The impact of contextual socioeconomic and demographic characteristics of residents on COVID-19 outcomes during public health restrictions in Sydney, Australia

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Abstract

Objective: To investigate the impact of contextual socioeconomic and demographic characteristics of residents on COVID-19 outcomes during public health measures.

Methods: Aggregated data from the NSW Notifiable Conditions Information Management System linked to Australian Census data, by periods of strict and relaxed measures, were used.

Results: During strict measures, residents of areas of lower socioeconomic status (SES) had a higher risk of infection, with the lowest areas having greater risk compared with the highest areas ((hazard ratio (HR)) 7.15, 95% confidence interval (CI) 6.24-8.19). The risk of infection was lower for those aged 40 and over and was higher for males (HR 1.34, 95% CI 1.27-1.40); those in living in areas with larger household sizes (HR 1.56, 95% CI 36-1.78); and individuals in areas with a large proportion of residents born in South Asia (HR 1.18; 95% CI 1.07-1.29), South East Asia (HR 1.20, 95% CI 1.07-1.36) and the Middle East and North Africa (HR 1.67, 95% CI 1.47-1.90). During relaxed restrictions, the impact of variables attenuated but remained significant.

Conclusions: Minorities, those residing in lower SES areas and those living in larger households had worse COVID-19 outcomes during strict public health measures.

Implications for Public Health: Decision-makers should tailor services to avoid inequities.

Key words: public health responses, COVID-19 outcomes, socioeconomic status, Sydney

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Background

The coronavirus disease (COVID-19) pandemic and the public health and policy measures adopted to prevent and control its spread have had an enormous impact on the world's population.[1–4]

Globally, COVID-19 disproportionately affected minority and vulnerable communities.[5–7] Consistent with this global trend, Australian evidence has also reported that COVID-19 incidence differed by education level, ethnic background, economic and employment-related factors, and housing-related factors.[8] People in low socioeconomic groups had higher incidence of COVID-19[8] and those born overseas had double the mortality compared with those born in Australia, with those born in the Middle East having the highest mortality.[9] Moreover, it has been demonstrated that contextual factors such as high population density and a high proportion of the vulnerable population, can influence the spatial clustering of COVID-19, which creates an increased risk in its immediate neighbouring municipalities.[10,11]

In Australia, nationwide COVID-19 responses were instituted from 2020 and remained in place throughout the study period. These included international travel restrictions, a quarantine program, residential subsidies, bulk purchase of vaccines, and additional clinical and telehealth services.[12] Social security measures included a temporary increase in unemployment payments under the existing JobSeeker program and payments to businesses to subsidise wages of retained staff during closures under the new JobKeeper program (March 2020–March 2021). Disability and family support payments, community grants, housing and homeless support programs, and emergency accommodation for isolation amongst others were also granted.[12–14]

Additional measures were implemented on state and local levels under public health orders. The public health response across Greater Sydney included use of indoor and outdoor masks, stay-at-home orders, travel restrictions to within five kilometres of home, limited outdoor exercise times, closure of non-essential venues, and working from home except for essential services that included some industrial workplaces.[12,15] Restrictions also varied in intensity by area, for example in south-western Sydney, additional restrictions were implemented and policed more robustly.[16] On 11 October 2021, after the COVID-19 vaccine rates in Sydney reached 70%, public health restrictions were progressively lifted for vaccinated (2 doses) individuals.[17]

Sydney Local Health District (SLHD) serves approximately 650,000 residents in Sydney.[18] The district is culturally and socially diverse, and there are areas of extreme socioeconomic advantage and disadvantage. The district has sizable communities of aboriginal Australians, refugees, asylum seekers and special humanitarian entrants and also holds large percentage of the state's boarding houses.[18]

In addition to the public health measures described above, SLHD also implemented specific measures to reach vulnerable communities including mobile outreach free-of-charge testing and vaccination teams visiting residential aged care, partnering with community organisations including liaising with their leaders, and housing assistance.[13,19]

Given reports of social inequities, socioeconomic profile and COVID-19 outcomes, the population in SLHD provided a socio-demographically diverse context to quantitatively measure the impact of public health responses and restrictions at a local level, and will add to existing Australian evidence in other metropolitan areas.[8]

This study sought to do the following: 1. Investigate socioeconomic, demographic characteristics of residents related to COVID-19 outcomes at the small geographical area of residence, including testing, infections, hospitalisations and deaths in SLHD; and 2. Identify the impact of these factors on COVID-19 outcomes during the period of strict (16 June, 2021, to 10 October, 2021) and relaxed public health restrictions (25 October, 2021, to 18 February, 2022).

Methods

Terminology

The literature, via ecological and spatial studies, has identified contextual factors such as location, population density, mean income, and proportion of migrants impacting COVID-19 outcomes.[10,11] Importantly, our study has explored similar factors (and its impact) conceptualised in this paper as socioeconomic and demographic factors including local government area (LGA) (location), household size, region of birth to be consistent and accurate to the concepts gleaned from the local database sources (e.g. ABS, NCIMS).

Data sources and participants

Results for COVID-19 testing performed in SLHD and demographics of the associated individuals were obtained from the SLHD Performance Unit. Also for the SLHD, COVID-19 cases, hospitalisations and deaths with dates of respective events were identified from the state's Notifiable Conditions Information Management System (NCIMS) along with age, and sex for cases for the study period (16 June, 2021, to 18 February, 2022).[20] Vaccination status (being vaccinated) were ascertained by linking NCIMS records with the Australian Government reports on vaccination rates by LGAs.[21] The vaccination program in Sydney began (progressively with priority for essential workers) in January 2021 and reached the government's target by February 2022 (2 shots administered with a 4-week interval between shots as recommended by TGA at the time).[22] It is important to note that there was no booster program in existence in New South Wales during the period of this study. Socioeconomic and demographic characteristics were defined by linking the NCIMS records to the 2016 Australian Census data by small geographical area of residence (statistical area level 1 (SA1)).[23] Data available at the individual level were aggregated (e.g. location) to LGA level to be consistent across both datasets.

It was assumed that there were no or very low rates of missing data, except for vaccination status data (those who were vaccinated) as mentioned above. Justification for this assumption was that testing for COVID-19 was provided free-of-charge, all positive COVID-19 results were reportable by law and recorded in NCIMS,[20] there was extensive follow-up of hospitalisations and deaths due to COVID-19 by NSW Health, and data from the 2016 Australian Census covered the entire population.

