

Vaccinations in children of non-European origin: The Vax4globe survey

Viviana Moschese^{a,*}, Simona Graziani^b, Antonietta Spadea^c, Maurizia D'Amore^c, Raffaella Mosco^c, Sara Ciampini^c, Nicola Di Giorgio^d, Susanna Arcano^e, Simona Ceccarelli^b, Marco Chianca^f, Simona Piccinini^b, Antonella Polito^b, Marta Porcari^g, Pamela Puliafito^b, Romina Silenzi^b, Elisabetta Del Duca^a, Claudio Pignata^h, Michele Miraglia Del Giudiceⁱ, Within the Italian Pediatric Research Society (SIRP) and the Italian Society of Pediatric Allergy and Immunology (SIAIP) Vaccine Committee¹

^a Pediatric Immunopathology and Allergology Unit, Policlinico Tor Vergata, University of Rome Tor Vergata, Rome, Italy

^b Local Health Agency Rome2, Rome, Italy

^c Vaccination Complex Operational Unit of Local Health Agency Rome1, Rome, Italy

^d Vaccination Center of Local Health Agency Rome6, Rome, Italy

^e Local Health Agency Rome5, Rome, Italy

^f Local Health Agency Rome1, Rome, Italy

^g Local Health Agency Rome6, Rome, Italy

^h Pediatric Section, Department of Translational Medical Science, Federico II University, Naples, Italy

ⁱ Department of Woman, Child and General and Specialized Surgery, University of Campania "Luigi Vanvitelli", 80138 Naples, Italy

ARTICLE INFO

Keywords:

Immunization
Vulnerable populations
Pregnancy
Childhood
Migrant status

ABSTRACT

Background: An equitable immunization coverage to “leave no one behind” is one of the World Health Organization Sustainable Development Goals. However, disparities in vaccination coverage exist. The present study aims to investigate vaccine attitude of non-European parents living in Italy and those factors affecting vaccine uptake and equity.

Methods: A cross sectional survey, named Vax4globe, on knowledge and immunization compliance in childhood and pregnancy of non-European (non-EU) parents was carried out among general pediatrician and Vaccine Centers located in Lazio Region, between February and July 2023. Logistic regression models were used in univariate and multivariate analyses to examine the socio-demographic parameters mainly associated with the vaccination status.

Results: A total of 310 parent/child pair were included in the study. Most children were born in Italy (262/310; 86.5 %), while while 40/310 (13.2 %) migrated from country of origin and 1/310 (0.3 %) was adopted. Mandatory vaccines were performed by 270/306 (88 %) children, however flu, papillomavirus and meningococcal group B were vaccines most commonly refused by 208/289 (72 %), 11/36 (31 %) and 9/36 (25 %) parents, respectively. A lower educational degree of parents ($p = 0.040$) and the migration status of children ($p < 0.001$) were associated to incomplete or missed immunization. As to maternal immunization 164/310 (53 %) non-EU women decided not to vaccinate and received less information (155/297; 52 %) compared to childhood immunization (268/305; 88 %) ($p < 0.0001$). The educational degree ($p = 0.017$), the origin from non-EU European countries ($p = 0.008$) and the age 25–40 years ($p = 0.036$) and > 40 years ($p = 0.007$) were associated to lack of immunization during pregnancy. Finally, while 279/310 (90 %) parents were vaccinated against Sars-CoV-2, only 60/199 (30 %) children had been immunized with this vaccine mainly due to the non-

Abbreviations: HPV, Human papilloma virus; MenB, Meningococcal group B; non-EU, non-European; non-EU ES, European States not belonging to European Union; PNPV, National Vaccination Prevention Plan 2023–2025; SIAIP, Italian Society of Pediatric Allergy and Immunology; SIRP, Italian Society of Pediatric Research; WHO, World Health Organization.

* Corresponding author at: Pediatric Immunopathology and Allergology Unit, Head Referral Center for Primary Immunodeficiencies – Regione Lazio, University of Rome Tor Vergata, Policlinico Tor Vergata, Viale Oxford, 81, 00133 Rome, Italy.

E-mail address: moschese@med.uniroma2.it (V. Moschese).

¹ Baldassarre Martire, Alessandra Beni, Giorgio Costagliola, Maria Felicia Mastrototaro, Davide Montin, Giorgio Ottaviano, Caterina Rizzo, Veronica Santilli, Mayla Sgrulletti

<https://doi.org/10.1016/j.vaccine.2024.126466>

Received 6 April 2024; Received in revised form 28 September 2024; Accepted 30 September 2024

Available online 31 October 2024

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mandatory vaccine request at pediatric age and to the doubts about its value according to 39/127 (31 %) and 29/127 (23 %) parents, respectively.

Conclusion: Our study highlights the need for targeted strategies to improve vaccine uptake both in childhood and in pregnancy among non-EU individuals living in Italy. Further, to achieve vaccination equity the role of institutions and healthcare personnel is pivotal to overcome vaccine hesitancy.

