,933,859	7,551,773	16,662,259	7,299,139	
<b>Upper respiratory tract infection</b>					
Events, N (%)	3,678,488 (46.4)	3,692,666 (48.9)	7,830,605 (47.0)	3,145,640 (43.1)	
PY [Year]	7,367,938.0	7,014,610.8	15,824,024.5	7,131,273.0	
Crude HR (95% CIs)	1.00 (Reference)	1.05 (1.05, 1.05)#	0.99 (0.99, 0.99)#	0.88 (0.88, 0.89)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	1.09 (1.09, 1.09)#	1.16 (1.15, 1.16)#	1.32 (1.32, 1.33)#	
Model 2	1.00 (Reference)	1.04 (1.03, 1.04)#	1.11 (1.10, 1.11)#	1.28 (1.27, 1.28)#	
Model 3	1.00 (Reference)	1.25 (1.24, 1.26)#	1.36 (1.35, 1.37)#	1.65 (1.64, 1.67)#	<0.001
Adjusted <i>p</i> -value	Reference	<0.001	<0.001	<0.001	
aSHR (95% CIs) in Model 3	1.00 (Reference)	1.26 (1.25, 1.27)#	1.38 (1.37, 1.38)#	1.68 (1.66, 1.69)#	
<b>Pneumonia</b>					
Events, N (%)	996,832 (12.6)	573,188 (7.6)	883,776 (5.3)	342,199 (4.7)	
PY [Year]	9,778,049.3	9,604,102.3	21,496,359.6	9,417,705.1	
Crude HR (95% CIs)	1.00 (Reference)	0.59 (0.58, 0.59)#	0.40 (0.40, 0.41)#	0.36 (0.36, 0.36)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	0.71 (0.71, 0.71)#	0.62 (0.61, 0.62)#	0.85 (0.84, 0.85)#	
Model 2	1.00 (Reference)	0.66 (0.65, 0.66)#	0.58 (0.58, 0.58)#	0.82 (0.81, 0.82)#	
Model 3	1.00 (Reference)	0.85 (0.84, 0.87)#	0.78 (0.77, 0.79)#	1.18 (1.16, 1.21)#	<0.001
Adjusted <i>p</i> -value	Reference	<0.001	<0.001	<0.001	
aSHR (95% CIs) in Model 3	1.00 (Reference)	0.86 (0.84, 0.87)#	0.79 (0.77, 0.80)#	1.20 (1.17, 1.22)#	
<b>Influenza Like Illness</b>					
Events, N (%)	777,053 (9.8)	535,361 (7.1)	743,054 (4.5)	141,548 (1.9)	
PY [Year]	9,876,113.4	9,612,599.6	21,562,774.8	9,533,754.3	
Crude HR (95% CIs)	1.00 (Reference)	0.71 (0.70, 0.71)#	0.44 (0.44, 0.44)#	0.19 (0.19, 0.19)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	0.96 (0.96, 0.96)#	0.83 (0.83, 0.83)#	0.76 (0.75, 0.76)#	
Model 2	1.00	0.87 (0.87, 0.87)	0.77 (0.77, 0.77)	0.72 (0.72, 0.72)	

