



# COVID-19 Vaccination, Morbidity, and Mortality During a 12-Month Period in Israel: Can We Maintain a “Herd Immunity” State?

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## Abstract

Despite widespread vaccination, the COVID-19 pandemic continues to cause global disruption. Authors describe the pace of COVID-19 vaccination in Israel and examine differences in morbidity and mortality rates over time between vaccinated and unvaccinated populations. Retrospective data were obtained between December 2020 and December 2021 on daily vaccine uptake by age group (20–39, 40–59, 60+ years): rate of hospitalized severely ill cases, vaccination status and age group, and death rate per 100,000 by date and vaccination status. Uptake of first and second doses was slower in 20–59-year olds, whereas in 60+-year olds, it occurred without delay. Once most adults were vaccinated, a gap appeared with much higher severe cases and deaths in unvaccinated versus vaccinated populations; this gap attenuated by late May with very low rates in both vaccinated and unvaccinated populations until mid-July, when rates began to rise again. A herd-immunity-like period occurred in Spring 2021, with unvaccinated benefitting from a highly vaccinated population. Staggered vaccine uptake led to unsynchronized high immunity, which contributed to the fourth pandemic wave. Population vaccination within a shorter timeframe or shorter intervals between boosters may be important to reduce viral transmission.

**Keywords:** COVID-19, herd immunity, vaccination

## Introduction

THE COVID-19 OUTBREAK HAS disrupted almost every domain of life, and almost every country across the globe. As of February 20, 2021, >400 million cases have been confirmed worldwide and >5.8 million have died.<sup>1</sup> Despite a wide range of measures such as social distancing, mask wearing, mass testing, contact tracing, and mobility restrictions implemented to varying degrees of stringency by almost every country in the world, the pandemic continues to spread. Alongside multipronged countermeasures, the emergence of

effective vaccines in December 2020 and the global rollout of COVID-19 vaccines and the associated campaigns were integrated in the fight against the pandemic, offering new hope for suppressing the virus transmission.<sup>2–6</sup> Although these measures have shown effectivity in reducing morbidity and mortality rates from COVID-19, long-lasting flattening of the epidemic curve has not yet been achieved.<sup>7,8</sup> The reluctance of large sectors of the public to receive recommended available vaccines may be propagated by a spectrum of held views regarding vaccination spanning from vigilant acceptors to complete deniers.

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Israel, a country of 9.3 million, navigated the pandemic by implementing 3 national lockdowns between March 2020 and January 2021 and rolled out a national vaccination campaign for 2 initial doses of the Pfizer BNT162b2 mRNA vaccine, as well as for a third “booster” dose. During the national lockdowns, by government order, nonessential businesses were shut down and schools switched to distance teaching; many nonessential workers moved to work from home; citizens were advised to stay home and were limited to traveling a certain distance from their homes, with fines imposed on those who broke lockdown rules; and the government issued an assurance that those who were on leave of absence would be financially compensated by the government for a temporary period of time.<sup>9</sup>

During the third lockdown, the first national vaccination drive began on December 20, 2020, where in the first weeks, health care workers, individuals aged 60+ years, and those considered to be at medical risk were invited to vaccinate, whereas younger people were gradually added to the target populations.<sup>6</sup> By March 1, 2021, 51% of the total population and 91% of those aged 60+ years had received their first COVID-19 vaccine dose.<sup>10</sup> Despite initial success and momentum in the vaccination drive, full inoculation of the public was hampered by vaccine hesitancy among the Israeli general population.<sup>10</sup>

To incentivize vaccination in Israel, a “green pass” certificate that would provide access to social, cultural, sports events, gyms, hotels, and restaurants was implemented.<sup>11</sup> The certificate also provides exemptions from isolation upon contact with a confirmed COVID-19 case or upon returning from international travel for those who were deemed to have achieved “immunity,” whether based on recovery from COVID-19 or by being fully vaccinated. In May 2021, Israel seemed to experience an almost disease-free reality, where it was perceived that the desired herd immunity status had been reached.

