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Exploring reported causes of vaccine hesitancy among European adolescents and parents: results of a citizen science project

Pere Millat-Martínez[1*], Ana Mora[2], Pol Ezquerra Condeminas[3,4], Miquel Castelló[3], Claudia Alsina[5], Beatriz Fiestas[1], Matteo Bason[6], Montserrat Esquerda[7], Alexandre Perera-LLuna[4,8], Begonya Nafria[5,9†] and Quique Bassat[1,10,11,12,13,14†]

Abstract

Background Progress in pediatric immunization is threatened by vaccine hesitancy. While recent estimates show 14–35% of European parents exhibit some degree of hesitancy, little is known about adolescents. We assessed vaccine hesitancy and associated factors in European adolescents and parents through the online Science4Pandemics platform.

Methods We conducted two cross-sectional surveys. One in individuals aged ≥ 12 and < 18 years, using a non-validated questionnaire adapted from the Parent Attitudes about Childhood Vaccines (PACV); and another using the PACV questionnaire in parents aged ≥ 18 years, who were not necessarily related to the adolescents.

Results 1877 adolescents from Italy, Portugal, Poland and Spain were included. Of these, 45.9% were aged 12–14 years, and 54.1% were 15–17 years. The prevalence of hesitancy (adapted PACV score ≥ 50%) was 20.8% (390 individuals). Hesitancy prevalence varied between countries, from 12.5% in Spain to 31.6% in Poland ($p < 0.001$). Geographic region was the only associated factor for hesitancy [Odds Ratio (OR) for Polish adolescents: 3.20 (95%CI: 2.29, 4.51); OR for Italian adolescents: 2.28 (95%CI: 1.62, 3.24); OR for Portuguese adolescents: 1.13 (95%CI: 0.77, 1.66); all compared to Spanish adolescents]. Country remained the only associated factor in the multivariate logistic regression analysis. In contrast, 1135 parents of children under 18 were included, with hesitancy observed in 20.4% (232 individuals). The main associated factors for hesitancy, both in the univariate and multivariate analyses, were country of residence [OR for Italian parents: 2.34 (95%CI: 1.47, 3.80); OR for Polish parents: 2.69 (95%CI: 1.70, 4.36); OR for Portuguese parents: 2.26 (95%CI: 1.41, 3.68); all compared to Spanish parents], and age, with older parents being less hesitant (OR: 0.97, 95%CI: 0.96, 1.00). In both parents and adolescents, the main reasons for vaccine hesitancy were fear of vaccine side effects (56.1% in adolescents, 51.9% in parents) and lack of trust in government recommendations (21.9% in adolescents, 22.8% in parents).

†Begonya Nafria and Quique Bassat contributed equally and should share senior authorship.

*Correspondence:
Pere Millat-Martínez
pere.millat@isglobal.org

Full list of author information is available at the end of the article

Conclusions Vaccine hesitancy in adolescents and parents in Europe is prevalent, with country of residence as a key influencing factor. Targeted strategies to educate both groups about immunization benefits and its side effects are essential, considering the heterogeneity across countries and reasons for hesitancy.

Keywords Adolescents, Citizen science, Vaccine hesitancy, Immunization, Parents, Vaccination

Background

Immunization is the most effective and safest method to confer protection against infections; with vaccines recognized as one of the most important public health achievements of the last century [1]. However, vaccine hesitancy is on the rise and has been identified as one of the top ten threats to global health [2]. The World Health Organization (WHO) defines vaccine hesitancy as a "delay in acceptance or refusal of vaccination despite availability of vaccination services" [3]. While various factors, such as economic constraints, logistical challenges, healthcare infrastructure, environmental conditions, and limited access to health and education contribute to the decline in vaccination coverage [4, 5], vaccine hesitancy has also been identified as a significant contributing factor [5–7]. As a result, outbreaks and epidemics of vaccine-preventable disease have re-emerged [8, 9]. Healthcare providers play an important role in building trust in vaccines [10], whereas anti-vaccination messaging and anti-vax social movements have increasingly influenced the opinion of parents and the general population [11, 12]. Therefore, addressing parental and family attitudes toward children vaccination is crucial.

Identifying vaccine-hesitant populations and understanding the reasons behind their hesitancy is essential for designing effective educational strategies and improving vaccination rates. The European Centre for Disease Prevention and Control (ECDC) provides guides and toolkits for healthcare workers, managers of immunization programs, and public health experts for addressing vaccine hesitancy. The ECDC recommends measuring vaccine hesitancy in different settings, allowing public health programs to develop targeted interventions tailored to specific populations and concerns [13]. The WHO vaccine working group has classified reasons for hesitancy under three categories: confidence (trust in the effectiveness and safety of the vaccines, the healthcare professionals, and the policy makers), complacency (the perceived risks of vaccine-preventable diseases are low and vaccination is not deemed a necessary preventive action), and convenience (challenges in access such as environmental, social, or economic issues) [14]. For instance, among parents of adolescents aged 11 to 17 years in the United States, confidence was the main issue, with 39% questioning vaccine efficacy and 41% expressing safety concerns, particularly regarding side effects [15].

Vaccine hesitancy has been primarily studied among healthcare providers, the general population, and parents. Moreover, the global COVID-19 vaccination campaigns provided an opportunity to further explore this topic. For instance, a survey conducted in 19 of the 35 countries most affected by the pandemic before the availability of COVID-19 vaccines found that 71.5% of adults were willing to receive the vaccine, while only 48.1% stated that they would accept their employer's recommendation to do so if the vaccine was approved by their government [16]. In this study, greater vaccine acceptance was associated with women and older populations (≥ 50-years old); however, the results were heterogeneous and strongly influenced by demographic factors and geographic location [17].