1. Introduction

To date, the World Health Organization (WHO) reports that the total number of migrants is approximately 281 million of which 36 million are children and 48 % are women [1]. In Italy, people of foreign origin were more than 5 millions at the beginning of 2023, accounting approximately for 9 % of the resident population [2]. Of these, about one million are under the age of 17 years, accounting for 11 % of young residents in the same age group. People of foreign origin might suffer social and health fragility including reduced access to health services in the host country and fit the condition of “vulnerables” with an increased risk of communicable diseases that may be prevented by immunization [3,4].

Currently, vaccination is a relevant tool for the safeguard of human health although it is frequently hindered by “vaccine hesitancy” [5]. As previously reported, several social, cultural and administrative factors might conduct to vaccine hesitancy and to delay or lack of vaccination in children with foreign-origin parents [6–9]. Despite several efforts to overcome immunization inequalities, one in five children worldwide still have no access to vaccination [10]. Also, significant differences in childhood vaccine coverage between native children and children of foreign-born origin have been reported [11]. Indeed, in USA a lower human papilloma virus (HPV) vaccination rate has been observed in children of migrant parents than in children of native parents, since only 2 % were informed on HPV vaccine and 48 % were unwilling to vaccinate their daughters [12]. Furthermore, in Italy 11–21 % of children born to foreign mothers are vaccinated after the recommended age and the risk of non-vaccination is greater in children of younger, multiparous and unemployed women [8]. When looking at Sars-CoV-2 vaccination these data become even more relevant [13].

Thus, one of the WHO Sustainable Development Goals is ensuring an equitable immunization coverage to “leave no one behind” [14]. Also, in Italy the recent National Vaccination Prevention Plan (PNPV) 2023–2025 aims to reduce inequalities and provide actions for hard-to-reach population groups and/or with low vaccine coverage. The actions focus to guarantee the vaccination offer according to the PNPV, including recommended vaccinations for at risk subjects as well as easy access to health services to encounter the disadvantaged [15]. The identification of those factors that impede vaccine engagement in vulnerable populations not only could help in the design of appropriate health services but also in the implementation of successful programs to reach disadvantaged or marginalized populations.

In the context of the Italian Society of Pediatric Research (SIRP) and the Italian Society of Pediatric Allergy and Immunology (SIAIP) we sought to assess the vaccination status of non-European (non-EU) origin children living in Italy and vaccine attitude of their non-European parents in relation to vaccine uptake and equity. Also, maternal immunization status of non-EU origin women was evaluated to dissect knowledge and adherence in this special population. Further, our results may assist tailored interventions for the vulnerables to advance health services and restore vaccine confidence.

2. Methods

2.1. Study design and study population

The survey, promoted by the Italian Society of Pediatric Research (SIRP) and the Italian Society of Pediatric Allergy and Immunology

(SIAIP) in collaboration with the Pediatric Immunopathology and Allergy Unit of Tor Vergata University Hospital, the Vaccination Complex Operational Unit of Local Health Agency Rome 1, the Vaccination Center of Local Health Agency Rome 6 and nine family pediatricians covering different locations in Rome and its province, was conducted between the period of February – July 2023.

The study population included parents of non-EU origin living in Lazio Region, aged >18 years with children aged 0–17 years, who attended the vaccine centers or the general pediatrician office for routine consultation during the aforementioned period.

2.2. Data collection

Data of this cross-sectional study were collected through a close-ended anonymous questionnaire formulated based on a review of the related literature [16,17]. The questionnaire was available in paper format and was created in Italian, English and French to facilitate parents understanding. It consisted of two sections: the first on demographic data of parents/child pair and the second included nine multiple choice questions on vaccine compliance, source of vaccine information, maternal immunization, Sars-CoV-2 vaccine and reasons for vaccine refusal. The questionnaire was administered to parents, while sitting in the waiting room, by pediatricians and/or trained healthcare personnel of vaccine centers after obtaining verbal informed consent and with no incentives.

2.3. Data analysis

Descriptive characteristics of the entire cohort, stratified by area of non-European origin, were summarized by means of frequencies and percentage values. In univariate analysis, non-parametric tests were performed for comparisons between groups (Chi-Squared and Fisher Exact test). Logistic regression models were used in univariate and multivariate analyses to assess whether the socio-demographic parameters were associated with the vaccination status. Odds Ratios (OR) and 95 % Confidence Intervals were reported as parameter results of the logistic regression models. All covariates were evaluated in univariate models and all factors with univariate association with p -values <0.15 were considered in the multivariate models. Backward and stepwise methods were applied to identify the multivariate models with a step-by-step iterative construction that involves the selection of independent variables to be considered in the final model. All tests were 2-sided, accepting $p < 0.05$ as statistically significant and confidence intervals were calculated at 95 % level. All analyses were performed using the R software, version 4.2.2.

