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Sociodemographic and socioeconomic disparities in COVID-19 vaccine uptake in Belgium: a nationwide record linkage study

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ABSTRACT

Background Recent studies have identified important social inequalities in SARS-CoV-2 infections and related COVID-19 outcomes in the Belgian population. The aim of our study was to investigate the sociodemographic and socioeconomic characteristics associated with the uptake of COVID-19 vaccine in Belgium.

Methods We conducted a cross-sectional analysis of the uptake of a first COVID-19 vaccine dose among 5 342 110 adults (≥18 years) in Belgium on 31 August 2021. We integrated data from four national data sources: the Belgian vaccine register (vaccination status), COVID-19 Healthdata (laboratory test results), DEMOBEL (sociodemographic/socioeconomic data) and the Common Base Register for HealthCare Actors (individuals licensed to practice a healthcare profession in Belgium). We used multivariable logistic regression analysis for identifying characteristics associated with not having obtained a first COVID-19 vaccine dose in Belgium and for each of its three regions (Flanders, Brussels and Wallonia).

Results During the study period, 10% (536 716/5 342 110) of the Belgian adult population included in our study sample was not vaccinated with a first COVID-19 vaccine dose. A lower COVID-19 vaccine uptake was found among young individuals, men, migrants, single parents, one-person households and disadvantaged socioeconomic groups (with lower levels of income and education, unemployed). Overall, the sociodemographic and socioeconomic disparities were comparable for all regions.

Conclusions The identification of sociodemographic and socioeconomic disparities in COVID-19 vaccination uptake is critical to develop strategies guaranteeing a more equitable vaccination coverage of the Belgian adult population.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ While previous studies have demonstrated that socioeconomically disadvantaged individuals are more likely to be infected with SARS-CoV-2 and to develop COVID-19 severe outcomes (eg, hospitalisation, death), the vaccine has proven to be effective in countering the transmission of the virus and the development of severe outcomes.

⇒ Most studies were focused on the socioeconomic disparities in COVID-19 vaccine hesitancy. The few studies focusing on socioeconomic disparities using actual COVID-19 vaccination coverage showed a lower COVID-19 vaccine uptake among socioeconomically disadvantaged groups.

WHAT THIS STUDY ADDS

⇒ Thanks to a unique individual data linkage allowing the use of a large and representative study population (N=5 342 110), a significant lower COVID-19 vaccination coverage was identified among socioeconomically disadvantaged groups in Belgium and within each Belgian region.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study identified social inequalities in COVID-19 vaccination coverage, highlighting the importance of strengthening vaccination strategies among disadvantaged socioeconomic groups whether in the context of the COVID-19 pandemic or potential future pandemics threatening population health and increasing social inequalities in health.

⇒ Future research on the factors underlying the refusal to be vaccinated in Belgium will help to better understand inequalities in the COVID-19 vaccination coverage and how to address them.

BACKGROUND

The presence of a social gradient in SARS-CoV-2 infections and subsequent COVID-19 outcomes has been clearly demonstrated through various international studies with a higher risk of getting infected and developing severe outcomes (eg, hospitalisation, death) among certain sociodemographic (SD) groups (eg, men, elderly, migrants) and socioeconomic (SE) disadvantaged groups.[1–3] In Belgium, the same patterns have been identified, whereby the most disadvantaged SE groups presented a higher incidence of SARS-CoV-2 infection as well as higher levels of excess mortality during the COVID-19 pandemic.[4–6]

Vaccination is a powerful public health instrument to decrease the transmission of the virus and

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lower the probability of developing severe COVID-19 health outcomes.[7 8] However, vaccine equity concerns remain as some studies have shown a lower COVID-19 vaccine uptake among SE disadvantaged groups.[9–11] The vaccine uptake is influenced by a range of factors, including vaccine accessibility, awareness (information about the disease and the vaccine) and willingness which can be influenced by the sociocultural environment, political and religious orientation, or pre-existing health needs.[12–14] Understanding the social patterns in COVID-19 vaccine uptake is crucial for future vaccination campaigns against COVID-19 or other vaccine-preventable infectious diseases and in the context of pandemic preparedness.

Belgium's nationwide vaccination campaign started on 28 December 2021, targeting first nursing home residents and staff, hospital-based and frontline health professionals, residents and staff of collective care facilities, individuals aged 65 and over, and individuals with comorbidities, before extending the vaccination campaign to all individuals aged 18 and over in order of decreasing age.[15 16] By 31 August 2021, 90% of the Belgian adult population invited for the vaccination had received the first COVID-19 vaccine dose. The objective of the present study was to investigate SD and SE disparities in the uptake of the first COVID-19 vaccine dose in the Belgian adult population.