Herd immunity refers to the indirect protection conferred to vulnerable individuals when a sufficiently large proportion of the population is immune.<sup>12</sup> This resulted in the withdrawal of green pass incentives, quickly followed by a resurgence in morbidity and mortality, resulting in a fourth wave in late June, dominated by the Delta (B.1.617.2) variant of SARS-CoV-2.

Despite findings indicating the effectiveness of the vaccine through the marked declines in incidence of SARS-CoV-2 infections, hospitalizations, and deaths, the management of the pandemic has been aggravated by the findings of the evolution and emergence of novel, highly infectious variants, such as the Delta and Omicron variants, alongside the obstacle of different durations of effective immunity or “time-limited immunity” to the vaccine.<sup>13–15</sup> These data were a contributing factor to the update in governmental regulation requiring a third “booster” dose for continuing eligibility for the “green pass,” which now expires 6 months after the third dose.

The booster campaign was offered to immunocompromised patients beginning on July 13, 2021, and was gradually expanded to include people aged >60 years (on July 30), 50 years (on August 12), 40 years (on August 19), 30 years (on August 24), and finally the entire population over the age of 12 years on August 30. As was previously observed, the initial administration of the booster proceeded rapidly. However, 3 months later only 44.8% of the total population had received the vaccine.

A fourth dose of the vaccine was offered to those >60 years and at-risk populations from January 2022, to prolong immunity.<sup>16</sup>

In this study, we aim to describe the pace of uptake of COVID-19 vaccination patterns by age group in the first year of an available COVID-19 vaccine in Israel and examine the differences in morbidity and mortality over time between vaccinated and unvaccinated populations.

## Methods

A retrospective study of COVID-19 vaccinations was taken by Israeli citizens during the period December 20, 2020 (start of the national vaccination drive) to December 7, 2021. Data are reported to the ministry of health (MOH) as encoded and unidentified individual-level data.

### Research ethics approval

Ethical approval was not required since all data used in this study were obtained from the publicly available open COVID database website, <https://datadashboard.health.gov.il/COVID-19/general>. No individual data were included in the study.

### Vaccine uptake

Details on the daily number of vaccine doses administered in Israel were obtained from Israel COVID-19 Data Tracker,<sup>17</sup> a database of the MOH. This data source contains updated reports of all vaccine doses administered by diverse providers, mainly the 4 Israeli Health Maintenance Organizations and the Israeli First Aid Organization (equivalent of the Red Cross).

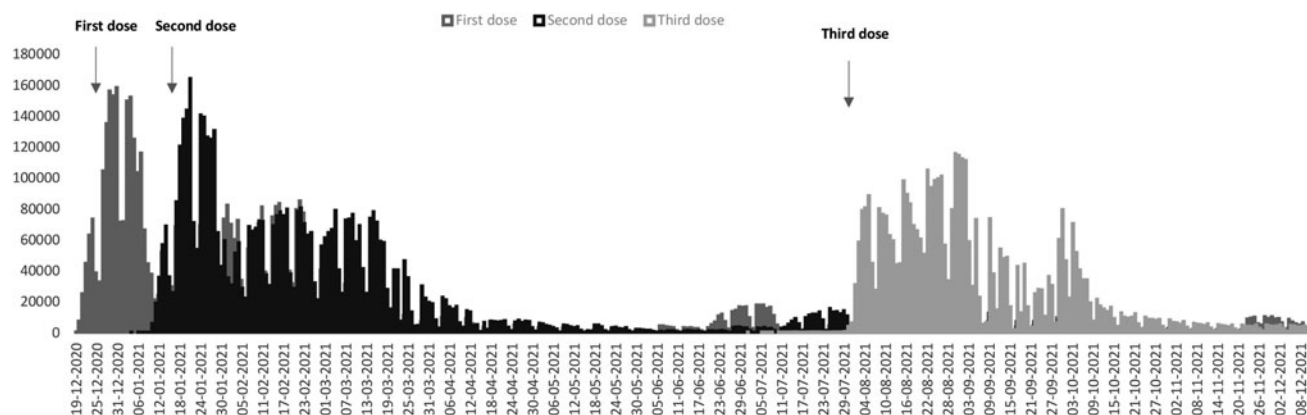
Data were analyzed by date, vaccine dose (first, second, and third “booster” dose), and age group (20–39, 40–59, 60+ years) and were aggregate, population level data. Vaccine uptake is presented overall as raw numbers (counts) of vaccines given by date, and as a rate per 10,000 by age group to allow for comparison between population groups of different size. Dates of the start of the vaccination campaign and when the vaccine was offered to the Israeli population, by age group and vaccine dose, were retrieved from MOH documents.