2.4. Ethical considerations

The study was conducted according to the Declaration of Helsinki. Informed consent was obtained verbally by all parents before answering the questionnaire. No Ethics Committees approval was necessary to collect and analyse the data since the questionnaire was anonymous and unreporting personal identifying data.

3. Results

3.1. General characteristics of interview participants

Out of 316 invited participants, 310 non-EU parents agreed by giving their informed consent and filling the questionnaire, with a response rate of 98 %. Most of foreign parents were from Asia (152/310;49 %), while of the remaining ones 72/310 (23 %), 48/310 (16 %) and 38/310 (12 %) came from Africa, America and European States not belonging to European Union (non-EU ES), respectively. All parents were residing in different urban areas of Rome and province. Socio-demographic data of non-EU parents are shown in Table 1. Globally, parents were mainly aged between 25 and 40 years (203/301; 67 %), 52/280 (19 %) referred a University degree, 201/310 (70 %) good Italian language skills and 217/301 (72 %) more than one child. In particular, parents showed an heterogeneous educational degree depending on the area of origin (global $p = 0.030$). Good understanding and knowledge of spoken Italian language were mostly referred by parents coming from non-EU ES (32/35;91 %) and America (39/47;83 %) than parents from Africa (47/69; 68 %) and Asia (83/137;61 %) ($p < 0.001$). Furthermore, a great heterogeneity in the number of children was observed with higher frequency of more than three children among African women (34/72; 47 %) ($p = 0.005$). The pediatric population was composed of 160/310 (51

Table 1
Socio-demographic data of non-European origin parents.

	Overall n = 310 (%)	Africa n = 72 (23 %)	Central- South America n = 48 (16 %)	Asia n = 152 (49 %)	Non-EU European States n = 38 (12 %)
Age (years)					
< 25	32 (11 %)	7 (10 %)	2 (4.3 %)	17 (12 %)	6 (16 %)
25–40	203 (67 %)	49 (70 %)	26 (55.3 %)	101 (69 %)	27 (71 %)
>40	66 (22 %)	14 (20 %)	19 (40.4 %)	28 (19 %)	5 (13 %)
Unknown	9	2	0	6	0
Educational Level					
Primary school	32 (11 %)	10 (15 %)	1 (2 %)	20 (15 %)	1 (3 %)
Middle school	83 (30 %)	16 (25 %)	18 (38 %)	39 (30 %)	10 (29 %)
High School	113 (40 %)	26 (40 %)	22 (46 %)	44 (33 %)	21 (60 %)
University degree	52 (19 %)	13 (20 %)	7 (14 %)	29 (22 %)	3 (8 %)
Unknown	30	7	0	20	3
Good Language Skills					
Italian	201 (70 %)	47 (68 %)	39 (83 %)	83 (61 %)	32 (91 %)
English	136 (59 %)	39 (63 %)	7 (29 %)	79 (66 %)	11 (44 %)
French	17 (13 %)	15 (33 %)	0 (0 %)	1 (2 %)	1 (6 %)
Spanish	39 (30 %)	3 (9 %)	33 (87 %)	1 (2 %)	2 (14 %)
Number of children					
1	84 (28 %)	14 (19.4 %)	14 (30 %)	43 (30 %)	13 (34 %)
2	129 (43 %)	24 (33.4 %)	21 (45 %)	63 (44 %)	21 (55 %)
≥ 3	88 (29 %)	34 (47.2 %)	12 (25 %)	38 (26 %)	4 (11 %)
Unknown	9	0	1	8	0

%) males and 150/310 (49 %) females, mainly aged <6 years. Particularly, 262/303 (86.5 %) children were born in Italy, 40/303 (13.2 %) migrated from their country of origin and 1/303 (0.3 %) was adopted (Table 2).

3.2. Childhood immunization: adherence and sources of information

Investigating vaccine adherence in childhood, we observed that 274/310 (88 %) of children have been vaccinated according to the vaccination schedule. As reported in Table 3, vaccine against flu (208/289; 72 %), human papilloma virus (11/36;31 %) and meningococcal group B (9/36; 25 %) were most frequently missed with no geographic differences.

The analysis of the main factors associated with missed or incomplete adherence to childhood vaccine schedule showed that unvaccinated or incompletely vaccinated children had parents with a lower educational degree ($p = 0.040$) and were migrants ($p < 0.001$) compared to foreign children born in Italy. In the univariate analysis, good Italian language skills (OR = 0.48; 95 %CI = 0.22–1.07; $p = 0.067$), parents' lower educational degree (OR = 1.82; 95 %CI = 0.88–3.83; $p = 0.11$) and migration status of children (OR = 0.23; 95 %CI = 0.10–0.52; $p < 0.001$) were significantly associated to the outcome (Table 4). Conversely, only the migration status of children (OR = 0.26; 95 %CI = 0.11–0.67; p -value = 0.004) remained significantly associated to the outcome in the multivariate analysis (Table 4).