METHODS

Study design and data sources

In this nationwide record linkage study, we investigated SD and SE disparities in the uptake of a first COVID-19 vaccine dose using data from the LINK-VACC project. LINK-VACC was set-up by Sciensano, the Belgian Institute of Health, and contains, within a pseudonymised environment, selected variables from multiple existing national health and social sector registers linked at an individual level using the Belgian social security number.[17 18] For the present study, four databases were used: (1) the Belgian vaccine register (Vaccinnet+), containing data on COVID-19 vaccine doses administered to Belgian residents as well as demographical data on the vaccinated person, (2) the COVID-19 Healthdata test database, containing data from COVID-19 laboratory tests performed in Belgium as well as demographical data on the tested person, (3) DEMODEL database provided by the Statistics Belgium (Statbel) containing variables related to SD and SE characteristics as well as information on the status in the national register, (4) the Common Base Register for HealthCare Actors (CoBRHA) allowing the identification of individuals licensed to practice a healthcare profession in Belgium.

Study population definition

The study population consists of all individuals residing in Belgium aged 18 and over tested at least once for COVID-19 (PCR and rapid antigen tests) before 31 August 2021, as recorded in the COVID-19 Healthdata test database (n=5 661 661). Thanks to an individual linkage with DEMOBEL, SD and SE data were available for 97.6% (n=5 525 634/5 661 661) of them. After this linkage, we excluded individuals who were deregistered, migrated and deceased based on their status in the national register available in DEMOBEL database as well as individuals with either age, sex or region unknown. Our final study population was composed of 5 342 110 adults (≥18 years) tested at least once in Belgium before 31 August 2021, for whom Vaccinnet+ was consulted in order to determine their vaccination status for a first COVID-19 vaccine dose. A flow chart demonstrating the process for selecting our final study population is available in figure 1.

Outcome

The outcome of this study was defined as the uptake of a first dose of any COVID-19 vaccine (approved by the European Union) between the start of the vaccination campaign (28 December 2020) and 31 August 2021. By this date, all individuals of 18 years and over officially residing in Belgium should have received an invitation to be vaccinated with a first dose and the opportunity to receive it. Figure 2 shows COVID-19 first-dose vaccination coverage over time by region and age group in Belgium. Moreover, administration of a first dose is a good predictor of a full primary course of vaccination, given that the proportion of individuals with a full primary course among those who received at least one dose is close to 100%.[19]

Covariates

To identify characteristics associated with the uptake of a first COVID-19 vaccine dose, we focused on several relevant SD and SE characteristics (online supplemental table 1). Age, sex and region of residence were available in Vaccinnet+ and COVID-19 Healthdata test database. Household type, migration background, income, education and employment status were available in DEMOBEL. Household type was divided in one-person households, couples without children, couples with children, single parents, collectivity (eg, prison, nursing homes) and other. Migration background was distinguished between Belgian natives, second-generation migrants, first generation European migrants and first-generation non-European migrants. Income was available as deciles of the net household income and was further categorised into low income (deciles 1–4), moderate income (deciles 5–7) and high income (deciles 8–10). Education was classified in eight categories using the International Standard Classification of Education (ISCED). We merged these different categories into three main education levels: low (ISCED0 to ISCED2), moderate (ISCED3 to ISCED4) and high (ISCED5 to ISCED8). The employment status was defined as employed or unemployed. Finally, we were able to determine whether individuals had a healthcare degree using a variable provided by CoBRHA. Missing SD or SE data were considered as a separate category as they were associated with certain SD and SE characteristics and not randomly distributed in the population (see online supplemental table 2).

Statistical analyses

For each SD and SE level, the number and proportion of first COVID-19 vaccine doses (not) administered were calculated. To compute adjusted odds ratios (ORs) and Wald 95% confidence intervals (CIs, we fitted a first logistic regression model including age, sex, region, migration background, household type and income as covariates. A second model was fitted only on individuals aged 25 and over adding education level and healthcare degree as additional covariates. Finally, a third model was fitted only on individuals aged between 25 and 65 adding employment status as additional covariate and removing income (highly correlated variables). Following the same procedures, we fitted logistic regression models stratified by regions (Flanders, Brussels, Wallonia) based on the individual postal code of residence, in view of the important differences in vaccination coverage between them (see table 1 and figure 2), and the responsibility of each regional health authority for the roll-out and practical implementation of the vaccination campaign.[15]

