Socioeconomic position and the COVID-19 care cascade from testing to mortality in Switzerland: a population-based analysis

Julien Riou*, Radoslaw Panczak*, Christian L Althaus, Christoph Junker, Damir Perisa, Katrin Schneider, Nicola G Criscuolo, Nicola Low, Matthias Egger

Summary

Background The inverse care law states that disadvantaged populations need more health care than advantaged populations but receive less. Gaps in COVID-19-related health care and infection control are not well understood. We aimed to examine inequalities in health in the care cascade from testing for SARS-CoV-2 to COVID-19-related hospitalisation, intensive care unit (ICU) admission, and death in Switzerland, a wealthy country strongly affected by the pandemic.

Methods We analysed surveillance data reported to the Swiss Federal Office of Public Health from March 1, 2020, to April 16, 2021, and 2018 population data. We geocoded residential addresses of notifications to identify the Swiss neighbourhood index of socioeconomic position (Swiss-SEP). The index describes 1·27 million small neighbourhoods of approximately 50 households each on the basis of rent per m², education and occupation of household heads, and crowding. We used negative binomial regression models to calculate incidence rate ratios (IRRs) with 95% credible intervals (CrIs) of the association between ten groups of the Swiss-SEP index defined by deciles (1=lowest, 10=highest) and outcomes. Models were adjusted for sex, age, canton, and wave of the epidemic (before or after June 8, 2020). We used three different denominators: the general population, the number of tests, and the number of positive tests.

Findings Analyses were based on 4 129 636 tests, 609 782 positive tests, 26 143 hospitalisations, 2432 ICU admissions, 9383 deaths, and 8 221 406 residents. Comparing the highest with the lowest Swiss-SEP group and using the general population as the denominator, more tests were done among people living in neighbourhoods of highest SEP compared with lowest SEP (adjusted IRR 1·18 [95% CrI 1·02–1·36]). Among tested people, test positivity was lower (0·75 [0·69–0·81]) in neighbourhoods of highest SEP than of lowest SEP. Among people testing positive, the adjusted IRR was 0·68 (0·62–0·74) for hospitalisation, and 0·6 (0·76–0·99) for death. The associations between neighbourhood SEP and outcomes were stronger in younger age groups and we found heterogeneity between areas.

Interpretation The inverse care law and socioeconomic inequalities were evident in Switzerland during the COVID-19 epidemic. People living in neighbourhoods of low SEP were less likely to be tested but more likely to test positive, be admitted to hospital, or die, compared with those in areas of high SEP. It is essential to continue to monitor testing for SARS-CoV-2, access and uptake of COVID-19 vaccination and outcomes of COVID-19. Governments and health-care systems should address this pandemic of inequality by taking measures to reduce health inequalities in response to the SARS-CoV-2 pandemic.

Funding Swiss Federal Office of Public Health, Swiss National Science Foundation, EU Horizon 2020, Branco Weiss Foundation.

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inequalities and inequities might also influence the outcomes of the COVID-19 pandemic. A study in Massachusetts, USA, SARS-CoV-2 testing resources had been disproportionately allocated to more affluent communities. In the UK Biobank cohort, testing positive for SARS-CoV-2 was related to area-level socioeconomic deprivation, lower educational level, and non-White ethnicity. The REal-time Assessment of Community deprivation, lower educational level, and non-White for SARS-CoV-2 was related to area-level socioeconomic communities. In the UK Biobank cohort, testing positive been disproportionately allocated to more affluent Massachusetts, USA, SARS-CoV-2 testing resources had been likely to die from COVID-19. Studies in the USA showed that patients from neighbourhoods or counties with lower median income or higher deprivation were more likely to require intensive care, and more likely to die from COVID-19. Inequalities and inequities in health care and infection control should be described and documented at the population level along the COVID-19 cascade—ie, from testing and testing positive to medical care and clinical outcomes. We analysed nationwide, population-based surveillance data from the Swiss Federal Office of Public Health (SFOPH) to examine the association of neighbourhood SEP with testing for SARS-CoV-2, testing positive, hospitalisation, intensive care unit (ICU) admission, and death.