The main source of information for childhood immunization in non-EU origin parents was represented by healthcare professionals, respectively pediatrician/general practitioner in 193/310 (62 %) and vaccination center operators in 123/310 (40 %); conversely institutional websites (8/310; 3 %), social networks (4/310; 1.3 %) and other sources (6/310; 2 %) were less used. Furthermore, 268/305 (88 %) non-EU origin parents declared to have received information on childhood immunization by healthcare professionals during a medical consultation. Of note, 241/268 (90 %) children of informed parents were vaccinated, whereas 28/37 (76 %) children of not informed parents were immunized

Table 2
Socio-demographic data of non-European origin children.

	Overall n = 310 (%)	Africa n = 72 (23 %)	Central- South America n = 48 (16 %)	Asia n = 152 (49 %)	Non-EU European States n = 38 (12 %)
Gender					
Female	150 (49 %)	37 (52 %)	17 (35 %)	79 (53 %)	17 (45 %)
Male	155 (51 %)	34 (48 %)	31 (65 %)	69 (47 %)	21 (55 %)
Unknown	5	1	0	4	0
Age (years)					
<3	145 (49 %)	34 (48 %)	18 (38 %)	76 (54 %)	17 (45 %)
3–6	63 (21 %)	14 (20 %)	8 (17 %)	32 (23 %)	9 (24 %)
7–12	57 (19 %)	15 (21 %)	9 (19 %)	22 (15 %)	11(29 %)
>12	33 (11 %)	8 (11 %)	12 (26 %)	12 (8 %)	1 (2 %)
Unknown	12	1	1	10	0
Children origin					
Born in Italy	262 (86.5 %)	63 (88 %)	42 (88 %)	123 (85 %)	34 (89 %)
Migrated	40 (13.2 %)	9 (12 %)	6 (12 %)	21 (14.4 %)	4 (11 %)
Adopted	1 (0.3 %)	0	0	1 (0.6 %)	0
Unknown	7	0	0	7	0

Table 3
Vaccines more frequently missed.

Vaccine	N (%)*
Flu	208/289 (72 %)
HPV	11/36 (31 %)
Meningococcal group B	9/36 (25 %)
Chickenpox	8/36 (22 %)
Hexavalent**	8/36 (22 %)
Measles-Mumps-Rubella	8/36 (22 %)
Meningococcal ACWY	7/36 (19 %)
Pneumococcal	6/36 (17 %)
Meningococcal C	5/36 (14 %)
Rotavirus	1/36 (2.8 %)

* In the survey specific item referred to flu immunization, explaining the different denominator compared to other vaccines.

** Hexavalent is a mandatory combined vaccine including antigens of *C. Diphtheria*, *Tetanus toxoid*, *Bordetella Pertussis*, *Poliovirus*, *Haemophilus influenzae type b* and *Hepatitis B*.

Table 4
Univariate and Multivariate Analysis of childhood vaccination failure according to parents socio-demographic characteristics.

	Univariate odds ratio		Multivariate odds ratio	
	OR (95 % CI)	p value	OR (95 % CI)	p value
Educational Level				
High school/ University degree	1.82 (0.88–3.83)	0.11	1.77 (0.77–4.11)	0.18
Language skills				
Poor Italian language skills	0.48 (0.22–1.07)	0.067	0.54 (0.24–1.27)	0.15
Children origin				
Adopted	215.41 (0.00-NA)	0.99	117–998 (0.00 – NA)	0.99
Migrated	0.23 (0.10–0.52)	<0.001	0.26 (0.11–0.67)	0.004

This table presents the results of univariate and multivariate analysis investigating the factors associated with failure to vaccinate in childhood. Low educational degree, good knowledge of the Italian language and being born in Italy were considered as reference groups in the respective sections. For each predictor we report the Odds Ratio (OR), the 95 % confidence interval (CI) and associated p-value.

($p = 0.025$) (Fig. 1a).

3.3. Maternal immunization

In our survey we also investigated vaccine adherence during pregnancy in non-EU mothers and we observed that 164/310 (53 %) women were not vaccinated with a significant predominance of women from

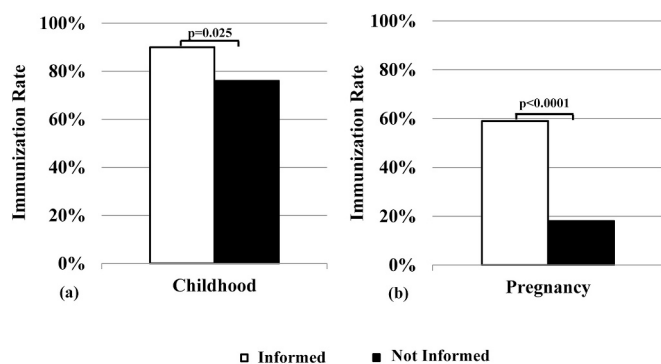


Fig. 1. Childhood vaccination (a) and maternal immunization (b) according to information received.

