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Factors associated with lower COVID-19 vaccine uptake among populations with a migration background in the Netherlands

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Abstract

Lower COVID-19 vaccination coverage was observed among some populations with a migration background in the Netherlands. This study examined determinants of being unvaccinated against COVID-19 in the primary vaccination round in adults and in the 2022 autumn booster round in persons aged ≥60 years, among four populations of non-Dutch origin with below average vaccination coverage: Moroccan, Turkish, Surinamese and Dutch-Caribbean, and persons of Dutch origin. We performed a population-wide register-based study, examining associations between potential determinants and being unvaccinated using multivariable logistic regression and computing population attributable fractions. Being a migrant with two foreign-born parents, younger age, living in highly/extremely urban areas and having a lower income, lower education level and low medical risk for severe COVID-19 were risk factors for being unvaccinated in all populations. Substantial differences in the (strength of) determinants and population attributable fractions between populations were also observed. Socioeconomic status only partially mediated the association with being a migrant with two foreign-born parents. These findings illustrate that interventions targeting specific ethnic minority and migrant populations need further study with the aim to optimize the impact of vaccination programmes and improve health equity. To understand reasons behind non-uptake and design (community-based) interventions, qualitative and survey-based research is needed.

Introduction

The COVID-19 pandemic increased health inequities both between and within countries. Not only are older adults and individuals with underlying medical conditions at higher risk of severe COVID-19 but also socioeconomically disadvantaged groups and ethnic minorities and migrants have been disproportionally affected [1, 2]. Having a migration background has been associated with increased risk of SARS-CoV-2 infection and increased COVID-19 severity in several high-income countries [1, 3–5]. In the Netherlands, COVID-19 hospitalization rates have remained relatively high among persons with a migration background, regardless of vaccination [6]. Explanations for this include that people with a migration background and socioeconomic disadvantaged groups are more likely to work in professions with greater interpersonal contact and live in crowded housing conditions, which could explain the higher infection risk, while a higher prevalence of comorbidities and obesity and poorer ability to navigate the healthcare system may increase severity [1, 7]. COVID-19 vaccination offers protection against severe disease, with ≥70% vaccine effectiveness of the primary series up to six months post-vaccination [8], and death. Booster rounds have been rolled out to improve and maintain protection over time [9]. To protect everyone and avoid increasing disparities, vaccination coverage should be particularly high in population groups with a high disease burden [10]. However, vaccine uptake is reported to be below average among subpopulations, including migrant and ethnic minority populations [2, 11–14].

In the Netherlands, vaccination against COVID-19 started on 6 January 2021 [9]. The primary vaccination series was implemented in a step-wise manner, until the whole population aged 12 years and older had been invited by mid-July 2021. While the primary series remained available, successive booster rounds started in November 2021, February 2022, and every autumn since 2022 [15]. Uptake of at least one dose of COVID-19 vaccine and vaccine uptake during the 2022 autumn booster campaign were generally lower among individuals of non-Dutch compared to Dutch origin [2, 14]. In the Dutch National Immunisation programme, differences in vaccine uptake by (parents') country of origin have also been observed [16–19]. Lower socioeconomic status in these populations may partially explain this, combined with a complex interplay between being of non-Dutch origin and trust in vaccination and government policy, risk perception of the disease, and influences from one's social network [20, 21].

Previous registry-based research into sociodemographic determinants of COVID-19 vaccine uptake in the overall Dutch population has identified age, income, socioeconomic position, whether a person or their parent(s) were born in the Netherlands, and political preference as important factors [2, 14]. The current study seeks to explore determinants of being unvaccinated against COVID-19 in the primary vaccination round in adults and in the 2022 autumn booster round in persons aged 60 years and older among four populations of non-Dutch origin: Moroccan, Turkish, Surinamese, and Dutch-Caribbean origin. We chose these groups as they had relatively large numbers of unvaccinated individuals and low vaccine uptake. We focussed on persons aged ≥60 years for the 2022 autumn booster campaign analyses because this high-risk age group was targeted in this booster campaign. Determinants were compared between these populations and with the population of Dutch origin. Improved understanding of determinants of being unvaccinated may provide guidance for future studies and strategies aiming to improve uptake within these groups.

Methods

Study design and population

We performed a population-wide retrospective database study among four populations of non-Dutch origin and, for comparison, persons of Dutch origin. For the analyses of the primary vaccination series, we included all persons aged ≥18 years in these populations, as registered in the national Personal Records Database of the Netherlands on 5 January 2021 [22]. For the analyses of the 2022 autumn booster campaign, the study population comprised all individuals aged ≥60 years in these populations, who were registered in both the personal records database and the national COVID-19-vaccination registry (COVID-19 Information and Monitoring System (CIMS [23])) on 18 September 2022 (the day before the vaccination campaign started) with at least one previous COVID-19 vaccination before the 2022 autumn booster campaign. The 2022 autumn booster campaign was the first autumn booster campaign targeted at persons aged ≥60 years and persons with underlying medical conditions, similar to subsequent years. For comparison, the analyses of the primary vaccination series were also performed among persons aged ≥60 years (results described in Supplement 6).

The study population was categorised into 14 foreign countries/regions of origin based on the classification of country of origin by Statistics Netherlands (CBS) [24]. Country/region of origin was defined based on an individual's and their parents' country of birth. The countries/regions for which the number of unvaccinated individuals was relatively high *and* vaccine uptake of the primary series was low were selected for the analyses (Supplement 1). The four thus selected countries/regions of origin were Morocco, Turkey, Suriname, and Caribbean part of the Kingdom of the Netherlands. For comparison, the analyses were repeated in persons of Dutch origin.

This study was reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [25].

Data sources and variables

The outcome of interest was vaccination status. Vaccination data were obtained from CIMS. Vaccine uptake of the primary series was defined as having received at least one COVID-19 vaccination between the launch of the COVID-19 vaccination programme on 6 January 2021 and the start of the first booster vaccination campaign on 18 November 2021. Completion of the primary series could not be assessed, since previous infections are not registered in the CIMS database, while individuals with a prior SARS-CoV-2 infection required only one vaccination to complete the primary series in the Netherlands. Vaccine uptake of the 2022 autumn booster round was defined as having received a COVID-19 vaccination labelled as 'booster' between 19 September 2022 and 15 September 2023.

Vaccinated individuals who did not consent to registration of their vaccination in CIMS were included as unvaccinated. Individuals who did not consent to registration of their primary vaccination series (7% of vaccinees) were not included in the autumn booster analysis, as they were not eligible for booster vaccination [23]. In the 2022 autumn booster round, 99.2% consented to registration in CIMS [23].

Data on the potential determinants of being unvaccinated were obtained from CBS registers (Supplement 2) and selected based on previous studies [2, 14, 18, 26–28]. At the individual level, we included age, sex, migration background (whether a persons and/or their parents were born in the Netherlands), socioeconomic position (primary source of income), and medical risk group (risk of severe COVID-19 based on underlying health conditions). Income, vehicle ownership, education level (highest completed education level of the household's main earner or their partner), urbanisation level, and distance to the nearest long-term vaccination location were included at the household level. The determinant data were linked to the vaccination data using pseudonymised citizen service numbers within the remote access environment of the CBS. Persons for which data on all variables were available were included in the final analyses (percentages of missing data are mentioned in Tables 1 and 2).

Statistical analyses

To identify independent determinants and mediators, we built several multivariable logistic regression models by subsequently adding (sets of) variables to the previous model. The sets reflect the proximity of the determinants to the outcome, from most distal to most proximate, based on prior assumptions about causality. To avoid inappropriately adjusting odds ratios for mediating factors [29], we present the adjusted odds ratios (aORs) of non-uptake of vaccination of the model where the variable was first introduced. First, a model including age, sex, and migration background was estimated. Socioeconomic position, household income, and household education level were added in model 2, medical risk group in model 3, urbanization level in model 4, household car ownership in model 5, and distance to the nearest long-term vaccination location in model 6. In a post-hoc sensitivity analysis, the medical risk group was added in model 2 and the socioeconomic factors in model 3. To assess whether the association with migration background was explained by other variables, we examined the change in aOR of migration background as more variables were added to the model.

Furthermore, population attributable fractions (PAFs) were calculated. The PAFs estimate the percentage of non-uptake of COVID-19 vaccination that can be attributed to each determinant. The PAFs were calculated based on probabilities estimated through an adaptation of model 6, whereby some categories were merged and reference levels were adapted to ease interpretation of the PAFs. The PAFs were calculated as the change in probability of non-uptake when the value of the determinant was changed from the

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Table 1. Characteristics of the populations by country of origin aged 18 years and older used for the analyses of determinants of being unvaccinated in the primary COVID-19 vaccination round