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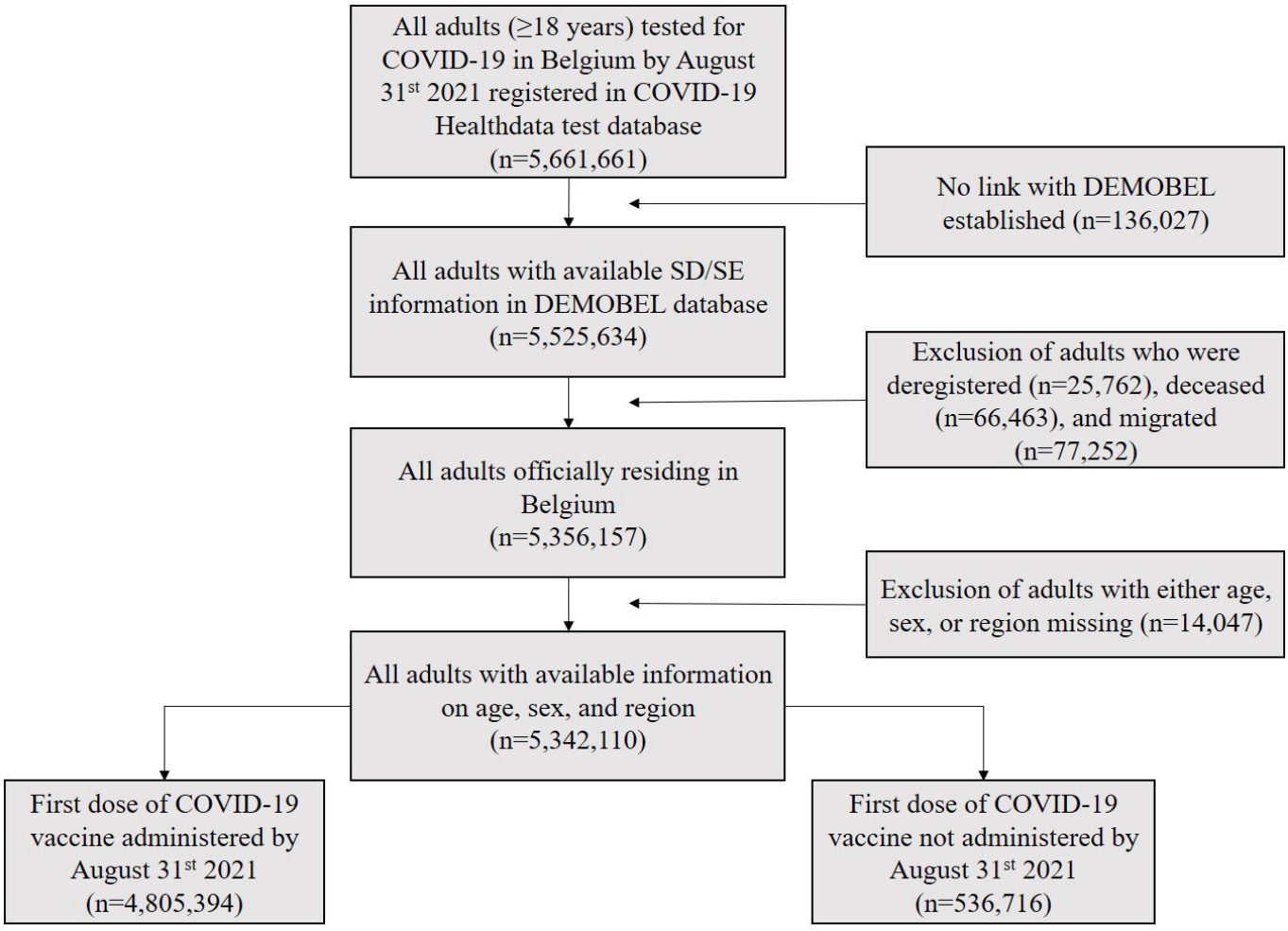

Figure 1 Flowchart of the study population based on the COVID-19 Healthdata test database, Belgium, 28 December 2020 to 31 August 2021. SD, sociodemographic; SE, socioeconomic.

We performed sensitivity analyses to determine whether adding interaction terms between region and each covariate of the model, instead of stratifying by region, had an influence on the results. To do this, we extracted and compared, for both methods, the conditional probabilities of not having obtained a first COVID-19 vaccine dose according to all SD and SE characteristics (online supplemental table 3).

All analyses were performed in R V.4.0.5.[20] The package 'Effects' was used to compute conditional probabilities.[21]