### Hospitalization

Israel has a national database consisting of daily mandatory reports from all acute care hospitals (n=29). Severity of hospitalized patients, based on the last report of individual patients’ status, was categorized into mild, moderate, severe, and critical. We present data on rate of severe hospitalization cases by date, vaccination status, and age group (>60 years vs. <60 years) as well as rate of deaths per 100,000 population by date and vaccination status from the MOH.

## Results

During the study period, 6,384,685 population (68.7% of the overall Israeli population of 9.293 million) were inoculated with the first vaccine dose, 5,785,098 population (62.2%) had received the second dose, and 4,198,460 population (44.2%) had received the third dose. Figure 1 shows the pace of vaccination among the total population, presenting number of vaccine doses by date. The most prominent peaks



**FIG. 1.** Overall daily number of vaccines taken by the Israeli population by date and vaccine dose, December 19, 2020 to December 8, 2021.

of vaccination, with up to 15,000 doses administered per day, occurred in the first 6 weeks of the vaccination drive. The first 2 peaks represent the first and second vaccine doses, taken 3 weeks apart.

These peaks were followed by a less prominent but still high daily rate (up to 8000 daily doses) lasting for another 6 weeks (early February to mid-March). From mid-March to late July 2021, the pace of vaccination, with both the first and second doses, was very slow. In early August, with the introduction of the booster dose (starting with those >60 years on the July 30), vaccination increased to levels of up to 12,000 daily doses of the third vaccine. The pace of vaccine uptake diminished with a relatively small new increase of first doses being dispensed from the last week of November 2021, with the approval of the vaccine for children aged 5–11 years and national efforts to increase uptake among children.

Analysis of vaccination pace and volume by age group shows different patterns for those younger than 60 years versus those 60 years and over.

Among 20–59-year olds, initial rate of uptake of the first and second doses was slower, that is, vaccination took place over a longer period of several months, whereas in 60+ year adults, uptake was quick for the first and second doses without delay with 2 defined spikes after the opening of vaccination drive (Fig. 2a, b). With decreasing age, the tail of vaccination grows longer, that is, spreads over a longer period of time. The same pattern was seen with uptake of the booster. The height of the peaks (number of daily vaccine doses taken) was highest among the 60+ year-old, lower in those 40–59-year-old, and lowest among 20–39-year-old population.

After the start of the vaccination campaign in December 2020 and once the majority of adults were vaccinated with 2 doses by mid-February 2021, a clear gap appears in the rate of severely hospitalized cases between vaccinated and nonvaccinated or those partially vaccinated. This gap disappeared in May–early July 2021 and reappeared in August 2021 (Fig. 3). Patterns were similar for both <60 years and >60 years; however, the amplitude of the gap was larger among the older population (Fig. 3a, b).