Methods
Data sources
In this population-based study of surveillance data, we used mandatory notifications for negative and positive SARS-CoV-2 tests, and for laboratory-confirmed hospitalisations and deaths related to COVID-19, received at the SFOPH until April 14, 2021. PCR testing capacity was low during the first wave and tests were mainly used for hospitalised patients with severe symptoms
compatible with COVID-19. Since June 24, 2020, the Swiss Federal Government has covered the costs of PCR tests, including for people with mild symptoms, those who were notified by the digital contact tracing app, SwissCovid, and people who were asked by health authorities to get tested following close contact with an infected person. Additionally, on Jan 27, 2021, the Federal Government expanded the criteria for reimbursement by covering the costs of tests in people without symptoms, and on March 12, 2021, by covering up to five rapid tests per month. We included records with a date after Feb 29, 2020 (May 22, 2020, for negative tests), from Swiss residents. We excluded notifications with missing or invalid information on age, sex, or place of residence, and duplicate notifications. We geocoded the residential address using geocoded general population data from the Swiss Federal Statistical Office (2018 edition). We used population data from 2018 and the directory of retirement and nursing homes to identify individuals living in such institutions.

Index of neighbourhood SEP

The Swiss neighbourhood index of SEP (Swiss-SEP) is based on the national house-to-house census from 2000. Swiss-SEP includes 1·27 million neighbourhoods of approximately 50 households each, centred on the individual’s residential building, with overlapping boundaries. The index uses the median rent per m², the proportion of households headed by a person with primary education or less, the proportion headed by a person in manual or unskilled occupation, and the mean number of people per room (crowding) to characterise neighbourhoods. No data on household income are collected in the Swiss census. The index was constructed using principal component analysis and validated using independent data on households’ financial situation and was standardised to range from 0 (lowest SEP) to 100 (highest SEP).

Geocoding and linkage to Swiss-SEP

Geocoding of the residential addresses was done using the publicly available data from the Swiss Federal Office of Topography or, in a few cases, using Google Maps Geocoding API. Swiss-SEP index values were aggregated into ten groups using deciles as cutoffs. Where only a postcode was available, we used the Swiss-SEP value corresponding to the centroid of the area. Data were aggregated by canton (26 groups), sex (two groups), age (nine groups: 10-year groups from 0 years to 79 years and ≥80 years), Swiss-SEP (ten groups), and epidemic wave (two groups: before June 8, 2020 [14 weeks], or from June 8, 2020, onwards [35 weeks]) at the SFOPH. June 8, 2020, was the beginning of the first week after the nadir of case counts. The dataset consisted of aggregated data only. We did this research using surveillance data according to the Swiss law on communicable diseases (EpG, SR 818.101). No ethics approval was required.

Statistical analysis

We examined the association between Swiss-SEP group and counts of SARS-CoV-2 tests, positive tests, hospitalisations, ICU admissions, and deaths in negative binomial regression models to account for unknown overdispersion. We used a Bayesian approach with weakly informative priors to improve the inference in situations with low numbers (eg, deaths in the age group 0–49 years) or multiple interactions. We considered three different denominators: the general population, the total number of tests, and the number of positive tests. Denominators were included as offsets in each model. In a univariate model, we estimated the incidence rate ratio (IRR) with 95% credibility intervals (CrIs) per unit increase in Swiss-SEP group for each outcome and denominator. The model assumes that the association with Swiss-SEP is linear on the logarithmic scale. We tested this assumption by comparing this model with one in which each group was included separately. We estimated the IRR adjusted for age group, sex, canton, and epidemic wave in a second model. The adjustment for canton included a random intercept and slope by canton, allowing for interaction between Swiss-SEP group and canton. In a third model, we assessed two-way interactions between Swiss-SEP, and age group, sex, and epidemic wave. We used the leave-one-out information criterion for model selection.

In sensitivity analyses, we (1) excluded all cases geocoded with the postal code and not the full address and (2) excluded cases with an address corresponding to one of 1586 retirement or nursing homes. All analyses were done using Stan (version 2.21.1) and R (version 4.0.4), with package rstanarm. We used weakly informative prior distributions for all model parameters. Calculations were done on UBELIX. The appendix (p 4) provides more information.