RESULTS

Descriptive statistics

The final analyses included 5 342 110 Belgian residents. By 31 August 2021, 89.95% of them received a first COVID-19 vaccine dose (table 1). The vaccination coverage was lower among young age groups, with 84.88% vaccinated among 18–24 years old compared with 97.06% vaccinated among 85 years old and over. The vaccination coverage was similar between males and females. The lowest vaccination coverage was observed in Brussels (78.02% vaccinated), compared with Flanders (92.83% vaccinated) and Wallonia (88.03% vaccinated). Second-generation migrants, first-generation European migrants and first-generation non-European migrants had a lower vaccination coverage (80.90%, 81.15%, 77.59% vaccinated, respectively), compared with Belgian natives (94.79% vaccinated). A lower vaccination coverage was observed among one-person households (89.52% vaccinated), couples with children (89.08% vaccinated) and single parents (84.50% vaccinated), compared with collectivities (96.59% vaccinated) and couples without children (94.44% vaccinated). The vaccination coverage was also lower among individuals with low education (89.15% vaccinated), low income (84.55% vaccinated) and without a healthcare degree (89.59% vaccinated), compared with individuals with high education (94.13% vaccinated), high income (94.94% vaccinated) and a healthcare degree (89.59% vaccinated). The vaccination coverage was similar between employed and unemployed individuals. Overall, the vaccination coverage was relatively low in categories with data indicated as missing: missing household type (76.91% vaccinated), missing education level (80.93% vaccinated), missing income (82.71% vaccinated), missing employment status (75.60% vaccinated).

Predictors of first dose of COVID-19 vaccine uptake

Multivariable model 1 (table 2), applied on all age groups, showed an age gradient in COVID-19 vaccination coverage from 25 to 84 years old: the younger the individuals were, the more likely they were to be unvaccinated (OR 5.49 (5.37–5.62) for 25–34 age group, compared with 75–84 age group). Men had a slightly lower COVID-19 vaccine uptake, compared with women (OR 1.05 (1.04–1.06)). Individuals with a migration background had higher odds of being unvaccinated, compared with Belgian natives (OR 2.25 (2.23–2.28) for second-generation migrants;

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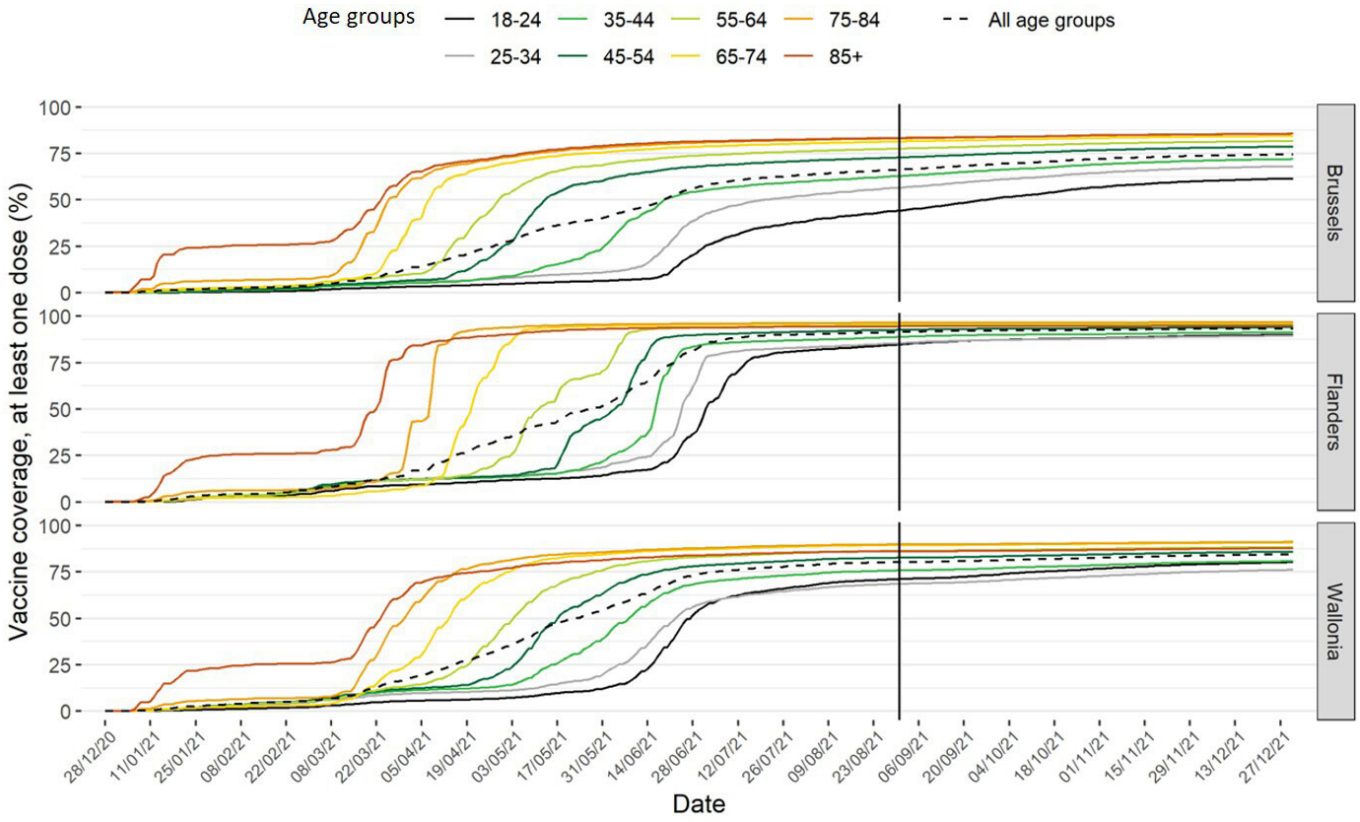

Figure 2 Vaccination coverage of a first dose of COVID-19 vaccine over time by age group and region, Belgium, 28 December 2020 to 27 December 2021.