A similar pattern was seen with the rate of deaths by vaccination status, with a higher rate of deaths in the unvaccinated (Fig. 4). The gap appeared 2 months after the beginning of the vaccination drive. This gap attenuated by late May with very low rates in both vaccinated and un-

vaccinated populations until mid-July, when death rates began to rise, with the highest rates in August to the first third of September among those partially vaccinated, that is, those with 1 or 2 doses given >6 months previously, but who had not yet received the booster, compared with much lower rates in fully vaccinated (after 3 doses). By November 2021, the gap between groups had once again attenuated.

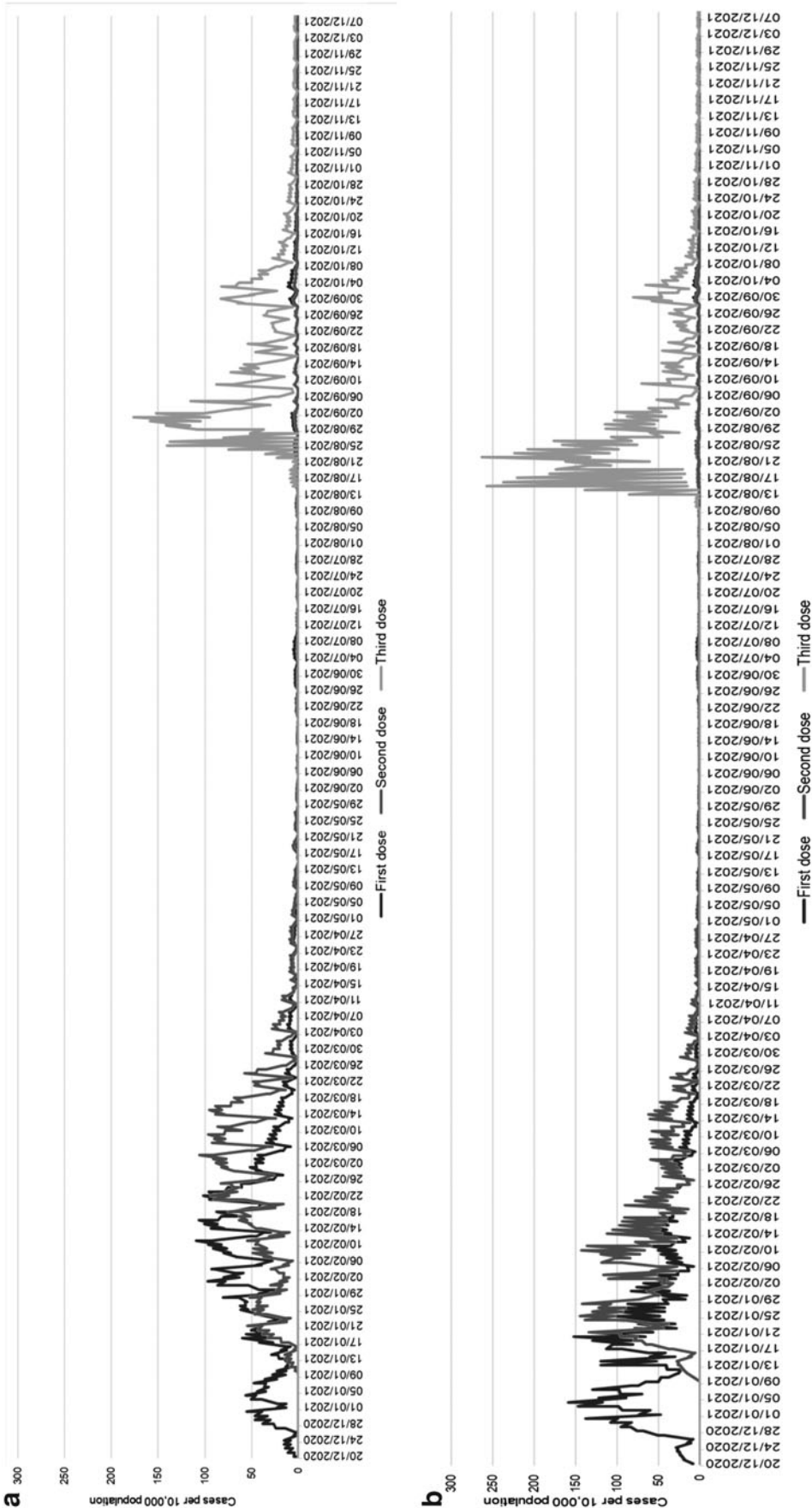