non-EU ES (29/38; 76 %) compared to women coming from Asia (69/152; 45 %), Africa (36/72; 50 %) and Central-South America (30/48; 63 %) ($p = 0.003$). Anti-pertussis, Sars-CoV-2 and flu vaccines were received by 48/310 (15 %), 40/310 (13 %) and 11/310 (3.5 %) women, respectively. Conversely, 30/310 (10 %) women had received all three vaccinations during pregnancy (Fig. 2). Particularly, we observed a significant discrepancy in terms of information received on maternal immunization (155/297; 52 %) compared to childhood vaccination (268/305; 88 %) ($p < 0.0001$). In details, 92/155 (59 %) informed pregnant were immunized versus 26/142 (18 %) not informed pregnant women who received at least one of recommended vaccines ($p < 0.0001$) (Fig. 1b).

Main factors associated with lack of maternal immunization were lower educational degree ($p = 0.017$) and the origin from non-EU ES ($p = 0.008$). However, the univariate analysis not only confirmed low educational degree (OR = 1.45; 95 % CI = 0.88–2.42; p -value = 0.15) and origin from non-EU ES (Africa vs non-EU ES: OR = 3.68, 95 % CI = 1.48–10.2, p value = 0.007; Central-South America vs non-EU ES: OR = 2.21, 95 % CI = 0.82–6.48, p value = 0.13; Asia vs non-EU ES: OR = 3.96, 95 % CI = 1.71–10.4; $p = 0.002$) as significantly associated to the outcome, but also that women aged 25–40 years (OR = 0.49, 95 % CI = 0.22–1.06; $p = 0.074$) and > 40 years (OR 0.34, 95 % CI 0.13–0.84; $p = 0.020$) were less compliant with vaccinations than younger women. The significant association of maternal immunization failure to low educational degree (OR = 1.93; 95 % CI = 1.12–3.39; p -value = 0.020), origin from non-EU ES (Africa vs non-EU ES: OR = 4.66, 95 % CI = 1.74–14.2, p -value = 0.004; Central-South America vs non-EU ES: OR = 3.32, 95 % CI = 1.14–10.8, p -value = 0.034; Asia vs non-EU ES: OR = 4.84, 95 % CI = 1.93–14.0, $p = 0.002$) and women older age (25–40 years: OR = 0.39, 95 % CI = 0.16–0.93; $p = 0.036$; > 40 years: OR 0.24, 95 % CI 0.08–0.66; $p = 0.007$) was also confirmed by the multivariate analysis (Table 5).

3.4. Sars-CoV-2 Vaccination and main reasons for parents' vaccine hesitancy

The analysis of Sars-CoV-2 vaccine adherence showed a higher uptake in parents than in children. In fact, while out of 279/310 (90 %) parents, one or both, decided to vaccinate, only 60/199 (30 %) vaccineable children were immunized ($p < 0.0001$) (Fig. 3). In detail, poor adherence to parents' vaccination was mainly due to doubts on the safety and efficacy of Sars-CoV-2 vaccine as reported by 11/37 (30 %) and 7/37 (19 %) parents, respectively (Table 6). Conversely, lack of Sars-CoV-2 vaccination in childhood was mainly due to the non-mandatory vaccine request at the pediatric age and to the doubts about its need according to 39/127 (31 %) and 29/127 (23 %) parents, respectively (Table 6).

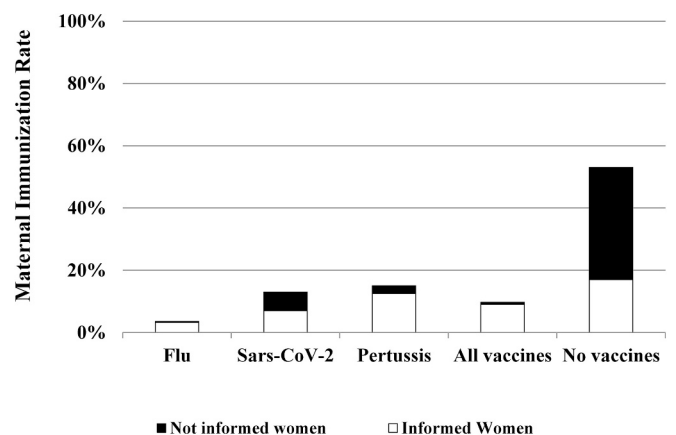


Fig. 2. Maternal immunization rate for recommended vaccines according to information received.

Table 5
Univariate and Multivariate Analysis of maternal immunization failure according to womens socio-demographic characteristics.