OR 2.90 (2.88–2.93) for first-generation European migrants; OR 2.98 (2.95–3.00) for first-generation non-European migrants). Compared with couples with children, one-person households (OR 1.18 (1.17–1.19) and single parents (OR 1.27 (1.26–1.29)) had higher odds of being unvaccinated. Individuals with missing information on the household type had also higher odds of being unvaccinated (OR 1.04 (1.01–1.08)). A lower COVID-19 vaccine uptake was identified among individuals with low (OR 2.36 (2.34–2.38)), moderate (OR 1.54 (1.52–1.55)) or missing income (OR 1.93 (1.89–1.96)), compared with individuals with high income. In model 2 (table 2), a lower COVID-19 vaccine uptake was identified among individuals with a low (OR 1.37 (1.36–1.39)), moderate (OR 1.31 (1.30–1.32)) or missing (OR 1.19 (1.18–1.21)) education level, compared with individuals with a high education level. Not having a healthcare degree was associated with a lower COVID-19 vaccine uptake (OR 1.41 (1.39–1.43)). In model 3 (table 2), being unemployed was associated with a higher odd of being unvaccinated (OR 1.46 (1.45–1.47)) as well as having a missing employment status (OR 1.16 (1.13–1.18)), compared with being employed. Overall, similar patterns could be identified in all regions (online supplemental table 4). The crude ORs for the Belgian models and those stratified by regions can be found in online supplemental tables 5 and 6, respectively.

DISCUSSION

Although only 34% of the Belgian population stated that they were definitively ready to be vaccinated against COVID-19 before the start of the vaccination campaign, Belgium achieved the seventh highest vaccination coverage for the primary vaccination course in the European Union (with 89% of individuals over 18 years old having completed their primary course on 8 April 2022).[15 16 22] Nevertheless, despite this high rate and free vaccination, important SD and SE disparities in COVID-19 vaccination coverage remained. Indeed, our findings showed a lower COVID-19 vaccination coverage among young individuals, men, migrants, single parents, one-person households and disadvantaged SE groups (lower levels of income and education, unemployment). Similar patterns were observed within each Belgian region.

A Swedish study also found that COVID-19 vaccination coverage was lower among young individuals, with low income, living alone and born outside Sweden.[9] A Danish study identified a lower COVID-19 vaccination coverage among men, individuals living in more deprived areas or urban areas, and ethnic groups other than white.[23] In the USA, Williams *et al* found a lower COVID-19 vaccine uptake among young people, SE disadvantaged groups and all racial and ethnic minority groups (except for Asians). They highlighted that age and SE factors (such as health insurance, income, education, employment) accounted for a large proportion of the social disparities and are therefore important key factors.[10] Our findings also partially confirm those of Barry *et al* who identified a lower COVID-19 vaccination coverage among single parents and individuals living in counties with lower SE status and with a high percentage of households with children.[24] In the USA, Farah *et al* found a higher initial vaccination coverage among healthcare workers compared with the general population national average,[25] similar to our results. A cohort study conducted by Azamgarhi *et al* during a time of high community COVID-19 prevalence in the UK also reported high early vaccination rates among healthcare workers.[26]

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Table 1 Sociodemographic and socioeconomic characteristics of the population according to the uptake of a first dose of COVID-19 vaccine in Belgium, 28 December 2020 to 31 August 2021