## Discussion

This study portrayed COVID-19 vaccine uptake, severe morbidity, and mortality throughout the first 12 months since the beginning of a national vaccination drive in Israel, which was among the first nations to offer the vaccine to its population as well as a third “booster” dose.<sup>18</sup>

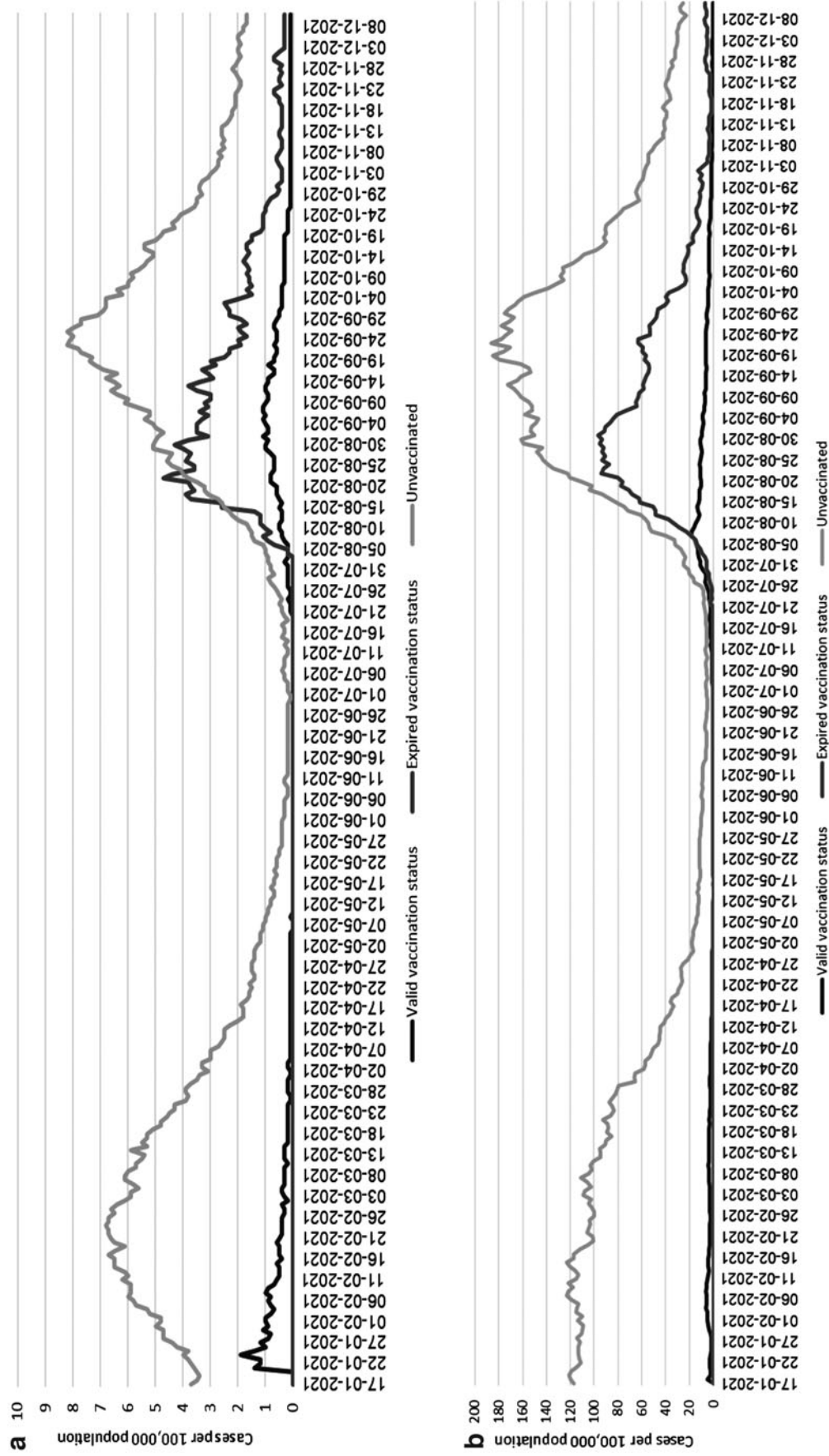
During the period between May and June 2021, a situation was observed suggesting “herd immunity” in Israel, where the morbidity and mortality rates saw a significant drop to almost 0 in both vaccinated and unvaccinated populations. Seemingly, the unvaccinated benefited from low viral circulation due to a high overall rate of protection from the vaccinated population. Nevertheless, this lull did not last, and a new wave of confirmed infections began in August 2021, triggered by the combination of the Delta COVID-19 variant of concern and waning immunity of the conferred vaccines over time.<sup>19</sup>