Figure 1: Evolution of notifications to the Federal Office of Public Health during the COVID-19 pandemic in Switzerland from March 1, 2020, to April 14, 2021

The counts of total tests were available only from May 23, 2020. The dashed line shows the date chosen for the separation between the first and second wave (June 8, 2020). ICU=intensive care unit.
Role of the funding source
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results
As of April 14, 2021, the SFOPH received 6872353 notifications related to COVID-19 during two epidemic waves (figure 1). 5910732 SARS-CoV-2 test results, 616239 (10.4%) positive SARS-CoV-2 tests, 26373 COVID-19 hospital admissions (4.3% of positive tests), 2458 COVID-19 ICU admissions (0.4% of positive cases), and 9550 deaths from COVID-19 (for a case fatality rate of 1.5%) met eligibility criteria (appendix p 2). Valid information on age, sex, and place of residence was available for 143143 people admitted to hospital. For 38.9% of positive tests, but for 88.2% of hospitalisations and 95.5% of ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths, whereas the highest SEP accounted for 43.6% of 2432 ICU admissions, and 1240 (13.2%) of 9383 deaths.

Table 1: Distribution of study data across age, sex, and neighbourhood index of SEP

<table>
<thead>
<tr>
<th>Neighbourhood index of SEP (group)</th>
<th>Total tests*</th>
<th>Positive tests</th>
<th>Hospitalisations</th>
<th>ICU admissions</th>
<th>Deaths</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (lowest)</td>
<td>452438 (11.0%)</td>
<td>82977 (13.6%)</td>
<td>40455 (15.5%)</td>
<td>398 (16.4%)</td>
<td>1240 (13.2%)</td>
<td>983036 (12.0%)</td>
</tr>
<tr>
<td>2</td>
<td>436720 (10.6%)</td>
<td>75319 (11.7%)</td>
<td>354 (14.6%)</td>
<td>1140 (12.1%)</td>
<td>885776 (10.8%)</td>
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</tr>
<tr>
<td>3</td>
<td>410169 (9.9%)</td>
<td>65886 (10.8%)</td>
<td>274 (11.3%)</td>
<td>1042 (11.1%)</td>
<td>842747 (10.3%)</td>
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</tr>
<tr>
<td>4</td>
<td>404986 (9.8%)</td>
<td>61757 (10.1%)</td>
<td>254 (10.4%)</td>
<td>977 (10.7%)</td>
<td>827400 (10.1%)</td>
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</tr>
<tr>
<td>5</td>
<td>408730 (9.9%)</td>
<td>60782 (10.0%)</td>
<td>262 (10.0%)</td>
<td>1033 (11.0%)</td>
<td>825493 (10.0%)</td>
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<tr>
<td>6</td>
<td>404213 (9.8%)</td>
<td>59656 (9.9%)</td>
<td>2533 (9.7%)</td>
<td>1044 (11.1%)</td>
<td>813599 (9.9%)</td>
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<td>7</td>
<td>408996 (9.9%)</td>
<td>56701 (9.3%)</td>
<td>2289 (8.8%)</td>
<td>825 (8.8%)</td>
<td>809336 (9.8%)</td>
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<tr>
<td>8</td>
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<td>55093 (9.2%)</td>
<td>2137 (8.2%)</td>
<td>864 (9.2%)</td>
<td>791945 (9.6%)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>392818 (9.5%)</td>
<td>52147 (8.6%)</td>
<td>1887 (7.2%)</td>
<td>644 (6.9%)</td>
<td>758723 (9.2%)</td>
<td></td>
</tr>
<tr>
<td>10 (highest)</td>
<td>407651 (9.9%)</td>
<td>43466 (7.3%)</td>
<td>1469 (5.6%)</td>
<td>574 (6.1%)</td>
<td>683752 (8.3%)</td>
<td></td>
</tr>
</tbody>
</table>

Data are n (%). ICU-intensive care unit. SEP-socioeconomic position. *Data on total tests relate to the period May 23, 2020, to April 14, 2021, rather than the full study period from March 1, 2020, to April 14, 2021. †The first wave of infections was before June 8, 2020. ‡The second wave was from June 8, 2020.
the number of people living in neighbourhoods of lower SEP is higher than in neighbourhoods of higher position. Most of the data were from the second wave, which lasted longer and was more severe than the first; 7808 (83·2%) deaths were from the second wave (table 1).