For the analysis of COVID-19 cases, the cohort was divided into two time periods: 1. Strict Restrictions: COVID-19 cases for the period 16

June, 2021, to 10 October, 2021 (117 days). This corresponded to the period from the date of the first case that led to the strictest public health restrictions in Greater Sydney to the date these restrictions were significantly relaxed; and 2. Relaxed Restrictions: COVID-19 cases were recorded for the period 25 October, 2021, to 18 February, 2022 (117 days), following the relaxation of public health measures. The period from 11 October, 2021, and 24 October, 2021, was not analysed to allow a transition period between strict and relaxed restrictions. For the analyses with the outcomes of hospitalisation and death, all COVID-19 cases from 16 June, 2021, to 18 February, 2022, were included. COVID-19 death was defined as the result of a clinically compatible illness, in a probable or confirmed COVID-19 case, unless there is a clear alternative cause of death that cannot be related to COVID-19 disease.[24]

Outcomes and risk factors

The primary outcome of interest was COVID-19 infection. Secondary outcomes were hospitalisation due to COVID-19, death, and testing rates. The following factors were included in the analyses: sex, age, region of birth, socioeconomic status, household size, vaccination status (being vaccinated), and COVID-19 variant, and the time until the event occurring represented by time dummy variables. The measure of socioeconomic status (SES) used was the Index of Relative Socio-Economic Disadvantage (IRSD). This index ranks area of residence on a continuum from most disadvantaged to least-disadvantaged based on income, education, employment, divorce status, one parent family, skilled jobs, and long-term disability.[25] Region of birth was calculated by grouping country of birth into seven categories: Australia, Europe, East Asia, South Asia, South East Asia, Middle East and North Africa, and other, consistent with World Head Organisation categories. For each SA1, the most common region of birth of residents not born in Australia was determined and used. Residents born in Australia were not included in the calculation of this variable as the most common country of birth for the vast majority of SA1 areas was Australia. The mean household size was extracted for each SA1 to create five categorical groups. Vaccination status (being vaccinated) was defined as having two doses of a vaccine recognised by the Australian Therapeutic Goods Administration (TGA) at least two weeks prior to infection. The vaccination program (began in January 2021 and reached the Government's target by February 2022).[22] COVID-19 variant was defined as the most common variant in NSW at the time of infection based on NSW Health Weekly Surveillance Reports.

Statistical analysis

Descriptive statistics were generated for each of the risk factors and cohorts. A logistic regression model was generated for the binary outcome of COVID-19 testing for the period 22 January, 2020, to 15 June, 2021, for the entire SLHD population, with associations reported as odds ratios (ORs) with 95% confidence intervals (CIs). Separate Cox proportional hazards models, were generated for the outcome of time to COVID-19 infection from the beginning of the periods of strict restrictions and relaxed restrictions to allow comparison between the risk factors on COVID-19 infections during the different public health measures. The associations between socio-demographic factors and the COVID-19 outcomes were reported as hazard ratios (HRs) with 95%CIs for the two Cox proportional hazards models estimated for each by type of the period (strict and relaxed). These models were checked for the proportional hazard assumption by generating log-minus-log plots for each variable. The outcomes of hospitalisation and death were analysed using logistic regression models in the subset of residents who had COVID-19 infection. The testing was estimated using a logistical regression model in the whole sample of residents.

All descriptive statistics and statistical models were generated using R version 3.3.2. Geospatial figures were produced using *COVID-Connect,* an application developed for the real-time management of COVID-19 by the SLHD Public Health Unit.

Results

COVID-19 testing

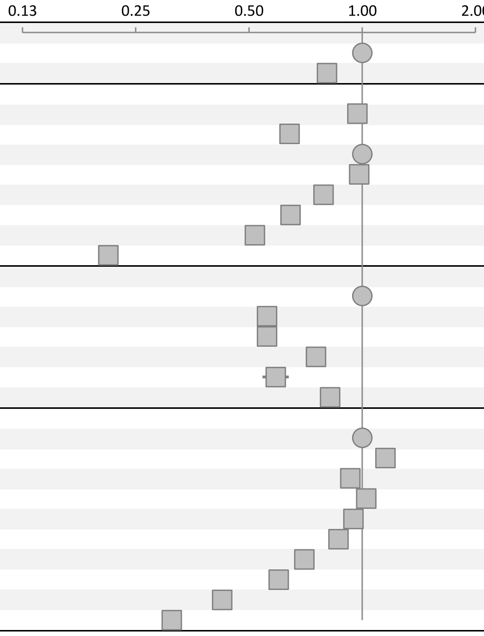
Males were less likely to test than females (OR=0.81, 95%CI: 0.79-0.82), residents living in the most disadvantaged areas were less likely to test compared with those living in the least disadvantaged areas (OR=0.31, 95%CI: 0.30-0.33), and older residents were less likely to test (OR=0.21, 95%CI: 0.20-0.22 for over 80 years-old compared with the reference age group of 30–39 years-old) (Table 1). Residents from areas where the most common foreign country of birth was not in Europe had lower testing rates: East Asia (OR=0.56, 95%CI: 0.55-0.57), South Asia (OR=0.56, 95%CI: 0.54-0.58), South East Asia (OR=0.75, 95%CI: 0.72-0.79), and Middle East and North Africa (OR=0.59, 95%CI: 0.54-0.64). Lower rates of COVID-19 testing were also observed in geographic locations with higher concentrations of socioeconomic disadvantage (**Figure 1**).

COVID-19 infection under strict restrictions

Population demographics, socioeconomic characteristics, COVID-19 infection (a positive test result) rates, and multivariate models with the outcome of COVID-19 infection, are presented in Table 2. During strict restrictions, the probability of COVID-19 infection was greater for males (hazard ratio (HR) = 1.34, 95%CI: 1.27-1.40) than females. The probability of infection was lower among older age groups compared to younger age groups, with those aged over 80 years having a lower relative risk of infection compared with the reference age group of 30–39 years-old (HR=0.64, 95%CI: 0.54-0.75). The risk of infection increased with decreasing SES, with individuals residing in the most disadvantaged areas having 7.15 times the risk of COVID-19 compared with individuals residing in the least-disadvantaged areas (HR=7.15, 95%CI: 6.24-8.19). This is also illustrated in **Figure 2**A, with areas of greater disadvantage having higher infection rates. Residents in areas with larger households also had a higher risk of COVID-19 infection, with those in households with the mean household size of over 3.5 people having 1.56 times the risk compared with those in mean households with a size of 2 or less people (HR=1.56, 95%CI: 1.36-1.78). Residents from areas where the most common foreign country of birth was in East Asia had a lower risk of infection (HR=0.88, 95%CI: 0.81-0.95) compared with Europe. While the risk was higher for South Asia (HR=1.18, 95%CI: 1.07-1.29), South East Asia (HR=1.20, 95%CI: 1.07-1.36), and Middle East and North Africa (HR=1.67, 95%CI: 1.47-1.90). Being vaccinated was associated with a

Table 1: Coronavirus disease testing rates in Sydney Local Health District, 22 January, 2020, to 15 June, 2021.[18,19]

