Sociodemographic disparities in COVID-19 burden: changing patterns over four pandemic waves in Israel

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ABSTRACT

Background Worldwide, the COVID-19 pandemic hit weakest populations hardest, with socioeconomic (SE), racial and ethnic disparities in COVID-19 burden. The study aimed to analyse patterns of SE and ethnic disparities in morbidity, hospitalisation, and vaccination throughout four pandemic waves.

Methods A retrospective-archive study was conducted in Israel from 11 March 2020 to 1 December 2021, with data on confirmed cases, hospitalisations, mortality and vaccinations (three doses), obtained from the Israeli Ministry of Health's open COVID-19 database, covering 98.8% of the population, by SE and ethnic characteristics of localities.

Findings At the outbreak of the pandemic, there was a higher caseload in Jewish, compared with Arab localities. In the second and third waves, low SE and Arab minority populations suffered 2–3 times higher morbidity, with a similar but attenuated pattern in the fourth wave. A similar trend was observed in hospitalisation of confirmed patients. COVID-19-associated mortality did not demonstrate a clear SE gradient.

A strong social gradient in vaccine uptake was demonstrated throughout the period, with 71% and 74% double vaccinated in the two highest SE clusters, and 43% and 27% in the two lowest clusters by December 2021. Uptake of the third dose was 57%–60% in the highest SE clusters and 31%–25% in the lowest clusters. SE disparities in vaccine uptake were larger among the younger age groups and gradually increased from first to third doses.

Conclusions Israel was among the first to lead a rapid vaccination drive, as well as to experience a fourth wave fuelled by diminishing immunity and the delta variant. SE and ethnic disparities were evident throughout most of the pandemic months, though less so for mortality. Despite higher COVID-19 burden, vaccine uptake was lower in disadvantaged groups, with greater disparities in the younger population which widened with subsequent doses.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Socioeconomic and ethnic disparities in COVID-19 burden and vaccination were documented in many countries.
⇒ Israel was among the first countries to experience a fourth pandemic wave, and introduce a third (booster) vaccine dose.

WHAT THIS STUDY ADDS

⇒ Early on in the COVID-19 pandemic, disease burden was higher among the more affluent populations in Israel.
⇒ This pattern subsequently reversed, revealing a socioeconomic gradient in COVID-19 burden, with less wealthy and minority populations experiencing greater caseload and hospitalisation.
⇒ Despite higher COVID-19 burden, vaccine uptake was lower in disadvantaged groups, with greater disparities in the younger population which widened with subsequent doses.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ Efforts are required to promote and improve access to vaccination in disadvantaged and minority groups.

INTRODUCTION

The COVID-19 pandemic, now prevailing for almost 2 years and causing over 5.4 million deaths by the end of 2021, has hit the weakest segments of the population hardest.[1] Living conditions, working circumstances, underlying chronic medical conditions, stigma and systemic inequalities have been suggested as explanatory factors for socioeconomic (SE) and racial and ethnic disparities in COVID-19 burden.[2]

In the USA, racial and ethnic disparities in COVID-19 infection, hospitalisation and death were evident in all regions. These disparities were maximal during May–July 2020 and decreased, but were still present, in December 2020, as the pandemic progressed.[3] In the UK, COVID-19 mortality demonstrated a clear social gradient, like other causes of mortality such as cardiovascular diseases or injuries.[4] In England and Wales, age-adjusted COVID-19 mortality was higher among ethnic minority groups. These differences were largely explained by location, living conditions, working exposure and health status.[5] In the UK, age-adjusted excess risk of COVID-19-related mortality was 4.2 times higher among black males and 4.3 higher among black females, compared with white males and females, respectively. After adjusting for age, deprivation and self-reported health and disability, the excess risk of death among the black population reduced but was still 1.9 times higher compared with the white population.[6]

The COVID-19 Marmot Review claimed that countries which began the pandemic with significant inequality fared badly, with higher mortality rates, and that the pandemic is 'exposing and magnifying inequalities'.[7]

Israel is a multiethnic, multicultural country with wide social disparities and a high poverty rate.[8] Poverty is disproportionally high in two subpopulations: Arabs and Ultra-Orthodox (Haredi) Jews, who comprise 21% and 12.5% of the total 9.21 million population, respectively.