The rates of SARS-CoV-2 tests per population increased with Swiss-SEP group (figure 2), whereas the rates decreased for positive tests, hospitalisations, ICU admissions, and deaths. The slopes for positive tests, hospitalisations, and ICU admissions were steeper when rates were calculated per test rather than by population, and somewhat less steep when expressed per positive test (figure 2).

Modelling Swiss-SEP groups as a continuous variable led to a similar or better model fit than with discrete variables (appendix p 5). Adjusting for age, sex, epidemic wave, and canton improved the fit further (appendix p 5). Visual comparison of model predictions and observed data from the latter model illustrates the good fit, with most observed data points within the 95% CrI of model estimates (appendix p 6). One exception was the high number of tests among people living in neighbourhoods in the highest Swiss-SEP group, which was not captured well. Additionally, several data points were outside the CrI for positive tests. The fit improved for positive tests when stratifying the data by epidemic wave (appendix p 14).

In both unadjusted and adjusted analyses, each increase in Swiss-SEP group was associated with an increase in SARS-CoV-2 testing per population (figure 3). The adjusted IRR was 1·02 (95% CrI 1·00–1·03) per group increase, corresponding to 18% (2–36) more tests in the highest compared with the lowest socioeconomic group (table 2). We did not find any association with positive tests per population (figure 3). The number of positive tests per number of tests decreased as Swiss-SEP group increased (adjusted IRR 0·97 [0·96–0·98]), corresponding to a 25% (19–31) lower test positivity in the highest compared with the lowest socioeconomic group (figure 3). The greater uptake of testing in neighbourhoods of higher socioeconomic position masked the higher number of positive tests among individuals from lower SEP than in higher SEP neighbourhoods. Rates of hospitalisations (adjusted IRR 0·94 [0·92–0·96]) and ICU admissions (0·90 [0·87–0·93]) per population decreased with higher SEP, corresponding to 44% (33–51) lower hospitalisation rates and 61% (47–72) lower ICU admission rates in the highest compared with the lowest socioeconomic group (figure 3). Estimates were similar in the unadjusted and adjusted analyses, and similar with different denominators (table 2; figure 3).

COVID-19-related mortality declined with increasing SEP of neighbourhoods (table 2). The association became stronger when excluding residents of retirement or nursing homes (figure 4A). After excluding such residents, the adjusted IRRs per increase in Swiss-SEP group were 0·94 (95% CrI 0·92–0·97) for COVID-19 mortality.
deaths per population, 0.94 (0.93–0.96) for deaths among those tested and 0.98 (0.96–0.99) for deaths among those testing positive (figure 4A, appendix p 17). These estimates translated into a lower mortality of 40% (24–52) per population, 40% (29–49) per test, and 18% (7–28) per positive test, comparing the highest with the lowest group (figure 4A).

Rates of testing, positive tests, and clinical outcomes were also associated with age and sex (appendix p 8). The testing rate per 100,000 population was lowest and positive tests were the least frequent in children aged 0–9 years (appendix p 9). The risk of hospitalisation increased with age and ICU admissions and mortality increased from age 50 years onwards. Testing and positive tests were about as frequent among men and women, but the rates of hospitalisations, ICU admissions, and mortality were all lower in women than in men. For all outcomes, we found heterogeneity across cantons (appendix p 9).

We examined two-way interactions between Swiss-SEP group and age, sex, epidemic wave, and canton (appendix pp 10–12). The associations between SEP and outcomes became weaker with increasing age (appendix pp 10–12). The interaction with age is illustrated in figure 4B for mortality in those testing positive. The association with neighbourhood SEP became weaker moving from age group 0–49 years to older age groups and disappeared in the age group 80 years and older (appendix pp 10–12). We found little evidence of interactions with sex or epidemic wave. There was also heterogeneity across cantons, particularly for testing and positive tests. The canton of Geneva was an outlier, with a stronger positive association of Swiss-SEP group with testing and a stronger negative association with test positivity compared with the national average. Associations with testing and test positivity were also somewhat stronger for the cantons of Bern, Obwalden, and Uri, and weaker or absent for other cantons (appendix pp 10–12).