Variables	All (n=5 342 110)	First dose administered by 31 August 2021 (n=4 805 394)	First dose not administered by 31 August 2021 (n=536 716)
	n ($\%_{column}$)	n ($\%_{row}$)	n ($\%_{row}$)
Age groups (years)			
18–24	645 416 (12.08)	547 826 (84.88)	97 590 (15.12)
25–34	1 051 576 (19.68)	886 846 (84.33)	164 730 (15.67)
35–44	978 478 (18.32)	857 111 (87.60)	121 367 (12.40)
45–54	903 514 (16.91)	827 999 (91.64)	75 515 (8.36)
55–64	797 786 (14.93)	752 601 (94.34)	45 185 (5.66)
65–74	511 784 (9.58)	492 092 (96.15)	19 692 (3.85)
75–84	296 974 (5.56)	288 939 (97.29)	8035 (2.71)
85+	156 582 (2.93)	151 980 (97.06)	4602 (2.94)
Regions			
Brussels	579 687 (10.85)	452 251 (78.02)	127 436 (21.98)
Flemish	3 348 547 (62.68)	3 108 510 (92.83)	240 037 (7.17)
Walloon	1 413 876 (26.47)	1 244 633 (88.03)	169 243 (11.97)
Sex			
Women	2 849 932 (53.35)	2 565 422 (90.02)	284 510 (9.98)
Men	2 492 178 (46.65)	2 239 972 (89.88)	252 206 (10.12)
Migration background			
Belgian natives	3 652 357 (68.37)	3 461 899 (94.79)	190 458 (5.21)
Second-generation migrants	324 420 (6.07)	262 465 (80.90)	61 955 (19.10)
First-generation European migrants	607 586 (11.37)	493 062 (81.15)	114 524 (18.85)
First-generation non-European migrants	757 747 (14.18)	587 968 (77.59)	169 779 (22.41)
Household type			
One-person households	878 506 (16.44)	786 400 (89.52)	92 106 (10.48)
Collectivity	96 213 (1.80)	92 929 (96.59)	3284 (3.41)
Couples without children	1 302 576 (24.38)	1 230 134 (94.44)	72 442 (5.56)
Couples with children	2 363 467 (44.24)	2 105 396 (89.08)	258 071 (10.92)
Single parents	548 369 (10.27)	463 386 (84.50)	84 983 (15.50)
Missing	26 752 (0.50)	20 574 (76.91)	6178 (23.09)
Other	126 227 (2.36)	106 575 (84.43)	19 652 (15.57)
Education level			
Low	1 567 744 (29.35)	1 397 598 (89.15)	170 146 (10.85)
Moderate	1 569 361 (29.38)	1 423 852 (90.73)	145 509 (9.27)
High	1 511 494 (28.29)	1 422 694 (94.13)	88 800 (5.87)
Missing	693 511 (12.98)	561 250 (80.93)	132 261 (19.07)
Income			
Low	1 815 339 (33.98)	1 534 829 (84.55)	280 510 (15.45)
Moderate	1 564 464 (29.29)	1 431 971 (91.53)	132 493 (8.47)
High	1 762 607 (32.99)	1 673 416 (94.94)	89 191 (5.06)
Missing	199 700 (3.74)	165 178 (82.71)	34 522 (17.29)
Healthcare degree			
Yes	423 852 (7.93)	398 902 (89.59)	24 950 (10.41)
No	4 918 258 (92.07)	4 406 492 (94.11)	511 766 (5.89)
Employment status			
Unemployed	1 874 544 (35.09)	1 695 122 (90.43)	179 422 (9.57)
Employed	3 364 795 (62.99)	3 032 575 (90.13)	332 220 (9.87)
Missing	102 771 (1.92)	77 697 (75.60)	25 074 (24.40)

n ($\%_{column}$): absolute number with percentage of the total population; n ($\%_{row}$): absolute number with percentage of the subgroup per sociodemographic and socioeconomic characteristics.

Prior to the implementation of COVID-19 vaccination, numerous studies examined SD and SE disparities in COVID-19 vaccine hesitancy and identified a higher vaccine hesitancy among females, parents, ethnic minorities and disadvantaged SE groups (ie, with lower levels of education and income, unemployment, and poor knowledge of COVID-19).[27–30] Our study partially supports these findings by showing lower vaccination coverage among migrants, single parents and SE disadvantaged groups. Although there may have been concerns about vaccination among healthcare workers, Wang *et al*[31] showed that they were less hesitant to be vaccinated, compared with non-healthcare workers, which is consistent with our findings.

Vaccine hesitancy in migrants and SE disadvantaged groups may be underlined by several factors: the more severe direct and indirect impact that the crisis has had on them (eg, higher rate of COVID-19 infection, subsequent negative health outcomes

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Table 2 Adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) for the association between sociodemographic and socioeconomic characteristics and the odds of not having received a first dose of COVID-19 vaccine, Belgium, 28 December 2020 to 31 August 2021