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	N	%	N	%	N	%	N	%	N	%
Total	294,480		333,090		304,370		136,230		10,660,430	
Sex										
Male	149,160	50.7	171,810	51.6	142,550	46.8	67,850	49.8	5,278,860	49.5
Female	145,320	49.3	161,290	48.4	161,820	53.2	68,380	50.2	5,381,570	50.5
Age										
18–22	36,610	12.4	35,130	10.5	25,930	8.5	16,070	11.8	774,790	7.3
23–27	32,090	10.9	37,540	11.3	26,350	8.7	18,260	13.4	745,180	7.0
28–32	32,620	11.1	39,430	11.8	29,230	9.6	17,070	12.5	750,360	7.0
33–37	31,760	10.8	36,000	10.8	30,470	10.0	14,610	10.7	704,150	6.6
38–42	33,070	11.2	38,130	11.4	27,100	8.9	12,640	9.3	697,920	6.5
43–47	31,240	10.6	35,340	10.6	25,710	8.4	10,450	7.7	740,040	6.9
48–52	28,080	9.5	35,340	10.6	30,840	10.1	10,820	7.9	961,020	9.0
53–57	21,630	7.3	27,990	8.4	29,480	9.7	9,380	6.9	998,150	9.4
58–62	15,510	5.3	18,440	5.5	26,610	8.7	9,030	6.6	968,580	9.1
63–67	9,750	3.3	9,510	2.9	21,340	7.0	7,210	5.3	873,750	8.2
68–74	10,250	3.5	9,860	3.0	18,030	5.9	6,570	4.8	1,159,940	10.9
75+	11,870	4.0	10,390	3.1	13,290	4.4	4,110	3.0	1,286,550	12.1
Migration background[a]										
Born NL, 1p	12,770	4.3	17,390	5.2	42,430	13.9	24,720	18.1	NA	NA
Born NL, 2p	112,310	38.1	1,22,620	36.8	86,370	28.4	18,430	13.5		
Migrant, 1p	250	0.1	480	0.1	3,000	1.0	4,320	3.2		
Migrant, 2p	169,020	57.4	1,92,380	57.8	170,950	56.2	81,880	60.1		
Migrant, 2p NL	120	0.0	220	0.1	1,620	0.5	6,880	5.1		
Socioeconomic position										
Employee	118,740	40.3	145,180	43.6	158,730	52.2	69,540	51.0	5,322,300	49.9
Self-employed	21,950	7.5	35,630	10.7	18,210	6.0	7,960	5.8	7,98,650	7.5
Pensioner	28,500	9.7	26,050	7.8	41,830	13.7	13,940	10.2	2,928,190	27.5
Child or student	24,430	8.3	25,020	7.5	22,050	7.2	16,980	12.5	566,690	5.3
On benefits	76,470	26.0	25,730	22.7	53,970	17.7	23,750	17.4	272,390	2.6
Other/unknown	24,410	8.3	75,490	7.7	9,580	3.1	4,060	3.0	772,210	7.2
Income[b,c]										
<10,000	9,530	3.2	10,790	3.2	10,310	3.4	10,390	7.6	223,900	2.1
10,000–20,000	109,810	37.3	91,290	27.4	69,750	22.9	36,380	26.7	1,229,840	11.5
20,000–30,000	85,020	28.9	94,230	28.3	81,600	26.8	36,770	27.0	2,815,900	26.4
30,000–40,000	52,920	18.0	75,540	22.7	71,690	23.6	26,770	19.7	2,892,640	27.1
40,000–50,000	22,320	7.6	35,610	10.7	40,960	13.5	13,810	10.1	1,851,480	17.4
50,000–1,00,000	11,730	4.0	20,510	6.2	26,250	8.6	9,990	7.3	1,489,450	14.0
≥1,00,000	740	0.3	1,420	0.4	1720	0.6	910	0.7	141,350	1.3
Education level[b,c,d]										
Primary	53,930	18.3	51,970	15.6	16,160	5.3	7,490	5.5	177,020	1.7
Lower secondary	69,150	23.5	71,360	21.4	49,560	16.3	19,630	14.4	1,261,790	11.8
Upper secondary	108,350	36.8	135,280	40.6	143,260	47.1	64,740	47.5	5,045,150	47.3

(*Continued*)

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Table 1. (*Continued*)

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	N	%	N	%	N	%	N	%	N	%
Bachelor	38,400	13.0	46,830	14.1	59,090	19.4	25,680	18.9	2,595,510	24.3
Master, doctor	18,330	6.2	21,160	6.4	28,320	9.3	14,060	10.3	1,382,250	13.0
Medical risk										
Low	218,960	74.4	251,770	75.6	216,730	71.2	106,020	77.8	7,850,350	73.6
Moderate	69,930	23.7	74,000	22.2	78,530	25.8	26,560	19.5	2,520,770	23.6
High	5,600	1.9	7,320	2.2	9,110	3.0	3,650	2.7	289,310	2.7
Urbanization level[b,c]										
Not urban	3,760	1.3	4,410	1.3	7,130	2.3	5,560	4.1	2,035,740	19.1
Somewhat urban	12,000	4.1	15,130	4.5	13,700	4.5	8,550	6.3	1,937,680	18.2
Moderately urban	30,800	10.5	42,690	12.8	34,000	11.2	16,030	11.8	2,061,160	19.3
Highly urban	83,460	28.3	102,890	30.9	90,980	29.9	40,650	29.8	2,614,900	24.5
Extremely urban	164,420	55.8	167,940	50.4	158,510	52.1	65,410	48.0	2,010,590	18.9
Vehicle ownership[b]										
No	81,540	27.7	80,800	24.3	103,030	33.9	56,690	41.6	8,825,180	17.2
Yes	212,940	72.3	252,290	75.7	201,340	66.1	79,540	58.4	1,835,250	82.8
Distance to vaccination location[b]										
<1 km	35,520	12.1	38,080	11.4	37,520	12.3	15,340	11.3	351,010	3.3
1–3 km	86,440	29.4	86,080	25.8	96,840	31.8	37,410	27.5	1,756,250	16.5
3–5 km	70,010	23.8	77,560	23.3	73,550	24.2	30,310	22.2	1,571,880	14.7
5–10 km	53,800	18.3	70,600	21.2	58,690	19.3	28,120	20.6	3,204,990	30.1
≥10 km	48,720	16.5	60,780	18.2	37,780	12.4	25,050	18.4	3,776,310	35.4

Note: Following CBS publication guidelines, all tables exclude frequencies <10 and all numbers and percentages are rounded to the nearest ten to avoid personally identifiable information.
[a]Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands.
[b]Measured at the household level.
[c]Percentage unknown ranged between 0.2% and 1.1% for income, between 1.9% and 3.4% for the education level, and between 0.003% and 0.02% for the urbanisation level.
[d]Education levels are described in more detail in Supplement 2.

original level (P_0) to the scenario level (P_{scen}), i.e., the reference level:

$$PAF = (P_0 - P_{scen})/P_0 * 100.$$

All analyses were conducted in RStudio, version 4.2.3, using tidyverse and the lubridate, stats, and broom packages.

Ethics statement

This study was deemed exempt from the law for medical research involving human subjects by the Centre for Clinical Expertise at the RIVM.

Results

Descriptive analyses

On 5 January 2021, the population of the Netherlands aged ≥18 years included 294,480 persons of Moroccan origin, 333,090 of Turkish origin, 304,370 of Surinamese origin, 136,230 of Dutch-Caribbean origin, and 10,660,430 of Dutch origin. The study population aged ≥60 years with at least one vaccination before the 2022 autumn booster round included 26,550 persons of Moroccan origin, 27,180 of Turkish origin, 54,750 of Surinamese origin, 16,900 of Dutch-Caribbean origin, and 3,434,890 of Dutch origin. The 60-plus populations of Moroccan and Turkish origin for the analyses of the 2022 autumn booster round were limited to migrants with two foreign-born parents (Moroccan: 26,490 persons, Turkish: 27,060 persons) because the other migration background categories contained too few individuals.

Uptake of at least one COVID-19 vaccination in the primary vaccination round and in the 2022 autumn booster round varied between the countries of origin (uptake primary vaccination: Moroccan: 40.5%, Turkish: 53.4%, Surinamese: 62.9%, Dutch-Caribbean: 51.8%, Dutch: 84.9%, uptake autumn booster round: Moroccan: 8.3%, Turkish: 14.7%, Surinamese: 46.4%, Dutch-Caribbean: 50.6%, Dutch: 69.5%). Supplements 3 and 4 show vaccine uptake by determinant.

For several potential determinants of being unvaccinated, the distributions were similar in the populations of Turkish and Moroccan origin but differed from the populations of Dutch-Caribbean and Surinamese origin (Tables 1 and 2). In the study populations of both vaccination rounds, the proportion of people working in employment, i.e., primary source of income was a salary from their employer (as opposed to self-employment or another primary source of income), income (only autumn booster round), education level, and vehicle ownership were lower in the former

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Table 2. Characteristics of the populations by country of origin aged 60 years and older used for the analyses of determinants of being unvaccinated in the autumn 2022 COVID-19 booster round