**Discussion**

In this whole-population study of the COVID-19 epidemic in Switzerland in 2020–21, we found that people living in areas with higher SEP were more likely to get tested for SARS-CoV-2 but less likely to test positive and be admitted to hospital or the ICU, and less likely to die, compared with those in areas of lower SEP. The strength of the association increased moving along the care cascade from test positivity to hospitalisation and ICU admission. Associations with neighbourhood SEP were similar during the two waves but more pronounced in some areas than others. Testing was less intense and positive tests were about as frequent among men and women, but hospitalisations, ICU admissions, and
mortality were all higher in men than in women, again confirming previous findings.26

We used national data for one country and its health system and covered the cascade from testing for SARS-CoV-2 to testing positive, hospital admission, death, in both waves of the COVID-19 epidemic for all ages. Our study of the Swiss resident population thus avoided the selection bias affecting many COVID-19 studies—eg, studies of patients admitted to hospital.21 Another strength is the use of the Swiss-SEP index, which has criterion validity, with mean household income continuously increasing from the lowest to highest SEP group, based on data from more than 1 million small neighbourhoods centred on individuals’ residences.6

We examined the association with SEP in three different populations: the general population, the population tested for SARS-CoV-2, and the group with positive tests. Associations were consistent across the three populations, except for the rate of positive tests in the population. The greater uptake of testing in higher SEP neighbourhoods masked the higher number of positive tests in those of lower SEP. The data also have weaknesses that limit interpretation. Each outcome is likely to be affected by some level of under-reporting, possibly creating bias if under-reporting is associated with SEP. However, individuals in lower SEP neighbourhoods might be more affected by under-reporting, meaning that our results would underestimate the association between SEP and test positivity, hospital admissions and deaths. The data on tests are limited by the absence of complete data on reasons for testing: the lower test positivity among young children could thus reflect that children were more likely to be tested for infection control rather than because of symptoms, compared with those in older age groups. Alternatively, the lower test positivity could indicate a lower susceptibility to SARS-CoV-2 infection in this age group. Not all notifications could be geocoded because of incomplete addresses. The Swiss-SEP index of retirement and nursing homes might not reflect the neighbourhood where residents spent most of their lives, thus misclassifying their SEP. This limitation might explain why the strength of the association increased when excluding deaths in residents of these institutions. Finally, the Swiss-SEP index is based on the 2000 census, although it continues to be strongly associated with income and mortality.22

Data on indicators of SEP are often not collected in clinical studies or routine surveillance systems. Khalatbari-Soltani and colleagues7 observed that, up to April, 2020, no study about COVID-19 had reported data on socioeconomic indicators such as educational level, income, or housing conditions.4 Since then, several studies have found associations between area-level deprivation and SARS-CoV-2 infection, increased severity of COVID-19 disease, and mortality.30-32,34 In common with these studies, our study used a small area-based measure of SEP. Area-based measures are more readily available than individual measures and have the advantage of capturing effects at the level of both the individual and the place. A seroprevalence study in the canton of Geneva, Switzerland, in 2020, did not find strong associations with individual-level indicators of social position, other than becoming unemployed.7 However, the study population was not representative of the population of Geneva, including many more individuals with tertiary education, fewer with mandatory school only, and fewer non-Swiss nationals compared with the general population.6 A Swedish study used individual-level data from population-based registers and found that people with lower income and level of education and immigrants from low-income or middle-income countries were at higher risk of death from COVID-19.2 Data on ethnicity are not recorded in the Swiss surveillance system, which is a weakness of our study. Of note, the proportion of non-White individuals in the Swiss population is less than 5%. A study of COVID-19 outcomes up to the end of 2020 in 17 million adults in England showed an increased risk of testing positive for SARS-CoV-2 and adverse outcomes in minority ethnic populations.34 A strength of both our study and the English study34 is that they covered the entire cascade from testing to mortality at the national level. Previous studies were often based on population surveys, with unequal participation across socioeconomic and ethnic groups.3,30,32,34