Risk Factor	Demographics: Did not test n=410,795	Demographics: Tested n=208,943	Multivariate Model[i]: Odds Ratio (95%CI[1])
Sex			
Female (reference)	201,526 (49.1%)	112,521 (53.9%)	1
Male	209,269 (50.9%)	96,422 (46.1%)	0.81 (0.79-0.82)
Age (years (SD[2]))	37.7 (21.7)	35.5 (19.4)	
0 – 17	66,669 (16.2%)	41,060 (19.7%)	0.97 (0.95-0.99)
18 – 29	101,710 (24.8%)	39,115 (18.7%)	0.64 (0.63-0.66)
30 - 39 (reference)	71,435 (17.4%)	45,659 (21.9%)	1
40 – 49	50,321 (12.2%)	33,728 (16.1%)	0.98 (0.96-1.01)
50 – 59	45,114 (11.0%)	23,750 (11.4%)	0.79 (0.77-0.81)
60 – 69	34,909 (8.5%)	15,086 (7.2%)	0.64 (0.62-0.67)
70 – 79	22,894 (5.6%)	7,969 (3.8%)	0.52 (0.50-0.54)
Over 80	17,743 (4.3%)	2,576 (1.2%)	0.21 (0.20-0.22)
Region of Birth[ii]			
Europe (reference)	121,458 (29.6%)	94,078 (45.0%)	1
East Asia	144,737 (35.2%)	51,669 (24.7%)	0.56 (0.55-0.57)
South Asia	45,341 (11.0%)	12,089 (5.8%)	0.56 (0.54-0.58)
South East Asia	16,999 (4.1%)	7,400 (3.5%)	0.75 (0.72-0.79)
Middle East and North Africa	8,348 (2.0%)	1,580 (0.8%)	0.59 (0.54-0.64)
Other	73,912 (18.0%)	42,127 (20.2%)	0.82 (0.80-0.84)
Socioeconomic Status (Decile)[iii]			
10 (highest, reference)	46,730 (11.4%)	34,149 (16.3%)	1
9	40,657 (9.9%)	32,912 (15.8%)	1.15 (1.12-1.19)
8	49,808 (12.1%)	30,265 (14.5%)	0.93 (0.90-0.96)
7	44,577 (10.9%)	28,841 (13.8%)	1.02 (1.00-1.05)
6	38,276 (9.3%)	22,352 (10.7%)	0.95 (0.92-0.98)
5	36,243 (8.8%)	18,239 (8.7%)	0.86 (0.84-0.89)
4	36,208 (8.8%)	14,008 (6.7%)	0.70 (0.68-0.73)
3	39,645 (9.7%)	12,986 (6.2%)	0.60 (0.58-0.62)
2	42,270 (10.3%)	9,227 (4.4%)	0.42 (0.41-0.44)
1 (most disadvantaged)	36,381 (8.9%)	5,964 (2.9%)	0.31 (0.30-0.33)



[i] Logistic Regression Model

[ii] The most common region of birth for residents not born in Australia at the statistical area 1 level. Europe: Bosnia, Croatia, England, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Northern Ireland, Poland, Scotland, South East Europe. East Asia: China, Hong Kong, Japan, Taiwan. South East Asia: Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam. Middle East and North Africa: Egypt, Iran, Iraq, Lebanon, Turkey. South Asia: Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka. Other: Canada, Chile, Fiji, Mauritius, New Zealand, Papua New Guinea, South Africa, USA, Elsewhere.

[iii] Index of Relative Socio-Economic Disadvantage for the local statistical area level 1, Socio-Economic Indexes for Areas, 2016 Census, Australian Bureau of Statistics.

[1] Confidence interval

[2] Standard deviation

greater risk of infection at the population level (HR=1.34, 95%CI: 1.26-1.41). However, this association is unlikely to be causative, but due to preferential vaccination of groups that were more likely to be exposed to, and test for, COVID-19 during the period relating to the implementation of public health measures.

COVID-19 infection under relaxed restrictions

There were 12 times as many COVID-19 cases reported during the 117 days of relaxed restrictions (25 October, 2021, to 18 February, 2022) compared with the 117 days of strict restrictions (77,777 compared with 6,462) (relative risk=12.17, 95%CI: 11.86-12.48). Compared with the model of strict restrictions above, the risk of infection for males was attenuated but remained greater than for females (HR=1.13, 95% CI: 1.12-1.15). Older age groups (40-49, 50-59, 60-69, 70-79, and over 80) also had a lower risk of infection, compared with strict restrictions (see Table 2). The effect of country of birth was attenuated for all regions. Similarly, the relative risk of infection was attenuated across all areas grouped by level of relative socio–socio-economic disadvantage but remained significant, with the relative risk of infection for the lowest SES group changing from 7.2 to 1.2. This is also evident in Figure 2B, which shows similar rates of COVID-19 infection across areas of different SES. As with the model of strict restrictions, being vaccinated (2 doses) was associated with a greater risk of infection after adjustment (HR=2.42, 95%CI: 2.36-2.48).

Hospitalisation and death rates in COVID-19 cases

There were 84,651 cases of COVID-19 between 16 June, 2021, and 18 February, 2022. There was no difference between the sexes in rates of hospitalisation among those who had COVID-19 (95%CI: 0.91-1.03) (Table 3). There were 280 COVID-19 related deaths during this period (Table 4). The odds of death were greater in males (OR=1.71, 95%CI: 1.43-2.04). In contrast to COVID-19 infections, which showed a negative association with age, age was positively associated with both hospitalisation and death: the odds of hospitalisation was OR=18.8 (95%CI: 16.60-21.33) among those 80 years of age and over compared with the reference group of 30–39 years-old; and the odds of death for the same age range was OR=340 (95%CI: 249-464) compared with the reference group. For both hospitalisation and death, East Asia was the only region of birth that had a significant (and protective) association (OR=0.89, 95%CI: 0.82-0.98 and OR=0.65, 95%CI: 0.50-0.85, respectively). As with COVID-19 infection, lower SES was positively associated with hospitalisation and death. The lowest SES group had an odds ratio of OR=2.0 (95%CI: 1.71-2.38) for hospitalisation and OR=4.2 (95%CI: 2.49-7.17)for death, compared with the highest SES group. Being vaccinated was protective of hospitalisation (OR=0.67, 95%CI: 0.61-0.73) and death (OR=0.77, 95% CI: 0.61-0.98). Infection when the Omicron variant (B.1.1.529) was the dominant variant in the community was associated with a reduced odds of hospitalisation (OR=0.20, 95%CI: 0.18-0.21) and death

Figure 1: COVID-19 testing and socioeconomic status by geographical area (SA1) for the period 22 January, 2020, to 15 June, 2021, for the entire Sydney Local Health District population. Socioeconomic status is represented as a continuum from red to green with red being the most disadvantaged and green being the least disadvantaged. The rate of COVID-19 testing is represented by circles with larger circles representing greater COVID-19 testing rates. Areas of lower socioeconomic status were with lower testing rates.