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	N	%	N	%	N	%	N	%	N	%
Total	26,550		27,180		54,750		16,900		3,434,890	
Sex										
Male	14,440	54.4	13,310	49.0	24,030	43.9	7,760	45.9	1,632,320	47.5
Female	12,110	45.6	13,870	51.0	30,720	56.1	9,140	54.1	1,802,570	52.5
Age										
60–69	14,530	54.7	15,740	57.9	35,370	64.6	10,620	62.8	1,615,430	47.0
70–79	8,620	32.5	8,510	31.3	14,840	27.1	5,160	30.5	1,253,180	36.5
80+	3,400	12.8	2,930	10.8	4,540	8.3	1,130	6.7	566,280	16.5
Migration background[a]										
Born NL, 1p	.	.	60	0.2	2,000	3.7	590	3.5	NA	NA
Born NL, 2p	.	.	.	.	390	0.7	60	0.4		
Migrant, 1p	20	0.1	20	0.1	580	1.2	970	5.7		
Migrant, 2p	26,490	99.8	27,060	99.6	51,370	93.8	12,670	75.0		
Migrant, 2p NL	40	0.2	40	0.1	410	0.7	2,610	15.4		
Socioeconomic position										
Employee	2,440	9.2	2,630	9.7	11,830	21.6	3,600	21.3	538,530	15.7
Self-employed	300	1.8	680	2.5	1,450	2.6	480	2.8	128,820	3.8
Pensioner	16,980	64.0	15,830	58.2	32,020	58.5	10,030	59.3	2,517,620	73.3
On benefits	5,540	20.9	6,830	25.1	8,340	15.2	2,280	13.5	166,290	4.8
Other/unknown	1,280	4.8	1,210	4.5	1,120	2.0	510	3.0	83,630	2.4
Income[b,c]										
<10,000	190	0.1	310	1.1	700	1.3	480	2.8	14,990	0.4
10,000–20,000	14,650	55.2	13,600	50.0	13,260	24.2	4,190	24.8	311,080	9.1
20,000–30,000	7,500	28.2	7,720	28.4	19,070	34.8	4,890	28.9	1,368,420	39.8
30,000–40,000	2,570	9.7	3,190	11.7	10,970	20.0	3,450	20.4	892,440	26.0
40,000–50,000	1,070	4.0	1,420	5.2	6,070	11.1	2020	12.0	457,290	13.3
50,000–1,00,000	510	1.9	810	3.0	4,340	7.9	1,630	9.6	354,940	10.3
≥1,00,000	20	0.01	60	0.2	220	0.4	150	0.9	33,280	1.0
Education level[b,c,d]										
Primary	10,990	41.4	10,040	36.9	5,330	9.7	1,260	7.5	77,090	2.2
Lower secondary	10,010	37.7	9,850	36.2	15,430	28.2	3,540	20.9	722,690	21.0
Upper secondary	3,750	14.1	4,840	17.8	22,230	40.6	7,140	42.2	1,722,220	50.1
Bachelor	1,070	4.0	1,440	5.3	7,670	14.0	3,080	18.2	647,300	18.8
Master, doctor	500	1.9	650	2.4	2,790	5.1	1,270	7.5	191,240	5.6
Medical risk										
Low	10,080	38.0	10,210	37.6	23,770	43.4	8,950	53.0	1,928,250	56.1
Moderate	15,380	57.9	15,840	58.3	28,100	51.3	7,060	41.8	1,354,440	39.4
High	1,090	4.1	1,140	4.2	2,880	5.3	890	5.3	152,200	4.4
Urbanization level[b,c]										
Not urban	190	0.7	200	0.7	1,140	2.1	900	5.3	652,610	19.0
Somewhat urban	790	3.0	900	3.3	2,000	3.7	1,320	7.8	633,080	18.4
Moderately urban	2,540	9.6	3,230	11.9	5,460	10.0	2,410	14.3	695,670	20.3

(*Continued*)

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Table 2. (*Continued*)

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	N	%	N	%	N	%	N	%	N	%
Highly urban	6,770	25.5	8,150	30.0	14,850	27.1	5,400	32.0	881,110	25.7
Extremely urban	16,270	61.3	14,710	54.1	31,300	57.2	6,870	40.7	571,370	16.6
Vehicle ownership[b]										
No	13,820	52.1	12,910	47.5	22,310	40.7	6,460	38.2	642,090	18.7
Yes	12,730	47.9	14,270	52.5	32,440	59.3	10,440	61.8	2,792,800	81.3
Distance to vaccination location[b]										
<1 km	2,650	10.0	2,500	9.2	4,860	8.9	1,360	8.0	158,250	4.6
1–3 km	10,600	40.0	9,510	35.0	22,370	40.9	5,850	34.6	744,820	21.7
3–5 km	8,010	30.2	7,860	28.9	17,470	31.9	4,440	26.3	671,070	19.5
5–10 km	2,780	10.5	4,180	15.4	7,170	13.1	3,250	19.2	1,020,530	29.7
≥10 km	2,500	9.4	3,130	11.5	2,870	5.2	2,000	11.8	839,150	24.4

Note: Following CBS publication guidelines, all tables exclude frequencies <10 and all numbers and percentages are rounded to the nearest ten to avoid personally identifiable information. Excluded numbers are replaced by ".."

[a]Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands.

[b]Measured at the household level.

[c]Percentage unknown ranged between 0.02% and 0.5% for income, between 0.9% and 3.6% for the education level, and between 0.00% and 0.03% for the urbanisation level.

[d]Education levels are described in more detail in Supplement 2.

populations. In the study population of the primary vaccination round, over one-third of people of Moroccan (38.1%) and Turkish (36.8%) origin were born in the Netherlands to two foreign-born parents, compared to only 13.5% of people of Dutch-Caribbean origin. The distributions of sex, age, medical risk, urbanization level, and distance to vaccination location were broadly similar across the four populations of non-Dutch origin in both vaccination rounds.

Determinants of being unvaccinated in the primary vaccination round

For many determinants, the associations were similar in all four populations of non-Dutch origin, but some differences were observed (Table 3). Overall, the odds of being unvaccinated in the primary vaccination round among persons aged ≥18 years increased as age decreased. This trend was observed for age groups below 63, 58, and 48 years in the populations of Surinamese, Moroccan, and Turkish origin, respectively. The odds of being unvaccinated were particularly high among young persons of Dutch-Caribbean or Moroccan origin (aORs >5 below 38 and 33 years, respectively). The odds of being unvaccinated in the primary vaccination round increased as income and education level decreased. The association with education was strongest in the population of Dutch-Caribbean origin. Being self-employed (aORs ranging between 1.53 and 1.75 for different countries of origin), a pensioner (aORs between 1.09 and 1.80), on benefits (aORs between 1.34 and 1.47) or having other/unknown socioeconomic position (aORs between 1.51 and 1.86) were associated with lower uptake in nearly all populations of non-Dutch origin. Moderate or no medical risk compared to high medical risk was also associated with lower uptake. Similar associations with age, income, education level, socioeconomic position, and medical risk were observed among persons of Dutch origin. Adding medical risk group to the model before income, education level, and socioeconomic position in the sensitivity analyses hardly changed the aORs of these socioeconomic variables, while the associations between moderate or no medical risk and being unvaccinated were somewhat weaker when not adjusted for these socioeconomic factors.

Being a migrant (i.e., born abroad) or being born in the Netherlands with two foreign-born parents, compared to being born in the Netherlands with one foreign-born parent, increased the odds of being unvaccinated in the primary vaccination round in all four populations of non-Dutch origin (born in the Netherlands with two foreign-born parents: aORs between 1.56 and 3.67, migrant with two foreign-born parents: aORs between 1.10 and 3.39). The association between being a migrant with two parents born abroad and being unvaccinated was reduced by adding socioeconomic position, income, and education level to the model, but hardly changed after adding any of the other variables in the populations of Dutch-Caribbean and Moroccan origin (Supplement 5; Table S5.1). This indicates that socioeconomic status partially mediates the association between being a migrant with two foreign-born parents and being unvaccinated. Among people of Turkish origin, the association was weak (aOR = 1.10) and inverted after adjustment for socioeconomic variables. For persons of Surinamese origin, the rather weak association (aOR = 1.21) weakened further after adjustment for socioeconomic variables. The association between being a migrant with one foreign-born parent and being unvaccinated in the primary vaccination round varied between populations from different countries of origin.

The associations between vaccine uptake and sex, urbanisation level, vehicle ownership, and distance to vaccination location were weaker or more ambiguous. Living in a highly or extremely urban area compared to a rural area was generally associated with lower uptake (aORs between 1.07 and 1.47) in the populations of non-Dutch origin, while the associations with living in a somewhat or moderately urban area were inconsistent. Associations between urbanisation level and being unvaccinated were strongest among persons of Moroccan origin, for whom the odds of being unvaccinated increased with each urbanisation level (aORs from

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Table 3. Results of multilevel multivariable models of the association between determinants and being unvaccinated in the primary COVID-19 vaccination round among persons aged 18 years and older of Moroccan, Turkish, Surinamese, Dutch-Caribbean and Dutch origin

