



SARS-CoV-2 vaccination uptake in six ethnic groups living in Amsterdam, the Netherlands: A registry-based study within the HELIUS cohort

Sophie L. Campman^{a,b,c,*}, Anders Boyd^{a,b,c,d}, Liza Coyer^{a,b,c}, Janke Schinkel^e, Charles Agyemang^{f,g}, Henrike Galenkamp^{f,h}, Anitra D.M. Koopman^{f,h}, Felix P. Chilunga^{f,h}, Maarten F. Schim van der Loeff^{a,b,c}, Lieke van Houtumⁱ, Tjalling Leenstra^{a,j}, Karien Stronks^{f,h}, Maria Prins^{a,b,c}

^a Department of Infectious Diseases, Public Health Service of Amsterdam, Amsterdam, the Netherlands

^b Amsterdam UMC location University of Amsterdam, Infectious Diseases, Meibergdreef 9, Amsterdam, the Netherlands

^c Amsterdam Institute for Infection and Immunity, Infectious Diseases, Amsterdam, the Netherlands

^d Stichting hiv monitoring, Amsterdam, the Netherlands

^e Amsterdam UMC location University of Amsterdam, Department of Medical Microbiology and Infection Prevention, Meibergdreef 15, Amsterdam, the Netherlands

^f Amsterdam UMC location University of Amsterdam, Department of Public and Occupational Health, Amsterdam, the Netherlands

^g Department of Medicine, Division of Endocrinology, Diabetes and Metabolism, Johns Hopkins University School of Medicine, Baltimore, MD, USA

^h Amsterdam Public Health, Health Behaviors and Chronic Diseases, Amsterdam, the Netherlands

ⁱ Department of Healthy Living, Public Health Service of Amsterdam, Amsterdam, the Netherlands

^j Centre for Infectious Disease Control, National Institute for Public Health and the Environment, Bilthoven, the Netherlands

ARTICLE INFO

Keywords:

HELIUS
SARS-CoV-2
COVID-19
Vaccination
Uptake
Ethnicity

ABSTRACT

Objective: Ethnic minority groups have experienced a disproportionate burden of COVID-19, and should therefore be especially encouraged to receive SARS-CoV-2 vaccination. This study compared first-dose uptake of the primary SARS-CoV-2 vaccination series across six ethnic groups in Amsterdam, the Netherlands in 2021.

Methods: We analyzed data from participants of the population-based HELIUS cohort. We linked their data to the SARS-CoV-2 vaccination registry data of the Public Health Service of Amsterdam. We included registry data from January 6, 2021 (the start of the Dutch vaccination campaign) until September 6, 2021 (a date by which all adults in the Netherlands could have received one or two vaccine doses). SARS-CoV-2 vaccination uptake was defined as having received at least one vaccine dose of the primary vaccination series. We examined the association between ethnicity and vaccination uptake using multivariable logistic regression, while accounting for the age and sex distribution of ethnic groups in Amsterdam.

Results: We included 19,006 participants (median age 53 years [interquartile range 41–62], 57% female). SARS-CoV-2 vaccination uptake was highest in the South-Asian Surinamese group (60.3%, 95%CI = 58.2–62.3%), followed by the Dutch (59.6%, 95%CI = 58.0–61.1%), Ghanaian (54.1%, 95%CI = 51.7–56.5%), Turkish (47.7%, 95%CI = 45.9–49.6%), African Surinamese (43.0%, 95%CI = 41.2–44.7%), and Moroccan (35.8%, 95%CI = 34.1–37.5%) groups. After adjusting for age, sex, perceived social support, and presence of relevant comorbidities, participants of African Surinamese, Ghanaian, Turkish and Moroccan origin were significantly less likely to be vaccinated than those of Dutch origin.

Conclusions: Prevention strategies should continue tailoring to specific ethnic groups to encourage vaccination uptake and reduce barriers to vaccination.

1. Introduction

Ethnic minority groups have been disproportionately affected by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the

causative agent of coronavirus disease 2019 (COVID-19), as they have experienced higher rates of infection, COVID-19-related hospitalization, intensive care unit admission, and mortality compared to the ethnic majority population (Irizar et al., 2023; Coyer et al., 2022a; Agyemang

* Corresponding author at: Nieuwe Achtergracht 100, 1018 WT Amsterdam, Netherlands.

E-mail address: scampman@ggd.amsterdam.nl (S.L. Campman).

<https://doi.org/10.1016/j.ypmed.2023.107822>

Received 5 September 2023; Received in revised form 1 December 2023; Accepted 11 December 2023

Available online 14 December 2023

0091-7435/© 2023 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

et al., 2021; Chilunga et al., 2023a). These disparities might be driven by ethnic differences in exposure to overcrowding (e.g., larger household size), occupational risk (e.g., over-representation in key worker occupations, reliance on public transportation), socioeconomic positions, and access to healthcare and health interventions (Coyer et al., 2022a; Katikireddi et al., 2021; Chilunga et al., 2023b); all of which might be exacerbated by systemic ethnic discrimination.

Vaccination against SARS-CoV-2 is one of the most important public health interventions to prevent infection and severe disease progression from COVID-19 (Haas et al., 2021). We have previously demonstrated that intent to vaccinate against SARS-CoV-2 was lower among five large ethnic minority groups (South-Asian Surinamese, African Surinamese, Ghanaian, Turkish, Moroccan) compared to individuals of Dutch ethnic origin in Amsterdam (Campman et al., 2023), a city where almost 60% of the population has a migration background (Research and Statistics. Bevolking naar migratieachtergrond, 2023). Likewise, studies from the United Kingdom (UK) and the United States (US) have identified hesitancy toward receiving SARS-CoV-2 vaccination (Hussain et al., 2022; Yasmin et al., 2021). This increased hesitancy toward vaccination could institute a major barrier to vaccination uptake.

Indeed, studies from the UK and US have shown lower uptake of SARS-CoV-2 vaccination among ethnic minority groups during their initial vaccination campaigns (Martin et al., 2021; Watkinson et al., 2022). Given the ethnic differences in vaccination intent in Amsterdam, the Netherlands, it could be assumed that these differences would also be apparent in vaccination uptake. However, the results from these studies cannot be directly extrapolated to the Netherlands as ethnic backgrounds and cultural histories of minority groups are different. Lower uptake of vaccination against infectious diseases included in the Dutch National Immunization Program has been previously reported in some ethnic minority groups compared to those of Dutch origin (de Munter et al., 2021; van Lier et al., 2014). SARS-CoV-2 vaccination might not be directly comparable to routine vaccinations, as it was implemented in the context of a pandemic and aimed at a broader target population. Therefore, there is a need to establish whether ethnic inequalities in vaccination uptake are present and to understand the potential mechanisms behind such inequalities.

This study then aimed to investigate first-dose uptake of SARS-CoV-2 vaccination of the primary vaccination series in six ethnic groups residing in Amsterdam, the Netherlands.