In Europe, vaccine coverage is regularly monitored. Poland is among the European countries with lower vaccine coverage, despite having mandatory routine childhood vaccination. For example, in 2023, the coverage for the first dose of the measles vaccine was 91%, while the second dose reached only 86% [18]. Additionally, some vaccines have experienced a decline in coverage over time, such as the third dose of the polio vaccine, which dropped from 96% in 1980 to 85% in 2023 [18]. A recent scoping review and metanalysis on parents' attitudes towards children's vaccination in Poland found vaccine acceptability rates ranging from 70 to 100%, with higher acceptance among younger, better educated parents, living in cities and with higher economic status [19]. Similarly, a 2018 prevalence survey in Italy, revealed that 34.7% of parents of children aged 2 to 6 years were hesitant to vaccinate their children [20]. Although vaccine coverage improved after the enforcement of mandatory childhood vaccinations in 2017 [21], it remains lower than in other European countries [18]. In contrast, parents from Portugal and Spain reported some of the highest vaccine confidence rates among the 18 European countries recently surveyed on vaccine hesitancy [22]. In both countries, childhood vaccination coverage remains high, despite immunization being recommended rather than compulsory [23]. As in Poland and Italy, major vaccines are funded by each National Health System, suggesting that vaccine coverage in Europe may be influenced by factors beyond economic barriers [22].

Despite extensive research on vaccine acceptability among parents, little is known about trust in vaccines among younger adults and adolescents, who play an important role in public health strategies. Recently, with

the rollout of COVID-19 vaccines, some studies have begun to assess trust within younger populations. For instance, in a 2021 cross-sectional survey conducted in China, 16.5% of adolescents aged 16–17 years and 7.9% of young adults (18–21 years-old) were hesitant to receive a COVID-19 vaccine [24]. Although there is limited evidence directly linking adolescent vaccine hesitancy to lower vaccination coverage, adolescents appear to be highly influenced by media messaging and social pressure [25, 26]. A study conducted in the US during the pandemic found that individuals aged 13–18 years had greater vaccine safety concerns based on social media compared to adults, and more than half reported that they would be more likely to get vaccinated if their peers did as well [27].

We assessed hesitancy toward routine vaccines and associated factors in adolescents aged 12 to < 18 years and parents through a cross-sectional survey in four European countries, using the Science4Pandemics digital platform. Science4Pandemics, a European project aimed at adolescents, develops citizen science research initiatives using digital data collection tools, while also fostering education to enhance pandemic preparedness.

Methods

Study design, setting and participants

The topic of interest and hypothesis for this study were selected through the participation of adolescents from different age groups at the Patients Engagement in Research Department at Institut de Recerca Sant Joan de Déu, Barcelona, Spain, as part of the citizen science project led by Science4Pandemics. Multiple sessions were organized to explore the topics of interest among adolescents, leading to the selection of vaccine hesitancy for this study. Additionally, adolescents from the Patients Engagement in Research Department contributed to the design of the study questionnaire, ensuring its comprehension across the age groups included in this research.

We conducted an online cross-sectional survey for adolescents aged ≥ 12 to < 18 years- old who were attending schools in four European countries. We selected 2 countries (Spain and Portugal) where vaccines are not compulsory and where child immunization coverage is over 92% for all recommended vaccines, and 2 more countries (Poland and Italy) where routine vaccines are mandatory and immunization coverage is slightly lower compared to the other two selected countries [18]. We included individuals that were literate, had access to internet, were willing to participate in the study and giving assent, and whose parents were informed and consented for the study. At the same time, a cross-sectional study was conducted for individuals > 18 years-old, parents of at least one child with age comprised between 1 and < 18 years-old, living in the same countries than the adolescents' survey, with internet access and willing to participate in the study. Importantly, parents could participate regardless of whether their children had accepted being part of the study.

To reach the potential participants, we designed a communication and dissemination plan that utilized various channels and strategies across the selected countries, with the aim to reach 3600. Initially, the study was announced on the Science4Pandemics project's official website and social networks, including Instagram and YouTube [28]. Additionally, the dissemination of the study was carried out through the websites and social networks of the project partners. A second strategy focused on schools, where we directly contacted them via phone and email to introduce the project and invite them to participate in the study. To encourage questionnaire completion, we included an educational toolkit containing information on how to implement educational projects related to pandemics and vaccines. Finally, a third dissemination strategy consisted on webinars aimed at raising vaccine awareness among secondary school students. These webinars not only covered vaccine-specific content but also explained the project and the study. A total of six webinars were conducted. In addition, a face-to-face event in Barcelona (Spain), organized by *Fundació La Caixa*, presented the study to educational institutions and teachers. These strategies were employed until we achieved the desired number of completed questionnaires.

Sample size calculations and sampling process

A minimum sample size of 1068 participants for assessing vaccine hesitancy in adolescents was calculated to achieve a 3.00% precision and a 95.00% bilateral normal confidence interval. For this calculation we considered a prevalence of hesitancy of 50%, given the heterogeneity of previous studies and the few information about hesitancy prevalence on this age group. To assess the prevalence on vaccine hesitancy in parents, a minimum sample size of 965 was calculated to provide a precision of 3.00% and a 95.00% bilateral normal confidence interval, based on a 34.5% reported prevalence of hesitancy in Italian parents [20]. We used R 4.2.0 version with the package pwrss v0.3.1 for the sample size calculations.

A convenience sampling was used for this study. We designed a dissemination plan, as previously described, aiming to reach approximately 3600 individuals across Spain, Portugal, Italy and Poland. After assenting for permission, adolescents and parents accessed the anonymous online questionnaire in the Science4Pandemics webpage [28].

Data collection

Data for this study were collected between the 2nd of November of 2022 and the 26th of October of 2023 using the Science4Pandemics platform: https://science4pandemics.eu. This educational project, funded by an EIT project, aims to enhance people's understanding of pandemics, equip them with important skills in resource management and decision-making, and improve their knowledge on measures to prevent and mitigate pandemics. A digital online platform was designed to provide educational toolkits for schools and an educational videogame that models five different infections with real-life data. One of the aims of this project is to increase young people's participation in citizen science studies, helping to collect real-world data used for collaborative research in pandemics [28]. Science4Pandemics platform was developed using the platter Ruby on Rails. The database for this study is safely stored at *Fundació Sant Joan de Déu Amazon Cloud*, and secured access is provided though REpresentational State Transfer (REST) APIs, avoiding unauthorized access.