Model 3	(Reference) 1.00	0.87)# 0.72 (0.71, 0.73)#	0.77)# 0.62 (0.61, 0.63)#	0.73)# 0.55 (0.54, 0.57)#	<0.001
Adjusted <i>p</i> -value aSHR (95% CIs) in Model 3	Reference 1.00	<0.001 0.72 (0.71, 0.73)#	<0.001 0.62 (0.61, 0.63)#	<0.001 0.56 (0.54, 0.57)#	
<b>Common cold</b>					
Events, N (%)	993,934 (12.5)	819,428 (10.8)	1,735,891 (10.4)	750,674 (10.3)	
PY [Year]	9,780,153.2	9,445,667.6	20,884,470.7	9,092,919.1	
Crude HR (95% CIs)	1.00 (Reference)	0.85 (0.85, 0.86)#	0.82 (0.82, 0.82)#	0.81 (0.81, 0.82)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	0.91 (0.91, 0.92)#	0.99 (0.98, 0.99)#	1.25 (1.24, 1.25)#	
Model 2	1.00 (Reference)	0.89 (0.89, 0.89)#	0.97 (0.96, 0.97)#	1.23 (1.22, 1.23)#	
Model 3	1.00 (Reference)	1.36 (1.34, 1.38)#	1.55 (1.53, 1.57)#	2.22 (2.18, 2.25)#	<0.001
Adjusted <i>p</i> -value aSHR (95% CIs) in Model 3	Reference 1.00	<0.001 1.37 (1.35, 1.38)#	<0.001 1.57 (1.55, 1.59)#	<0.001 2.24 (2.20, 2.28)#	
<b>Pertussis</b>					
Events, N (%)	7,296 (0.09)	3,007 (0.04)	1,759 (0.01)	428 (0.01)	
PY [Year]	10,542,860.5	10,053,110.8	22,167,825.7	9,648,262.7	
Crude HR (95% CIs)	1.00 (Reference)	0.43 (0.41, 0.45)#	0.12 (0.11, 0.12)#	0.06 (0.06, 0.07)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	0.91 (0.87, 0.95)#	0.42 (0.40, 0.45)#	0.84 (0.75, 0.94)#	
Model 2	1.00 (Reference)	0.81 (0.77, 0.85)#	0.40 (0.37, 0.42)#	0.85 (0.76, 0.95)#	
Model 3	1.00 (Reference)	0.12 (0.10, 0.16)#	0.05 (0.04, 0.06)#	0.06 (0.04, 0.08)#	<0.001
Adjusted <i>p</i> -value aSHR (95% CIs) in Model 3	Reference 1.00	<0.001 0.12 (0.11, 0.15)#	<0.001 0.05 (0.04, 0.06)#	<0.001 0.06 (0.04, 0.08)#	
<b>Tuberculosis</b>					
Events, N (%)	4,368 (0.06)	3,067 (0.04)	9,736 (0.06)	11,100 (0.15)	
PY [Year]	10,541,496.4	10,051,637.6	22,161,372.4	9,640,946.1	
Crude HR (95% CIs)	1.00 (Reference)	0.74 (0.70, 0.77)#	1.06 (1.02, 1.10)**	2.78 (2.68, 2.88)#	
aHR (95% CIs)					
Model 1	1.00 (Reference)	1.07 (1.02, 1.13)**	1.00 (0.96, 1.03)	1.01 (0.97, 1.05)	
Model 2	1.00 (Reference)	1.08 (1.03, 1.13)**	1.00 (0.96, 1.03)	1.01 (0.97, 1.05)	
Model 3	1.00 (Reference)	1.12 (0.97, 1.29)	1.04 (0.89, 1.21)	1.06 (0.88, 1.28)	0.049
Adjusted <i>p</i> -value aSHR (95% CIs) in Model 3	Reference 1.00	0.190 1.16 (1.01, 1.33)*	0.668 1.09 (0.93, 1.27)	0.650 1.14 (0.94, 1.37)	

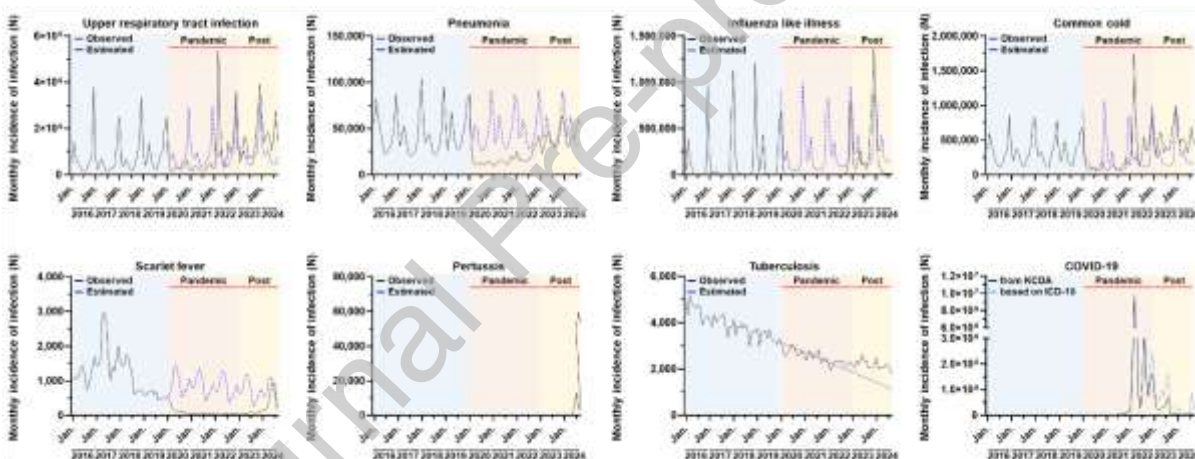
453 HRs (95% CIs) and *p*-value were calculated, using the Cox proportional hazards model, with the following