Variables	Model 1*	Model 2†	Model 3‡
	Adjusted OR (95% CI)	Adjusted OR (95% CI)	Adjusted OR (95% CI)
Age groups			
18–24	4.78 (4.66 – 4.89)	–	–
25–34	5.49 (5.37 – 5.62)	5.98 (5.84 – 6.12)	2.75 (2.71 – 2.78)
35–44	3.89 (3.80 – 3.99)	4.22 (4.12 – 4.32)	1.97 (1.94 – 1.99)
45–54	2.67 (2.60 – 2.73)	2.83 (2.76 – 2.90)	1.34 (1.32 – 1.36)
55–64	2.15 (2.10 – 2.21)	2.23 (2.18 – 2.29)	1.00
65–74	1.43 (1.40 – 1.47)	1.47 (1.43 – 1.51)	–
75–84	1.00	1.00	–
85+	1.19 (1.14 – 1.23)	1.15 (1.11 – 1.20)	–
Sex			
Women	1.00	1.00	1.00
Men	1.05 (1.04 – 1.06)	0.99 (0.98 – 1.00)	1.07 (1.06 – 1.07)
Regions			
Flemish	1.00	1.00	1.00
Brussels	1.80 (1.78 – 1.81)	1.76 (1.74 – 1.78)	1.77 (1.75 – 1.78)
Walloon	1.63 (1.62 – 1.64)	1.67 (1.66 – 1.68)	1.67 (1.66 – 1.68)
Migration background			
Belgian natives	1.00	1.00	1.00
Second-generation migrants	2.25 (2.23 – 2.28)	1.94 (1.91 – 1.96)	2.12 (2.09 – 2.15)
First-generation European migrants	2.90 (2.88 – 2.93)	2.64 (2.62 – 2.67)	3.10 (3.07 – 3.13)
First-generation non-European migrants	2.98 (2.95 – 3.00)	2.76 (2.73 – 2.78)	3.45 (3.42 – 3.48)
Household type			
Couples with children	1.00	1.00	1.00
Couples without children	0.88 (0.87 – 0.89)	0.84 (0.83 – 0.84)	0.83 (0.82 – 0.84)
Single parents	1.27 (1.26 – 1.29)	1.32 (1.30 – 1.33)	1.49 (1.47 – 1.51)
One-person households	1.18 (1.17 – 1.19)	1.17 (1.16 – 1.18)	1.26 (1.25 – 1.27)
Collectivity	0.63 (0.60 – 0.65)	0.61 (0.58 – 0.63)	0.53 (0.50 – 0.56)
Other	1.23 (1.21 – 1.25)	1.24 (1.22 – 1.26)	1.21 (1.19 – 1.23)
Missing	1.04 (1.01 – 1.08)	1.04 (1.00 – 1.08)	1.16 (1.13 – 1.18)
Income			
High	1.00	1.00	–
Moderate	1.54 (1.52 – 1.55)	1.44 (1.43 – 1.46)	–
Low	2.36 (2.34 – 2.38)	2.08 (2.06 – 2.10)	–
Missing	1.93 (1.89 – 1.96)	1.68 (1.65 – 1.71)	–
Education level			
High	–	1.00	–
Moderate	–	1.31 (1.30 – 1.32)	–
Low	–	1.37 (1.36 – 1.39)	–
Missing	–	1.19 (1.18 – 1.21)	–
Healthcare degree			
Yes	–	1.00	–
No	–	1.41 (1.39 – 1.43)	–
Employment status			
Employed	–	–	1.00
Unemployed	–	–	1.46 (1.45 – 1.47)
Missing	–	–	1.16 (1.13 – 1.18)

*Logistic regression model applied on all age groups (n=5 342 110). ORs are adjusted for age, sex, region, migration background, household type and income.
†Logistic regression model applied only to individuals aged over 25 years (n=4 696 694). ORs are adjusted for age, sex, region, migration background, household type, income, education level and healthcare degree.
‡Logistic regression model applied only to individuals aged 25 to 65 years (n=3 792 100). ORs are adjusted for age, sex, region, migration background, household type and employment status. Income being strongly correlated with employment status, OR are not adjusted for income when employment status is included in the model.

and unemployment) may have increased distrust of governments, healthcare systems and immunisation[2 3 32 33]; decreased willingness to participate in public health measures as a result of decreased access to healthcare and resources[33]; and raised concerns and negative assumptions about vaccination due to a lack of health literacy and recognition of misinformation, potentially accentuated by the rapid development of the COVID-19 vaccine which has led to a higher level of mistrust of its benefits and concerns about its side effects (the strongest predictors of COVID-19 vaccine uptake).[14 27 33–36] Other factors that may explain the disparities identified in COVID-19 vaccine uptake include administrative hurdles which can partly explain

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the lower coverage in some SE groups. Indeed, our results, demonstrating lower vaccine coverage among individuals with missing SD or SE information, may be indicative of a hard-to-reach population in the context of a broad automated invitation process. Language barriers may also be an obstacle to accessing COVID-19 vaccination information, primarily available in the Belgian official languages.

Our study has important strengths. First, to our knowledge, this is the first large representative study investigating, thanks to an individual data linkage established within the LINK-VACC project, SD and SE disparities in COVID-19 vaccination coverage in Belgium and all regions with up-to-date SD and SE information. Second, our study covered a significant timeframe, namely 8 months from the beginning of the vaccination campaign, which is sufficiently representative of the first vaccination campaign in Belgium. The data analysed therefore help understanding the combination of vaccine hesitancy and the gaps in the vaccination campaign (ie, failure in health communication, vaccine accessibility) that led to the SD and SE disparities identified in our study. Third, the lessons learned are essential for pandemic preparedness and future population-wide vaccination campaigns. The lessons can be extrapolated and used to improve routine adult vaccination campaigns, with targeted communications and awareness-raising initiatives aimed at groups with the lowest vaccine coverage. Fourth, the nationwide nature of the data makes the results generalisable at the country level.