Both populations are younger, with lower household income and more crowded living conditions, compared with the majority Jewish population. Both groups have lower trust in the government and have limited access to mainstream governmental information, posing significant public health challenges in times of a health crisis.

The Israeli Arab population demonstrates a higher prevalence of chronic diseases, including chronic lung disease among Arab men, and higher prevalence of diabetes and cardiovascular disease among both genders, compared with the Jewish population.[9]

In Israel, the first new COVID-19 case was confirmed at the end of February 2020. In the following 21 months, Israel has witnessed four waves or peaks of disease activity: The first wave, in March–April 2020, with up to 550 new confirmed daily cases (~6 per 100 000 population); the second wave in September–October 2020, with up 9000 new cases per day (~98 cases per 100k population); the third wave in December 2020 to February 2021 with 10 000 daily cases (~109 per 100k) and the fourth wave, from mid-June to mid-October 2021, reaching 10 100 cases per day (~110 cases per 100k).[10]

The Arab population experienced lower morbidity during the first wave[11] but as the pandemic progressed, showed excess infections, severe disease and deaths relative to their population size.[12] The introduction of the Pfizer COVID-19 vaccine in December 2020, and the rapid national vaccination drive, resulted in two-dose vaccination of 59% of the total population and more than 90% of those aged 60+ by March 2020,[13] allowing Israel to enjoy a few months of very low disease activity and withdrawal of most public health measures. This pause was reversed in June 2021, with the arrival of the more contagious Delta variant and probably the effect of waning immunity, since a large proportion of the adult population was vaccinated during January-February 2021. The high incidence of new confirmed cases led to the approval of a third dose of the vaccine (booster) on 30 July 2021, initially indicated in persons 60+ who had received a second dose at least 5 months earlier.

The aim of this study is to analyse patterns of SE and ethnic disparities in morbidity, hospitalisation, mortality and vaccination throughout the four pandemic waves at the national level.

METHODS

A retrospective-archive study was conducted in Israel from March 2020 to December 2021. Data were obtained from the Israeli Ministry of Health's (MOH) open COVID-19 database,[14] which includes information on 281 medium or large (1493 inhabitants or more) urban localities. COVID-19 information by SE and ethnic characteristics is not available at the individual level and therefore was analysed by place of residence as an acceptable, widely used, proxy. Analysis included all 281 localities, which include 9,183,559 residents, comprising 99% of the total 9.21 million population.[15]

The database contains national data on the number of COVID-19 diagnostic tests performed (excluding tests for recovered people) the number of confirmed cases (ie, those that tested positive by real-time quantitative reverse-transcriptase PCR assay), number of hospitalisations, number of deaths and rates of vaccination with two or three doses of the COVID-19 vaccine. Since Pfizer BNT162b2 COVID-19 vaccine was the only vaccine administered in Israel during the first year of the vaccination drive, fully vaccinated status was uniformly defined as 7 days following second vaccine dose, and after the third (booster) dose was introduced 7 days following dose 3. All figures were presented as rates per population.

We linked each locality in the MOH database to its SE cluster. SE clusters are homogenous units on a scale of 1 (lowest) to 10 (highest) that are determined by the Central Bureau of Statistics (CBS) according to population demography, education, employment and standard of living.[16] For comparison between the Jewish and Arab populations, localities with homogeneous ethnic composition (more than 90% of the population), were defined as 'Jewish' or 'Arab' localities. Cities with at least 10% Arab residents are defined as 'mixed cities'. Out of 8 939 993 citizens (97% of the total population) for whom residence is specified, 5 610 025 (62.7%) reside in Jewish localities, 1 398 547 (15.6%) in Arab localities and 1 931 421 (21.6%) in eight mixed localities. Jerusalem is the largest mixed city, with 38% of its 920 000 citizens of Arab ethnicity. In Tel-Aviv, on the other end of the scale, only 4.5% of 469 000 citizens are of Arab ethnicity.[17]

Data analysis

MOH data on confirmed cases and hospitalisations were analysed by SE cluster and ethnicity for each month of the pandemic, from March 2020 to December 2021. Mortality data were analysed only by SE cluster, since ethnic data on mortality was incomplete. Analysis of cumulative proportion of the population receiving vaccines during December 2020–December 2021 was performed by SE cluster only (due to incomplete data for analysis of ethnic trends) for the overall population and by age group (0–19, 20–64, 65+ years old).