50 years ago, Tudor Hart proposed the inverse care law, which stipulates that “the availability of good medical care

<table>
<thead>
<tr>
<th>Unadjusted IRR per Swiss-SEP group increase (95% CrI)</th>
<th>Adjusted IRR per Swiss-SEP group increase (95% CrI)</th>
<th>Adjusted IRR comparing highest and lowest Swiss-SEP group (95% CrI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total tests*</td>
<td>Per population 1.02 (1.01–1.04)</td>
<td>1.02 (1.00–1.03)</td>
</tr>
<tr>
<td>Positive tests</td>
<td>Per population 0.99 (0.98–1.00)</td>
<td>0.99 (0.98–1.01)</td>
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<tr>
<td></td>
<td>Per total test* 0.97 (0.97–0.98)</td>
<td>0.97 (0.96–0.98)</td>
</tr>
<tr>
<td>Hospitalisations</td>
<td>Per population 0.94 (0.92–0.95)</td>
<td>0.94 (0.92–0.96)</td>
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<td></td>
<td>Per total test* 0.94 (0.92–0.95)</td>
<td>0.92 (0.91–0.94)</td>
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<td></td>
<td>Per positive test 0.96 (0.95–0.98)</td>
<td>0.96 (0.95–0.97)</td>
</tr>
<tr>
<td>ICU admissions</td>
<td>Per population 0.92 (0.89–0.94)</td>
<td>0.90 (0.87–0.93)</td>
</tr>
<tr>
<td></td>
<td>Per total test* 0.90 (0.87–0.93)</td>
<td>0.90 (0.88–0.93)</td>
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<td></td>
<td>Per positive test 0.93 (0.91–0.96)</td>
<td>0.93 (0.91–0.96)</td>
</tr>
<tr>
<td>Deaths</td>
<td>Per population 0.96 (0.93–0.99)</td>
<td>0.96 (0.92–1.01)</td>
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<td></td>
<td>Per total test* 0.98 (0.94–1.01)</td>
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<td>Per positive test 0.97 (0.95–1.00)</td>
<td>0.98 (0.97–1.00)</td>
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</tbody>
</table>

Three denominators were considered: population, total tests, and positive tests. CrI=credibility interval. IRR=incidence rate ratio. Swiss-SEP=Swiss neighbourhood index of socioeconomic position. *Data on total tests relate to the period May 23, 2020, to April 14, 2021, rather than the full study period from March 1, 2020, to April 14, 2021.

Table 2: Association of Swiss-SEP group with five outcomes related to SARS-CoV-2 surveillance and care
Articles

Deaths per positive test

June 8, 2020.

IRRs for COVID-19 deaths per positive test by age group, sex, and epidemic wave. IRR=incidence rate ratio.

(A) Adjusted IRRs per increase in group of neighbourhood SEP for COVID-19 deaths per population, per test, or per positive test in the baseline analysis or in sensitivity analyses: (1) excluding all cases geocoded from the postcode only and (2) excluding cases with a residential address corresponding to retirement or nursing homes. (B) Adjusted IRRs from sensitivity analyses

Figure 4: Adjusted IRRs from sensitivity analyses

(A) Adjusted IRRs per increase in group of neighbourhood SEP for COVID-19 deaths per population, per test, or per positive test in the baseline analysis or in sensitivity analyses: (1) excluding all cases geocoded from the postcode only and (2) excluding cases with a residential address corresponding to retirement or nursing homes. (B) Adjusted IRRs from sensitivity analyses

SEP=socioeconomic position. The first wave of infections was before June 8, 2020, and the second wave from June 8, 2020.

tends to vary inversely with the need for it in the population served.44 In 2000, Victora and colleagues29 proposed an analogous inverse equity hypothesis, which states that new health interventions are initially adopted by the wealthier segments of a population who have the least need. Our study bears out both hypotheses in the unique setting of a pandemic. Early diagnosis of SARS-CoV-2 infections and adequate initial management might improve the prognosis of individuals with COVID-19, whereas prognosis is worse in patients diagnosed late, with low oxygen saturation and signs of pneumonia.38 Rapid diagnosis and isolation are the key to preventing transmission; communities with higher testing levels will benefit from lower rates of transmission. The SARS-CoV-2 tests were a new technology and testing capacity was limited in Switzerland, particularly during the first wave of the pandemic. In both waves, testing was less intense in neighbourhoods of lower SEP. People living in these areas might have had less access to test centres because of reduced access to private transport or an inability to take time off work. Greater availability of testing and conditions that eased uptake in these areas could have improved outcomes and reduced transmission.