This fourth wave galvanized the MOH’s decision to offer a third (booster) shot for those who were at least 5 months beyond receiving the second vaccine dose. Subsequently, disease activity began to dwindle again. A similar pattern was seen in other countries, for example, according to U.K. data, the initial gaps in deaths between vaccinated and unvaccinated in January–March 2021 dwindled in May–June 2021 and began to rise again in July 2021, but this pattern was not seen in all countries, that is, in the United States where the death rate has been consistently higher among the unvaccinated population.<sup>20,21</sup>

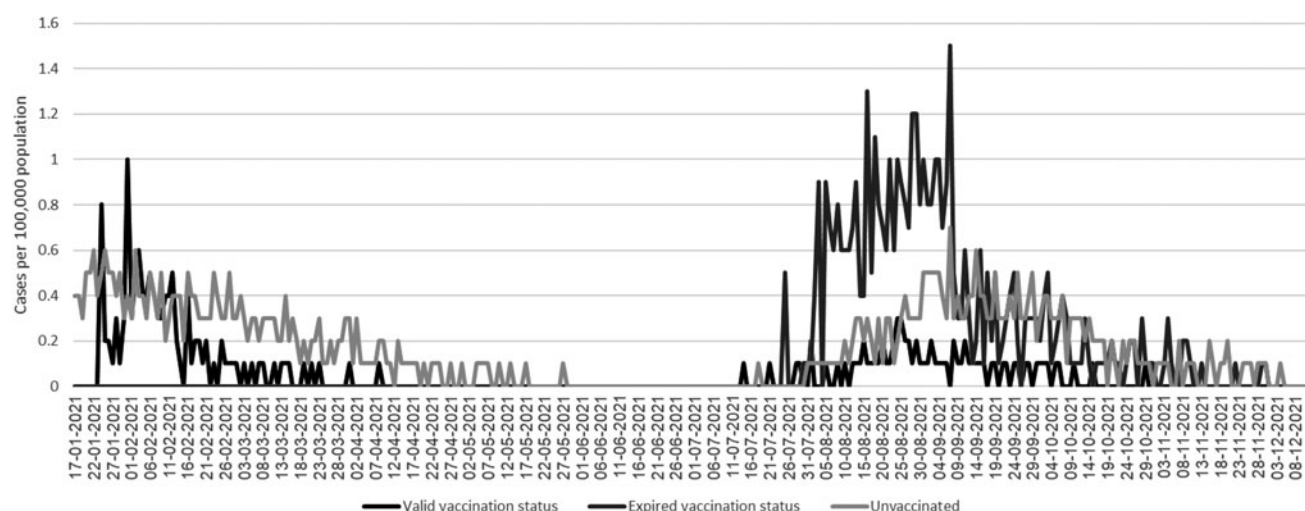
This difference could be attributed to the low population vaccination rate in the United States (where by February 2022, 65.9% of the population were vaccinated with 2 doses and 29.3% had received the third booster) as compared with the United Kingdom (where 72.9% had received 2 doses and 56.9% of the population had received the third booster). Israel’s vaccination rates at the end of February were similar to those of the United Kingdom, with 66.5% vaccinated with 2 doses and 56.6% having received the third booster.