Pearson correlation test examined the association between proportion of positive tests and SE cluster, and between each vaccine dose and SE cluster, by age.

We also conducted one-way analysis of variance test to examine the variance between hospitalisation rate and ethnicity.

RESULTS

Confirmed cases

During the study period, 26 203 053 diagnostic tests were performed and 1 184 087 confirmed cases were identified (overall 4.52% positive tests, reaching peaks of 16.5%, 11.3%, 8.8% and 5.6% in the first, second, third and fourth waves, respectively).

During the second and third pandemic waves, the highest rates of positive tests were among the lowest SE (1–4) clusters, with intermediate rates in clusters 5–7 and the lowest rates in the highest (8–10) clusters (figure 1A). In October 2020 (the peak of the second pandemic wave), the rate of positive tests was 18% and 16% for SE cluster 1 and 2, and 5% and 6% in clusters 9 and 10, respectively. In February 2021 (the peak of the third wave), rates were 19% and 15% in clusters 1 and 2 and 3%–5% in clusters 8–10. A similar picture was seen in the first and fourth waves, but with smaller SE differences.

Analysis of confirmed cases by ethnicity (figure 1B) revealed a reversing trend. In the first wave, rates were higher in Jewish, compared with Arab cities. During the second, third and fourth waves, rates were higher among Arab, compared with Jewish cities. Mixed cities demonstrated the highest rates in the first three waves, while Arab cities showed highest rates
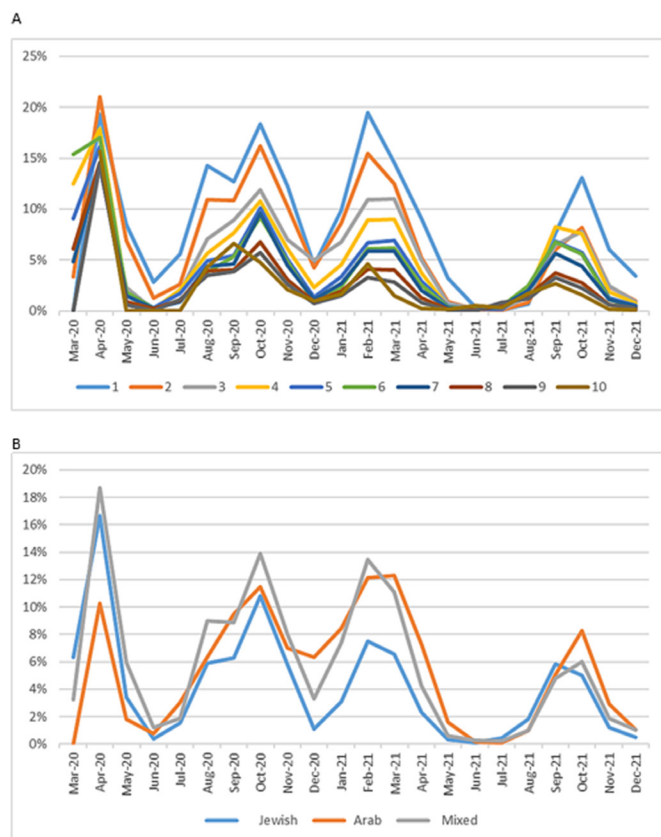
Figure 1 Monthly rate of tests that were found positive for COVID-19, by sociodemographic characteristics, March 2020 to December 2021. (A) Monthly rate of confirmed tests by SE cluster. (B) Monthly rate of confirmed tests by ethnicity (Jewish, Arab, mixed cities).