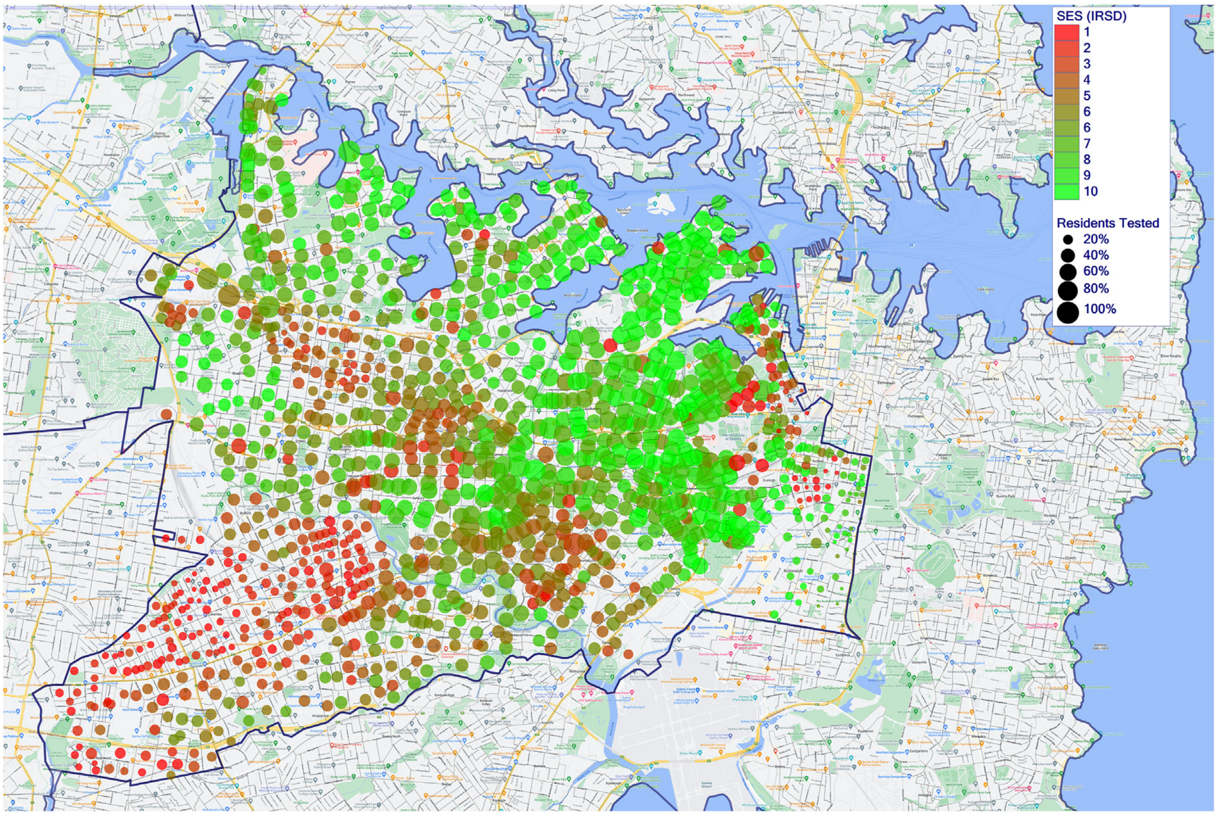
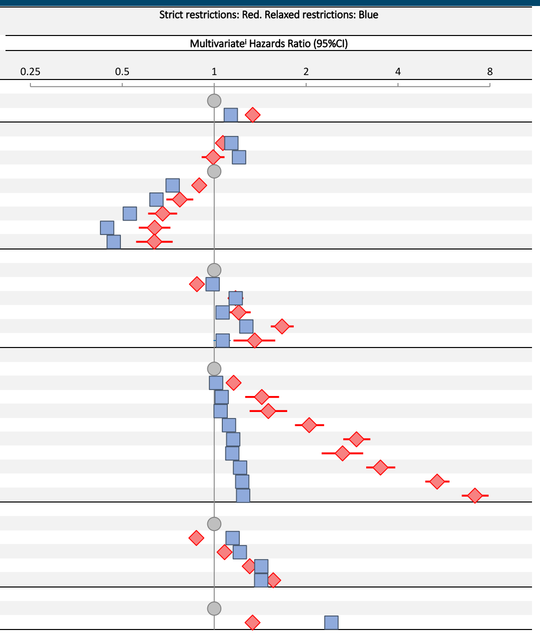


Table 2: Coronavirus disease infection rates in Sydney Local Health District (SLHD) under strict (16 June, 2021, to 10 October, 2021) and relaxed (25 October to 18 February) restrictions.[18,19]

Risk Factor	Strict Restrictions 16 June 2021 – 10 October 2021 (117 days) Demographics Not cases n=611,706	Cases n=6,462	Multivariate Model[i] Hazard ratio (95%CI)	Relaxed Restrictions 25 October 2021 – 18 February 2022 (117 days) Demographics Not cases n=533,633	Cases n=77,777	Multivariate Model[i] Hazard ratio (95%CI)
Sex						
Female (reference)	316,561 (51.8%)	2,838 (43.9%)	1	278,610 (52.2%)	37,814 (48.6%)	1
Male	295,145 (48.2%)	3,624 (56.1%)	1.34 (1.27-1.40)	255,023 (47.8%)	39,963 (51.4%)	1.13 (1.12-1.15)
Age (years (SD))	37.0 (21.0)	34.3 (20.2)		37.4 (21.3)	34.3 (18.2)	
0 – 17	105,540 (17.3%)	1,336 (20.7%)	1.07 (0.99-1.16)	94,860 (17.8%)	10,614 (13.6%)	1.14 (1.10-1.17)
18 – 29	139,560 (22.8%)	1,586 (24.5%)	0.99 (0.92-1.07)	114,500 (21.5%)	24,994 (32.1%)	1.21 (1.18-1.23)
30 - 39 (reference)	114,593 (18.7%)	1,281 (19.8%)	1	97,069 (18.2%)	17,474 (22.5%)	1
40 – 49	83,183 (13.6%)	825 (12.8%)	0.89 (0.82-0.97)	73,572 (13.8%)	9,586 (12.3%)	0.73 (0.71-0.75)
50 – 59	68,514 (11.2%)	622 (9.6%)	0.77 (0.70-0.85)	61,406 (11.5%)	7,069 (9.1%)	0.65 (0.63-0.66)
60 – 69	49,870 (8.2%)	404 (6.3%)	0.68 (0.61-0.76)	45,600 (8.5%)	4,249 (5.5%)	0.53 (0.51-0.55)
70 – 79	30,207 (4.9%)	243 (3.8%)	0.64 (0.56-0.73)	27,974 (5.2%)	2,214 (2.8%)	0.45 (0.43-0.47)
Over 80	20,239 (3.3%)	165 (2.6%)	0.64 (0.54-0.75)	18,652 (3.5%)	1,577 (2.0%)	0.47 (0.45-0.49)
Region of Birth[ii]						
Europe (reference)	213,970 (35.0%)	1,316 (20.4%)	1	190,272 (35.7%)	23,631 (30.4%)	1
East Asia	193,990 (31.7%)	1,745 (27.0%)	0.88 (0.81-0.95)	168,374 (31.6%)	25,559 (32.9%)	0.99 (0.97-1.01)
South Asia	56,014 (9.2%)	1,269 (19.6%)	1.18 (1.07-1.29)	46,311 (8.7%)	9,643 (12.4%)	1.18 (1.14-1.21)
South East Asia	24,007 (3.9%)	392 (6.1%)	1.20 (1.07-1.36)	20,649 (3.9%)	3,346 (4.3%)	1.06 (1.03-1.11)
Middle East and North Africa	9,493 (1.6%)	436 (6.7%)	1.67 (1.47-1.90)	7,731 (1.4%)	1,737 (2.2%)	1.27 (1.21-1.35)
Other	114,232 (18.7%)	1,304 (20.2%)	1.36 (1.25-1.47)	100,296 (18.8%)	13,861 (17.8%)	1.07 (1.04-1.09)
Socioeconomic Status[iii] (Decile)						
10 (least disadvantaged, reference)	80,384 (13.1%)	301 (4.7%)	1	71,912 (13.5%)	8,460 (10.9%)	1
9	72,857 (11.9%)	314 (4.9%)	1.16 (0.99-1.36)	64,929 (12.2%)	7,914 (10.2%)	1.01 (0.98-1.05)
8	79,548 (13.0%)	420 (6.5%)	1.43 (1.23-1.66)	70,073 (13.1%)	9,449 (12.1%)	1.06 (1.03-1.09)
7	72,864 (11.9%)	414 (6.4%)	1.50 (1.30-1.75)	64,213 (12.0%)	8,638 (11.1%)	1.05 (1.02-1.08)
6	60,139 (9.8%)	488 (7.6%)	2.05 (1.77-2.37)	52,419 (9.8%)	7,701 (9.9%)	1.12 (1.08-1.15)
5	53,721 (8.8%)	608 (9.4%)	2.93 (2.54-3.37)	46,422 (8.7%)	7,267 (9.3%)	1.15 (1.12-1.19)
4	49,717 (8.1%)	512 (7.9%)	2.63 (2.28-3.05)	42,924 (8.0%)	6,763 (8.7%)	1.15 (1.11-1.18)
3	51,290 (8.4%)	734 (11.4%)	3.50 (3.05-4.03)	43,773 (8.2%)	7,479 (9.6%)	1.22 (1.18-1.26)
2	50,303 (8.2%)	1,198 (18.5%)	5.37 (4.69-6.15)	42,418 (7.9%)	7,825 (10.1%)	1.23 (1.19-1.28)
1 (most disadvantaged)	40,883 (6.7%)	1,473 (22.8%)	7.15 (6.24-8.19)	34,550 (6.5%)	6,281 (8.1%)	1.24 (1.20-1.29)
Average Household Size[iv]						
2 or less (reference)	53,504 (8.7%)	594 (9.2%)	1	47,805 (9.0%)	5,685 (7.3%)	1
2 – 2.5	213,374 (34.9%)	1,357 (21.0%)	0.87 (0.79-0.97)	188,238 (35.3%)	25,056 (32.2%)	1.15 (1.12-1.18)
2.5 – 3.0	214,084 (35.0%)	2,242 (34.7%)	1.08 (0.98-1.19)	186,838 (35.0%)	27,139 (34.9%)	1.21 (1.18-1.25)
3.0 – 3.5	113,517 (18.6%)	1,802 (27.9%)	1.31 (1.18-1.45)	96,286 (18.0%)	17,156 (22.1%)	1.43 (1.38-1.47)
Over 3.5	17,227 (2.8%)	467 (7.2%)	1.56 (1.36-1.78)	14,466 (2.7%)	2,741 (3.5%)	1.42 (1.36-1.49)
Vaccinated[v]						
No (reference)	262,334 (42.9%)	4,051 (62.7%)	1	154,074 (28.9%)	12,401 (15.9%)	1
Yes	349,372 (57.1%)	2,411 (37.3%)	1.34 (1.26-1.41)	379,559 (71.1%)	65,376 (84.1%)	2.42 (2.36-2.48)