2. Methods

2.1. Study design and population

We used data from the Healthy Life in an Urban Setting (HELIUS) study, which is a population-based multi-ethnic prospective cohort study conducted in Amsterdam that focuses on the causes of potential ethnic disparities in cardiovascular disease, mental health, and infectious diseases. Detailed procedures have been previously described (Snijder et al., 2017). Briefly, HELIUS comprises 24,781 adult individuals of Dutch, Surinamese, Ghanaian, Turkish, and Moroccan origin living in Amsterdam, who were included between January 2011 and December 2015. Individuals were randomly sampled, stratified by ethnic origin, through the municipality register of Amsterdam, and invited to participate (Snijder et al., 2017; Stronks et al., 2009). This register contains data on country of birth of citizens and their parents, which we used to determine ethnic origin. We are aware that ethnicity is a complex and largely socially constructed concept that encompasses multiple dimensions, such as country of birth, language, religion, and culture. There might therefore be some heterogeneity within ethnic groups. However, the country of birth indicator, which is widely accepted for ethnic origin in the Netherlands, is more objective and stable over time compared to other indicators, and cross-validation studies have shown a high correlation between the country of birth indicator and self-identified ethnic group indicator among Turkish,

Moroccan and Surinamese people in the Netherlands (Stronks et al., 2009). We defined ethnic origin groups other than Dutch as: (1) the individual, and at least one parent, were not born in the Netherlands (first generation), and (2) the individual was born in the Netherlands, but both parents were not (second generation). People who are born in the same country might have a different ethnic background, which in the Dutch context is applicable to the Surinamese population (Snijder et al., 2017; Stronks et al., 2009). Hence, we further classified participants with a Surinamese background into African, South-Asian, Javanese or 'other' based on self-report. Participants completed a questionnaire and underwent physical examination during which biological samples were obtained. For this study, we excluded participants who did not complete both the physical examination and questionnaire at the HELIUS baseline visit. We also excluded individuals of unknown ethnic origin ($n = 43$), and individuals of Javanese Surinamese ($n = 217$), or other Surinamese ($n = 235$) origin due to relatively small sample sizes.

The HELIUS study was approved by the Academic Medical Center Ethical Review Board, and written informed consent was obtained from all participants (Snijder et al., 2017).

2.2. Data linkage

In the Netherlands, vaccination against SARS-CoV-2 became available on January 6, 2021. By the end of July 2021, all adults had had the opportunity to receive at least one vaccine dose, which was free of charge. Vaccination was largely offered by the Public Health Services, and for specific groups through general practitioners (GP) (e.g., those 60 to 64 years of age, those with limited mobility, and those with medical indications), institutional physicians (e.g., nursing homes and those with an intellectual disability living in residential care facilities) or hospitals (e.g., healthcare workers) (National Institute for Public Health and the Environment (RIVM), 2021a; National Institute for Public Health and the Environment (RIVM), 2021b).

HELIUS data were linked to SARS-CoV-2 testing and vaccination data registered by the Public Health Service of Amsterdam (GGD Amsterdam) in a database named CoronIT, while including registries dating from April 29, 2020 until September 6, 2021. More detailed information on the data linkage is described in Supplementary Methods A1. For this study, we included registry data from January 6, 2021 (i.e., the start of the Dutch vaccination campaign) until September 6, 2021 (i.e., a date by which all adults residing in the Netherlands had the opportunity to be vaccinated) (National Institute for Public Health and the Environment (RIVM), 2022). During this period, only vaccinations administered by the GGD Amsterdam were stored in the CoronIT database. Therefore, vaccinations administered by GPs and other institutions were not available for our analyses (approximately 8% and 6% of all vaccinations administered during this period in Amsterdam, respectively [S. Hahné & S. Lanooij, National Institute of Public Health and the Environment, personal communication, August 2023]). For this study, we assumed that all HELIUS participants who were not linked to CoronIT data had not been vaccinated against SARS-CoV-2, and had not been tested for SARS-CoV-2 by a health care provider using a Nucleic Acid Amplification Test (NAAT)-based assay.

2.3. Outcome

SARS-CoV-2 vaccination uptake was determined from CoronIT data and was defined as having received at least one successfully administered vaccine dose regardless of vaccine manufacturer (i.e., Pfizer, Moderna, AstraZeneca, or Janssen). We defined complete uptake of the primary vaccination series as having received two doses of Pfizer, Moderna or AstraZeneca, at least one dose of Janssen, or having a registered past infection and subsequently receiving at least one dose of any vaccine, based on the guidelines of the Dutch government (National Institute for Public Health and the Environment (RIVM), 2023).

2.4. Covariates

We selected *a priori* several putative determinants of SARS-CoV-2 vaccination uptake, which were related to specific dimensions of ethnicity, to pathways that might cause differential SARS-CoV-2 exposure, and to susceptibility to infection and disease (Katikireddi et al., 2021). We used the following data from the HELIUS baseline visit: socio-demographics (i.e., age [recalculated for age on May 1, 2021], sex, ethnicity), indicators for access to health (i.e., Dutch language proficiency, subjective health literacy), cultural orientation, perceived discrimination because of their background, social support, and comorbidities (i.e., cardiovascular disease [CVD], diabetes, asthma/Chronic Obstructive Pulmonary Disease, severe obesity [body mass index ≥ 40 kg/m²]). These comorbidities have been described as medical indications for severe illness in the Dutch COVID-19 vaccination guidelines, and individuals with these comorbidities were prioritized for vaccination (National Institute for Public Health and the Environment (RIVM), 2023; National Institute for Public Health and the Environment (RIVM), 2020). We combined the comorbidities and categorized them into having none, one, or at least two. More detailed information on the instruments used is described in Supplementary Methods A2.

We used the following data from the CoronIT database: SARS-CoV-2 test result (measured using a NAAT-based assay), testing date, vaccine name, whether the vaccine was actually administered, and vaccination date.

2.5. Statistical analysis

The percent of SARS-CoV-2 vaccination uptake was calculated per ethnic group and compared between ethnic groups using Pearson's χ^2 test. We modeled the probability of SARS-CoV-2 vaccination uptake in different ethnic groups using logistic regression. We calculated the univariable odds ratio (OR) and its 95% confidence interval (CI) comparing the odds of being vaccinated versus unvaccinated across ethnic groups. We then used a series of multivariable models to examine whether differences between ethnic groups remained while accounting for *a priori* selected determinants of vaccination uptake. In a first model (i.e., model 1), age and sex were included to understand the potential confounding bias induced by basic sociodemographic factors. We did not include educational level in our model, as ethnicity is already a social determinant and together with educational level would likely lead to collider bias on the association between ethnicity and vaccination uptake. In a second model (i.e., model 2), we additionally included perceived social support and presence of comorbidities. In a third model (i.e., model 3), we added the variables ever perceived discrimination, Dutch language proficiency, cultural orientation and health literacy to the variables in model 2, while excluding individuals of Dutch origin. These variables were added to assess the confounding bias induced by specific aspects related to ethnicity. We tested the interaction between all determinants and ethnic group in models 2 and 3, using separate models for each determinant, to assess whether the strength of association between determinant and vaccination uptake differed across ethnic groups.