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Sex[a]										
Male	(ref)		(ref)		(ref)		(ref)		(ref)	
Female	**1.10**	1.08–1.12	1.00	0.99–1.02	**0.97**	0.96–0.99	1.01	0.99–1.03	**0.95**	0.95–0.96
Age[b]										
75+	(ref)		(ref)		(ref)		(ref)		(ref)	
68–74	**0.87**	0.82–0.92	**1.10**	1.04–1.17	**0.91**	0.86–0.97	**1.16**	1.06–1.28	**0.76**	0.76–0.77
63–67	**0.85**	0.80–0.90	0.99	0.94–1.06	**0.94**	0.89–1.00	**1.35**	1.23–1.47	**0.88**	0.88–0.89
58–62	0.95	0.91–1.00	**0.87**	0.83–0.92	**1.07**	1.02–1.13	**1.61**	1.47–1.75	**1.07**	1.06–1.07
53–57	**1.09**	1.04–1.14	**0.91**	0.87–0.96	**1.37**	1.30–1.44	**2.03**	1.87–2.21	**1.37**	1.36–1.38
48–52	**1.32**	1.26–1.38	0.98	0.94–1.03	**1.63**	1.55–1.71	**2.45**	2.25–2.67	**1.61**	1.60–1.63
43–47	**1.59**	1.52–1.66	**1.09**	1.04–1.14	**1.96**	1.86–2.06	**2.97**	2.73–3.24	**1.87**	1.85–1.89
38–42	**2.14**	2.05–2.24	**1.24**	1.18–1.30	**2.70**	2.56–2.84	**3.78**	3.48–4.11	**2.33**	2.31–2.35
33–37	**3.37**	3.22–3.53	**1.81**	1.73–1.90	**3.69**	3.51–3.88	**5.24**	4.83–5.69	**2.97**	2.95–3.00
28–32	**5.33**	5.08–5.60	**2.65**	2.52–2.78	**4.73**	4.50–4.98	**6.40**	5.90–6.95	**3.54**	3.51–3.57
23–27	**6.51**	6.18–6.85	**3.57**	3.39–3.75	**5.00**	4.74–5.26	**6.62**	6.10–7.18	**3.39**	3.36–3.42
18–22	**7.06**	6.70–7.43	**3.83**	3.64–4.03	**4.09**	3.88–4.32	**6.71**	6.18–7.29	**2.91**	2.88–2.93
Migration background[c]										
Born NL, 1p	(ref)		(ref)		(ref)		(ref)		NA	NA
Born NL, 2p	**2.71**	2.60–2.81	**1.58**	1.52–1.63	**1.56**	1.52–1.60	**3.67**	3.52–3.83		
Migrant, 1p	1.22	0.93–1.59	**0.73**	0.61–0.88	**1.17**	1.08–1.27	0.98	0.91–1.06		
Migrant, 2p	**2.16**	2.07–2.26	**1.10**	1.06–1.14	**1.21**	1.18–1.25	**3.39**	3.28–3.50		
Migrant, 2p NL	0.70	0.46–1.07	**0.61**	0.45–0.81	**0.62**	0.55–0.71	**0.56**	0.52–0.60		
Socioeconomic position[d]										
Employee	(ref)		(ref)		(ref)		(ref)		(ref)	
Self-employed	**1.61**	1.56–1.67	**1.75**	1.71–1.80	**1.53**	1.48–1.58	**1.73**	1.64–1.82	**1.96**	1.95–1.97
Pensioner	**1.59**	1.50–1.69	**1.80**	1.69–1.91	**1.18**	1.11–1.25	1.09	0.99–1.19	**1.18**	1.16–1.19
Child or student	**0.77**	0.74–0.81	**0.74**	0.72–0.77	**0.63**	0.60–0.65	**0.69**	0.65–0.73	**0.48**	0.48–0.49
On benefits	**1.45**	1.41–1.48	**1.47**	1.44–1.50	**1.34**	1.31–1.37	**1.44**	1.39–1.50	**1.66**	1.65–1.68
Other/unknown	**1.57**	1.52–1.63	**1.86**	1.80–1.92	**1.51**	1.43–1.59	**1.72**	1.58–1.88	**1.95**	1.93–1.97
Income[e]										
≥1,00,000	(ref)		(ref)		(ref)		(ref)		(ref)	
50,000–1,00,000	1.02	0.87–1.20	1.05	0.93–1.18	**1.31**	1.15–1.50	**1.23**	1.01–1.52	0.99	0.97–1.01
40,000–50,000	**1.22**	1.04–1.44	**1.14**	1.01–1.29	**1.53**	1.35–1.75	**1.67**	1.37–2.06	**1.08**	1.06–1.10
30,000–40,000	**1.34**	1.14–1.57	**1.26**	1.12–1.43	**1.80**	1.59–2.06	**1.94**	1.59–2.38	**1.23**	1.21–1.26
20,000–30,000	**1.50**	1.28–1.76	**1.39**	1.24–1.57	**2.35**	2.06–2.67	**2.49**	2.04–3.06	**1.56**	1.531.59
10,000–20,000	**1.58**	1.35–1.85	**1.53**	1.36–1.72	**2.91**	2.56–3.33	**2.98**	2.44–3.67	**2.19**	2.15–2.24
<10,000	**2.01**	1.70–2.37	**1.99**	1.76–2.26	**3.07**	2.68–3.52	**2.36**	1.93–2.92	**2.15**	2.11–2.20
Education level[f]										
Master, doctor	(ref)		(ref)		(ref)		(ref)		(ref)	
Bachelor	**1.38**	1.33–1.43	**1.40**	1.35–1.45	**1.46**	1.41–1.51	**1.67**	1.59–1.75	**1.51**	1.50–1.52
Upper secondary	**1.58**	1.53–1.64	**1.58**	1.53–1.63	**1.74**	1.68–1.79	**2.46**	2.34–2.58	**2.03**	2.02–2.05
Lower secondary	**1.65**	1.59–1.71	**1.60**	1.54–1.65	**1.88**	1.81–1.95	**2.97**	2.81–3.15	**2.58**	2.55–2.60

(*Continued*)

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Table 3. (*Continued*)

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Primary	**1.82**	1.75–1.90	**1.79**	1.72–1.85	**1.74**	1.66–1.83	**3.41**	3.18–3.67	**3.14**	3.10–3.18
Medical risk[g]										
High risk	(ref)		(ref)		(ref)		(ref)		(ref)	
Moderate risk	**1.36**	1.28–1.44	**1.38**	1.31–1.46	**1.12**	1.06–1.18	**1.35**	1.24–1.46	**1.08**	1.06–1.09
None	**1.75**	1.65–1.85	**1.74**	1.65–1.84	**1.71**	1.63–1.80	**1.67**	1.55–1.81	**1.35**	1.33–1.36
Urbanization level[h]										
Not urban	(ref)		(ref)		(ref)		(ref)		(ref)	
Somewhat urban	**1.21**	1.11–1.32	1.01	0.94–1.09	0.98	0.91–1.04	**0.92**	0.84–1.00	**0.86**	0.86–0.87
Moderately urban	**1.20**	1.11–1.30	1.05	0.98–1.13	1.00	0.94–1.06	0.96	0.89–1.04	**0.86**	0.85–0.86
Highly urban	**1.31**	1.21–1.41	**1.14**	1.06–1.23	**1.16**	1.10–1.23	**1.10**	1.02–1.17	**0.92**	0.91–0.92
Extremely urban	**1.47**	1.36–1.59	**1.29**	1.20–1.39	**1.15**	1.09–1.22	1.07	0.99–1.14	**0.82**	0.81–0.82
Vehicle ownership[i]										
No	(ref)		(ref)		(ref)		(ref)		(ref)	
Yes	**1.08**	1.06–1.10	**1.09**	1.07–1.11	**0.82**	0.80–0.84	**1.13**	1.09–1.16	**0.99**	0.98–1.00
Distance to vaccination location[j]										
<1 km	(ref)		(ref)		(ref)		(ref)		(ref)	
1–3 km	**0.92**	0.90–0.95	**0.84**	0.81–0.86	**0.92**	0.90–0.95	**0.85**	0.81–0.89	**0.92**	0.91–0.93
3–5 km	**0.91**	0.89–0.94	**0.83**	0.81–0.85	**0.81**	0.79–0.84	**0.82**	0.79–0.86	**0.96**	0.95–0.97
5–10 km	**0.92**	0.89–0.95	**0.88**	0.85–0.90	**0.83**	0.80–0.85	**0.84**	0.80–0.88	**0.97**	0.96–0.98
≥10 km	**0.86**	0.83–0.89	**0.81**	0.79–0.84	**0.82**	0.79–0.85	**0.82**	0.78–0.86	1.00	0.99–1.01

[a]Adjusted for age and migration background (populations of Dutch-Caribbean and Surinamese origin only).
[b]Adjusted for sex and migration background (populations of Dutch-Caribbean and Surinamese origin only).
[c]Adjusted for age and sex. Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands. For the populations of Moroccan, Surinamese and Turkish origin, the migrant categories were merged into: Migrant = born abroad. Not applicable (N.A.) for the population of Dutch origin.
[d]Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), income, and education level.
[e]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, and education level.
[f]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, and income. Education levels are described in more detail in Supplement 2.
[g]Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, income, and education level.
[h]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income, and education level.
[i]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income, education level, and urbanisation level.
[j]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income, education level, urbanisation level, and vehicle ownership.
Bold entries indicate significant a ssociations ($p < 0.05$).

1.21 to 1.47). This is in contrast to the population of Dutch origin, whereby higher urbanisation was associated with higher uptake. Vehicle ownership was weakly associated with lower uptake in all groups of non-Dutch origin (aORs between 1.08 and 1.13), except in the population of Surinamese origin (aOR = 0.82). Among persons of Dutch origin the association between vehicle ownership and being unvaccinated was negligible (aOR = 0.99). The associations between vaccine uptake and distance to vaccination location were weak and no clear patterns were observed.

Determinants of being unvaccinated in the autumn 2022 booster round for individuals aged 60 years and older

Due to smaller study populations of people aged ≥60 years and the distribution of certain determinants in these populations, the models were adapted. In the models for persons of Moroccan and Turkish origin, migration background was excluded, and the highest income levels were merged. Being a student was merged with an unknown/other socioeconomic position in all models on the population aged ≥60 years.

In all four populations of non-Dutch origin, the odds of not having received an autumn 2022 booster increased as the education level decreased (Table 4). This association was strongest among persons of Moroccan and Turkish origin, with aOR = 4.41 and aOR = 3.65, respectively, for primary education compared to the master/doctor level. Living in highly or extremely urban areas compared to a rural area was associated with lower uptake in all populations of non-Dutch origin (aORs between 1.15 and 3.53), while living in somewhat or moderately urban areas was only associated with lower uptake in the populations of Moroccan and Turkish origin (aORs between 1.53 and 2.50). This was in contrast to the association between urbanisation level and being unvaccinated in the

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Table 4. Results of multilevel multivariable models of the association between determinants and being unvaccinated in the autumn 2022 COVID-19 booster round among persons aged 60 years and older of Moroccan, Turkish, Surinamese, Dutch-Caribbean, and Dutch origin