Figure 3 Rate of hospitalisations (new cases), by month and sociodemographic characteristics, March 2020 to December 2021. (A) Rate of hospitalisations by month and SE cluster. (B) Rate of hospitalisations by month and ethnicity (Jewish, Arab, mixed cities).

in the fourth wave. The largest gaps were observed in April 2020 with 10% and 17% positivity rate in Arab and Jewish cities, respectively, and in March 2021, with 12% and 7% positivity rate in Arab and Jewish cities, respectively.

Figure 2 shows the product of Pearson coefficient examining the correlation between the proportion of positive tests and SE cluster. A positive correlation between SE cluster and confirmed cases was observed in the first wave (March 2020) and then again at the beginning of the fourth wave (July–August 2021) indicating higher proportion of confirmed COVID-19 cases among the higher SE clusters. Throughout the second, third and latter half of the fourth waves, the correlation was negative, that is, higher burden of infections among the lowest
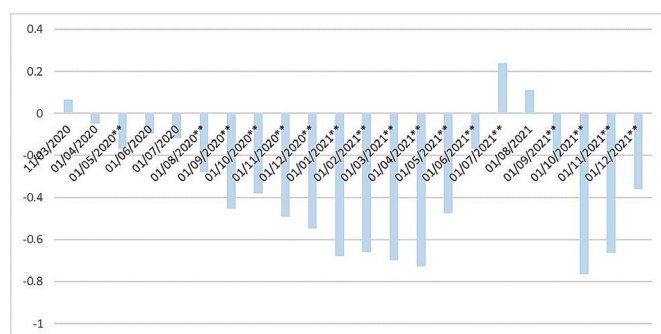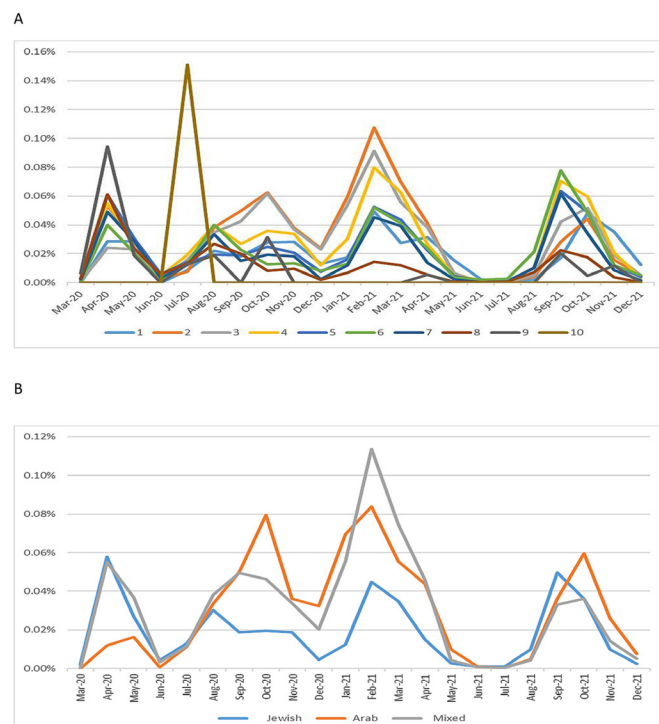
SE clusters. The inverse correlation between SE and positivity rate was highest towards the end of the fourth wave, during October 2021 ($r = -0.76$, $p < 0.01$).

Hospitalisations
During the second and third waves, the proportion of new hospitalisations was higher among SE clusters 2–3, while in the first wave clusters 8–9 demonstrated the highest rates (figure 3A). A peak of the highest cluster (10) was evident between the first and second pandemic waves. Highest proportions of new hospitalisations in the fourth wave were observed for intermediate SE clusters (4–7).

Higher hospitalisation rates were observed in Jewish cities, compared with Arab cities during the first wave, while an opposite trend was observed in the second and third waves (figure 3B). In the fourth wave, higher rates were observed in Arab cities, but with much smaller differences. Mixed cities demonstrated inconsistent trends. These differences were found to be statistically significant ($p < 0.001$).