[i] Cox Proportional Hazards Model

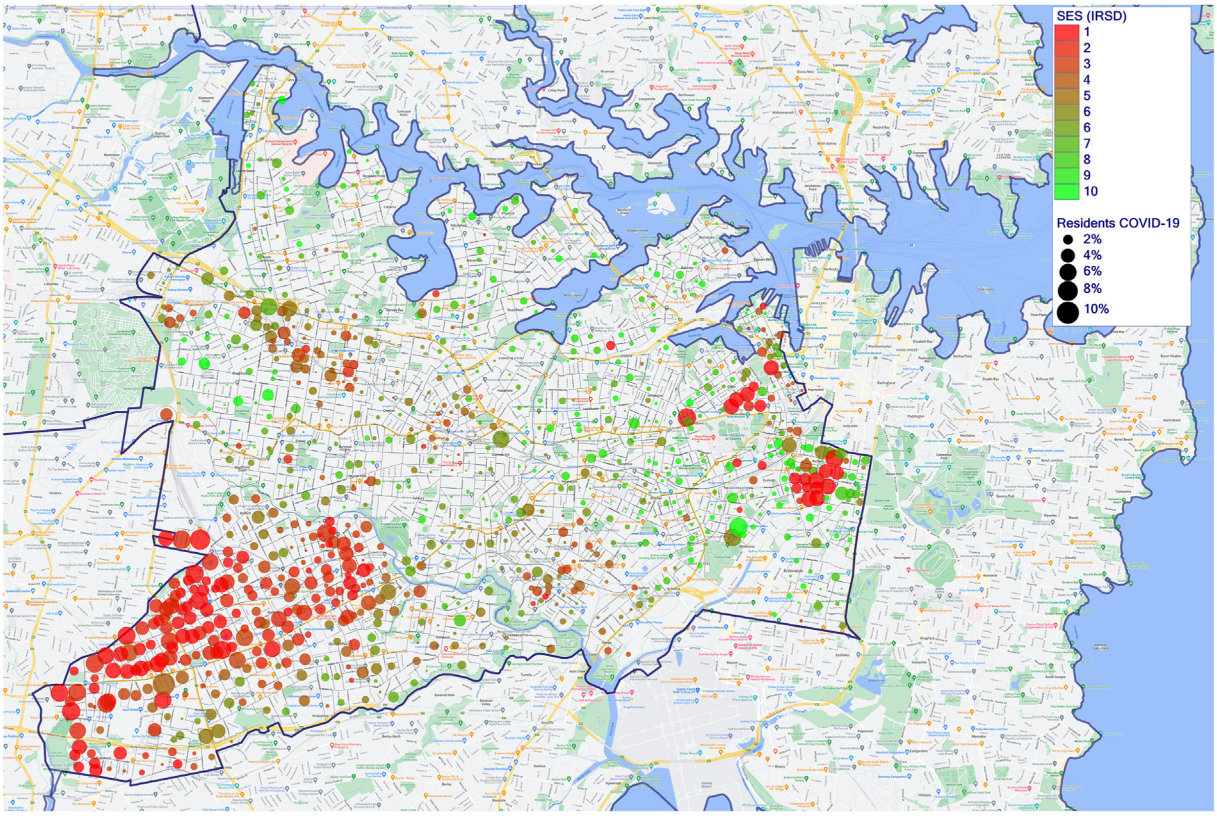
[ii] The most common region of birth for residents not born in Australia at the statistical area 1 level . Europe: Bosnia, Croatia, England, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Northern Ireland, Poland, Scotland, South East Europe. East Asia: China, Hong Kong, Japan, Taiwan. South East Asia: Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam. Middle East and North Africa: Egypt, Iran, Iraq, Lebanon, Turkey. South Asia: Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka. Other: Canada, Chile, Fiji, Mauritius, New Zealand, Papua New Guinea, South Africa, USA, Elsewhere.

[iii] Index of Relative Socio-Economic Disadvantage for the local statistical area level 1, Socio-Economic Indexes for Areas, 2016 Census, Australian Bureau of Statistics.

[iv] Mean household size for the local statistical area level 1.

[v] Vaccination status was defined as having at least two doses of a vaccine recognised by the Australian Therapeutic Goods Administration at least two weeks prior to infection.

Figure 2: COVID-19 cases and socioeconomic status by geographical area (SA1) under A. strict and B. relaxed restrictions. Socioeconomic status is represented as a continuum from red to green with red being the most disadvantaged and green being the least disadvantaged. The rate of COVID-19 infections is represented by circles with larger circles representing greater COVID-19 infection rates. Areas of lower socioeconomic status were associated with higher infection rates during strict restrictions compared with relaxed restrictions.