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Sex[a]										
Male	(ref)		(ref)		(ref)		(ref)		(ref)	
Female	**2.00**	1.83–2.22	**1.68**	1.57–1.81	**1.15**	1.11–1.19	**1.09**	1.03–1.16	**1.06**	1.06–1.07
Age[b]										
80+	(ref)		(ref)		(ref)		(ref)		(ref)	
70–79	**0.79**	0.69–0.91	**1.13**	1.01–1.26	0.97	0.90–1.03	0.88	0.77–1.00	**0.83**	0.83–0.84
60–69	**1.20**	1.04–1.37	**1.77**	1.59–1.96	**1.66**	1.56–1.76	**1.58**	1.39–1.80	**1.63**	1.62–1.64
Migration background[c]										
Born NL, 1p	NA		NA		(ref)		(ref)		NA	
Born NL, 2p					1.17	0.94–1.46	0.91	0.51–1.58		
Migrant, 1p					1.05	0.87–1.28	0.90	0.73–1.12		
Migrant, 2p					**2.22**	2.02–2.44	**2.51**	2.12–2.99		
Migrant, 2p NL					**0.69**	0.54–0.87	**0.70**	0.58–0.85		
Socioeconomic position[d]										
Employee	(ref)		(ref)		(ref)		(ref)		(ref)	
Self-employed	1.16	0.76–1.84	1.07	0.84–1.37	**1.20**	1.07–1.34	1.04	0.85–1.27	**1.24**	1.23–1.26
Pensioner	**0.63**	0.52–0.75	**0.73**	0.63–0.84	**0.62**	0.59–0.65	**0.47**	0.43–0.52	**0.52**	0.52–0.53
On benefits	1.01	0.83–1.22	1.10	0.95–1.27	**0.89**	0.84–0.95	**0.75**	0.66–0.85	**0.87**	0.86–0.88
Other/unknown	0.99	0.72–1.39	1.27	0.99–1.64	**0.81**	0.70–0.94	**0.66**	0.52–0.85	**0.79**	0.78–0.80
Income[e]										
≥1,00,000	(ref)		(ref)		(ref)		(ref)		(ref)	
50,000–1,00,000					**1.36**	1.02–1.82	0.99	0.68–1.45	1.02	1.00–1.05
40,000–50,000	1.19	0.88–1.60	1.19	0.95–1.49	**1.43**	1.07–1.91	1.16	0.81–1.70	**1.09**	1.06–1.12
30,000–40,000	**1.41**	1.07–1.85	**1.23**	1.00–1.50	**1.54**	1.16–2.05	**1.50**	1.04–2.18	**1.14**	1.11–1.17
20,000–30,000	**1.31**	1.00–1.69	1.14	0.94–1.39	**1.77**	1.33–2.37	**1.78**	1.23–2.60	**1.38**	1.34–1.41
10,000–20,000	**1.84**	1.40–2.39	**1.30**	1.06–1.58	**2.10**	1.58–2.82	**2.75**	1.90–4.04	**1.73**	1.68–1.77
<10,000	**2.00**	1.02–4.42	1.29	0.87–1.97	**1.90**	1.34–2.69	**2.63**	1.71–4.09	**1.49**	1.42–1.55
Education level[f]										
Master, doctor	(ref)		(ref)		(ref)		(ref)		(ref)	
Bachelor	**1.44**	1.10–1.89	**1.44**	1.16–1.79	**1.11**	1.02–1.22	**1.38**	1.19–1.60	**1.49**	1.42–1.55
Upper secondary	**2.03**	1.59–2.58	**2.19**	1.80–2.66	**1.33**	1.22–1.44	**1.67**	1.45–1.92	**1.61**	1.60–1.63
Lower secondary	**3.39**	2.66–4.29	**2.84**	2.34–3.45	**1.54**	1.41–1.69	**2.19**	1.87–2.57	**2.06**	2.04–2.09
Primary	**4.41**	3.45–5.60	**3.65**	2.99–4.45	**2.01**	1.82–2.23	**2.91**	2.40–3.53	**2.82**	2.77–2.88
Medical risk[g]										
High risk	(ref)		(ref)		(ref)		(ref)		(ref)	
Moderate risk	**1.35**	1.09–1.65	**1.23**	1.04–1.45	1.01	0.93–1.09	1.09	0.94–1.27	**1.02**	1.01–1.03
None	**1.55**	1.24–1.90	**1.30**	1.09–1.54	**1.12**	1.03–1.21	**1.16**	1.00–1.35	**1.09**	1.07–1.10
Urbanization level[h]										
Not urban	(ref)		(ref)		(ref)		(ref)		(ref)	
Somewhat urban	**1.72**	1.12–2.59	**1.53**	1.02–2.26	0.90	0.77–1.06	0.91	0.75–1.10	**0.85**	0.85–0.86
Moderately urban	**2.50**	1.68–3.65	**1.76**	1.21–2.52	1.03	0.89–1.18	0.99	0.83–1.17	**0.81**	0.80–0.82
Highly urban	**2.69**	1.84–3.88	**1.85**	1.28–2.63	**1.15**	1.01–1.32	**1.22**	1.04–1.44	**0.83**	0.82–0.83

(*Continued*)

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Table 4. (*Continued*)

	Moroccan origin		Turkish origin		Surinamese origin		Dutch-Caribbean origin		Dutch origin	
	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI	aOR	95% CI
Extremely urban	**3.53**	2.42–5.06	**2.32**	1.61–3.30	**1.43**	1.25–1.62	**1.28**	1.09–1.51	**0.86**	0.85–0.86
Vehicle ownership[i]										
No	(ref)		(ref)		(ref)		(ref)		(ref)	
Yes	1.05	0.95–1.17	1.02	0.94–1.10	**0.80**	0.77–0.84	**0.83**	0.76–0.90	**0.70**	0.70–0.71
Distance to vaccination location[j]										
<1 km	(ref)		(ref)		(ref)		(ref)		(ref)	
1–3 km	1.03	0.88–1.21	1.03	0.90–1.16	1.04	0.97–1.11	1.01	0.89–1.15	**1.04**	1.03–1.05
3–5 km	**1.19**	1.00–1.41	1.08	0.95–1.23	1.06	0.99–1.13	1.03	0.90–1.18	**1.07**	1.05–1.08
5–10 km	0.97	0.79–1.19	**1.32**	1.13–1.53	1.00	0.93–1.09	0.98	0.85–1.13	**1.09**	1.08–1.11
≥10 km	0.97	0.79–1.20	**1.19**	1.01–1.39	**0.90**	0.81–1.00	1.06	0.91–1.24	**1.06**	1.04–1.07

[a]Adjusted for age and migration background (populations of Dutch-Caribbean and Surinamese origin only).
[b]Adjusted for sex and migration background (populations of Dutch-Caribbean and Surinamese origin only).
[c]Adjusted for age and sex. Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands. Not applicable (N.A.) for the populations of Moroccan, Turkish, and Dutch origin.
[d]Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), income, and education level.
[e]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, and education level.
[f]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, and income. Education levels are described in more detail in Supplement 2.
[g]Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), socioeconomic position, income, and education level.
[h]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income and education level.
[i]Measured at household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income, education level, and urbanization level.
[j]Measured at the household level. Adjusted for age, sex, migration background (populations of Dutch-Caribbean and Surinamese origin only), medical risk, socioeconomic position, income, education level, urbanization level, and vehicle ownership.
Bold entries indicate significant a ssociations ($p < 0.05$).

population of Dutch origin (aORs between 0.81 and 0.86). Likewise, compared to high medical risk, no medical risk was associated with lower uptake (aORs between 1.12 and 1.55), but for moderate medical risk, this association was only found in the populations of Moroccan and Turkish origin (aOR = 1.35 and aOR = 1.23, respectively). The odds of not having received an autumn 2022 booster increased as income declined, but this was not as explicit in the population of Turkish origin. Compared to working in employment, being a pensioner (aORs between 0.47 and 0.73) was associated with higher uptake in all populations of non-Dutch origin, while being on benefits (aORs between 0.75 and 0.89) and other/unknown socioeconomic position (aORs between 0.66 and 0.81) were associated with higher uptake among persons of Dutch-Caribbean and Surinamese origin only. Being self-employed was associated with lower uptake in population of Surinamese origin (aOR = 1.20). Compared to age ≥80 years, being aged 60–69 years was associated with lower uptake in all populations of non-Dutch origin, while the association with being aged 70–79 varied (Moroccan: aOR = 0.79, Turkish: aOR = 1.13, Dutch-Caribbean and Surinamese: no significant association). Finally, being female was associated with lower uptake of the autumn 2022 booster, especially among persons of Moroccan origin (aOR = 2.00). Associations of age, sex, income, education level, socioeconomic position, and medical risk in the population of Dutch origin were largely comparable with those among persons of Dutch-Caribbean and Surinamese origin. The associations between socioeconomic position, income and education level and being unvaccinated hardly changed in the sensitivity analysis, while most associations with medical risk were slightly weaker.

Vehicle ownership was only associated with lower odds of not having received an autumn 2022 booster in the populations of Dutch-Caribbean, Surinamese (and Dutch) origin. The associations between not having received an autumn 2022 booster and distance to vaccination location were ambiguous and varied between subgroups.

Being a migrant with two foreign-born parents, compared to being born in the Netherlands with one parent born abroad, was associated with higher odds of not having received an autumn 2022 booster in the populations of Dutch-Caribbean and Surinamese origin (the only populations for which migration background was included) (aOR = 2.51 and aOR = 2.22, respectively). Being a migrant with two parents born in the Netherlands was associated with higher uptake in these populations (aOR = 0.70 and aOR = 0.69, respectively). The aORs of being a migrant with two foreign-born parents decreased after adding socioeconomic position, income, and education level to the model for persons of Dutch-Caribbean origin and, albeit less strongly, for persons of Surinamese origin (Supplement 5; Table S5.2). This indicates that socioeconomic status partially mediated the association between being a migrant with two foreign-born parents and being unvaccinated in the autumn 2022 booster round. The associations weakened slightly after adding urbanisation level as well, indicating that this determinant might also have a mediating effect.