Mortality
No such clear gradient was observed for COVID-19 associated mortality when analysed by SE cluster. A clear peak was observed for the highest SE cluster at the end of the third wave. In the second and fourth waves, highest mortality rates were observed for SE cluster 9. Note that 9 and 10 are the smallest SES clusters in terms of confirmed cases per cluster, 127 109 and 5295, respectively, so in absolute numbers this relates to a small number of deaths (figure 4).

Vaccination
The national vaccination drive started on 20 December 2020 with the second dose beginning 21 days later, and the third dose

Figure 2 Pearson correlation coefficient between positive rate among tested population and SE cluster, March 2020 to December 2021. **$p < 0.01$.
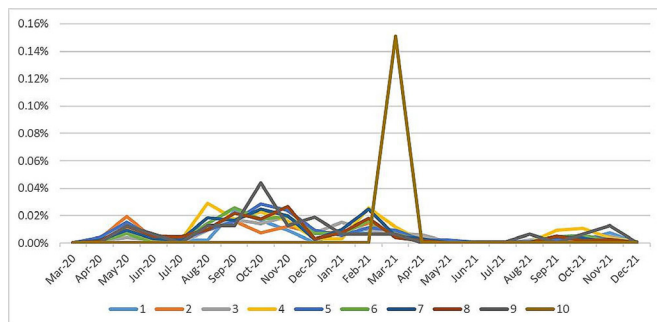
Figure 4 Monthly population rate of COVID-19-related deaths by SE cluster, March 2020 to December 2021.

administered from July 2021. Analysis of the proportion double vaccinated by SE cluster, demonstrates an increasing vaccination rate with higher SE cluster (a social gradient in health) with the exception of higher rate among the 9th, compared with the 10th clusters. The rates in the lowest first and second clusters (27% and 43% in December 2021, respectively) were considerably lower compared with 74% and 71% of the 9th and 10th clusters, respectively (figure 5).

A very similar gradient was observed in uptake of the third dose.

Figure 6 presents vaccine uptake by SE cluster and age group. SE disparities (higher to lowest ratios) were smallest in the first dose, of intermediate magnitude in the second dose and largest in the third dose. SE disparities were largest in the younger (0–19) age group and smallest in the older (65+) group. For example, dose-3 vaccine uptake was 14.7 times higher in the 10th, compared with the first SE cluster in the younger age group and 'only' 2.99 times higher in the older age group. For dose 1, the relative gaps were 5.44 and 1.58, respectively.
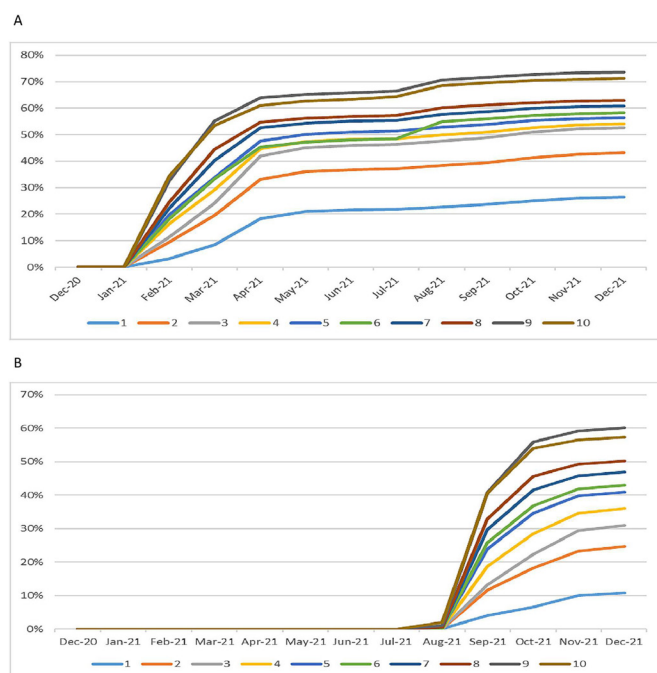