	Univariate odds ratio		Multivariate odds ratio	
	OR (95 % CI)	p value	OR (95 % CI)	p value
Age				
25–40 years	0.49 (0.22–1.06)	0.074	0.39 (0.16–0.93)	0.036
>40 years	0.34 (0.13–0.84)	0.020	0.24 (0.08–0.66)	0.007
Educational Level				
High school/ University degree	1.45 (0.88–2.42)	0.15	1.93 (1.12–3.39)	0.020
Geographic area of origin				
Africa	3.68 (1.48–10.2)	0.007	4.66 (1.74–14.2)	0.004
Central-South America	2.21 (0.82–6.48)	0.13	3.32 (1.14–10.8)	0.034
Asia	3.96 (1.71–10.4)	0.002	4.84 (1.93–14.0)	0.002

This table presents the results of univariate and multivariate analysis investigating the factors associated with failure to vaccinate in pregnancy. Age < 25 years, low educational degree and the origin from non-EU European countries were considered as reference groups in the respective sections. For each predictor we report the Odds Ratio (OR), the 95 % confidence interval (CI) and associated p-value.

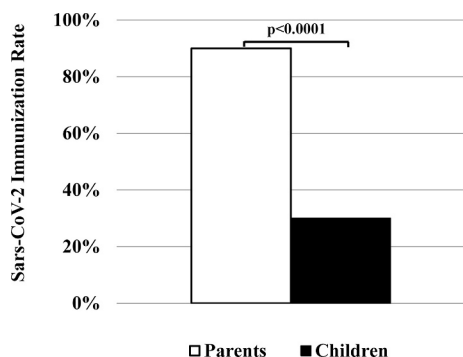


Fig. 3. Sars-CoV-2 immunization rate in parents compared to children.

Table 6
Reasons for parents' vaccine hesitancy according to the type of vaccine.

	Vaccines as per PNPV n = 36 (%)	Sars-CoV-2 vaccine for children n = 127 (%)	Sars-COV-2 vaccine for adults n = 37 (%)
Doubts about the efficacy of vaccination	1 (2.8 %)	13 (10 %)	7 (19 %)
Doubts about the safety of vaccination	2 (5.6 %)	18 (14 %)	11 (30 %)
Doubts about the need for vaccination	1 (2.8 %)	29 (23 %)	6 (16.2 %)
Preference for a "natural immunity"	7 (19.4 %)	13 (10 %)	4 (11 %)
No obligation to vaccine	7 (19.4 %)	39 (31 %)	5 (13.5 %)
Ethical-religious reasons	1 (2.8 %)	2 (1.6 %)	2 (5.4 %)
Difficulty to make an appointment at the Vaccine Center	8 (22.2 %)	2 (1.6 %)	2 (5.4 %)
No information received about vaccine	7 (19.4 %)	24 (19 %)	2 (5.4 %)

3.5. Parents' vaccine hesitancy for their children immunization: Sars-CoV-2 vaccine compared to PNPV vaccines

Reasons of parents' vaccine hesitancy on children immunization were found to be different for PNPV vaccines compared to Sars-CoV-2 vaccine. Indeed, the difficulty to make an appointment at the vaccine center, poor vaccine information by healthcare providers and preference for natural immunity were reported for childhood PNPV vaccine failure by 8/36 (22 %), 7/36 (19 %) and 7/36 (19 %) parents, respectively (Table 6). Conversely, doubts on the need, efficacy and safety were rarely reported for PNPV vaccines compared to Sars-CoV-2 vaccine.

4. Discussion

Over time the great ethical and social value of vaccination has been extensively demonstrated. Based on this principle, the recent Italian National Vaccination Prevention Plan (PNPV) 2023–2025 has included individuals with social and economic vulnerability as one of the at risk categories who benefit an active and free vaccine offer. In the present study, vaccine knowledge and attitude of non-EU parents living in Italy and factors affecting their vaccine uptake and equity have been investigated to design strategies aimed at ensuring appropriate vaccination coverage and inequality reduction.

Globally, childhood vaccine coverage is extremely heterogeneous. The pandemic and several war conflicts have contributed to the uptake decline that has been observed in the last years [18–20]. Particularly, in Italy the latest 2021 childhood vaccination data have shown suboptimal coverage rate for polio and measles [21]. In our study, 88 % of children with non-EU origin have been vaccinated according to the vaccination schedule, thus not reaching the vaccination rate of the Italian pediatric population of 90–95 %, as generally recommended by the Italian PNPV, according to the type of vaccine and age groups. In USA children with foreign origin mothers were 14 % less likely to complete vaccinations than children of American-born mothers [22]. Conversely, other studies report good adherence to vaccination schedule by children with foreign origin parents [6,23,24]. The extreme heterogeneity of data on immunization of children with foreign origin parents might be not related to the country they migrate to but might reflect the different social norms and cultural habits arising from their ethnicity.

In our study 12 % of children were partially immunized or unimmunized and the most frequently missed vaccines were against flu (72 %), human papilloma virus (HPV) (31 %) and meningococcal group B (MenB) (25 %).