The study questionnaire for parents included demographic questions, a validated scale for measuring hesitancy in parents, the Parent Attitudes about Childhood Vaccines (PACV) [29, 30], and additional questions to understand reasons for hesitancy. The PACV scale has been validated in different geographic and demographic parents' samples [13, 31, 32], and contains 15 items under 3 domains: behavior, safety and efficacy, and general attitudes. To assess the prevalence of hesitancy in parents we calculated a score ranging from 0 to 100 based on their responses to the 15 PACV questions. Responses were scored as follows: hesitant = 2, non-hesitant = 0, and "don't know" = 1. Each of the item scores were summed unweighted to obtain a total raw score. This raw score was then converted linearly to a scale ranging from 0 (least hesitant) to 100 (most hesitant). A score of ≥ 50 was considered as "hesitant", while scores < 50 indicated "non hesitant", as explained elsewhere [30].

For adolescents, the questionnaire included demographic questions, a non-validated questionnaire adapted from the PACV, and the WHO validated questionnaire for causes of hesitation (supplementary material 1). This adapted questionnaire was first tested for comprehension by adolescents from different age groups through the Patients Engagement in Research Department at Institut de Recerca Sant Joan de Déu, Barcelona, Spain. To assess hesitancy, we applied the same scoring system used in the PACV for parents, obtaining a scale from 0 to 100, with a score > 50 considered "hesitant". However, the adapted questionnaire included 17 questions instead of 15, dividing 2 complex questions for clarity purposes. Each question scored individually, as in the PACV; however, the modified questions (questions 18 to 21, supplementary material 1) were assigned half the points to ensure the total score could align with the PACV for parents.

The questionnaires were first written in English and then translated into Spanish, Portuguese, Italian and Polish. Finally, they were tested in a subgroup of individuals from each country before collecting data for the study.

Statistical analysis

Data were analysed using the computer package R 4.2.0 version (R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/). Categ orical variables were summarised using frequencies and percentages. Mean and standard deviation (SD) were calculated for age, the only continuous variable collected in the survey. Age was also reclassified into a categorical variable following age groups (12 to 14 years-old and 15 to 17 years-old in the adolescent populations, and ≤ 30 years-old, between 31 and 45 years-old, and ≥ 45 years-old in the parents' population). To compare demographic characteristics across countries, we calculated *p*-values through Chi-Square test for the categorical variables and ANOVA for the continuous variable. After calculating prevalence of vaccine hesitancy as previously described, it was correlated with demographic and geographic characteristics. Univariate and multivariate logistic regression analyses were done for the calculation of odds ratios and adjusted odds ratios with 95% confidence intervals (95% CI), evaluating factors associated with hesitancy. For this, we used the glm() function from the stats package in R [4.3.2]. The glm() function is used to fit generalized linear models, specified by providing a symbolic description of the linear predictor and an error distribution. The statistical significance of our models was assessed using the Wald test. Causes of hesitancy were assessed in the whole study population, describing data using frequencies and percentages and assessing differences between hesitant and non-hesitant populations through Chi-Square test.

Results

Cross-sectional study in adolescents

A total of 2275 adolescents opened and responded the online questionnaire. We defined our study population as those individuals having completed the questionnaire's block needed for assessing the primary objective of hesitancy prevalence (last question of the adapted PACV scale; question 22 in supplementary material 1). Hence, we excluded 398 (17.5%) individuals that dropped out before this question, and a total of 1877 adolescents were included in the analysis. Of them, 862 (45.9%) were younger participants (12–14-years-old) and 1015 (54.1%) comprised the 15–17-year-old group; and 1061 (56.5%) identified as gender male, 812 (43.3%) as gender female and 4 (0.2%) identified as non-binary. Distribution was

equally across the four countries, with 473 (25.2%) participants being from Italy, 472 (25.1%) from Poland, 470 (25.0%) from Portugal, and 462 (24.6%) from Spain. Most of the adolescents (48.8%) were attending secondary education, while others were attending primary school (21.6%), or a vocational training (11.3%). Participants attending high school (Bachillerato in Spain, Scuola Superiore in Italy, Liceum in Poland, or Ensino Secundário in Portugal) were 18.2%. Table 1 shows the demographic characteristics of the participants divided by country of residence; showing the Spanish participants being slightly older than the rest of the cohort (mean age and SD of 15.1 ± 1.5 years compared to 14.5 ± 1.6 years in Italy, 14.4 ± 1.6 years in Poland, and 14.5 ± 1.6 years in Portugal; *p*-value < 0.001).

Overall prevalence of vaccine hesitancy (adapted PACV scoring ≥ 50) in adolescents was 20.8% (390/1877). Distribution of hesitancy degree for adolescents can be seen in Fig. 1, with few participants (87, 4.6% of the total) having scored ≥ 70 (high hesitancy degree). Figure 2 shows the prevalence of hesitancy by country. Adolescents living in Poland and Italy had higher prevalence of hesitancy (31.6% and 24.7% respectively) compared to those living in Portugal (14.0%) and Spain (12.5%), $p < 0.001$. The univariate logistic regression analysis showed country of residence being associated with hesitancy (Table 2). The odds ratio (OR) for Polish participants compared to those from Spain was 3.20 (95%CI: 2.29, 4.51), 2.28 (95%CI: 1.62, 3.24) for Italians, and 1.13 (95%CI: 0.77, 1.66) for Portuguese. Gender was not associated with hesitancy [OR for males was 0.88 (95%CI: 0.71, 1.10) compared to females], and neither was age [OR 0.95 (95%CI: 0.88, 1.01)]. Country of residence was, again, the only associated factor in the multivariate logistic regression analysis (Table 2), with adjusted odds ratio (aOR) for Polish adolescents being 2.89 (95% CI: 1.93, 4.32), aOR for Italian adolescents being 2.23 (95% CI: 1.52, 3.25), and aOR for Portuguese adolescents 1.03 (95%CI: 0.67, 1.59), all compared to Spanish adolescents.