454 adjustments:

455 Model 1: age, sex, income level, and Charlson comorbidity index  
 456 Model 2: Model 1 + COVID-19  
 457 Model 3: Model 2 + severity, phase of infection, interval between last inoculation and May 31, 2023.  
 458 SHRs (95% CIs) and *p*-value were calculated, using the Fine-Gray sub-distribution hazards model (mortality as  
 459 competing event), with the adjustments (Model 3).  
 460 Abbreviation: number (N); Person year (PY); hazard ratio (HR); adjusted hazard ratio (aHR); confidence intervals  
 461 (CIs); adjusted sub-distribution hazard ratio (aSHR).  
 462 Unadjusted *p*-value: \* < 0.05; \*\* < 0.01; # < 0.001 / Adjusted *p*-value, using Benjamini-Hochberg method.

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465 **Figure langed**

466

467 **Figure 1. Monthly incidence of respiratory infectious diseases in Korea.** From January  
 468 2016 to September 2024, monthly incidence of respiratory infectious diseases (ICD-10 codes):  
 469 upper respiratory tract infection (URI, J00–J06), pneumonia (J10–J18), influenza like illness  
 470 (J09–J11), acute nasopharyngitis (common cold, J00), scarlet fever (A38), pertussis (A37),  
 471 tuberculosis (A15–A19, B90, U84.3, and U88), and COVID-19 (U07.1 and U07.2). While the  
 472 black solid line is the observed incidence, the blue dashed line indicates an estimated incidence  
 473 using autoregressive integrated moving average exogenous (ARIMAX) or seasonal

474 autoregressive integrated moving average exogenous (SRIMAX) models with a trend of 2017–  
475 2019 and inputs of age, sex, income levels, and Charlson comorbidity index.

476

477

478 **Disclosures**

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483 *Generative AI and AI-assisted technologies:* Generative AI (ChatGPT) was used exclusively to  
484 clarify sentences and to check grammar. All research processes, including data analysis,  
485 presentation of results (tables, figures, and supplementary materials), and manuscript writing,  
486 were entirely conducted by the authors and authored under the full responsibility of the authors.

487 **Ethical Approval and Guidelines.**

488 The Institutional Review Board of Seoul National University Hospital approved this study  
489 (Notice of Ethics Review and Results (Exemption): **E-2405-013-1534**), which complies with the  
490 principles of the Declaration of Helsinki: the encrypted information and no informed consent.  
491 Individuals cannot be identified through de-identified data of authorized institutions, raw data can  
492 only be accessed at security centers, and finally, processed results (tables and graphs) can only be  
493 taken out with approval.

494 This retrospective cohort and observation study followed the Strengthening the Reporting of  
495 Observational Studies in Epidemiology (STROBE) guidelines and checklist.

496 **Data Sharing Statement**

497 The original and processed data in this cohort study are only accessible to qualified researchers in  
498 permitted security facilities for a certain period since the used database was

499 based on records of national insurance. Thus, the raw data cannot be shared openly. However,  
500 access to the code used in this study can be shared for noncommercial and academic purposes.

501 **Author Contributions**

502 J. Song and SM. Park had full access to all of the data.

503 *Study concept and design:* J. Song, A. Y. Chun, and SM. Park

504 *Analysis of data:* J. Song

505 *Validation:* J. Jung, S. Jeong, and SJ. Park

506 *Interpretation of data:* All authors.

507 *Writing the manuscript:* All authors.

508 *Revision of the manuscript:* All authors.

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