In sensitivity analyses, we calculated the percent of complete uptake of the primary SARS-CoV-2 vaccination series per ethnic group, and assessed whether the association between ethnicity and vaccination uptake remained similar when using complete uptake of the primary vaccination series as the outcome. Additionally, we calculated the percent of SARS-CoV-2 vaccination uptake as well as the association between ethnicity and vaccination uptake among those <60 years old.

A *P*-value <0.05 was considered statistically significant. The percent of SARS-CoV-2 vaccination uptake and regression analyses were rendered representative of the population structure of Amsterdam, by assigning post-stratification weights corresponding to the distribution of age and sex in the specific ethnic groups in Amsterdam (Coyer et al., 2022b). All analyses were performed using STATA version 17.0 (College

Station, TX, USA).

3. Results

3.1. Description of the study population

Of the 24,781 individuals who participated in the HELIUS baseline study, 20,348 (82.1%) gave informed consent for data linkage to a health registry database, were alive on March 1, 2020, and thus were eligible for linkage. We excluded 1342 individuals, as they did not participate in the baseline physical examination or questionnaire, or were not of Dutch, South-Asian Surinamese, African Surinamese, Ghanaian, Turkish, or Moroccan origin. We analyzed data of 19,006 participants (Fig. 1).

Participant characteristics are shown in Table 1. Median age was 53 years (interquartile range [IQR] 41–62) and ranged between 23 and 80 years. The slight majority of the study population was female (56.9%). Participants of Ghanaian origin were the most likely to have difficulty with the Dutch language (83.3%) and the least likely to report adequate health literacy (64.7%). Participants of Turkish origin were the least likely to be classified as integrated into the host country (28.7% not integrated). The percentage of participants who ever had perceived discrimination because of their background was higher in ethnic minority groups (varying between 76.2% in the Ghanaian group and 88.7% in the African Surinamese) compared to the Dutch group (22.1%). The prevalence of having at least one comorbidity was higher in ethnic minority groups (varying between 22.3% in the Ghanaian group and 35.2% in the South-Asian Surinamese group) compared to the Dutch group (12.8%).

3.2. Ethnic variation in SARS-CoV-2 vaccination uptake

Of all included participants, 52.8% received at least one SARS-CoV-2 vaccine dose, and vaccination uptake differed significantly between ethnic groups (Table 1). Uncorrected vaccination uptake estimates per ethnic group and estimates accounting for the population structure of Amsterdam are shown in Fig. 2. Individuals of South-Asian Surinamese origin had the highest vaccination uptake (corrected percentage 60.3%, 95%CI = 58.2–62.3%), followed by the Dutch (59.6%, 95%CI = 58.0–61.1%), Ghanaian (54.1%, 95%CI = 51.7–56.5%), Turkish (47.7%, 95%CI = 45.9–49.6%), African Surinamese (43.0%, 95%CI = 41.2–44.7%), and Moroccan (35.8%, 95%CI = 34.1–37.5%) groups.

In univariable analysis, as well as the analysis adjusted for age and sex (model 1) and additionally for perceived social support and presence of comorbidities (model 2), participants of other than Dutch origin were significantly less likely to have SARS-CoV-2 vaccination uptake than those of Dutch origin, except for those of South-Asian Surinamese origin (Table 2). Results of sensitivity analyses are reported in Supplementary Results A1.

3.3. Determinants of SARS-CoV-2 vaccination uptake

Most participant characteristics slightly differed between those who were vaccinated versus unvaccinated (Table A1).

In both models 1 and 2, the odds of SARS-CoV-2 vaccination uptake generally increased significantly with age (Table A2). There were no statistically significant associations between sex, perceived social support, or presence of comorbidities (model 2) and vaccination uptake. In model 2, the strength of associations between age (*p* for interaction <0.001) or sex (*p* for interaction <0.001) and vaccination uptake significantly differed across ethnic groups. For instance, the odds of vaccination uptake generally increased more strongly with age in the groups of other than Dutch origin compared to those of Dutch origin (Table A3). Females were significantly less likely to be vaccinated than males in the Moroccan group, while they were more likely to be vaccinated in the Ghanaian group.

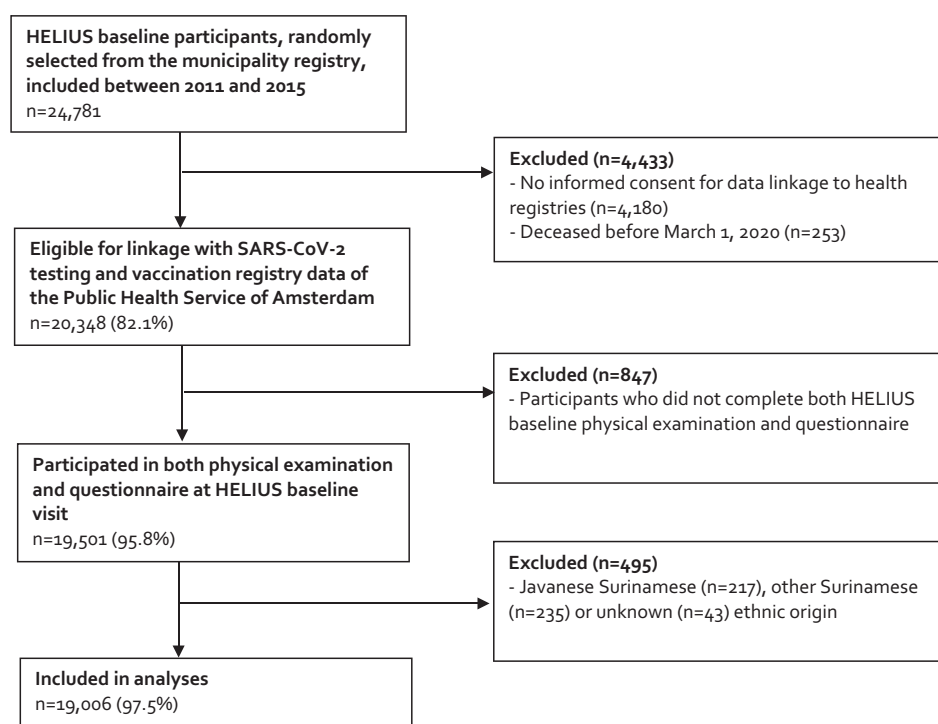


Fig. 1. Flowchart of the inclusion of HELIUS participants, Amsterdam, the Netherlands. Abbreviations: *HELIUS* Healthy Life in an Urban Setting; *SARS-CoV-2* Severe Acute Respiratory Syndrome Coronavirus 2.

When examining the additional determinants in model 3, being classified as less integrated versus more integrated in the host society was associated with lower vaccination uptake (Table A2). There were no significant associations between perceived discrimination, Dutch language proficiency, or health literacy and vaccination uptake. The association between cultural orientation (p for interaction = 0.027) and vaccination uptake was significantly different across the ethnic minority groups. Being classified as less integrated in the host society, compared to being classified as more integrated, was significantly associated with lower vaccination uptake in the African Surinamese, Turkish and Moroccan groups (Table A3).