To date, flu vaccine coverage rate in childhood is extremely heterogeneous worldwide and mainly below the national immunization targets with data fluctuations according to the age group and nationality [25–29]. Most of available data on child flu vaccine coverage rarely distinguish children based on their nationality and age. A Danish study reported rates for first- and second- generation migrant children of 1 % and 10 %, respectively [30]. In Italy, childhood flu vaccine coverage rate is approximately 31 % in preschool age [29] and a recent Italian pilot study on school-located flu vaccination campaign among pre-school children reported that 59 % of all immunized children in the cohort had foreign origin [31]. Therefore, the design and implementation of informative vaccine campaigns in specific public locations, such as schools, and easy access to health services may represent an effective strategy to reach the most disadvantaged and vulnerable populations which ensures an increase of immunization with public health benefit.

In our cohort data of missed HPV vaccination are similar to those of an American study where 43–58 % of migrant parents were not in favor of vaccinating their daughters [12]. The low percentage of HPV vaccination, also confirmed by other studies [23,32–34], highlights the need to increase awareness in the prevention of HPV disease and related cancer. Thus, a broad and targeted informative campaign is required to raise vaccine coverage and ensure completeness of the HPV immunization program, since unimmunization as well as a delay or failure of the

immunization program are frequent in children with foreign parents [8,12,23,35]. Furthermore, since HPV vaccine can be incorrectly associated to sexual activity according to the culture and social habits of each population, healthcare professionals' training is pivotal in order to ensure adequate information respecting cultural beliefs.

The efficacy of meningococcal group B (MenB) vaccine in preventing meningococcal disease has been widely demonstrated [36], however little data are available about this vaccine uptake in children with foreign parents worldwide. In our study 25 % of these children were unimmunized against MenB, confirming that vaccine hesitancy needs to be overcome among different ethnic groups residing in the national territory.

In our study the main factors associated with missed or incomplete adherence to childhood vaccine schedule were a lower educational degree of parents, as previously reported [11,32,37], and foreign birth of the child. Indeed, while migrants status may affect optimal vaccine adherence due to different vaccine schedule among various countries and to missing/incomplete vaccine documentation of the country of origin, birth in Italy favors regular immunization according to national schedule and guarantees better adherence. Other factors may contribute to a missed or incomplete childhood immunization, such as different social inclusion, accessibility to healthcare services, systems of vaccine offering and the methodology in providing information across countries [4,11,36,38]. Therefore, the implementation of strategies to increase vaccine awareness and to overcome socio-cultural barriers affecting foreign populations in host countries is mandatory. Moreover, to share standardized protocols on dealing with unknown or incomplete immunizations and updated vaccination registers among different countries could be an appropriate action.

The source of information is pivotal to implement vaccine knowledge. As widely proven [39,40], healthcare professionals are essential for promoting immunization culture while alternative sources of information, such as social media or non-institutional sites, have been frequently associated to a greater vaccine hesitancy [41]. In our study the main source of information for non-EU origin parents was represented by healthcare professionals confirming their crucial role to combat vaccine fears and concerns. However, although the percentage between 40 % and 62 % of non-EU origin parents with confidence in healthcare professionals is relevant, it does not reach that of native parents [16,29], demonstrating once again the need to improve confidence in the host country's health service and staff.

To date the importance of maternal immunization in the protection of mother-newborn dyad has been widely demonstrated, however in our study 53 % of women of foreign origin were not immunized during pregnancy. Our data confirm that mainly women from non-UE ES, with older age and low educational degree are less compliant with immunization, as previously reported [42]. The influence of country of origin on immunization compliance could be explained with substantial differences in the immunization offers and programs, thus impacting on preventable infectious diseases awareness. The close relationship between educational attainment and health status has been frequently highlighted [43] and higher educational level may increase women's awareness of infectious risk. Furthermore, younger age has been previously recognized as a factor closely related to pregnancy immunization knowledge and adherence [43–45].

In contrast to the recent Morbidity and Mortality Weekly Report that found a greater immunization rate for influenza (10 %) among pregnant women regardless of their origin [42], we found pertussis vaccine as the most commonly received. The higher maternal immunization against pertussis compared to Sars-CoV-2 and flu may derive not only from greater information provided on its benefits, effectiveness and safety but also limited available data on the recently introduced Sars-CoV-2 vaccine combined with socio-cultural barriers. Moreover, the general low rate of immunization during pregnancy may be due to poorer information and knowledge compared to that of childhood vaccination [46–48]. Indeed, we observed that 90 % of informed parents had their children

vaccinated, conversely only 59 % of women carried out at least one vaccine during pregnancy despite the information received. This finding might be ascribed to the fact that in Italy any child is granted a free assignment to a pediatrician who regularly follows the child in the first months of life, corresponding to the beginning of the immunization program. Conversely, low maternal immunization awareness may be due to hard access to health services during pregnancy for women of foreign origin and difficulties in language and communication with healthcare personnel [49]. In addition to linguistic and cultural barriers, higher mobility of these foreign women and the need for an healthcare insurance in some countries may also affect maternal immunization.