Cross-sectional study in parents

A total of 1206 parents opened and responded the online questionnaire. We excluded 5 individuals aged < 18 years-old that filled the questionnaire and 66 (5.5%) individuals that dropped out before the last question of the PACV scale, needed for the assessment of the primary objective. Hence, the total study population of parents was 1135. Of them, 34 (3.0%) were 30 years-old or younger, 631 (55.6%) were between 31 and 45 years-old, and 470 (41.4%) were older than 45 years-old. In the case of the parents, 582 (51.3%) respondents were female, 551 (48.5%) were male, and 2 (0.2%) identified as non-binary gender. Distribution across the four countries was equal, with 292 (25.7%) of individuals living in Italy, 291 (25.6%) living in Portugal, 290 (25.7%) living in Poland, and 262 (23.1%) being from Spain. The highest educational level for parents was

Table 1 Demographic characteristics of adolescents and parents' participants by country

Variable		Italy	Poland	Portugal	Spain	*p*-value
Adolescents' participants (N)		473	472	470	462	
Gender [N (%)]	Female	189 (40.0)	230 (48.7)	198 (42.1)	195 (42.2)	0.058
	Male	284 (60.0)	241 (51.1)	271 (57.7)	265 (57.4)	
	Non-binary	0	1 (0.2)	1 (0.2)	2 (0.4)	
Age [mean ± SD]		14.5 ± 1.6	14.4 ± 1.6	14.5 ± 1.6	15.1 ± 1.5	< 0.001
Educational level [N (%)]	High school	199 (42.1)	0	0	143 (31.0)	< 0.001
	Vocational training	120 (25.4)	15 (3.2)	34 (7.2)	44 (9.5)	
	Secondary	154 (32.6)	251 (53.2)	244 (51.9)	268 (58.0)	
	Primary	0	206 (43.6)	192 (40.9)	7 (1.5)	
Parents' participants (N)		292	290	291	262	
Gender [N (%)]	Female	147 (50.3)	155 (53.4)	146 (50.2)	134 (51.1)	0.895
	Male	145 (49.7)	134 (46.2)	144 (49.5)	128 (48.9)	
	Non-binary	0	1 (0.3)	1 (0.3)	0	
Age [mean ± SD]		46.7 ± 7.1	41.6 ± 6.9	43.8 ± 5.9	43.3 ± 7.0	< 0.001
Educational level [N (%)]	High school	145 (49.7)	106 (36.6)	0	70 (26.7)	< 0.001
	PhD	16 (5.5)	7 (2.4)	2 (0.7)	11 (4.2)	
	Master's	57 (19.5)	78 (26.9)	22 (7.6)	31 (11.8)	
	University degree	39 (13.4)	55 (19.0)	84 (28.9)	91 (34.7)	
	Vocational training	0	25 (8.6)	0	0	
	Secondary	32 (11.0)	7 (2.4)	161 (55.3)	21 (8.0)	
	Primary	3 (1.0)	12 (4.1)	22 (7.6)	38 (14.5)	
Number of children [mean ± SD]		1.8 ± 0.7	1.9 ± 0.9	1.8 ± 0.6	1.7 ± 0.7	0.002

Main demographic characteristics across the four participating countries. P values for comparison were obtained using Chi-square test; ANOVA test was used for the age variable. Abbreviations: N = number, SD = Standard Deviation

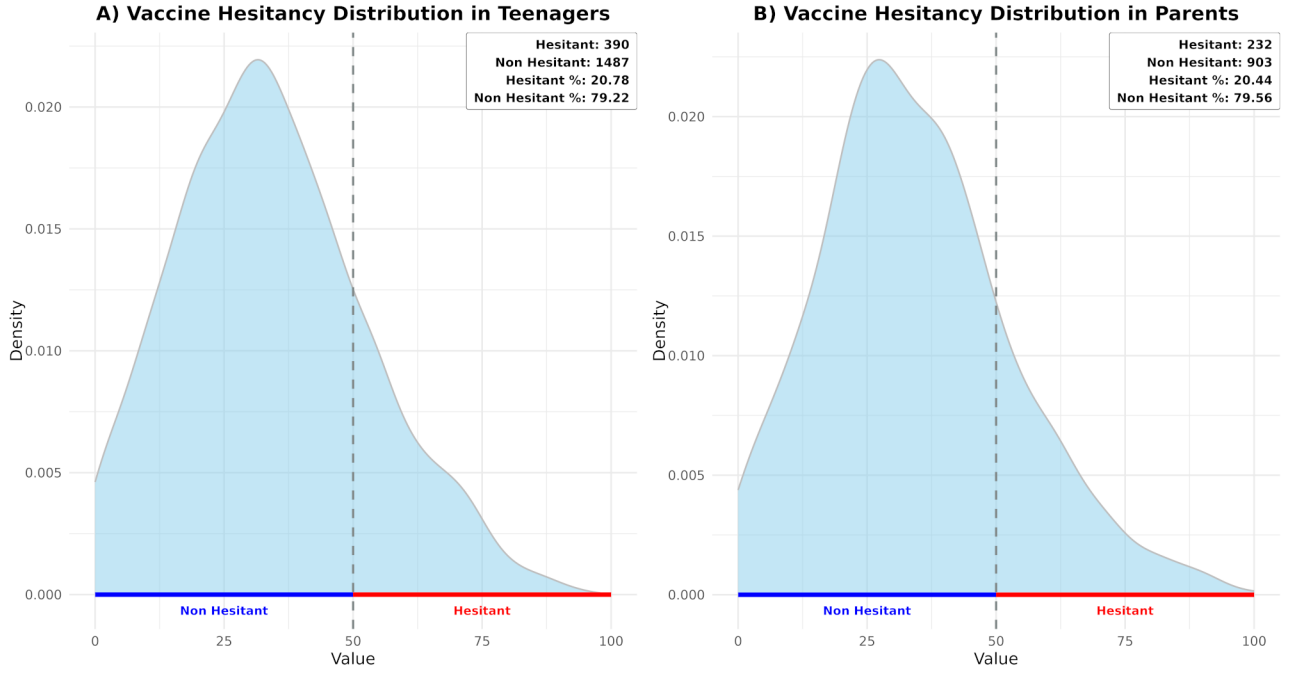

Fig. 1 Degree of vaccine hesitancy in the study population. (**A**) distribution of degree of hesitancy in European adolescents aged ≥ 12 to < 18 years-old; (**B**) distribution of degree of hesitancy in European parents