PAFs of determinants of being unvaccinated in the primary vaccination round

The PAFs are presented in Figure 1. The determinants with highest PAFs for being unvaccinated against COVID-19 in the primary vaccination round among persons aged ≥18 years of Dutch-Caribbean, Moroccan, Surinamese, and Turkish origin were being

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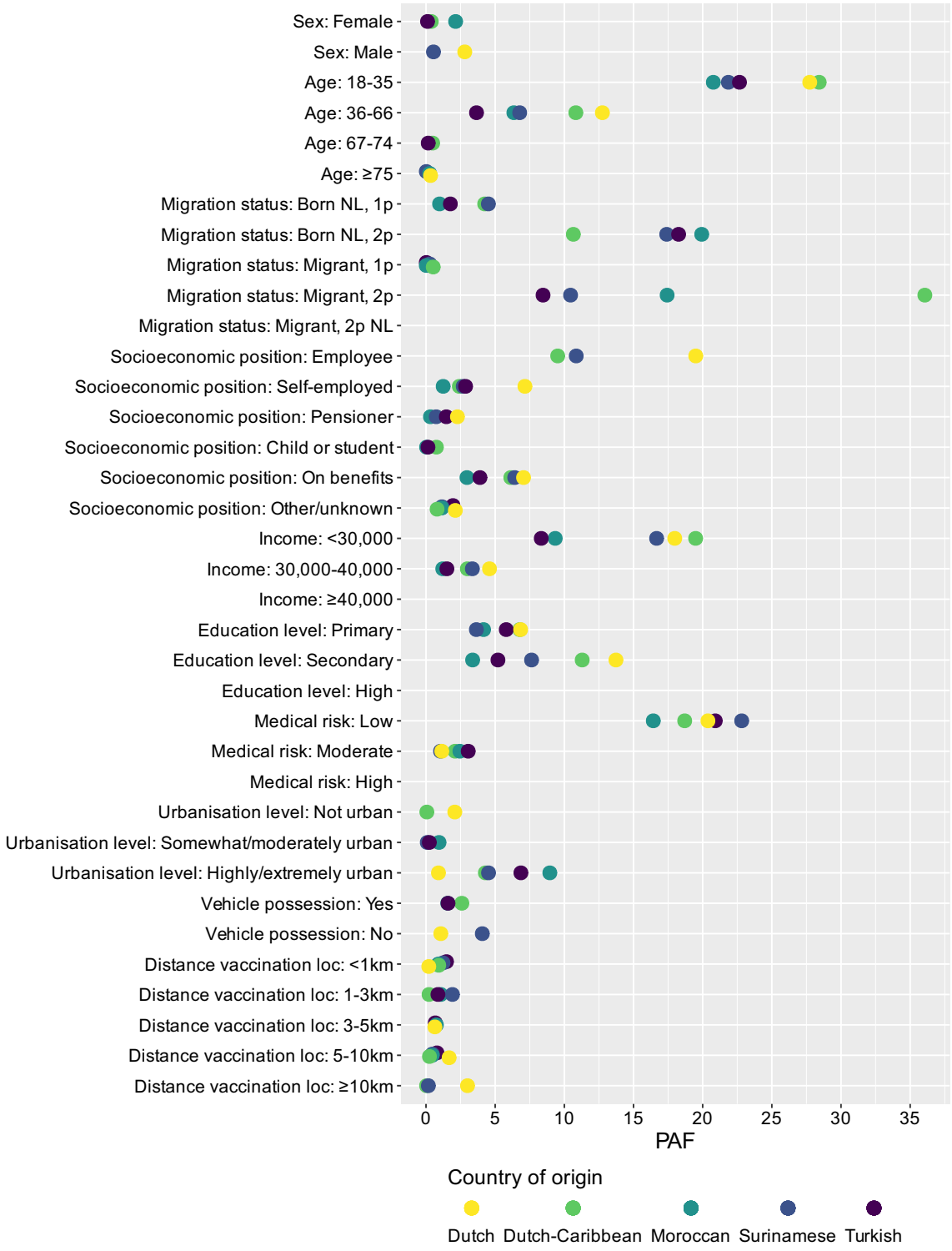

Figure 1. Population attributable fractions (PAFs) of the contribution of each determinant to being unvaccinated in the primary COVID-19 vaccination round by country of origin among persons aged 18 years and older.
Notes: [a] Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands. Not applicable to Dutch country of origin. [b] Income, education level, urbanisation level, vehicle possession, and distance to vaccination location were measured at the household level. [c] The reference category for each country of origin does not feature a dot for that country of origin.

aged 18–35 years (PAFs ranging between 20.8% and 28.4% for different countries of origin), being born in the Netherlands to two foreign-born parents (PAFs between 10.7% and 19.9%), being a migrant with two foreign-born parents (PAFs between 8.5% and 36.1%), not belonging to a medical risk group (PAFs between 16.4% and 22.8%) and having an annual household income below €30,000 (PAFs between 8.3% and 19.5%). The importance of these determinants in terms of PAF varied by country of origin. The impact of

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being aged 18–35 years and being a migrant with two foreign-born parents was particularly large among persons of Dutch-Caribbean origin (PAF = 28.4% and PAF = 36.1%, respectively). The PAFs for low income were largest in the populations of Dutch-Caribbean and Surinamese origin.

Some high PAFs were observed in specific populations. Among persons of Dutch-Caribbean origin, age 36–66 (PAF = 10.8%) contributed strongly to being unvaccinated in the primary vaccination round. The PAFs of being an employee, compared to a pensioner (Dutch-Caribbean origin) or student (Surinamese origin), were quite high due to the large number of individuals working in employment (PAF = 9.5% and PAF = 10.9%, respectively). The impact of education level on being unvaccinated was also considerable, particularly completing secondary education versus higher education among persons with of Dutch-Caribbean origin (PAF = 11.3%). For the population of Dutch origin, PAFs per determinant were comparable to those of Dutch-Caribbean origin, except for migration background (by definition). Among persons of Moroccan origin, living in a highly or extremely urbanized area had a considerable impact on being unvaccinated (PAF = 9.0%).

PAFs of determinants of being unvaccinated in the autumn 2022 booster round for individuals aged 60 years and older

The PAFs of the studied determinants differed considerably between population countries of origin (Figure 2). Only living in highly or extremely urban areas (PAFs between 8.0% and 12.7%) and to a lesser degree primary education level (PAFs between 6.9% and 11.7%) had an impact in all populations of non-Dutch origin. These determinants yielded the only two substantial PAFs for the populations of Moroccan and Turkish origin. In the populations of Dutch-Caribbean and Surinamese origin, the impact of being a migrant and having two foreign-born parents could be investigated and had an important impact (PAF = 30.3% and PAF = 35.7%, respectively). In the population of Dutch origin, primary and secondary education level, compared to high education level, had PAFs of 8.3% and 9.3%, respectively, while living in highly or extremely urban areas had no impact. Younger age (60–69 years) contributed to being unvaccinated among persons of Dutch-Caribbean, Surinamese, and Dutch origin (PAFs between 10.6 and 17.0%). Income below €30,000 only had considerable PAFs for the populations of Dutch-Caribbean and Dutch origin (PAF = 13.7 and PAF = 8.7%, respectively). Low medical risk and, especially among the populations of Moroccan and Turkish origin, vehicle ownership had no impact on being unvaccinated in the autumn 2022 booster round, while they did in the primary vaccination round.

Discussion

We identified determinants associated with being unvaccinated against COVID-19 in the primary and 2022 autumn booster vaccination campaigns among the main populations of non-Dutch origin in the Netherlands: being a migrant with two foreign-born parents, younger age, living in highly or extremely urban areas and having a lower income, lower education level, and low medical risk. Being born in the Netherlands with two foreign-born parents, being self-employed, a pensioner, on benefits or having other/unknown socioeconomic position and having a moderate medical risk were additional risk factors for being unvaccinated in the primary vaccination round, while female sex was an additional risk factor in the 2022 autumn booster round in the study population aged ≥60 years. The PAFs largely confirmed the impact of these determinants. We also found differences in the (strength of) some determinants of being unvaccinated, such as education and urbanization level, between persons of Moroccan, Turkish, Surinamese, and Dutch-Caribbean origin for both vaccination rounds. This emphasises the importance of future in-depth research into barriers to vaccination in each of these populations and of tailoring efforts towards increasing vaccine uptake, to maximise the impact of vaccination programmes across the whole population of the Netherlands.

The role of age, income, and education level in all four populations of non-Dutch origin under study are consistent with previous research, including among migrants and ethnic minorities [2, 14, 27, 30]. In contrast to our findings, belonging to a medical risk group was not an important predictor of being unvaccinated in two previous Dutch studies, which used similar data and risk groups [2, 14]. It is possible that age differences explain the association with medical risk group and that there was residual confounding by age. Results of studies in other countries are inconsistent [31–33]. The association between being a pensioner and not being vaccinated in the primary vaccination round among the population aged ≥18 years may also be explained by a correlation with age, although similar associations were found in most populations of non-Dutch origin among persons aged ≥60 years.

Being a migrant with two foreign-born parents, compared to being born in the Netherlands with one parent born abroad, was a strong risk factor for being unvaccinated in both vaccination rounds. Previous studies have found divergent effects of country of origin and migrant generation on vaccine uptake [34, 35]. We explored to which other determinants explained the association between migration background and being unvaccinated. While socioeconomic determinants, and for the autumn booster also urbanisation level, did reduce the odds of being unvaccinated, the association with being a migrant with two foreign-born parents persisted. This suggests that other factors play a role. For instance, social integration, which may be lower for migrants with two foreign-born parents, has been found to be positively associated with higher vaccine acceptance [36, 37]. This may also explain the strong association between being born in the Netherlands with two, compared to one, foreign-born parents and not having received any COVID-19 vaccination.