Globally speaking, a different vaccination attitude against Sars-CoV-2 in non-EU origin parents compared to their children was observed, since non-EU origin parents had a coverage rate similar to that of the adult Italian population. In this case the green pass allowing mobility more than the migration status may have played a pivotal role for the adults' compliance at the beginning of the vaccination campaign. However, doubts about safety and effectiveness of the vaccine were the main reasons provided by non-EU Sars-CoV-2 unimmunized parents, as previously reported [50,51]. Conversely, when it concerns to their children, non-EU parents declared that the non-mandatory nature of Sars-CoV-2 vaccine in children and doubts on the safety and need for the vaccine itself represented the main reasons of their hesitancy, as reported by Italian parents [52,53]. The awareness of Sars-CoV-2 disease complications in childhood is still low among parents regardless their ethnicity, therefore an adequate informative campaign by healthcare personnel is essential to clarify vaccine relevance to limit the spread of the virus if new variants emerge. With respect to PNPV vaccines, parents' hesitancy was mainly ascribed to the difficulty to access to the vaccination centers and the scarce information received. However, the mandatory nature of some vaccines is relevant for the immunization adherence and in our study it explains the high vaccine coverage rate since the majority of non-EU origin children were born in Italy.

Therefore, tailored vaccine campaigns adequately planned and directed to vulnerable populations, such as non-EU origin families, should promote specific educational and communicative interventions directed to the individual, family, society and health services. The creation of open days for some categories, such as migrants and adopted children, or a close partnership with pharmacies to administer vaccine on site as already done in some countries [54,55] and increase awareness on the importance of immunization deserves consideration. Furthermore, linguistic mediators to ensure better communication and understanding and easy access of foreign pregnant women to free childbirth education courses in different languages may be other strategic tools to provide accurate and clear information on maternal and childhood immunization.

In brief, the implementation of a widespread territorial network, including also community-based organizations, is crucial to reach everyone and overcome social and bureaucratic obstacles. In this context, the use of artificial intelligence for dedicated informative campaigns could represent a valuable tool to increase vaccine coverage of vulnerable populations and exploit an holistic approach to reduce health inequalities.

Limitations.

Our study presents noteworthy limitations. First, the number of parents enrolled is limited and confined to a small geographical area, therefore our results could not be considered nationally-representative. Second, since the majority of participating parents were enrolled in healthcare sites they might have a greater socio-cultural integration in the area of residence, a higher attitude to vaccinate their children and a higher confidence on family pediatricians and vaccination center personnel to care for their children's health, thus leading to the high vaccine coverage rate observed. Third, our survey excludes all "invisible" people who cannot access to healthcare services. Finally, all collected data were self-reported by participants who were extremely heterogeneous for their ethnicity and educational degree that may affect

comprehension and response to the questionnaire.

5. Conclusions

Our study reveals the pivotal role of governmental and non-governmental institutions as well as healthcare personnel to improve vaccine uptake in non-EU origin people. Thus, combined inclusive and innovative actions targeting educational activities and campaigns at national and local levels could promote a greater integration of individuals of non-EU origin overcoming not only political-administrative but also socio-cultural barriers in order to reduce vaccination hesitancy and improve immunization equity among vulnerable populations.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRedit authorship contribution statement

Viviana Moschese: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Conceptualization. **Simona Graziani:** Writing – review & editing, Writing – original draft, Visualization, Resources, Data curation. **Antonietta Spadea:** Writing – review & editing, Supervision, Resources, Data curation. **Maurizia D'Amore:** Writing – review & editing, Data curation. **Raffaella Mosco:** Writing – review & editing, Data curation. **Sara Ciampini:** Writing – review & editing, Data curation. **Nicola Di Giorgio:** Writing – review & editing, Data curation. **Susanna Arcano:** Writing – review & editing, Data curation. **Simona Ceccarelli:** Writing – review & editing, Data curation. **Marco Chianca:** Writing – review & editing, Data curation. **Simona Piccinini:** Writing – review & editing, Data curation. **Antonella Polito:** Writing – review & editing, Data curation. **Marta Porcari:** Writing – review & editing, Data curation. **Pamela Puliafito:** Writing – review & editing, Data curation. **Romina Silenzi:** Writing – review & editing, Data curation. **Elisabetta Del Duca:** Writing – review & editing, Data curation. **Claudio Pignata:** Writing – review & editing, Supervision. **Michele Miraglia Del Giudice:** Writing – review & editing, Supervision.

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 will be made available on request.

Acknowledgements

We acknowledge the support of the Italian Society of Pediatric Allergy and Immunology (SIAIP) and the Italian Society of Pediatric Research (SIRP) for study assistance as well as the support of Alfonso Picocchi for statistical analysis. The authors would like to thank all families who allowed the present study.

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