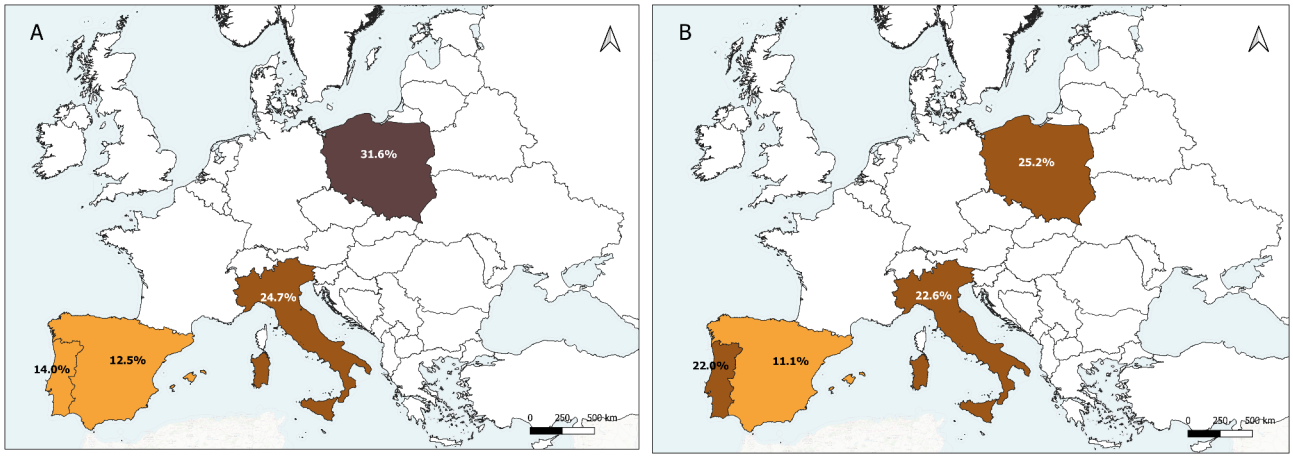

Fig. 2 Prevalence of vaccine hesitancy by country. (**A**) Prevalence of hesitancy in adolescents aged ≥ 12 to < 18 years-old living in Italy, Poland, Portugal and Spain; (**B**) Prevalence of hesitancy in parents living in Italy, Poland, Portugal and Spain

having completed high school (321 individuals, 28.3%), having a university degree (269 individuals, 23.7%), having completed Secondary school (221 individuals, 19.5%), and having a Master's degree or higher education (188 participants, 16.6%). The rest, had finished Primary school (75 participants, 6.6%) or had a vocational training (25 participants, 2.2%). Most of the parents had 2 children (580 participants, 51.11%) or only 1 (402 participants, 35.4%). Table 1 shows the demographic characteristics of the participants divided by country of residence. The Italian participants were the oldest and the Polish the youngest of the cohort (mean age and SD of 46.7 ± 7.1 years in Italy, 43.8 ± 5.9 years in Portugal, 43.3 ± 7.0 years in Spain, and 41.6 ± 7.1 years in Poland; p-value < 0.001); the Polish parents had the highest mean (± SD) of number of children and the Spanish participants had the lowest (1.9 ± 0.9 children in Poland, 1.8 ± 0.7 children in Italy, 1.8 ± 0.6 children in Portugal, and 1.7 ± 0.7 children in Spain; p-value < 0.001); and the education level was heterogenous across countries.

In the case of the parents' population, the prevalence of vaccine hesitancy (PACV scoring ≥ 50) was of 20.4% (232 individuals), as seen in Fig. 1. Only 68 (5.1%) scored ≥ 70 (high hesitancy degree). Table 3 shows the results of the

Table 2 Prevalence of hesitancy in European adolescents and determinants for hesitancy

Variable		Hesitancy	Univariate analysis		Multivariate analysis	
		% (n/N)	OR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Gender	Female	21.9 (178/812)	reference group	-	reference group	-
	Male	19.9 (211/1061)	0.88 (0.71, 1.11)	0.31	0.89 (0.71, 1.12)	0.33
	Non-binary*	25.0 (1/4)	-	-	- -	-
Age (years)**			0.95 (0.88, 1.01)	0.11	0.99 (0.89, 1.10)	0.85
Country	Spain	12.5 (58/462)	reference group	-	reference group	-
	Portugal	14.0 (66/470)	1.13 (0.78, 1.67)	0.56	1.03 (0.67, 1.59)	0.88
	Italy	24.7 (117/473)	2.28 (1.62, 3.25)	<0.001	2.23 (1.52, 3.25)	< 0.001
	Poland	31.6 (149/472)	3.20 (2.30, 4.52)	<0.001	2.89 (1.93, 4.32)	< 0.001
Educational level	High school	17.8 (61/342)	reference group	-	reference group	-
	Vocational training	23.9 (51/405)	1.45 (0.95, 2.21)	0.08	1.40 (0.91, 2.15)	0.13
	Secondary	19.5 (179/917)	1.12 (0.81, 1.55)	0.52	1.13 (0.72, 1.76)	0.61
	Primary	24.4 (99/405)	1.49 (1.04, 2.14)	0.03	1.30 (0.65, 2.60)	0.46

*Prevalence of hesitancy (adapted PACV scoring ≥ 50) in percentage (%) and number (n)/denominator (N), and results of the univariate and multivariate logistic regression analyses showing Odds Ratios (OR) and adjusted OR (aOR) with 95% Confidence Interval (CI). *non-binary gender was not assessed in the logistic regression analysis due to the small sample size (N = 4), **Age was treated as a continue variable in the logistic regression analyses*

Table 3 Prevalence of hesitancy in European parents and determinants for hesitancy