4. Discussion

This analysis of a large multi-ethnic cohort shows that adults of four of five large ethnic minority groups in Amsterdam, the Netherlands, had a significantly lower SARS-CoV-2 vaccination uptake than those of Dutch origin. These findings remained when adjusting for age, sex, perceived social support, and presence of comorbidities. Of note, vaccination uptake, as analyzed in our study, covers the period from the beginning of the Dutch vaccination campaign until September 6, 2021 – a date by which all adults residing in the Netherlands could have had access to vaccination.

In Amsterdam, first-dose uptake of SARS-CoV-2 vaccination administered by the GGD Amsterdam by September 6, 2021 was estimated to be 66% among individuals aged 24 to 84 years, which excludes vaccinations administered by GPs and other institutions (approximately 14% of all vaccinations administered). More specifically, the uptake was lower in city districts where a large proportion of the population comprises people with a migration background from low and middle income countries (New-West and Southeast, estimated vaccination uptake 53% and 54%, respectively), compared to Amsterdam's other city districts (Center, West, South, East, and North, estimated between 61% and 71%), which is in line with the lower uptake we observed among the Ghanaian (54%), Turkish (48%), African Surinamese (43%), and Moroccan (36%) groups compared to the Dutch group (60%).

We previously investigated the intent to vaccinate against SARS-CoV-2 in a subgroup of individuals from the currently studied ethnic groups, and found that vaccination intent was remarkably lower in the ethnic minority groups compared to those of Dutch origin (Campman et al., 2023). Likewise, individuals of African Surinamese, Ghanaian, Turkish, and Moroccan origin were significantly less likely to actually receive a SARS-CoV-2 vaccine dose than those of Dutch origin. These findings mirror a UK study conducted in February 2021 among healthcare workers in which a lower SARS-CoV-2 vaccination uptake was observed in ethnic minority groups compared to the host population (Martin et al., 2021). It is worrying that the vaccination uptake is lower in ethnic minority groups, as they have generally been at higher risk of SARS-CoV-2 infection and severe disease outcomes (Irizar et al., 2023). Nevertheless, it is reassuring that vaccination uptake is not lower in all ethnic minority groups compared to the majority population – the uptake among individuals of South-Asian Surinamese origin was similar to those of Dutch origin, whereas their intent was lower. Exact reasons for this finding are unknown. Previous findings from the HELIUS study suggested lower healthcare usage in their country of origin among individuals of South-Asian Surinamese origin, and perhaps this ethnic group had more trust in the Dutch healthcare system as opposed to other ethnic groups (Şekercan et al., 2015).

SARS-CoV-2 vaccination uptake generally increased with age. For both age and sex, the strength and direction of associations with vaccination uptake varied across ethnic groups, indicating that interventions to encourage vaccination uptake should be tailored to the needs within demographic subgroups of specific ethnicities.

In the model where we only included participants of other than Dutch origin, we found that being classified as less integrated in the host society was associated with lower SARS-CoV-2 vaccination uptake. This aligns partly with previous studies where cultural alienation and marginalization, as well as discrimination (which was not significantly associated with vaccination uptake in our study), were found to promote vaccine hesitancy (Crawshaw et al., 2022). Other barriers to SARS-CoV-2 vaccination uptake that could be present in ethnic minority groups include concerns about vaccine effectiveness and safety, mistrust in the

Table 1
Characteristics of HELIUS participants ^a, per ethnic group, Amsterdam, the Netherlands.