**FIG. 2.** Rate of vaccine uptake by the Israeli adult population by date, vaccine dose, and age group, from December 20, 2020 to December 7, 2021. (a) 20–39-year-old population, (b) 40–59-year-old population.



**FIG. 3.** Cumulative rate of hospitalized severely ill cases by date, vaccination status, and age group, from January 17, 2021 to December 8, 2021. \*Valid vaccination: received the booster, or <6 months passed since the second vaccine dose; expired vaccine status: received 1 or 2 vaccine doses, >6 month elapsed since the last vaccine dose; unvaccinated: did not take any COVID-19 vaccine dose. **(a)** Under the age of 60 years old, **(b)** 60 years old and over.



**FIG. 4.** Rate of deaths per 100,000 population by date and vaccination status, from January 17, 2021 to December 8, 2021.

Although achieving herd immunity is one possible explanation for the disappearing gap between the vaccinated and unvaccinated in May–June 2021, additional explanations may exist, such as changes regarding policies of mask wearing and social distancing, alongside the emergence of new variants with differing levels of disease severity and infectiousness.

Furthermore, confirming previous findings, vaccine uptake was faster in the >60-year olds, since they are at greater risk from COVID-19: In the first weeks of the pandemic, 94% of the mortality in 7 countries, including the United States, China, and Italy, was documented in >60-year olds.<sup>22</sup> In Israel to date, 91% of COVID-19 deaths occurred in those aged 60+ years.<sup>13</sup> Therefore, this group was the first to be invited to vaccinate, together with health care workers. Uptake was lower and slower in younger adults (20–59-year olds), taking place over a longer period of time for all 3 vaccine doses. This gap is only partially explained by the few weeks' lag between the time the vaccine was offered to the younger, compared with that of the older population groups.

Differing rates of uptake between age groups meant that there was noncongruous high coverage of immunity of all groups, which may have contributed to the fourth and fifth waves of new infections that previously were declining. Indeed, as of mid-December 2021, the arrival of the Omicron strain caused the Israeli MOH to debate a fourth vaccine dose, which was recommended in older and at-risk groups. Once again in December 2021, the mortality gap between vaccinated and unvaccinated populations was attenuated, only to reappear in late January to early February 2022.

To prevent disease resurgence and maintain herd immunity, conditions need to be created that will encourage the vast majority of the eligible population to be vaccinated within a relatively short span of time, to achieve high levels of simultaneous high immunity. Although logistically these efforts may present a challenge to authorities, this may be a key element to flattening the curve. This would require the opening vaccination drives earlier for younger populations and targeting efforts to ensure early and large-scale uptake.

The individual's decision to take the newly developed m-RNA vaccine can be perceived as an attitude more open to the acceptance of innovation. Diffusion of innovation theory refers to the process that occurs as people adopt a new idea, product, or philosophy. In most cases, a few people (“early adopters”) are initially open to and embrace a novel idea, spreading the word to more people until the creation of a critical mass.<sup>23</sup> Using this theory to promote vaccine uptake, segments of the population that adopt early will need to influence later adopters.