Figure 5 Cumulative monthly per cent of the total population receiving vaccine doses 2 and 3 by SE cluster, December 2020 to December 2021. (A) Vaccine dose 2, by month and SE cluster. (B) Vaccine dose 3, by month and and SE cluster.
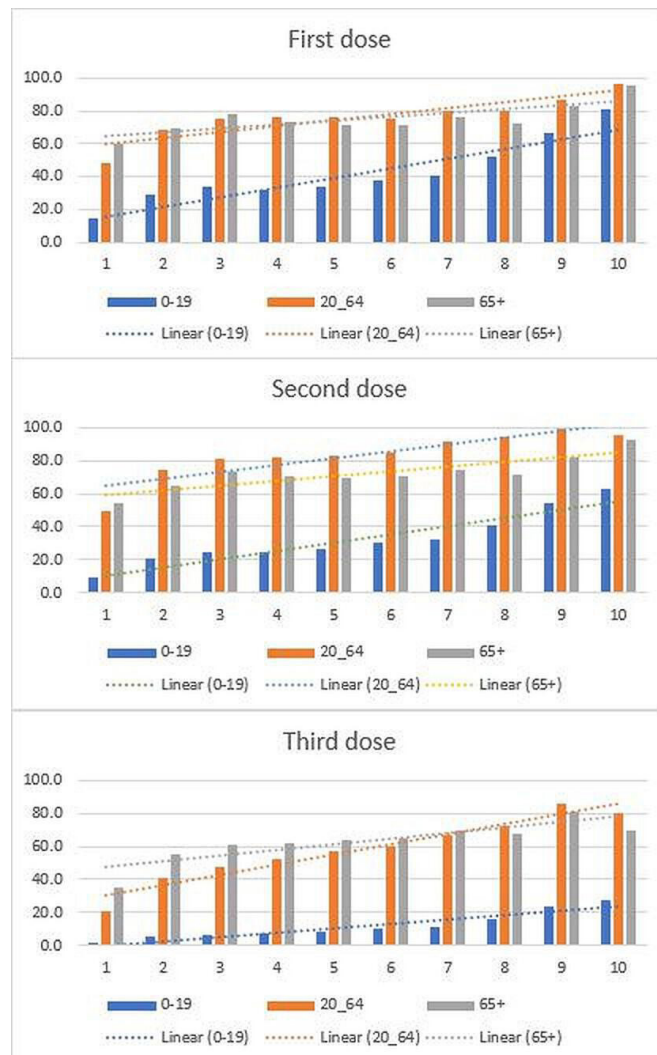

Figure 6 Cumulative per cent of the total population receiving vaccine (first, second and third dose) by age and SE cluster, December 2020 through December 2021.

For vaccine dose 1, the linear trend between vaccination and SE cluster is present for all age groups (age 0–19–R2=0.86; age 20–64–R2=0.79; age 65+ R2=0.60). Similar trends, with stronger correlation, were founds in vaccine dose 2 and 3 (vaccine 2 (age 0–19–R2=0.89; age 20–64–R2=0.79; age 65+R2=0.72); vaccine 3 (age 0–19–R2=0.87; age 20–64–R2=0.93; age 65+R2=0.71). SE differences were more marked for the younger age group.

DISCUSSION

Our study analysed national data on confirmed COVID-19 cases, hospitalisation, mortality and vaccine uptake by SE background and ethnicity in Israel. Vaccine uptake was also analysed by age. Analysis found distinct patterns, corresponding with the four waves of disease activity, during the first 21 months of the COVID-19 pandemic in Israel.

In the first month, higher incidence of COVID-19 cases was noted among more affluent populations. During the second and third waves, the chance of testing positive was 2–3 times higher among the lowest, compared with the highest SE clusters. Such a social gradient was not seen at the beginning of the fourth wave. A similar pattern was seen elsewhere. In the early stages of the

pandemic in the USA, counties of higher SE composition were hit harder. With time, social distancing took place and the SE effect reversed with faster growth and higher case-fatality rate in weaker counties.[18]