Characteristic	Total (n = 19,006)	Dutch (n = 4230)	South-Asian Surinamese (n = 2734)	African Surinamese (n = 3620)	Ghanaian (n = 2085)	Turkish (n = 3075)	Moroccan (n = 3262)	P value
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Age in years, median [IQR] ^b	53 [41–62]	55 [41–65]	55 [43–64]	58 [48–65]	54 [46–61]	49 [38–57]	48 [37–58]	<0.001
Age in categories								<0.001
<30	1289 (6.8)	199 (4.7)	158 (5.8)	137 (3.8)	119 (5.7)	323 (10.5)	353 (10.8)	
30–34	1470 (7.7)	367 (8.7)	210 (7.7)	190 (5.3)	89 (4.3)	279 (9.1)	335 (10.3)	
35–39	1625 (8.6)	417 (9.9)	221 (8.1)	227 (6.3)	112 (5.4)	309 (10.1)	339 (10.4)	
40–44	1653 (8.7)	365 (8.6)	172 (6.3)	230 (6.4)	174 (8.4)	330 (10.7)	382 (11.7)	
45–49	1910 (10.1)	372 (8.8)	246 (9.0)	276 (7.6)	248 (11.9)	384 (12.5)	384 (11.8)	
50–54	2418 (12.7)	419 (9.9)	354 (13.0)	413 (11.4)	335 (16.1)	479 (15.6)	418 (12.8)	
55–59	2813 (14.8)	497 (11.8)	415 (15.2)	604 (16.7)	408 (19.6)	476 (15.5)	413 (12.7)	
60–64	2524 (13.3)	501 (11.8)	387 (14.2)	654 (18.1)	380 (18.2)	298 (9.7)	304 (9.3)	
65–69	1812 (9.5)	490 (11.6)	308 (11.3)	527 (14.6)	173 (8.3)	115 (3.7)	199 (6.1)	
≥70	1492 (7.9)	603 (14.3)	263 (9.6)	362 (10.0)	47 (2.3)	82 (2.7)	135 (4.1)	
Sex								<0.001
Male	8184 (43.1)	1966 (46.5)	1230 (45.0)	1436 (39.7)	816 (39.1)	1420 (46.2)	1316 (40.3)	
Female	10,822 (56.9)	2264 (53.5)	1504 (55.0)	2184 (60.3)	1269 (60.9)	1655 (53.8)	1946 (59.7)	
Education level								<0.001
No school/elementary school	3373 (17.9)	143 (3.4)	402 (14.8)	207 (5.8)	595 (29.0)	974 (32.0)	1052 (32.5)	
Lower vocational/lower secondary school	5005 (26.6)	602 (14.3)	931 (34.3)	1304 (36.4)	810 (39.5)	767 (25.2)	591 (18.3)	
Intermediate vocational/intermediate secondary school	5468 (29.0)	928 (22.0)	788 (29.0)	1282 (35.7)	516 (25.2)	873 (28.7)	1081 (33.4)	
Higher vocational/university	5000 (26.5)	2539 (60.3)	598 (22.0)	794 (22.1)	129 (6.3)	431 (14.2)	509 (15.7)	
Missing	160	18	15	33	35	30	29	
Difficulty with Dutch language								<0.001
No	12,699 (67.2)	4230 (100.0)	2067 (75.9)	3146 (87.3)	344 (16.7)	1209 (39.8)	1703 (52.5)	
Yes	6211 (32.9)	0	657 (24.1)	459 (12.7)	1721 (83.3)	1830 (60.2)	1544 (47.6)	
Missing	96	0	10	15	20	36	15	
Health literacy								<0.001
Adequate	16,138 (85.3)	4198 (99.3)	2527 (92.8)	3511 (97.2)	1336 (64.7)	2167 (71.0)	2399 (74.0)	
Low	2786 (14.7)	30 (0.7)	196 (7.2)	101 (2.8)	728 (35.3)	887 (29.0)	844 (26.0)	
Missing	82	2	11	8	21	21	19	
Cultural orientation ^c								<0.001
More integrated	15,995 (85.4)	4230 (100.0)	2330 (86.3)	3145 (88.0)	1539 (75.5)	2138 (71.3)	2613 (81.8)	
Less integrated	2741 (14.6)	0	371 (13.7)	430 (12.0)	499 (24.5)	860 (28.7)	581 (18.2)	
Missing	270	0	33	45	47	77	68	
Perceived discrimination								<0.001
Never	5737 (30.5)	3291 (78.0)	435 (16.0)	405 (11.3)	487 (23.8)	585 (19.3)	534 (16.5)	
Ever	13,099 (69.5)	931 (22.1)	2277 (84.0)	3181 (88.7)	1563 (76.2)	2445 (80.7)	2702 (83.5)	
Missing	170	8	22	34	35	45	26	
Social support								<0.001
Sufficient (regularly/often)	12,151 (65.1)	3250 (77.1)	1702 (63.0)	2449 (68.6)	1379 (68.5)	1433 (47.7)	1938 (61.1)	
Limited (never/seldom/now and then)	6526 (34.9)	968 (23.0)	1001 (37.0)	1119 (31.4)	634 (31.5)	1572 (52.3)	1232 (38.9)	
Missing	329	12	31	52	72	70	92	
Diabetes mellitus								<0.001
No	16,833 (89.0)	4061 (96.4)	2185 (80.2)	3158 (87.9)	1826 (88.1)	2734 (89.5)	2869 (88.2)	
Yes	2076 (11.0)	151 (3.6)	541 (19.9)	433 (12.1)	246 (11.9)	322 (10.5)	383 (11.8)	
Missing	97	18	8	29	13	19	10	
BMI (in kg/m ²), median [IQR]	26.4 [23.4–30.0]	24.1 [21.9–26.8]	25.8 [23.2–28.9]	27.1 [24.0–30.9]	27.9 [25.0–31.1]	28.0 [24.7–31.7]	27.1 [24.0–30.9]	<0.001
<25	7301 (38.5)	2525 (59.7)	1165 (42.6)	1189 (32.9)	522 (25.1)	823 (26.8)	1077 (33.0)	
25–29.9	6875 (36.2)	1272 (30.1)	1040 (38.1)	1339 (37.1)	856 (41.1)	1151 (37.5)	1217 (37.3)	
30–39.9	4401 (23.2)	403 (9.5)	489 (17.9)	969 (26.8)	659 (31.6)	980 (31.9)	901 (27.6)	
≥40	412 (2.2)	27 (0.6)	38 (1.4)	116 (3.2)	46 (2.2)	119 (3.9)	66 (2.0)	
Missing	17	3	2	7	2	2	1	
Cardiovascular disease								<0.001
No	16,819 (89.0)	4047 (95.8)	2321 (85.3)	3218 (89.3)	1873 (91.2)	2554 (83.8)	2806 (86.4)	
Yes	2082 (11.0)	179 (4.2)	399 (14.7)	387 (10.7)	180 (8.8)	495 (16.2)	442 (13.6)	
Missing	105	4	14	15	32	26	14	
Asthma/COPD								<0.001
No	17,964 (94.5)	4006 (94.7)	2535 (92.7)	3443 (95.1)	2031 (97.4)	2857 (92.9)	3092 (94.8)	
Yes	1042 (5.5)	224 (5.3)	199 (7.3)	177 (4.9)	54 (2.6)	218 (7.1)	170 (5.2)	
Number of comorbidities ^d								<0.001
0	14,078 (74.7)	3670 (87.2)	1759 (64.8)	2641 (73.6)	1569 (76.7)	2103 (69.0)	2336 (71.9)	
1	4015 (21.3)	497 (11.8)	760 (28.0)	788 (22.0)	429 (21.0)	763 (25.0)	778 (24.0)	
≥2	760 (4.0)	43 (1.0)	197 (7.3)	158 (4.4)	47 (2.3)	182 (6.0)	133 (4.1)	
Missing	153	20	18	33	40	27	15	

(continued on next page)

Table 1 (continued)

Characteristic	Total (n = 19,006)	Dutch (n = 4230)	South-Asian Surinamese (n = 2734)	African Surinamese (n = 3620)	Ghanaian (n = 2085)	Turkish (n = 3075)	Moroccan (n = 3262)	P value
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
SARS-CoV-2 testing history ^a								<0.001
Never tested	10,404 (54.7)	2192 (51.8)	1418 (51.9)	2014 (55.6)	1583 (75.9)	1494 (48.6)	1703 (52.2)	
Tested, never positive	5999 (31.6)	1731 (40.9)	928 (33.9)	1123 (31.0)	362 (17.4)	963 (31.3)	892 (27.4)	
Tested, ever positive	2603 (13.7)	307 (7.3)	388 (14.2)	483 (13.3)	140 (6.7)	618 (20.1)	667 (20.5)	
SARS-CoV-2 vaccination uptake (primary series) ^f								<0.001
Unvaccinated	8973 (47.2)	1656 (39.1)	1013 (37.1)	1920 (53.0)	898 (43.1)	1458 (47.4)	2028 (62.2)	
Partly vaccinated ^g	970 (5.1)	171 (4.0)	139 (5.1)	188 (5.2)	138 (6.6)	186 (6.0)	148 (4.5)	
Completely vaccinated ^h	9063 (47.7)	2403 (56.8)	1582 (57.9)	1512 (41.8)	1049 (50.3)	1431 (46.5)	1086 (33.3)	
At least one dose administered ⁱ	10,033 (52.8)	2574 (60.9)	1721 (62.9)	1700 (47.0)	1187 (56.9)	1617 (52.6)	1234 (37.8)	

Abbreviations: *HELIUS* Healthy Life in an Urban Setting; *IQR* interquartile range; *BMI* Body mass index; *COPD* Chronic obstructive pulmonary disease; *SARS-CoV-2* Severe Acute Respiratory Syndrome Coronavirus 2.

^a Characteristics were measured at baseline (2011–2015), except SARS-CoV-2 testing history (2020–2021) and vaccination uptake (2021).

^b Age was recalculated to age on May 1, 2021.

^c Participants were classified as being more integrated into the host society when not applicable (Dutch ethnic origin) or when measured to be integrated or assimilated; participants were classified as less integrated when measured to be separated or marginalized, according to Berry's acculturation strategies (reference: Berry JW. Immigration, Acculturation, and Adaptation. *Applied Psychol: An International Review* 1997;46:5–68).

^d Comorbidities include cardiovascular disease, diabetes, asthma/Chronic Obstructive Pulmonary Disease, and body mass index ≥ 40 kg/m².