(OR=0.24, 95%CI: 0.19-0.29), compared with the Delta (B.1.617.2) variant.

Discussion

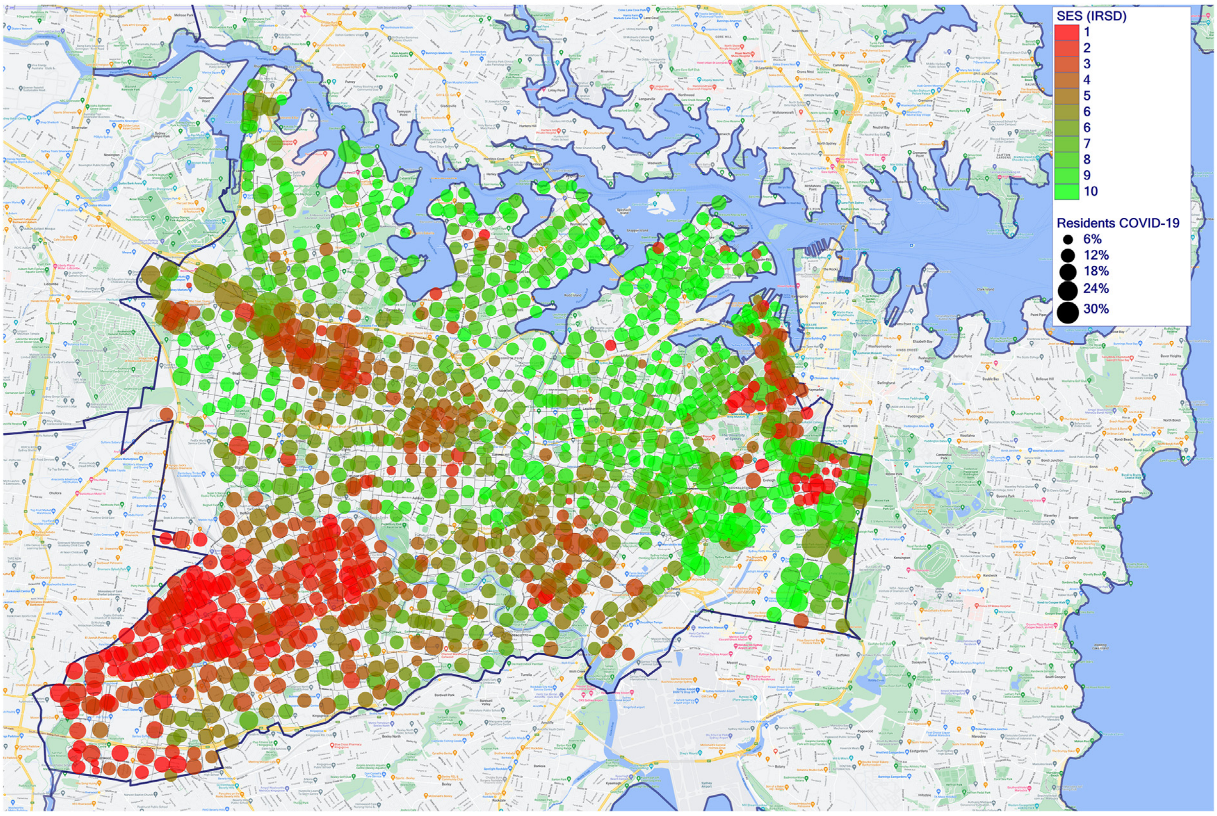
The current study sought to identify demographic and contextual socioeconomic factors associated with community testing rates and COVID-19 outcomes in SLHD under strict public health measures (robust rules about movement, free testing, isolation and quarantine) and relaxed public health measures (no restricting of movement for the community, no tracing, no quarantine) when there was community transmission of COVID-19. Our study found that the strict restrictions imposed by the NSW Government during the period 16 June, 2021, to 10 October, 2021, were effective in reducing COVID-19 cases in the general population, especially in the elderly and higher SES groups. These findings are consistent with other studies that have shown that in the absence of vaccines, public health measures were effective in controlling the spread of COVID-19.[26,27] However, while these implemented were effective within the general population, our findings show that some racially and ethnically diverse communities, those with lower SES and those living in larger households had poorer COVID-19 related outcomes.

This is consistent with other studies that have demonstrated that COVID-19 vulnerability and poverty are closely intertwined.[28] COVID-19 has been previously associated with contextual socioeconomic context, including education, income, type of employment, age, country of birth, lifestyle and the extent of social communication[29]; and as a social problem, it has disrupted the quality of life of citizens in most societies.[30] There are several factors accounting for COVID-19 risk.

Financially poorer individuals are often employed in occupations that do not provide opportunities to work from home (and other work conditions) and are more likely to live in overcrowded housing that can facilitate the spread of the virus.[8,31] In addition, disadvantaged and migrant groups are more likely to be employed as essential workers involving close contact either with the public (e.g. taxi drivers, bus and coach drivers, carers, cleaners, grocery shop workers) or other similar workers (e.g. meat factory workers).[32]

Another factor accounting for COVID-19 risk is poorer implementation and uptake of measures to vulnerable groups.[4] This was seen in this study with vulnerable groups having lower testing rates and being more affected during strict public health measures. Compliance has been linked with public trust and appropriate communication strategies whereby the public receives full, transparent information

Figure 2: Continued.



presented in simple and clear terms and the rationale behind the measures being implemented in the various local languages. However, lack of trust in authorities, poor health literacy and the provision of confusing or 'too technical' information appears to be a challenge when engaging with local communities with high proportions of disadvantaged individuals and migrants.[4,33]

While Australia adopted reactive health[12,13,15] and social[14,34] policies to mitigate COVID-19 spread, these were designed, governed and implemented within existing fragmented health and social care systems with a lack of continuity and planning beyond the emergency response. The SLHD-integrated COVID-19 plan sought to address the expected social disparities[19] but the present study demonstrates these persisted. Future efforts should expand strategies and establish sustainable governance to facilitate community trust and regular, accurate, socioeconomically, linguistically and culturally appropriate public communication and information sharing, alongside community mobilisation (for example, community leaders' involvement) to mitigate risk.[35]

As the impacts of the pandemic are likely to exacerbate socioeconomic barriers to health and health inequities, it is an appropriate time to apply lessons learned during the recent years to re-evaluate efforts to strengthen, scale and sustain the integrated health and social care sectors' activities. Importantly, COVID-19 has re-emphasised the interdependence of the health and social care sectors and shifting health systems to scale tools for identifying and addressing social needs (for example, homelessness and crowded housing).[36] Reducing crowded housing by funding new government housing for the vulnerable can also play a role. In addition, there is a need for better access to health and social services for groups with low SES, unskilled occupations, migrant and refugee populations, regardless of age, gender, or migration status.