Variable		Hesitancy	Univariate analysis		Multivariate analysis	
		% (n/N)	OR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Gender	Female	20.1 (117/582)	reference group	-	reference group	-
	Male	20.7 (114/551)	1.04 (0.78, 1.38)	0.83	1.11 (0.82, 1.50)	0.49
	Non-binary*	50.0 (1/2)	-	-	-	-
Age (years)**			0.97 (0.96, 1.00)	0.02	0.97 (0.95, 0.99)	0.01
Country	Spain	11.1 (29/262)	reference group	-	reference group	-
	Portugal	22.0 (64/291)	2.26 (1.41, 3.68)	< 0.001	1.72 (1.01, 2.93)	< 0.05
	Italy	22.6 (66/292)	2.34 (1.47, 3.80)	< 0.001	2.51 (1.52, 4.14)	<0.001
	Poland	25.2 (73/290)	2.69 (1.70, 4.36)	< 0.001	2.63 (1.59, 4.34)	<0.001
Educational level	High school	21.2 (68/321)	reference group	-	reference group	-
	PhD	19.4 (7/36)	0.91 (0.35, 2.08)	1	0.95 (0.40, 2.35)	0.95
	Master's	18.1 (34/188)	0.82 (0.52, 1.29)	0.42	0.81 (0.50, 1.29)	0.37
	University Degree	16.7 (45/269)	0.75 (0.49, 1,.13)	0.17	0.88 (0.56, 1.39)	0.59
	Vocational training	28.0 (7/25)	1.46 (0.54, 3.54)	0.45	1.23 (0.47, 3.19)	0.67
	Secondary school	26.7 (59/221)	1.35 (0.91, 2.02)	0.15	1.65 (0.99, 2.78)	0.06
	Primary school	16.0 (12/75)	0.72 (0.35, 1.36)	0.34	0.93 (0.45, 1.92)	0.84
Number of children	1	19.6 (79/402)	reference group	-	reference group	-
	2	20.2 (117/580)	1.03 (0.75, 1.42)	0.87	0.61 (0.78, 1.51)	0.61
	3	23.1 (31/134)	1.23 (0.76, 1.96)	0.39	1.11 (0.68, 1.80)	0.67
	4	31.2 (5/16)	1.89 (0.57, 5.47)	0.34	1.65 (0.52, 5.22)	0.4
	5 or more	0.0 (0/3)	-	-	-	-

*Prevalence of hesitancy (PACV scoring ≥ 50) in percentage (%) and number (n)/denominator (N), and results of the univariate and multivariate logistic regression analyses showing Odds Ratios (OR) and adjusted OR (aOR) with 95% Confidence Interval (CI). *non-binary gender was not assessed in the logistic regression analysis due to the small sample size (N = 2). ** Age was treated as a continue variable in the logistic regression analyses*

prevalence of hesitancy for the different demographic and geographic characteristics and the logistic regression analyses. Figure 2 shows the prevalence of hesitancy by country. Similar to the adolescents' group, the strongest factor related with hesitancy was geographic area, with parents living in Spain being less hesitant (11.1%) and those living in Poland being the most hesitant (25.2%). The OR for Italian parents was 2.34 (95%CI: 1.47, 3.80), for Polish parents was 2.69 (95%CI: 1.70, 4.36), and for Portuguese parents was 2.26 (95%CI: 1.41, 3.68) compared to the Spanish participants (all comparisons $p < 0.001$). Country of residence was also shown to be an independent associated factor for hesitancy, with aOR of 2.63 (95%CI: 1.59, 4.34) for Polish parents, aOR of 2.51 (95%CI: 1.52, 4.14) for Italian parents, and aOR of 1.72 (95%CI: 1.01, 2.93) for Portuguese parents; all compared to the Spanish parents. Gender, educational level, and number of children per parent did not show association with hesitancy; while older age was associated to less

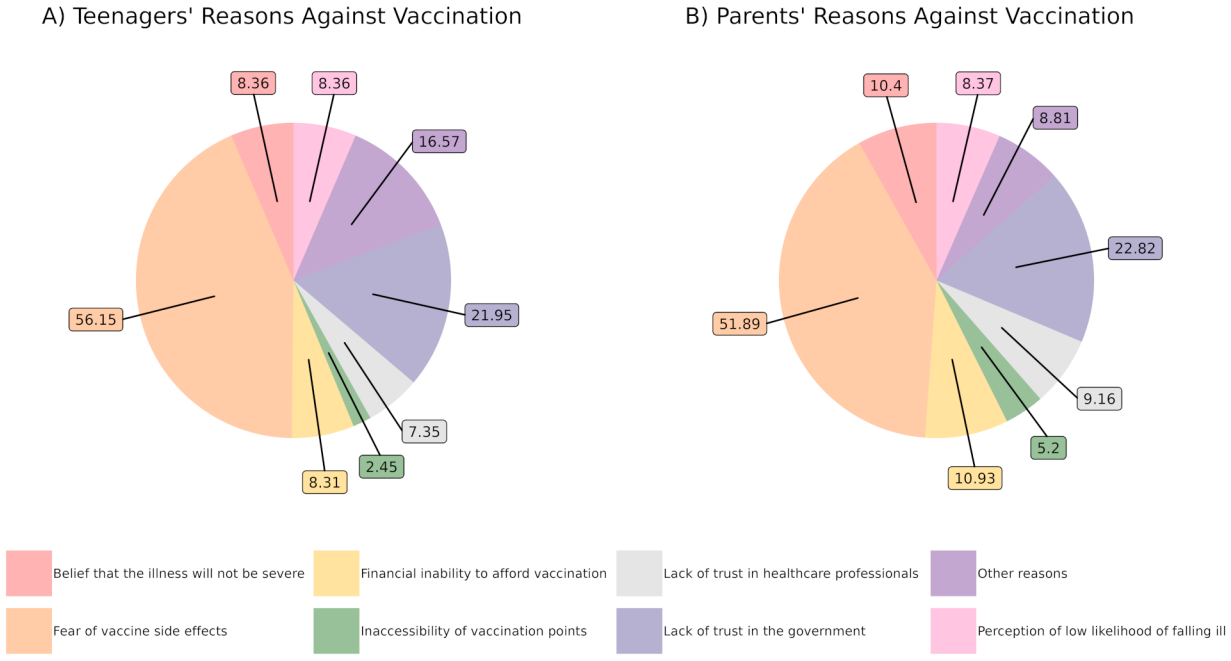

Fig. 3 Causes of vaccine hesitancy in the study population. (**A**) causes of hesitancy in European adolescents aged ≥ 12 to < 18 years-old, in percentage; (**B**) causes of hesitancy in European parents, in percentage. Multiple answers were possible in both questionnaires

Table 4 Reasons of hesitancy in adolescents and parents in hesitant and non-hesitant participants