In Israel, higher incidence among the wealthiest in the first wave has been attributed to a higher proportion of travel among higher SE clusters,[19] with the disease 'imported' from abroad in its early stages. Later, the known combination of crowded living, working in manual jobs that do not allow remote work, greater use of public transportation and insufficient cultural adaptation of public health messages might explain the widening disparity. In Israel, institutional distrust has been shown to be more prevalent within the Arab and the ultra Orthodox Jewish populations,[11] contributing to lower compliance with public health measures such as social distancing and face mask wearing.[20]

The reversal seen during the beginning of the fourth wave (July–August 2021), which hit the wealthier population far harder, reflecting the pattern at the beginning of the pandemic, deserves attention. In late June–July, 2021, the ultra Orthodox Jewish localities demonstrated relatively low rates of infection, unlike previous months. Community leaders explain this phenomenon by a combination of high per cent of people infected and recovered, especially children and adolescents; higher accountability of communities and members to comply with the public health measures and lower proportion of people who travel abroad or even within the country.[20] Indeed, ultra Orthodox Jews reported high levels of sense of coherence and other markers of resilience in a study carried out during the second pandemic wave in Israel.[21] The stronger, more affluent older population was vaccinated early on and likely demonstrated waning immunity by July–August (6 months following vaccination of the majority of the adult population).[11] Waning immunity was demonstrated in a longitudinal prospective study involving vaccinated healthcare workers in Israel, demonstrating a substantial decrease in humoral response, 6 months after receipt of the second dose of the BNT162b2 vaccine.[22] Given the combination of immunological and epidemiologic evidence regarding the vaccine's decreasing effectiveness over time, many countries including the UK, USA and Israel decided on a third (booster) vaccine.[23]

Furthermore, the more affluent population travelled abroad in the spring and summer months, increasing exposure to the Delta variant and distributing it among the stronger communities.[24] A trend similar to the SE gradient in confirmed cases was evident among ethnic groups, with people living in Arab localities demonstrating higher positive rates in the latter waves while people living in Jewish localities demonstrated higher confirmed rates in the first wave and the beginning of the fourth wave. Higher burden of confirmed cases among Jews in Israel was also reported by Birenabum-Carmeli and her colleagues during the first wave.[25] Despite higher burden of comorbidities, the Arab population maintained lower numbers of infections and deaths, compared with the Jewish population, during the first wave, a finding that has been attributed to the positive role of the Arab leadership, among other factors.[11]

Reversal of confirmed rates and mortality trends among the Arab population during the second and third waves has been described by Saban et al.[26] Furthermore, while excess mortality in Israel was reported in 2020 compared with previous years, this was reported to be higher among the Arab compared with the Jewish population.[27] Unfortunately, incomplete ethnic data on mortality did not allow analysis of COVID-19-related deaths by ethnicity. Residents of mixed cities demonstrated high rates of cases in the first, second and third waves and lower (similar to

that of the Arab cities) rates in the fourth wave. 490 000 Arabs, comprising a quarter of the total Arab population, live in mixed cities, the majority (74%) in Jerusalem,[28] a city characterised by low SE composition (SE cluster of 3 out of 10). Higher disease burden in mixed cities cannot be explained by SE characteristics, which are similar to those of the solely Arab cities. However, most mixed cities are characterised by separate neighbourhoods, educational systems and cultural life as well as sense of inequitable allocation of municipal resources, among the Arab citizens, all of which might explain lower community resilience and less compliance with governmental and local authority measures.[29]

Of note, the marked SE differences in rates of confirmed cases and hospitalisation were not reflected in mortality rates in the same way. While there are significant economic disparities between groups within Israel, public healthcare is available to all citizens, guaranteed by a National Health Insurance Law. This might have contributed to the relatively low case fatality rate in Israel (6119 deaths per million confirmed cases), compared with the USA (16 091) and the UK (14 115) by 1 December 2021.[30]