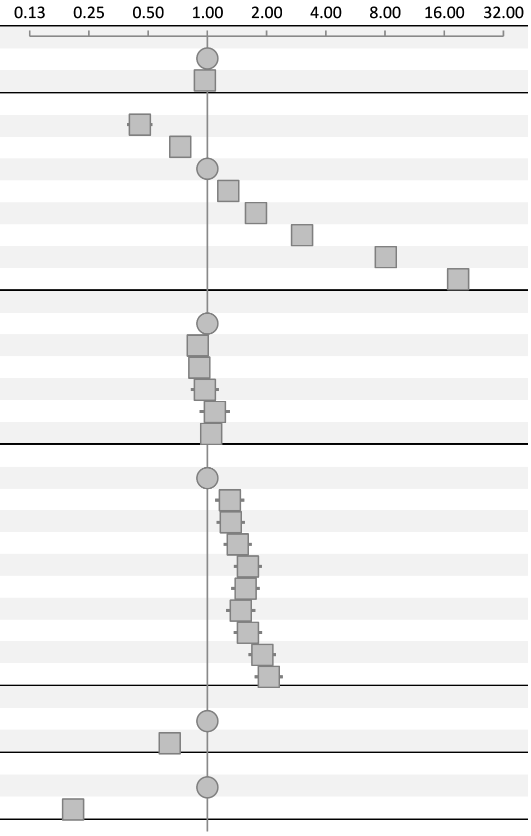
Limitations of this study must be noted. The different time periods of the two groups (strict and relaxed restrictions) varied in four key respects: community attitudes, dominant COVID-19 variants, vaccination rates and seasonal effects making interpretation difficult. Moreover, our results demonstrate a relatively low protective effect of vaccination compared with international studies that disaggregate by age, duration of infection since vaccination, duration of survival following a positive test, and other pre-existing risk factors,[37] as well as the lack of a booster being administered in Sydney at the time of the study period.

In addition, our analysis compared outcomes from 2021–2022 to the 2016 Australia Census data as this was the latest dataset available at the time of publication. During COVID-19 the mobility of residents increased, with many foreign individuals relocating back to their country of origin as well as locals moving inter- and intra-state, changing the demographic and socioeconomic landscape of the SLHD catchment. Moreover, there were changes in testing methods and varied testing preferences over the study period and this might have impacted the testing rates in the study population.

In terms of the modelling, we note that in COVID-19 infection model for the relaxed period the chance of infection could have been attenuated by immunity against reinfection that was conferred in the strict period. We observed that the impact of socio-economic and

Table 3: Coronavirus disease hospitalisation rates within coronavirus disease cases in Sydney Local Health District from 16 June, 2021, to 18 February, 2022.[18,19]

Risk Factor	Demographics: Not hospitalised n=80,872	Demographics: Hospitalised n=3,779	Multivariate Model[i]: Odds ratio (95%CI[1])
Sex			
Female (reference)	38,991 (48.2%)	1,843 (48.8%)	1
Male	41,881 (51.8%)	1,936 (51.2%)	0.97 (0.91-1.03)
Age (years (SD[2]))	33.5 (17.6)	50.8 (24.8)	
0 – 17	11,775 (14.6%)	278 (7.4%)	0.46 (0.40-0.53)
18 – 29	26,073 (32.2%)	595 (15.7%)	0.73 (0.66-0.81)
30 - 39 (reference)	18,253 (22.6%)	572 (15.1%)	1
40 – 49	10,040 (12.4%)	415 (11.0%)	1.26 (1.12-1.43)
50 – 59	7,323 (9.1%)	415 (11.0%)	1.75 (1.55-1.98)
60 – 69	4,269 (5.3%)	407 (10.8%)	2.99 (2.64-3.39)
70 – 79	1,995 (2.5%)	486 (12.9%)	8.04 (7.09-9.10)
Over 80	1,144 (1.4%)	611 (16.2%)	18.82 (16.60-21.33)
Region of Birth[ii]			
Europe (reference)	23,923 (29.6%)	1,137 (30.1%)	1
East Asia	26,394 (32.6%)	993 (26.3%)	0.89 (0.82-0.98)
South Asia	10,430 (12.9%)	560 (14.8%)	0.92 (0.82-1.04)
South East Asia	3,576 (4.4%)	178 (4.7%)	0.98 (0.83-1.15)
Middle East and North Africa	2,020 (2.5%)	182 (4.8%)	1.08 (0.91-1.30)
Other	14,529 (18.0%)	729 (19.3%)	1.05 (0.95-1.15)
Socioeconomic Status[iii] (Decile)			
10 (least disadvantaged, reference)	8,570 (10.6%)	221 (5.8%)	1
9	7,976 (9.9%)	281 (7.4%)	1.30 (1.09-1.54)
8	9,573 (11.8%)	328 (8.7%)	1.30 (1.10-1.54)
7	8,725 (10.8%)	347 (9.2%)	1.42 (1.20-1.67)
6	7,843 (9.7%)	380 (10.1%)	1.59 (1.35-1.87)
5	7,565 (9.4%)	351 (9.3%)	1.54 (1.30-1.82)
4	6,992 (8.6%)	317 (8.4%)	1.45 (1.22-1.72)
3	7,873 (9.7%)	396 (10.5%)	1.57 (1.33-1.86)
2	8,540 (10.6%)	554 (14.7%)	1.85 (1.58-2.18)
1 (most disadvantaged)	7,215 (8.9%)	604 (16.0%)	2.02 (1.71-2.38)
Vaccination status[iv]			
No (reference)	15,578 (19.3%)	1,014 (26.8%)	1
Yes	65,294 (80.7%)	2,765 (73.2%)	0.67 (0.61-0.73)
COVID-19 Variant[v]			
Delta (reference)	7,838 (9.7%)	1,372 (36.3%)	1
Omicron	73,034 (90.3%)	2,407 (63.7%)	0.20 (0.18-0.21)



[i] Logistic Regression Model

[ii] The most common region of birth for residents not born in Australia at the statistical area 1 level . Europe: Bosnia, Croatia, England, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Northern Ireland, Poland, Scotland, South East Europe. East Asia: China, Hong Kong, Japan, Taiwan. South East Asia: Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam. Middle East and North Africa: Egypt, Iran, Iraq, Lebanon, Turkey. South Asia: Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka. Other: Canada, Chile, Fiji, Mauritius, New Zealand, Papua New Guinea, South Africa, USA, Elsewhere.

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[iv] Vaccination was defined as having at least two doses of a vaccine recognised by the Australian Therapeutic Goods Administration at least two weeks prior to infection.

[v] COVID-19 dominant variant. Delta (B.1.617.2): 16 June 2021 - 15 December 2022; Omicron (B.1.1.529): 16 December 2021 - 18 February 2022.

[1] Confidence interval

[2] Standard deviation

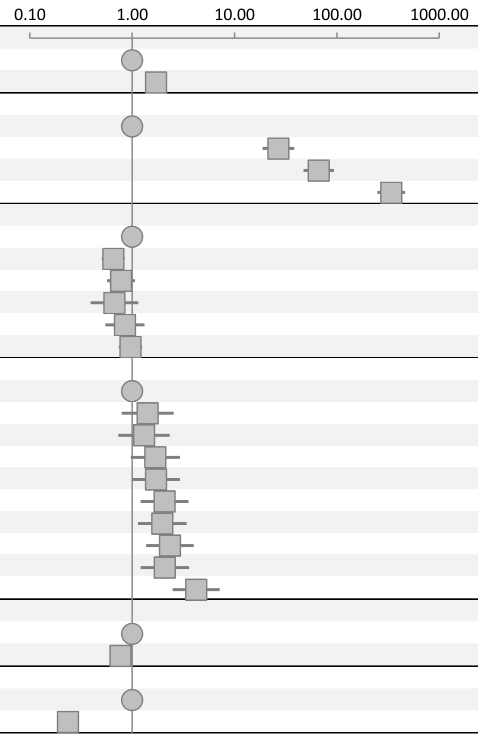
demographic characteristics attenuated but remained significant in the infection model. This attenuation could be associated to the greater immunity of the population in the remained period.