^e SARS-CoV-2 testing history includes data registered by the Public Health service of Amsterdam between April 29, 2020 and September 6, 2021. Nucleic Acid Amplification Test-based assays were used to detect SARS-CoV-2. This was conducted by a testing center affiliated with the Public Health Service of Amsterdam.

^f Uptake of SARS-CoV-2 in the primary series among *HELIUS* participants, as registered by the Public Health Service of Amsterdam, including data registered between January 6, 2021 and September 6, 2021.

^g Partly vaccinated was defined as having received one dose of Pfizer, Moderna, or AstraZeneca, without evidence of testing positive for SARS-CoV-2 before administration of vaccine.

^h Completely vaccinated was defined as having received two doses of Pfizer, Moderna, or AstraZeneca, at least one dose of Janssen, or having a registered past infection and subsequently administration of at least one dose of any vaccine.

ⁱ Partly and completely vaccinated combined.

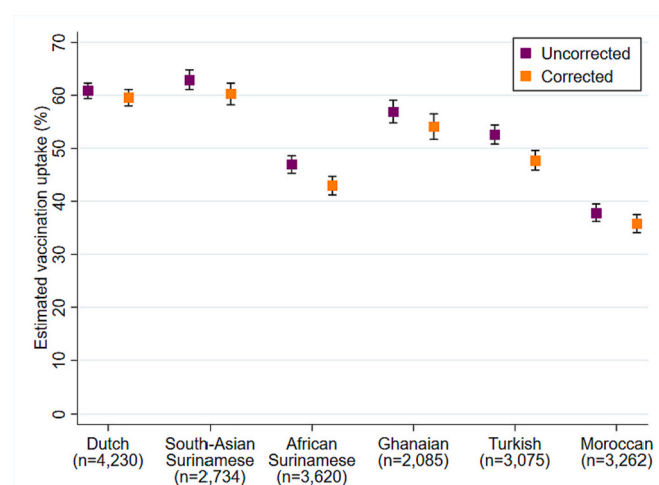


Fig. 2. Uncorrected and corrected uptake of at least one SARS-CoV-2 vaccine dose in the primary vaccination series among *HELIUS* participants, as registered by the Public Health Service of Amsterdam, per ethnic group, Amsterdam, the Netherlands, January 6, 2021 - September 6, 2021 (n = 19,006). Boxes represent the estimated vaccination uptake, bands the corresponding 95% confidence interval. Corrected uptake estimates account for age and sex distribution of the Amsterdam population through post-stratification weights. Abbreviations: *SARS-CoV-2* Severe Acute Respiratory Syndrome Coronavirus 2; *HELIUS* Healthy Life in an Urban Setting.

government and health systems, and misinformation (Crawshaw et al., 2022; Abba-Aji et al., 2022; Antwi-Berko et al., 2022).

It should be mentioned that ethnic disparities in vaccination uptake and structural barriers to uptake are not exclusive to SARS-CoV-2 and might be driven by underlying systemic ethnic discrimination (Katikireddi et al., 2021; Crawshaw et al., 2022). These barriers might be

difficult to address in public health campaigns, which makes it challenging to close the gap in access to care and prevention activities, and to implement targeted interventions to encourage vaccination uptake. It is, however, crucial to put effort into addressing underlying structural disadvantages among ethnic minority groups, as this could help promote vaccination in general. During the pandemic, the GGD Amsterdam deployed various tailored interventions to encourage vaccination uptake among ethnic minority groups, including collaboration with trusted community sources (e.g., religious leaders), provision of accessible and comprehensive information on vaccination in native languages, and removal of practical barriers to vaccination (e.g., using mobile vaccination units). Nevertheless, it remains imperative to explore whether structural barriers to vaccination, such as institutional mistrust, are more apparent in certain demographic subgroups (i.e., ethnic groups, age and gender identity groups), whether reasons of mistrust can be elucidated in different groups, and especially how policy makers and healthcare workers can better serve different groups with prevention activities. Communities should then be involved in co-creating interventions in order to properly act upon their needs regarding mistrust, concerns, barriers, and information and dissemination strategies.

This study has provided valuable insight into SARS-CoV-2 vaccination uptake in the ethnically diverse population of Amsterdam, the Netherlands. However, there were some limitations. First, data on vaccinations administered by GPs, other institutions and other Public Health Services than the GGD Amsterdam were unavailable to us, so some participants were likely misclassified as unvaccinated. Data could have been lacking particularly for those aged 60 to 64 years as vaccination was mainly offered by their GPs. We indeed found a substantially lower proportion of participants who received vaccination among 60-to-64-year-olds compared to the other age groups. Additionally, eligibility for vaccination by their GP was probably higher in ethnic minority groups compared to individuals of Dutch origin as the prevalence of comorbidities in under 60-year-old individuals is higher in these groups (data not shown). Therefore, differences in vaccination uptake between

Table 2

Ethnic variation in SARS-CoV-2 vaccination uptake in the primary vaccination series^a among HELIUS participants, Amsterdam, the Netherlands, January 6, 2021 – September 6, 2021^b.

	Univariable model (n = 19,006)		Multivariable model 1 (n = 19,006)		Multivariable model 2 (n = 18,534)	
	OR (95%CI)	P value	aOR (95%CI)	P value	aOR (95%CI)	P value
Ethnicity						
Dutch	Ref	Ref	Ref	Ref	Ref	Ref
South-Asian Surinamese	1.03 (0.92–1.15)	0.591	1.07 (0.95–1.21)	0.264	1.08 (0.96–1.23)	0.201
African Surinamese	0.51 (0.46–0.56)	<0.001	0.48 (0.43–0.53)	<0.001	0.48 (0.44–0.54)	<0.001
Ghanaian	0.80 (0.71–0.90)	<0.001	0.84 (0.74–0.96)	0.010	0.85 (0.74–0.97)	0.017
Turkish	0.62 (0.56–0.68)	<0.001	0.66 (0.59–0.73)	<0.001	0.67 (0.60–0.76)	<0.001
Moroccan	0.38 (0.34–0.42)	<0.001	0.37 (0.33–0.41)	<0.001	0.37 (0.33–0.41)	<0.001

Abbreviations: SARS-CoV-2 Severe Acute Respiratory Syndrome Coronavirus 2; HELIUS Healthy Life in an Urban Setting; OR Odds ratio; aOR Adjusted odds ratio; CI Confidence interval; Ref Reference category.

^a Received at least one SARS-CoV-2 vaccine dose, as registered by the Public Health Service of Amsterdam.