The higher rate of positive tests in neighbourhoods of lower SEP might reflect higher risks of SARS-CoV-2 infection at work and at home. People in manual occupations are unable to work from home and are likely to have more unprotected contacts with others, on building sites, or in factories compared with those who could work from home. At home, living conditions might also be more crowded in lower SEP areas than in higher SEP areas. A study from the USA used mobile phone data to show that the adoption of physical distancing was lower in counties with higher proportions of people below the poverty level.36 Detailed maps of the SEP of Swiss neighbourhoods have been published.46 Health policy measures should consider the susceptibility of different communities and prevent inequities in health and infection control. The Swiss National COVID-19 Science Taskforce recommended that, in this unpredictable crisis, the state should assume the role of insurer and cushion the negative effects with appropriate economic and social policies.47 Without such support, those affected will understandably not favour control measures that threaten their livelihoods.

Switzerland is one of the wealthiest countries globally, with wealth more unequally distributed than in other European countries—the Gini coefficient is estimated at 0·86 using 2015 tax data.33 Switzerland has a well developed health-care system and universally mandated health insurance, which in principle guarantees access to care for all. The Swiss health-care system has been described as providing a good balance between individual responsibility and community solidarity,48 but evidence exists that high out-of-pocket payments, including co-payments and deductibles, might prompt some individuals not to seek care. A survey in the canton of Geneva33 showed that up to 31% of respondents reported having foregone health care for economic reasons depending on income. In our study, Geneva was the canton with the strongest association between neighbourhood SEP and testing. Geneva also had the highest Gini index for wealth (0·92).49

In conclusion, this nationwide study found that people living in neighbourhoods of higher SEP are more likely to be tested in Switzerland but less likely to test positive, be hospitalised, or die, compared with those living in areas of lower SEP. The higher incidence of SARS-CoV-2 infections, combined with a higher prevalence of comorbidities in neighbourhoods of lower SEP compared with higher SEP is likely to have contributed to worse outcomes, including the higher risk of hospitalisation and death. By June 2021, vaccination coverage had increased considerably, with over 40% of the population having received at least one dose of SARS-CoV 2 vaccine, and the Government is gradually easing preventive measures. It is essential to continue to monitor testing for SARS-CoV-2, access and uptake of COVID-19 vaccination, and outcomes of COVID-19. Governments and health-care systems should address this pandemic of inequality by taking measures to reduce health inequalities in their response to the SARS-CoV-2 pandemic.46

Contributors
ME, JR, RP, NL, and CLA conceived the study. JR, RP, NL, and ME drafted the first version of the manuscript. JR and RP did all statistical analyses, DP, KS, and CJ managed the data at the Federal Office of Public Health. NGC programmed the geocoding routine, and RP assigned the values of the neighbourhood index of socio-economic position. JR and RP directly accessed and verified the aggregated
analysis dataset, and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors contributed to the interpretation of data and read and approved the final manuscript.

Declaration of interests
We declare no competing interests.

Data sharing
The data are accessible to researchers upon reasonable request for data sharing to the corresponding author. Requests for data need to be approved by the SFOPH. The code is available from https://github.com/jriou/covid-sep-ch.

Acknowledgments
This study would not have been possible without the extraordinary efforts of the data science team at the SFOPH: Samuel Colin, Jeffrey Keller, Anne Laube, Urs Mayr, and Serge Zaugg. We are also grateful to Thomas Van Breeschel and Carole Dupont for helpful comments on an earlier draft of this paper. This study was funded by the SFOPH and the Swiss National Science Foundation (189498). NL and CLA acknowledge funding from the EU’s Horizon 2020 research and innovation programme (project EpiloPse, 101003688). Nicola Criscuolo was supported by the Branco Weiss Foundation.

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