Determinants that were associated with being unvaccinated in our study were for a considerable part comparable between persons of non-Dutch and Dutch origin, and thus are unlikely to fully explain the observed differences in vaccine uptake between the groups, although interactions between the determinants or a cumulative effect may be present. This underlines the need to assess the role of other factors, including religion, trust in authorities, trust in science, social influences, and language skills [21, 27, 38], which may also interact with determinants we identified [20]. Survey data and qualitative research might shed more light on these factors. A recent survey-based study by the CBS identified religion, trust in the political and healthcare institutions, social participation, and self-reported health as COVID-19 vaccination determinants [39]. It would be relevant to stratify such studies by migration background.

Additionally, studying the 'transmission' of vaccine uptake within social networks, as well as how vaccine uptake in these networks influences the decision to get an additional booster each round, seems a promising avenue for further research [40]. The influence of social networks is not limited to populations of non-Dutch origin, but particularly within cities, communities of people with a migration background are often concentrated in certain

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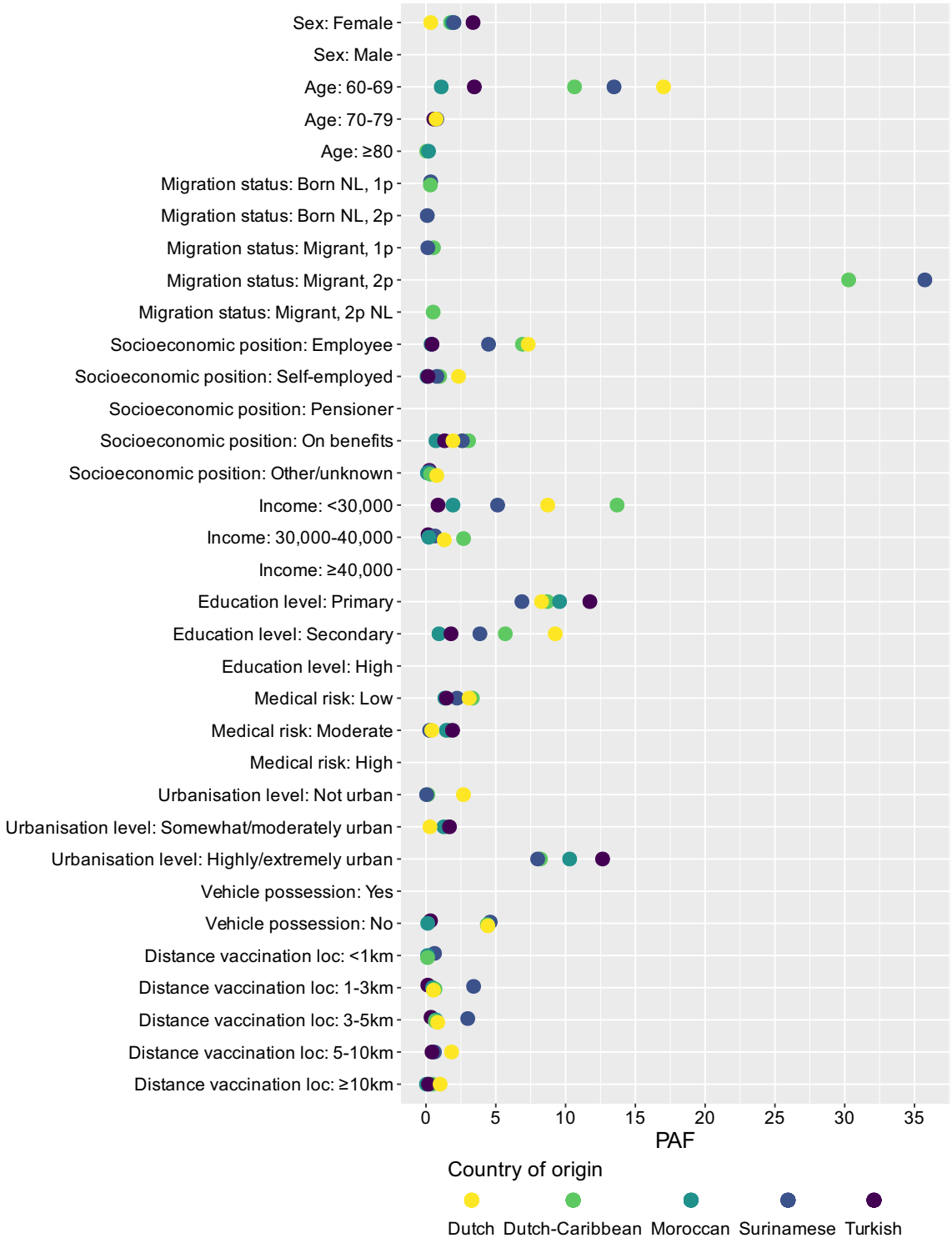

Figure 2. Population attributable fractions (PAFs) of the contribution of each determinant to being unvaccinated in the autumn 2022 COVID-19 booster round by country of origin among persons aged 60 years and older.
Notes: [a] Born NL, 1p = born in the Netherlands with one parent born abroad; Born NL, 2p = born in the Netherlands with two parents born abroad; Migrant, 1p = born abroad with one parent born abroad; Migrant, 2p = born abroad with two parents born abroad; Migrant, 2p NL = born abroad with two parents born in the Netherlands. Not applicable to Moroccan, Turkish, and Dutch country of origin. [b] Income, education level, urbanisation level, vehicle possession, and distance to vaccination location were measured at the household level. [c] The reference category for each country of origin does not feature a dot for that country of origin.

neighbourhoods, and vaccine hesitancy may easily spread between community members, resulting in lower vaccine uptake in these communities [38, 41–43]. This potentially explains the observed association between living in a highly/extremely urbanised area and lower uptake, which was particularly strong among persons of Moroccan origin. A better understanding of these dynamics may provide the basis for community-based interventions to address vaccine hesitancy. Studies could explore the role of trusted

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community-based organisations and key figures in the community [20, 44, 45]. Considering the important role of friends and family in reinforcing or alleviating vaccine hesitancy and ultimately in vaccine uptake, studies focussed on how vaccine recipients can be ambassadors to recruit others to get vaccinated are needed as well [38, 41, 42].

The observed differences in the influence of some determinants between populations from different countries of origin further highlights the need for community-based interventions targeted at specific ethnic minority and migrant populations. Besides urbanisation level, we observed differences in the influence of education level and income in both vaccination rounds. When targeting interventions, it is relevant to consider both the strength of the associations and the size of the population that they apply to. PAFs can be interpreted as the percentage of not receiving vaccination against COVID-19 attributable to each determinant. The PAFs highlight that groups of young age, migrants with two foreign-born parents, low income, low education level, or low medical risk and, in the autumn 2022 booster round, groups living in a highly or extremely urbanised area at the population level contributed considerably to low vaccine uptake.

This study on determinants associated with being unvaccinated against COVID-19 among four large populations of non-Dutch origin is a first step of the World Health Organization (WHO) Tailoring Health Programmes (THP), specifically the tailoring Immunization programmes (TIPs), approach [46]. This step is referred to as 'situational research'. Following the WHO TIP process, this study should be used as a basis for more in-depth research on barriers and drivers of vaccination in specific subgroups with lower uptake, which can subsequently inform interventions with the aim to increase vaccination coverage [46, 47].

A key strength of this study is the use of population-wide individual-level and household-level data, which avoids ecological fallacies that may result from using aggregated data. By studying the primary vaccination round and the autumn 2022 booster round and four populations of non-Dutch origin as well as people of Dutch origin, we made a comprehensive assessment of determinants of being unvaccinated both initially and for repeat vaccinations.

There are some limitations that need to be considered. First, vaccine uptake was underestimated in the primary vaccination round, as people who did not consent to nationally registering their vaccination were included as unvaccinated. This may have biased the estimates in different ways, depending on the characteristics of persons with higher and lower consent percentages. This is less relevant for the booster vaccination, as this consent rate was very high (99.2%). Second, as we used population-level data, we could not include some potential determinants of vaccine uptake, like religion, trust in authorities and science, language skills, healthcare-seeking behaviour and health literacy, which may be especially relevant in migrant and ethnic minority populations [21, 27, 38]. Third, some underlying medical conditions and distance to vaccination locations were hard to identify based on available data, so some misclassification of these determinants may be present. Additionally, to minimise missingness, the education level was based on a multiple imputed dataset by the CBS.

Conclusion

This study identified several common risk factors for being unvaccinated against COVID-19 observed in four large populations of non-Dutch origin and found substantial differences in the (strength of the) determinants and corresponding PAFs between the populations of Moroccan, Turkish, Surinamese, and Dutch-Caribbean origin. Importantly, the higher odds of being unvaccinated for migrants with two foreign-born parents compared to persons born in the Netherlands with one foreign-born parent could only partially be explained by socioeconomic variables. This indicates that socioeconomic status only partially mediated this association. The findings illustrate that interventions specifically targeted at these ethnic minority and migrant populations require further study to optimise the impact of vaccination programmes across the whole population of the Netherlands. Although these findings provide some guidance to target vaccination programmes, qualitative and survey-based research is needed to further understand reasons behind not receiving vaccination in these populations and design (community-based) interventions.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/S0950268825100216.

Data availability statement. Results are based on non-public microdata from Statistics Netherlands. Under certain conditions, these microdata are accessible for statistical and scientific research. For further information: microdata@cbs.nl.

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References

[1] **Khanijahani A**, et al. (2021) A systematic review of racial/ethnic and sociodemographic disparities in COVID-19. *International Journal for Equity in Health* **20**, 248–278.

[2] **Van Roekel C**, et al. (2024) Factors associated with COVID-19 autumn 2022 booster uptake in the Netherlands among older adults aged ≥60 years and younger adults with chronic conditions. *Vaccine* **42**, 146–155.

[3] **Coyer L**, et al. (2022) 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 – Europe* **13**, 100284.

[4] **Sze S**, et al. (2020) Ethnicity and clinical outcomes in COVID-19: A systematic review and meta-analysis. *eClinicalMedicine* **29**, 100630.