^b Analyses were performed using logistic regression. All models account for age and sex distribution of the Amsterdam population through post-stratification weights. Model 1: adjusted for age, sex. Model 2: adjusted for age, sex, perceived social support, having comorbidities. Comorbidities include cardiovascular disease, diabetes, asthma/Chronic Obstructive Pulmonary Disease, and body mass index ≥ 40 kg/m².

the Dutch and ethnic minority groups might be slightly overestimated in our study. As data stratified on specific ethnic groups are unavailable on the location of vaccination, the extent of this bias cannot be inferred. Nevertheless, other data from the Netherlands have consistently shown differences in vaccine uptake according to migration background or ethnicity (Pijpers et al., 2023; Labuschagne et al., 2023). Our conclusions would be consistent with these previous studies. Second, we only had data available on vaccinations administered in the first eight months after the start of the national vaccination campaign. The proportion of vaccinated people might have changed following the shifts in SARS-CoV-2 variants and perceived threat and additional measures nationwide occurring after this date (i.e., a “COVID Certificate”, showing vaccinated, tested or recovered from SARS-CoV-2 status, which became mandatory at the end of September 2021). Such changes in e.g., perceptions and measures might have led to delayed vaccination uptake, so it would be interesting to explore differences in vaccination uptake between ethnic groups over a longer period, including the difference in time to vaccination uptake. Our findings might not relate to ongoing booster vaccination, which merits further exploration. Finally, changes may have occurred in measured psychosocial, access-to-healthcare indicators, cultural orientation, and comorbidity variables since the baseline visit of the HELIUS study (i.e., 2011–2015). These covariates might not fully capture their status at the time of the SARS-CoV-2 vaccination program.

In conclusion, SARS-CoV-2 vaccination uptake was lower among those of African Surinamese, Ghanaian, Turkish and Moroccan ethnic origin compared to people of Dutch origin in Amsterdam, the Netherlands. Prevention strategies should therefore continue to support and encourage SARS-CoV-2 vaccination uptake in Amsterdam, especially in ethnic groups where the uptake remained lower. Prevention activities for future vaccination campaigns should continue (1) to reduce barriers by ensuring the provision of clear, culturally appropriate, evidence-based informational materials and communication in native languages; (2) to strengthen collaborations with trusted networks, such as community leaders; (3) to engage communities in identifying structural barriers toward vaccination (e.g., institutional mistrust and safety concerns) and co-creating interventions aimed at reducing such barriers; and (4) to closely monitor vaccination and booster uptake to identify demographic groups where prevention efforts are most needed (Hussain et al., 2022). Not only can such efforts contribute to limiting severe COVID-19 outcomes, but they might also guide future vaccination campaigns in infectious disease control.

Authors contributions

MP, KS, JS and CA conceived, designed, or oversaw the study. HG, AK, JS, SC and LC were involved in the acquisition of data. SC conducted

the statistical analysis and drafted the manuscript under the supervision of AB and MP. All authors read and approved the final manuscript.

Funding

This work was supported by ZonMw (10430022010002) and the (Public Health Service of Amsterdam Research and Development 2021 75722692, Public Health Laboratory grant 2022). The HELIUS study is conducted by Amsterdam UMC, location Academic Medical Center and the Public Health Service of Amsterdam. Both organizations provided core support for HELIUS. The HELIUS study is also funded by the Dutch Heart Foundation (2010T084), ZonMw (200500003), the European Union (FP-7) (278901), and the European Fund for the Integration of non-EU immigrants (EIF) (2013EIF013).

CRediT authorship contribution statement

Sophie L. Campman: Formal analysis, Writing – original draft. **Anders Boyd:** Methodology, Supervision, Writing – review & editing. **Liza Coyer:** Data curation, Writing – review & editing. **Janke Schinkel:** Conceptualization, Data curation, Writing – review & editing. **Charles Agyemang:** Conceptualization, Data curation, Funding acquisition, Writing – review & editing. **Henrike Galenkamp:** Data curation, Writing – review & editing. **Anitra D.M. Koopman:** Data curation, Writing – review & editing. **Felix P. Chilunga:** Writing – review & editing. **Maarten F. Schim van der Loeff:** Writing – review & editing. **Lieke van Houtum:** Writing – review & editing. **Tjalling Leenstra:** Writing – review & editing. **Karien Stronks:** Conceptualization, Data curation, Funding acquisition, Writing – review & editing. **Maria Prins:** Conceptualization, Data curation, Funding acquisition, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data requests can be submitted to the steering committee of the HELIUS study.

Acknowledgments

The authors would like to acknowledge the HELIUS study participants for their contribution, the HELIUS team for data collection and

management, and the data team of the Public Health Service of Amsterdam for providing data and assisting in the linkage process. In addition, the authors would like to thank Emiel Koene (data team, Public Health Service of Amsterdam), Susan Lanooij and Susan Hahné (National Institute of Public Health and the Environment) for providing data and input on the SARS-CoV-2 vaccination uptake in Amsterdam.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ypmed.2023.107822>.