Reasons for hesitancy	Adolescents			Parents		
	Hesitant *N* (%)	Non-hesitant *N* (%)	*p*-value	Hesitant *N* (%)	Non-hesitant *N* (%)	*p*-value
Fear of vaccine side effects	284 (39.2)	770 (45.2)	0.008	133 (32.7)	456 (43.8)	< 0.001
Distrust in government recommendations	197 (27.2)	215 (12.6)	< 0.001	99 (24.3)	160 (15.4)	< 0.001
Distrust in healthcare professionals	87 (12.0)	51 (3.0)	< 0.001	52 (12.8)	52 (5.0)	< 0.001
Low likelihood of falling ill	66 (9.1)	91 (5.3)	< 0.001	41 (10.1)	54 (5.2)	0.001
Vaccine-preventable diseases are not severe	49 (6.8)	108 (6.3)	0.762	44 (10.8)	74 (7.1)	0.027
Financial constraints	28 (3.9)	128 (7.5)	0.001	21 (5.2)	103 (9.9)	0.005
Accessibility issues	4 (0.6)	42 (2.5)	< 0.001	10 (2.5)	49 (4.7)	0.072
Other reasons	10 (1.4)	301 (17.6)	< 0.001	7 (1.7)	93 (8.9)	< 0.001

Number (N) and percentage (%) of individuals reporting reasons for hesitancy. P values for comparison were obtained using Chi-square test

prevalence of vaccine hesitancy [OR: 0.97 (95%CI: 0.96, 1.00); and aOR = 0.97 (95% CI: 0.95, 0.99)].

Reasons for hesitancy

Figure 3 shows the main reasons for vaccine hesitancy among both adolescents and parents. We assessed hesitancy reasons using a multiple-choice question in both questionnaires. In adolescents, the most frequently selected reasons were fear of vaccine side effects (56.1%, 1054 individuals) and distrust in government recommendations (22.0%, 412 individuals); followed by the belief that vaccine-preventable infections are not severe (8.4%, 157 individuals), the perception of low likelihood of falling ill (8.4%, 157 individuals), and financial inability to afford vaccination (8.3%, 156 individuals). Lack of trust in healthcare professionals was selected by 7.3% of the respondents, while 2.4% cited inaccessibility of vaccination points, and 16.6% reported other unexplored reasons. Table 4 presents the reasons for vaccine hesitancy, comparing hesitant and non-hesitant adolescents. The analysis revealed significant differences between groups. Distrust in government recommendations and healthcare workers was more prevalent among hesitant adolescents (27.2% and 12.0%, respectively) compared to non-hesitant adolescents (12.6% and 3.0%, respectively), both with a p-value < 0.001. Additionally, hesitant adolescents were more likely to perceive a low likelihood of falling ill. In contrast, non-hesitant adolescents were more concerned about vaccine side effects (45.2% vs. 39.2% In hesitant adolescents, p-value = 0.008) and reported greater concerns regarding accessibility and financial constraints.

Similarly, among parents, the most common reasons for vaccine hesitancy were fear of vaccine side effects (51.9%, 589 individuals) and distrust in government recommendations (22.8%, 259 individuals). These were followed by financial inability to afford vaccines (10.9%, 124 individuals), the belief that vaccine-preventable infections are not severe (10.4%, 118 individuals), and lack of trust in healthcare professionals (9.2%, 104 individuals). Additionally, 8.4% of parents perceived a low likelihood of their child falling ill, while 8.8% cited other unexplored reasons. As observed in the adolescents' survey, hesitant parents were more likely to report distrust in government recommendations, distrust in healthcare professionals, and the perception of a low likelihood of falling ill than their non-hesitant peers. In contrast, fear of vaccine side effects was slightly more common among non-hesitant parents (Table 4). However, the results of this analysis in the parent population should be interpreted with caution, as the number of responses for some of the options was low.

Discussion

Our study aimed to explore the prevalence of routine vaccine hesitancy among adolescents aged 12 to <18 years across four European countries - Italy, Poland, Portugal, and Spain– with varying vaccine coverage rates and different vaccination policies. Additionally, we compared adolescents' responses with parental attitudes towards vaccination in a sample of parents from the same countries, who were not necessarily related to the adolescents included. We found a significant prevalence of vaccine hesitancy among adolescents (20.8%) and parents (20.4%). These findings align with trends observed in European adults. A survey of 28,782 individuals from 28 European Union member states reported most respondents agreed that vaccines are important (90.0%), safe (82.8%), and effective (87.8%) [33].

However, data on adolescent attitudes toward vaccination are scarce, and our study is among the first to provide valuable insights into hesitancy rates in this age group. The relatively high hesitancy rates among adolescents highlight the need for targeted public health campaigns that enhance communication, transparency, and trust. Previous works have stressed the role of better communication strategies and health literacy on vaccine effectiveness and side effects in parents for reducing hesitancy [34, 35]. In adolescents, a recent literature review on attitudes toward COVID-19 vaccination noted that while hesitancy determinants varied wildly due to population heterogeneity, vaccine safety concerns were universally reported [36]. In this regard, adolescents often seek vaccine-related information from school or online sources, highlighting the importance of school-based vaccination education programs, which could improve the health literacy of this population group.

Our study also revealed significant differences in hesitancy rates across countries. Polish and Italian participants exhibited a higher likelihood of hesitancy compared to the Spanish participants (among parents) and Portuguese and Spanish participants (among adolescents). Indeed, Poland has been identified as the European country with the largest decline in vaccine confidence in the recent years [33]. Although vaccination is mandatory and free of charge in Poland, strong anti-vaccination movements have influenced parental decisions, resulting into lower vaccination rates [37, 38]. Previous studies have suggested that improving the quality of vaccine-related information provided by healthcare professionals is crucial in addressing hesitancy in Poland [39].

In Italy, our results align with a 2018 survey using the PACV score among parents of young children, which reported a vaccine hesitancy rate of 34.5% [20]. Additionally, vaccine confidence in the general population has been relatively low. A large-scale 2015 survey on global attitudes toward vaccination, which included 67 countries (30 from Europe), found that Italian participants were among those expressing the highest levels of skepticism about vaccine importance and concerns about their effectiveness, with 18.7% of respondents questioning their efficacy [40].

In contrast, we observed lower rates of hesitancy in Portuguese and Spanish adolescents compared to their peers in Italy and Poland. Of note, Portuguese adolescents showed lower hesitancy rates than Portuguese parents, possibly reflecting the impact of intensive educational campaigns implemented in recent years. This includes mass media efforts during the measles outbreak in 2017 [41], and the COVID-19 vaccination campaigns that emphasized evidence-based messaging while minimizing exposure to anti-vax narratives [42]. The role of media in shaping public perception on vaccines has also been studied in Spain, where the tone and content of media coverage on vaccination have shown to correlate with childhood vaccination rates, and should be considered as a tool for improving hesitancy [43].