Testing rates might also be influenced by individuals' motivation for testing (e.g. social, economic and demographic characteristics); however, this study did not explore this further due to limited information available. In addition, not all symptomatic individuals tested themselves and those who were asymptomatic were less likely to be captured in the data sample. In relation to the COVID-19 death data in NCIMS, we have information on the outcome (death or not) and the cause of this outcome (COVID-19 or other communicable disease only). To the best to our knowledge, at the time of the study period, the death caused by COVID-19 data was sourced from death registrations and there were special arrangements in place for timeliness during COVID-19. If the local public health unit (PHU), part of the Local Health District, were informed about a death caused by COVID-19, they were able to enter it onto NCIMS. As numbers increased, it is more likely that this was completed through other means. For instance, documenting COVID-19 deaths was undertaken centrally, not at local PHU. Further, a specific timeframe between positive COVID-19 results and death was not part of the analysis because this information was not available.

A major strength of this study is that it used representative population-level data for a catchment that experienced two discrete periods of contrasting public health measures, allowing for the evaluation of public health responses in the context of socioeconomic and other factors. In addition, this novel study demonstrates that accessible timely routinely collected data can be used and should inform the generation of appropriate national and local policies to addresses both social and health needs of the community including minority, racially and ethnically diverse, and socioeconomically disadvantaged populations.

Table 4: Coronavirus disease death rates within coronavirus disease cases in Sydney Local Health District from 16 June, 2021, to 18 February, 2022.[18,19]

Risk Factor	Demographics: Alive n=84,371	Demographics: Died n=280	Multivariate Model[i]: Odds ratio (95%CI[1])
Sex			
Female (reference)	40,723 (48.3%)	111 (39.6%)	1
Male	43,648 (51.7%)	169 (60.4%)	1.71 (1.43-2.04)
Age (years (SD[2]))	34.2 (18.2)	78.8 (12.8)	
0 – 59 (reference)	57,544 (68.2%)	2 (0.7%)	1
60 – 69	10,451 (12.4%)	4 (1.4%)	26.83 (18.77-38.35)
70 – 79	7,720 (9.2%)	18 (6.4%)	66.43 (47.20-93.50)
Over 80	4,636 (5.5%)	40 (14.3%)	339.85 (249.10-463.66)
Region of Birth[ii]	2,427 (2.9%)	54 (19.3%)	
Europe (reference)	1,593 (1.9%)	162 (57.9%)	1
East Asia			0.65 (0.50-0.85)
South Asia	24,953 (29.6%)	107 (38.2%)	0.78 (0.57-1.07)
South East Asia	27,337 (32.4%)	50 (17.9%)	0.67 (0.39-1.15)
Middle East and North Africa	10,948 (13.0%)	42 (15.0%)	0.85 (0.55-1.32)
Other	3,746 (4.4%)	8 (2.9%)	0.96 (0.74-1.25)
Socioeconomic Status[iii] (Decile)	2,187 (2.6%)	15 (5.4%)	
10 (least disadvantaged, reference)	15,200 (18.0%)	58 (20.7%)	1
9			1.42 (0.79-2.54)
8	8,782 (10.4%)	9 (3.2%)	1.30 (0.73-2.33)
7	8,241 (9.8%)	16 (5.7%)	1.69 (0.97-2.93)
6	9,884 (11.7%)	17 (6.1%)	1.71 (1.00-2.93)
5	9,049 (10.7%)	23 (8.2%)	2.07 (1.21-3.55)
4	8,194 (9.7%)	29 (10.4%)	1.97 (1.14-3.41)
3	7,886 (9.3%)	30 (10.7%)	2.34 (1.37-4.00)
2	7,282 (8.6%)	27 (9.6%)	2.09 (1.21-3.60)
1 (most disadvantaged)	8,235 (9.8%)	34 (12.1%)	4.22 (2.49-7.17)
Vaccination status[iv]	9,062 (10.7%)	32 (11.4%)	
No (reference)	7,756 (9.2%)	63 (22.5%)	1
Yes			0.77 (0.61-0.98)
COVID-19 Variant[v]	16,532 (19.6%)	60 (21.3%)	
Delta (reference)	67,839 (80.4%)	220 (78.7%)	1
Omicron			0.24 (0.19-0.29)



[i] Logistic Regression Model

[ii] The most common region of birth for residents not born in Australia at the statistical area 1 level. Europe: Bosnia, Croatia, England, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Northern Ireland, Poland, Scotland, South East Europe. East Asia: China, Hong Kong, Japan, Taiwan. South East Asia: Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam. Middle East and North Africa: Egypt, Iran, Iraq, Lebanon, Turkey. South Asia: Afghanistan, Bangladesh, India, Nepal, Pakistan, Sri Lanka. Other: Canada, Chile, Fiji, Mauritius, New Zealand, Papua New Guinea, South Africa, USA, Elsewhere.

[iii] Index of Relative Socio-Economic Disadvantage for the local statistical area level 1, Socio-Economic Indexes for Areas, 2016 Census, Australian Bureau of Statistics.

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[v] COVID-19 dominant variant. Delta (B.1.617.2): 16 June 2021 - 15 December 2022; Omicron (B.1.1.529): 16 December 2021 - 18 February 2022.

[1] Confidence interval

[2] Standard deviation

Conclusion

While public health measures were effective in controlling the spread of COVID-19, this study shows a high discrepancy of COVID-19 outcomes, with some minority groups, those residing in lower SES areas and those living in areas with larger households having poorer COVID-19 outcomes when strict public health measures were in place.

When responding to pandemics, decision-makers should tailor their delivery of services to avoid deepening health and social inequities. It is understood that if vulnerable groups are not properly identified and responded to appropriately, differential ongoing impacts of pandemics can be expected. Nationally and locally the challenge is to strengthen, scale and sustain community engagement and relationships initiated during COVID-19 outbreaks.

Consent for Publication

Not applicable.

Conflicts of interest

None to declare.

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Ethics approval and consent to participate

Ethics approval for the current study was granted by the Research Ethics & Governance Office, Royal Prince Alfred Hospital, Sydney Local Health District (X20-0426, 2020/ETH02492, X21-0180, 2021/ETH00947).

Authors' contribution

GU, CM, AW, LG, JE, and CHS conceived the study design. GU, CM and AT performed data management. Analysis was conducted by GU, CM, AP, LG, EQ and FM.

IK, PH, MC, JG, AP, CHS, and JE obtained funding. GU, CM, AP, LG, EQ, SW, JE, AW, IK and VG contributed to the methodology. GU and CM were responsible for the project administration. Visualisation of data was conducted by GU, CM, MC, AP, CHS, PA, LG and EQ. All authors wrote and approved the original draft.

Availability of data and materials

Under the NSW Public Health Act, public health data at an individual-identifiable level can only be released under very limited circumstances. It was legally accessible for this study because one of the authors was an employee of the public health service and could undertake the initial aggregation and de-identification in that role. This would apply more generally to persons seeking to reproduce this study, that is, they could request aggregated data.

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