References

- Abba-Aji, M., Stuckler, D., Galea, S., McKee, M., 2022. Ethnic/racial minorities' and migrants' access to COVID-19 vaccines: a systematic review of barriers and facilitators. *J. Migration Health*, 100086. <https://doi.org/10.1016/j.jmh.2022.100086>.
- Agyemang, C., Richters, A., Jolani, S., Hendriks, S., Zalpuri, S., Yu, E., et al., 2021. Ethnic minority status as social determinant for COVID-19 infection, hospitalisation, severity, ICU admission and deaths in the early phase of the pandemic: a meta-analysis. *BMJ Glob. Health* 6 (11), e007433. <https://doi.org/10.1136/bmjgh-2021-007433>.
- Antwi-Berko, D., Bakuri, A.Z., Otobil, K.B., Kwarteng, A., 2022. Determinants and variations of COVID-19 vaccine uptake and responses among minority ethnic groups in Amsterdam, the Netherlands: a cross-sectional analysis of the HELIUS study. *Vaccine*. <https://doi.org/10.1016/j.vaccine.2023.02.030>.
- Chilunga, F.P., Stoeldraijer, L., Agyemang, C., Stronks, K., Harmsen, C., Kunst, A.E., 2023a. Inequalities in COVID-19 deaths by migration background during the first wave, interwave period and second wave of the COVID-19 pandemic: a closed cohort study of 17 million inhabitants of the Netherlands. *J. Epidemiol. Community Health* 77 (1), 9–16. <https://doi.org/10.1136/jech-2022-219521>.
- Chilunga, F.P., Campman, S., Galenkamp, H., Boyd, A., Bolijn, R., Leenstra, T., et al., 2023b. Relative contributions of pre-pandemic factors and intra-pandemic activities to differential COVID-19 risk among migrant and non-migrant populations in the Netherlands: lessons for future pandemic preparedness. *Int. J. Equity Health* 22 (1), 127.
- Coyer, L., Boyd, A., Schinkel, J., Agyemang, C., Galenkamp, H., Koopman, A.D., et al., 2022a. Differences in SARS-CoV-2 infections during the first and second wave of SARS-CoV-2 between six ethnic groups in Amsterdam, the Netherlands: a population-based longitudinal serological study. *Lancet Regional Health Eur.* 13, 100284. <https://doi.org/10.1016/j.lanep.2021.100284>.
- Coyer, L., Boyd, A., Schinkel, J., Agyemang, C., Galenkamp, H., Koopman, A.D., et al., 2022b. SARS-CoV-2 antibody prevalence and correlates of six ethnic groups living in Amsterdam, the Netherlands: a population-based cross-sectional study, June–October 2020. *BMJ Open* 12 (1), e052752. <https://doi.org/10.1136/bmjopen-2021-052752>.
- Crawshaw, A.F., Farah, Y., Deal, A., Rustage, K., Hayward, S.E., Carter, J., et al., 2022. Defining the determinants of vaccine uptake and undervaccination in migrant populations in Europe to improve routine and COVID-19 vaccine uptake: a systematic review. *Lancet Infect. Dis.* [https://doi.org/10.1016/S1473-3099\(22\)00066-4](https://doi.org/10.1016/S1473-3099(22)00066-4).
- de Munter, A., Klooster, T., van Lier, A., Akkermans, R., de Melker, H., Ruijs, W., 2021. Determinants of HPV-vaccination uptake and subgroups with a lower uptake in the Netherlands. *BMC Public Health* 21 (1), 1–13. <https://doi.org/10.1186/s12889-021-11897-0>.
- Haas, E.J., Angulo, F.J., McLaughlin, J.M., Anis, E., Singer, S.R., Khan, F., et al., 2021. Impact and effectiveness of mRNA BNT162b2 vaccine against SARS-CoV-2 infections and COVID-19 cases, hospitalisations, and deaths following a nationwide vaccination campaign in Israel: an observational study using national surveillance data. *Lancet* 397 (10287), 1819–1829. [https://doi.org/10.1016/S0140-6736\(21\)00947-8](https://doi.org/10.1016/S0140-6736(21)00947-8).
- Hussain, B., Latif, A., Timmons, S., Nkhoma, K., Nellums, L.B., 2022. Overcoming COVID-19 vaccine hesitancy among ethnic minorities: a systematic review of UK studies. *Vaccine*. <https://doi.org/10.1016/j.vaccine.2022.04.030>.
- Irizar, P., Pan, D., Kapadia, D., Bécares, L., Sze, S., Taylor, H., et al., 2023. Ethnic inequalities in COVID-19 infection, hospitalisation, intensive care admission, and death: a global systematic review and meta-analysis of over 200 million study participants. *EclinicalMedicine*. <https://doi.org/10.1016/j.eclinm.2023.101877>.
- Katikireddi, S.V., Lal, S., Carrol, E.D., Niedzwiedz, C.L., Khunti, K., Dundas, R., et al., 2021. Unequal impact of the COVID-19 crisis on minority ethnic groups: a framework for understanding and addressing inequalities. *J. Epidemiol. Community Health* 75 (10), 970–974. <https://doi.org/10.1136/jech-2020-216061>.
- Labuschagne, L.J., Smorenburg, N., van de Kasstele, J., Bom, B., de Weerd, A.C., de Melker, H.E., et al., 2023. Neighbourhood sociodemographic factors and COVID-19 vaccine uptake in the Netherlands: an ecological analysis. *BMC Public Health* 23 (1), 1696. <https://doi.org/10.1186/s12889-023-16600-z>.
- Martin, C.A., Marshall, C., Patel, P., Goss, C., Jenkins, D.R., Ellwood, C., et al., 2021. SARS-CoV-2 vaccine uptake in a multi-ethnic UK healthcare workforce: a cross-sectional study. *PLoS Med.* 18 (11), e1003823. <https://doi.org/10.1371/journal.pmed.1003823>.
- National Institute for Public Health and the Environment (RIVM), 2020. Richtlijn uitvoering COVID-19 vaccinatie 2021. Available from: <https://rivm.sitearchief.nl> (Accessed on 28 March 2023).
- National Institute for Public Health and the Environment (RIVM), 2021a. Nieuwsbrief voor professionals betrokken bij COVID-19 vaccinatie. Jaargang 2, Editie 4, 13 januari 2021. Available from: <https://www.rivm.nl/nieuwsbrief?id=101500-1151-93457&pid=508151> (Accessed on 27 June 2023).
- National Institute for Public Health and the Environment (RIVM), 2021b. Deelname COVID-19-vaccinatie in Nederland. Available from: https://www.rivm.nl/sites/default/files/2021-05/Wekelijkse%20rapportage%20COVID-19%20Vaccinatiegraad_25_05_2021.pdf (Accessed on 22 August 2023).
- National Institute for Public Health and the Environment (RIVM), 2022. Wekelijkse update deelname COVID-19 vaccinatie in Nederland. Available from: <https://www.rivm.nl/covid-19-vaccinatie/wekelijkse-update-deelname-covid-19-vaccinatie-in-nederland> (Accessed on 8 August 2022).
- National Institute for Public Health and the Environment (RIVM), 2023. COVID-19-vaccinatie. Available from: <https://ci.rivm.nl/richtlijnen/covid-19-vaccinatie> (Accessed on 20 March 2023).
- Pijpers, J., van Roon, A., van Roekel, C., Labuschagne, L., Smagge, B., Ferreira, J.A., et al., 2023. Determinants of COVID-19 vaccine uptake in the Netherlands: a nationwide registry-based study. *Vaccines*. 11 (9), 1409. <https://doi.org/10.3390/vaccines11091409>.
- Research and Statistics. Bevolking naar migratieachtergrond, 2023. [Electronic Dataset]. Municipality of Amsterdam. Available from: <https://onderzoek.amsterdam.nl/data/set/stand-van-de-bevolking-amsterdam>.
- Şekercan, A., Lamkaddem, M., Snijder, M.B., Peters, R.J., Essink-Bot, M.-L., 2015. Healthcare consumption by ethnic minority people in their country of origin. *Eur. J. Public Health* 25 (3), 384–390. <https://doi.org/10.1093/eurpub/cku205>.
- Snijder, M.B., Galenkamp, H., Prins, M., Derks, E.M., Peters, R.J., Zwinderman, A.H., et al., 2017. Cohort profile: the healthy life in an urban setting (HELIUS) study in Amsterdam, the Netherlands. *BMJ Open* 7 (12), e017873. <https://doi.org/10.1136/bmjopen-2017-017873>.
- Stronks, K., Kulu-Glasgow, I., Agyemang, C., 2009. The utility of 'country of birth' for the classification of ethnic groups in health research: the Dutch experience. *Ethn. Health* 14 (3), 255–269. <https://doi.org/10.1080/13557850802509206>.
- van Lier, A., van de Kasstele, J., de Hoogh, P., Drijfhout, I., de Melker, H., 2014. Vaccine uptake determinants in the Netherlands. *Eur. J. Public Health* 24 (2), 304–309. <https://doi.org/10.1093/eurpub/ckt042>.
- Watkinson, R.E., Williams, R., Gillibrand, S., Sanders, C., Sutton, M., 2022. Ethnic inequalities in COVID-19 vaccine uptake and comparison to seasonal influenza vaccine uptake in greater Manchester, UK: a cohort study. *PLoS Med.* 19 (3), e1003932. <https://doi.org/10.1371/journal.pmed.1003932>.
- Yasmin, F., Najeeb, H., Moeed, A., Naeem, U., Asghar, M.S., Chughtai, N.U., et al., 2021. COVID-19 vaccine hesitancy in the United States: a systematic review. *Front. Public Health* 9. <https://doi.org/10.3389/fpubh.2021.770985>.