Efforts to promote such a sequence need to be creative and multifaceted, for example, by providing rewards or incentives for vaccine completion by framing vaccination as “a desirable opportunity not to be missed.”<sup>24</sup> Vaccine hesitancy has been defined as a “delay in acceptance or refusal of vaccines despite availability of vaccinations services.”<sup>25</sup> Even before the emergence of the COVID-19 pandemic, the WHO defined it as one of the top 10 global health threats.<sup>26</sup>

A systematic literature review defined the following reasons for vaccine hesitancy: concerns about vaccine safety, perception of low risk of contracting vaccine-preventable diseases and low severity of disease if contracted, perception that the vaccine is not effective, and overall lack of information.<sup>27</sup> It has been widely defined in the literature that vaccine hesitancy exists in more intense pockets among those of younger age groups, with lower educational attainment, and ethnic minorities.<sup>28–30</sup>

Creating a positive public discourse that praises early adopters and strengthens attitudes on all media platforms, particularly social media, is one method of fostering vaccination uptake among younger populations. Indeed, communicating messages about the essential role of all members of the public to ensure a state of herd immunity may be effective in improving vaccine intentions. Social solidarity may be raised among this population by reflecting their responsibility to create a safer environment for those at risk, that is, their parents and grandparents. Arguments related to the burden imposed on society at large, including the high health-related costs of disease complications and the economic burden caused by repeated lockdowns could further motivate vaccine uptake.

How should we confront arguments related to the individual's right to autonomy over one's body? This principle is protected by constitutional law of human dignity and liberty.<sup>31,32</sup> This includes the right to choose whether to vaccinate without intimidation or manipulation. Israel has implemented external motivators such as the "green pass" incentive scheme.<sup>11</sup> However, research has shown that the use of rewards and penalties may displace other motivations for desirable behavior, such as altruism or civic duty. Policymakers may consider whether reinforcing mutual social responsibility may raise intrinsic motivation to vaccinate, alongside external incentives.<sup>33</sup>

In the near future, given the presented data, it may be decided that boosters ought to be given after a shorter period of time to prolong immunity and prevent subsequent waves. Past diseases were eradicated with vaccines that needed just 1 or 2 doses (eg, smallpox) and did not require continual updating, however, many childhood vaccines do require several doses. Uncertainty remains regarding COVID-19 and the vaccines' ability to eradicate it, especially if future variants become progressively more resistant to the vaccine developed against the original virus. These uncertainties might reduce willingness to accept repeated boosters. Indeed, "pandemic fatigue" has been cited in influencing behavior related to the pandemic, for example, reducing adherence to mask wearing and social distancing but could also apply to repeated calls to vaccinate.<sup>34,35</sup>

To ensure continued adherence and uptake to vaccine boosters, people must have faith in the institutions through transparency of data, particularly regarding vaccine safety, to hearten more of the public to become early adopters. In the context of Israel, 2 minority groups—the Arab ethnic minority and ultraorthodox Jews—have documented lower trust in governmental institutions and may delay or avoid repeated vaccination. These populations, similar to younger groups, require targeted outreach and culturally appropriate risk communication on the subject.<sup>36</sup>

In conclusion, a 12-month experience with COVID-19 vaccines at the national level allows us to analyze different patterns of vaccine uptake by younger and older populations; analysis points to the importance of synchronization of vaccine drives between different population groups while decreasing the intervals between doses to maintain a "herd immunity" state. Understanding the mechanism of breakthrough infections might help timing of the booster shots, which may be required on a more frequent basis. Lastly, risk communication must be tailored to the unique populations with slower vaccine uptake.<sup>37</sup>

### Authors' Contributions

Dr. Saban and Mr. Kaim conceptualized and designed the study, provided insights on data interpretation, performed analyses, contributed to writing the first draft, and revised the article and prepared some of the figures. Dr. Myers contributed to writing the first draft and revised the article. Dr. Wilf-Miron conceptualized the study and reviewed and revised the article for important intellectual content. All authors approved the final article and agreed to be accountable for all aspects of the study.

### Author Disclosure Statement

No competing financial interests exist.

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