Our study has several limitations. First, individuals never tested for COVID-19 before 31 August 2021 are not included in our study population. Indeed, because of the General Data Protection Regulation, individual's SD/SE information from the DEMOBEL database could not be obtained from the total Belgian population, the master database used for the linkage consists of the COVID-19 Healthdata test database obtained on 31 August 2021. This resulted in a slight over-representation of vaccinated individuals in our study population compared with the actual vaccination coverage in Belgium (90.0% vs 85.4%, respectively). However, despite this slight over-representation of vaccinated individuals in our study population, it should be pointed out that the trends in vaccination coverage per region, age group and sex are very similar to those of the overall Belgian adult population (see online supplemental figure 1). A second limitation is that our study sample does not include the unregistered population (eg, undocumented migrants, people staying in Belgium for a limited period of time), a group of about 100 000–150 000 individuals, as no information on this population was available in DEMOBEL. Third, Belgian residents vaccinated abroad (eg, frontier workers) are not automatically registered in Vaccinnet+. Fourth, we did not account for a potential confounding effect of having been infected prior to vaccination on vaccine uptake. It has been shown recently that having been infected prior to vaccination is related to a lower probability of being vaccinated.[37] Our sample includes individuals who tested both negative and positive and this may have introduced a confounding bias. However, it should be pointed out that testing positive prior to vaccination is not the most reliable indicator of prior infection, mainly because many infections went unidentified due to the scarcity of PCR tests during the early phases of the pandemic in Belgium.

Future research should be focused on SD and SE disparities in COVID-19 vaccination coverage among adolescents and children and on factors influencing the uptake of the boosters. Another perspective would be to investigate the factors underlying the refusal to be vaccinated to determine whether these inequities are based on personal convictions or inequity in the distribution of the vaccine.

In conclusion, despite the success of the vaccination campaign in Belgium (89% of adults vaccinated with primary course), free vaccination and the efforts made by the regional health authorities to reach all citizens, important SD and SE inequalities in COVID-19 vaccine uptake were identified. Our study contributes to a better identification of disparities in COVID-19 vaccination and helps to better target vaccination strategies to more vulnerable groups with the goal of acquiring the broadest possible vaccine coverage to limit the circulation of the virus and the development of severe negative health outcomes, whether in the context of the COVID-19 pandemic or other potential health threats.

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Contributors LCavillot reviewed the literature. LCavillot, JAFvL, BD, LVdB, NS, RDP, LCatteau and PH conceived the study. LCavillot, JAFvL, LVdB, RDP, LCatteau and PH selected the population. LCavillot and PH reviewed all available data. LCavillot, JAFvL, BD, LVdB, NS, RDP and PH designed the statistical methodology. LCavillot conducted the statistical analyses. LCavillot, JAFvL, LVdB, RDP and PH interpreted the findings. LCavillot and PH designed the figures. LCavillot wrote the first draft of the paper. All authors revised the text. LCavillot, JAFvL, MB, VS, LCatteau and PH have directly access to the data of the present study. LCavillot, JAFvL, MB, VS, LCatteau and PH have full access to all the data in the study. LCavillot and PH has verified the underlying data of the study. PH accepted the full responsability for the work and the conduct of the study, has access to the data, and controlled the decision to publish. All authors approved the final version of this manuscript and accepted responsibility for its submission for publication.

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Patient consent for publication Not applicable.

Ethics approval This study involves human participants and the protocol of the LINK-VACC project was approved by the Medical Ethics Committee from the Vrije Universiteit of Brussels on 3 February 2021 (B.U.N 1432020000371) and obtained authorisation from the Information Security Committee (ISC) Social Security and Health (reference number: IVC/KSZG/21/034). As confirmed by sections 23 and 24 of the Guidelines 03/2020 on the processing of data concerning health for the purpose of scientific research in the context of the COVID-19 outbreak of the European Data Protection Board (V1.0 of 21 April 2020), this survey falls under Article 6 §1(e) and Article 9 §2(i) of the General Data Protection Regulation (GDPR). In appliance with these GDPR legal grounds of data processing, no informed consent had to be signed by the patients.

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Data availability statement Data may be obtained from a third party and are not publicly available. Due to the General Data Protection Regulation (GDPR) legislations in Belgium, these data are not publicly available. Data request must be addressed to the Information Security Committee (ISC).

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