[5] **Labberton AS**, et al. (2022) SARS-CoV-2 infections and hospitalisations among immigrants in Norway-significance of occupation, household crowding, education, household income and medical risk: A nationwide register study. *Scandinavian Journal of Public Health* **50**, 772–781.

[6] **Centrum Infectieziektebestrijding** (2024) COVID-19 vaccinatie: Achtergrondinformatie voor de Gezondheidsraad. National Institute for Public Health and the Environment (RIVM); RIVM rapport 2024–0055 [in Dutch]. Available at https://rivm.openrepository.com/handle/10029/627437 (accessed 12 April 2024).

[7] **Collard D**, et al. (2022) Ethnic differences in coronavirus disease 2019 hospitalization and hospital outcomes in a multiethnic population in the Netherlands. *Open Forum Infectious Diseases* **9**, ofac257.

[8] **Feikin DR**, et al. (2022) Duration of effectiveness of vaccines against SARS-CoV-2 infection and COVID-19 disease: Results of a systematic review and meta-regression. *The Lancet* **399**, 924–944.

[9] **Lanooij SJ**, et al. (2024) Vaccinatiegraad COVID-19 vaccinatie Nederland, 2022. National Institute for Public Health and the Environment (RIVM); RIVM-briefrapport 2023–0428 [in Dutch]. Available at https://rivm.openrepository.com/handle/10029/627386 (accessed 12 April 2024).

[10] **Rosenstrom ET**, et al. (2022) Can vaccine prioritization reduce disparities in COVID-19 burden for historically marginalized populations? *PNAS Nexus* **1**, 1–9.

[11] **Kraft KB**, et al. (2022) COVID-19 vaccination coverage by immigrant background. *Tidsskrift for Den norske legeforening* **142**, 127–132.

[12] **Spetz M**, et al. (2022) An intersectional analysis of sociodemographic disparities in Covid-19 vaccination: A nationwide register-based study in Sweden. *Vaccine* **40**, 6640–6648.

[13] **Dolby T**, et al. (2022) Monitoring sociodemographic inequality in COVID-19 vaccination uptake in England: A national linked data study. *Journal of Epidemiology and Community Health* **76**, 646–652.

[14] **Pijpers J**, et al. (2023) Determinants of COVID-19 vaccine uptake in the Netherlands: A nationwide registry-based study. *Vaccine* **11**, 1409.

[15] **Pluijmakers A**, et al. (2023) The National Immunisation Programme in the Netherlands. Surveillance and developments in 2022–2023. National Institute for Public Health and the Environment (RIVM); RIVM report 2023-0330. Available at https://rivm.openrepository.com/handle/10029/627074 (accessed 15 December 2023).

[16] **Steens A**, et al. (2013) Association between human papillomavirus vaccine uptake and cervical cancer screening in the Netherlands: Implications for future impact on prevention. *International Journal of Cancer* **132**, 932–943.

[17] **De P**, et al. (2020) MenACWY vaccination campaign for adolescents in the Netherlands: Uptake and its determinants. *Vaccine* **38**, 5516–5524.

[18] **Van Lier A**, et al. (2014) Vaccine uptake determinants in the Netherlands. *European Journal of Public Health* **24**, 304–309.

[19] **De Munter AC**, et al. (2021) Determinants of HPV-vaccination uptake and subgroups with a lower uptake in the Netherlands. *BMC Public Health* **21**, 1848.

[20] **RIVM Corona Gedragsunit** (2021) Vaccinatiebereidheid COVID-19 onder groepen met een migratieachtergrond; verkenning van beïnvloedende factoren en strategieën voor communicatie en beleid. National Institute for Public Health and the Environment (RIVM) [in Dutch]. Available at https://www.rivm.nl/documenten/vaccinatiebereidheid-covid-19-onder-groepen-met-migratieachtergrond (accessed 4 October 2024).

[21] **Campman SL**, et al. (2023) Intent to vaccinate against SARS-CoV-2 and its determinants across six ethnic groups living in Amsterdam, the Netherlands: A cross-sectional analysis of the HELIUS study. *Vaccine* **41**, 2035–2045.

[22] **Personal Records Database (BRP)**. https://www.government.nl/topics/personal-data/personal-records-database-brp (accessed 11 April 2025).

[23] **Cims: COVID-vaccinatie Informatie- en Monitoringssysteem**. https://www.cbs.nl/nl-nl/onze-diensten/maatwerk-en-microdata/microdata-zelf-onderzoek-doen/microdatabestanden/cims-covid-vaccinatie-informatie-en-monitoringssysteem [in Dutch] (accessed 11 April 2025).

[24] **CBS introduceert nieuwe indeling bevolking naar herkomst**. https://www.cbs.nl/nl-nl/nieuws/2022/07/cbs-introduceert-nieuwe-indeling-bevolking-naar-herkomst [in Dutch] (accessed 22 May 2024).

[25] **Von Elm E**, et al. (2007) The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. *Annals of Internal Medicine* **147**, 573–577.

[26] **Abba-Aji M**, et al. (2022) Ethnic/racial minorities' and migrants' access to COVID-19 vaccines: A systematic review of barriers and facilitators. *Journal of Migration and Health* **5**, 100086.

[27] **Crawshaw AF**, 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. *The Lancet Infectious Diseases* **22**, e254–e265.

[28] **Labuschagne LJE**, et al. (2023) Neighbourhood sociodemographic factors and COVID-19 vaccine uptake in the Netherlands: An ecological analysis. *BMC Public Health* **23**, 1696.

[29] **Victora CG**, et al. (1997) The role of conceptual frameworks in epidemiological analysis: A hierarchical approach. *International Journal of Epidemiology* **26**, 224–227.

[30] **Williams AM**, **Clayton HB and Singleton JA** (2022) Racial and ethnic disparities in COVID-19 vaccination coverage: The contribution of socioeconomic and demographic factors. *American Journal of Preventive Medicine* **62**, 473–482.

[31] **Kerr S**, et al. (2024) Undervaccination and severe COVID-19 outcomes: Meta-analysis of national cohort studies in England, Northern Ireland, Scotland, and Wales. *The Lancet* **403**, 554–566.

[32] **Yuan J**, et al. (2024) Dynamic predictors of COVID-19 vaccination uptake and their interconnections over two years in Hong Kong. *Nature Communications* **15**, 290.

[33] **Biswas MR**, et al. (2021) A scoping review to find out worldwide COVID-19 vaccine hesitancy and its underlying determinants. *Vaccine* **9**, 1243.

[34] **de Casadevante VF**, et al. (2016) Ethnic background and human papillomavirus vaccine uptake in Denmark: A countrywide retrospective cohort study including 274,154 women aged 19–28 years. *Papillomavirus Research* **2**, 78–84.

[35] **Charania NA**, et al. (2019) Vaccine-preventable diseases and immunisation coverage among migrants and non-migrants worldwide: A scoping review of published literature, 2006 to 2016. *Vaccine* **37**, 2661–2669.

[36] **Teng Y**, **Hanibuchi T and Nakaya T** (2023) Does the integration of migrants in the host society raise COVID-19 vaccine acceptance? Evidence from a nationwide survey in Japan. *Journal of Immigrant and Minority Health* **25**, 255–265.

[37] **Lin S**, et al. (2021) Associations of elements of parental social integration with migrant children's vaccination: An epidemiological analysis of national survey data in China. *Vaccine* **9**, 884.

[38] **Antwi-Berko D** (2022) Determinants and variations of COVID-19 vaccine uptake and responses among minority ethnic groups in Amsterdam, the Netherlands. *Frontiers in Public Health* **10**, 761987.

[39] **Derksen E**, **Janssen L and Tummers-van der AM** (2023) COVID-19-vaccinatiegedrag. Statistics Netherlands (CBS), 2023 [in Dutch]. Available at https://www.cbs.nl/nl-nl/longread/rapportages/2023/covid-19-vaccinatiegedrag (accessed 13 February 2024).

[40] **Konstantinou P**, et al. (2021) Transmission of vaccination attitudes and uptake based on social contagion theory: A scoping review. *Vaccine* **9**, 607.

[41] **Morales GI**, et al. (2022) Exploring vaccine hesitancy determinants during the COVID-19 pandemic: An in-depth interview study. *SSM – Qualitative Research in Health* **2**, 100045.

[42] **Marquez C**, et al. (2021) A multi-component, community-based strategy to facilitate COVID-19 vaccine uptake among Latinx populations. *PLoS One* **16**, e0257111.

[43] **World Health Organization (WHO)** (2020) *Strengthening Preparedness for COVID-19 in Cities and Urban Settings: Interim Guidance for Local Authorities*. Geneva: WHO; WHO/2019-nCoV/ Urban_preparedness/2020.1. Available at https://www.who.int/publications/i/item/WHO-2019-nCoV-Urban_preparedness-2020.1 (accessed 24 June 2024).

[44] **Mansfield LN**, et al. (2023) Community-based organization perspectives on participating in state-wide community canvassing program aimed to reduce COVID-19 vaccine disparities in California. *BMC Public Health* **23**, 1356.

[45] **Demeke J**, et al. (2023) Strategies that promote equity in COVID-19 vaccine uptake for Latinx communities: A review. *Journal of Racial and Ethnic Health Disparities* **10**, 1349–1357.

[46] **World Health Organization (WHO)** (2019) Tailoring Immunization Programmes (TIP). Copenhagen: WHO Regional Office for Europe. Available at: https://www.who.int/europe/publications/i/item/9789289054492 (accessed 18 April 2025).

[47] **Dubé E**, et al. (2018) The WHO tailoring immunization programmes (TIP) approach: Review of implementation to date. *Vaccine* **36**, 1509–1515.