Hospitalisation of patients with severe COVID-19 disease demonstrated a distinct social gradient during the second and third waves, with rates 10 times higher in clusters 2 and 3 compared with 9 and 10. Greater disease severity among the most disadvantaged segments is related to vaccination rates. COVID-19 vaccines have proved very effective against hospitalisation and death for a variety of strains, including Delta.[31] This low rate of vaccination, combined with higher rates of underlying risk factors such as smoking and comorbid conditions like diabetes, that increase the probability of more severe COVID-19, characterises disadvantaged populations.[32] The higher hospitalisation rates among stronger SE clusters in the first stages of the disease might be related to higher disease burden of people who travel abroad more frequently and were infected outside Israel, an infection that progressed to more severe disease in the prevaccine era. Furthermore, at the beginning of the pandemic, hospitalisation was not based on disease severity, and even mild cases were admitted.[24]

Ethnic disparities in hospitalisation followed a pattern similar to that of the confirmed case rate: Higher rates among the Jewish population in the first and at the beginning of the fourth waves, with distinct dominance of the Arab and mixed-cities population during the second and third waves. In comparison, in 12 US states, hospitalisations among black and Hispanic patients were higher than their proportion in the population.[33]

The progress of the national vaccination drive also demonstrated a considerable social gradient, with cumulative rate more than twice as high among the highest, compared with the lowest, SE clusters. This disparity was most marked in younger age groups and gradually widened from the first to the third vaccine doses. In Israel, a negative association was demonstrated between vaccination with dose-1 and locality's COVID-19 burden.[29] It is possible that communities who were hit hard in the prevaccine era, perceived themselves as 'immune', and therefore, demonstrated lower vaccine acceptance.

In the USA, a cross-sectional study found that both education and income levels were positively and significantly related, in a dose-response manner, with vaccine initiation. Considerable financial difficulties were linked to 35%–44% lower odds of vaccination. One would expect that the weakest segments of the population, with higher risk of contracting COVID-19 infection and having more severe disease, would desire the protection of the vaccine, which in Israel were offered for

free and delivered in a very accessible manner.[34] By 10 August 2021, only 27% of the residents of the ultra Orthodox Jewish city of Bnei Brak (SE cluster 2) and 43% of residents of the Arab city of Taibe (SE cluster 3), had received two doses of the vaccine, while the figures in the secular Jewish cities Tel Aviv and Ramat Hasharon (clusters 8 and 9) were 63% and 75%, respectively. Some of the difference is explained by a larger proportion of children under 12 (not eligible for vaccination before October 2021) in the Arab and ultraorthodox Jewish populations, compared with the non-Orthodox Jewish majority.

Similar to the larger disparities among the younger populations, Gorelik *et al* found that among Israeli population groups, differences in COVID-19 vaccine initiation increased as age decreased. Young, ultra Orthodox Jews were the group with the lowest rates of vaccine uptake in Israel.[35]

Limitations of the study

1. Regarding the mixed cities category, three quarters of the Arab population in mixed cities live in Jerusalem, which has unique characteristics. Therefore, the attributes of the other seven mixed cities might be obscured by the dominance of Jerusalem, making it harder to produce practical recommendations regarding interventions aimed at reducing disparities.
2. The current study is based on the Open Database of the Israeli MOH, which contains aggregated data. In the absence of individual-level data, analyses and conclusions are purely ecological.
3. Despite vaccination of large proportions of the population, new variants continue challenging the healthcare system, contributing to a fifth and probably more future waves. This might reduce the ability to forecast the sociodemographic attributes of the 'upcoming' waves.
4. The analysis included repeated COVID-19 tests, since some people do multiple tests before being labelled 'confirmed'. Indeed, it might create an underestimation of the true rate of confirmed tests. However, since the national method of data collection and reporting has been stable throughout the months of the pandemic, and since, at the time of the study, COVID-19 testing was free of charge for the entire Israeli population, we believe that this should not create a bias.

CONCLUSIONS

Israel was among the first nations to lead a rapid vaccination drive, reaching most of its adult and at-risk population by March 2021. It was also among the first nations to experience a fourth pandemic wave, fuelled by a combination of waning immunity (following early vaccination) and delta variant dominance. Despite initial lower morbidity of weaker populations, subsequent waves returned to expected patterns with low SE and minority populations being hit harder, by both greater exposure and lower vaccine uptake, although smaller disparities in mortality are encouraging.

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