Regarding the reasons for hesitancy identified in our study, they align with those reported in a systematic literature review on perceived vaccine risks among European populations. This review found that the foremost concern was vaccine safety, followed by perceptions of low probability of contracting vaccine-preventable infections, perceptions of the low severity of these infections, doubts about vaccine efficacy, and an overall lack of information [44].

Confidence-related issues were the most prevalent in our study groups, with fear of side effects being the leading cause, consistent with findings from a previous

review on parental vaccine refusal [45]. Another frequent reason was distrust in government recommendations. Remarkably, distrust in government recommendations and distrust in healthcare workers was higher in the hesitant population, compared to the non-hesitant, both in adolescents and parents. Confidence-related issues must be urgently addressed, as they pos a risk for reduction of coverage, as it has been shown in the US, where they cause delay or refusal of vaccine doses among parents of children aged 24–35 months [46].

A 2021 systematic review on vaccine hesitancy among adolescents, which analyzed data from 20 studies, half of them focused on European adolescents, specifically explored the reasons for hesitancy in this population [47]. Similar to our findings, the authors identified comparable causes for hesitancy and concluded that improving knowledge on vaccine-preventable infections, enhancing confidence in vaccines, and actively involving adolescents in the decision-making process could positively influence their trust in vaccination.

Complacency-related issues, such as low perceived risks of contracting vaccine-preventable diseases or low perception of severity of these infectious diseases were also common causes in our study. Interestingly, convenience-related issues such as financial and accessibility concerns, were more frequently reported by parents than by adolescents, suggesting that these barriers are more apparent to adults. These findings align with previous research on adolescents, where complacency and convenience concerns were less prevalent than confidence-related issues [47].

While our study provides valuable insights, it is not without limitations. One of the main challenges in the study design was defining vaccine hesitancy among adolescents and determining how to measure it, as no standardized instruments are available, a challenge highlighted by other authors [36]. Consequently, our results may be subject to observational error, potentially yielding different outcomes if repeated measurements were conducted. To mitigate this risk, we conducted a comprehension test before implementation, which demonstrated satisfactory results across different adolescents age groups. The similarity in responses between parents and adolescents in both questionnaires is reassuring; however, our findings may not be generalizable to other settings. Researchers working with adolescents should seek consensus on the most appropriate tool for assessing hesitancy in this population group.

Another limitation of our study is the use of an anonymous and self-administered online questionnaire, as we were unable to verify the reliability of the responses. When we distributed the project and questionnaires to schools, many informed us they had shared the materials with parents and sought their permission to conduct the survey during school hours, ensuring that the participants' ages were verified. However, we could not determine how many of the completed questionnaires followed this process, nor verify the accuracy of the responses. Additionally, the online questionnaire may have introduced selection bias, potentially excluding individuals without internet access. To mitigate this, we provided digital tools to participating schools to facilitate access to the questionnaire during lectures or awareness-related sessions. Moreover, self-reported data on vaccine attitudes may be subject to social desirability bias.

Despite these limitations, the use of citizen science through an online platform offered several advantages. It allowed us to reach a broad audience, efficiently distribute the study questionnaires, and incorporate educational materials for our target population, as well as teachers and parents.

Conclusions

Our study reveals a noteworthy prevalence of vaccine hesitancy among adolescents and parents in Europe, with significant geographic variations. Confidence-related concerns, particularly occurrence of adverse events and distrust in government recommendations, were the most common reasons for hesitancy. In contrast, convenience-related barriers were less prominent, suggesting that declining vaccination coverage in Europe may be driven more by misconceptions on vaccine efficacy and safety than by economic or healthcare access constraints. These findings emphasize the urgent need for improving public health strategies to address vaccine hesitancy and ensure optimal vaccine coverage. Importantly, adolescents should be a key focus of awareness campaigns, leveraging mass media and school-based initiatives to enhance vaccine confidence in this age group.

Abbreviations

CI	Confidence interval
ECDC	European centre for disease prevention and control
PACV	Parent attitudes about childhood vaccines
OR	Odds ratio
US	United states of america
WHO	World health organization

Supplementary Information

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Supplementary Material 1

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Author contributions
PMM, AM, BN and QB designed the study and wrote the study protocol with inputs from MB and ME. PMM, AM, CA, BF, BN and QB implemented the data collection. PEC, MC and AP conducted the statistical analysis. PMM wrote the manuscript with important inputs of all authors. PMM, PEC, MC and AP prepared the figures. All authors interpreted the data and critically revised the manuscript for important intellectual content. All authors have seen and approved the final version of the manuscript.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Research Ethics Committee of Hospital Sant Joan de Déu, Esplugues, Spain (approval number: PIC-112-22), who waived the need from collecting individual informed consent. Participation in the study was voluntary, and participants were fully informed about the purpose and objectives of the research. They were also informed that they could withdraw at any time without penalty. The surveys were fully anonymous, with no personal or identifiable data collected. In line with ethical guidelines, data was used solely for research purposes and securely stored, with access limited to the research team. Given the anonymous nature of the study, individual informed consent was not required, as no information could directly or indirectly identify participants. Regarding the participation of minors, informed consent from parents or guardians was not required as per the ethical guidelines applied, given that the surveys were anonymous and non-intrusive, focusing on general opinions about vaccination rather than personal or sensitive information. All research activities were conducted following the ethical principles of the Declaration of Helsinki and adhered to relevant institutional guidelines and national regulations for research with human subjects.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]ISGlobal, Barcelona, Spain
[2]Clinical Study Unit - Sanofi, Barcelona, Spain
[3]Beyond You, Barcelona, Spain
[4]Departament d'Enginyeria de Sistemes, Automàtica i Informàtica Industrial, B2SLab, Universitat Politècnica de Catalunya, Barcelona, Spain
[5]Institut de Recerca Sant Joan de Déu, Esplugues de Llobregat, Barcelona, Spain
[6]Fondazione Penta ETS, Padova, Italy
[7]Institut Borja de Bioètica– Universitat Ramon Llull, Esplugues de Llobregat, Barcelona, Spain
[8]Networking Biomedical Research Centre in the Subject Area of Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Madrid, Spain
[9]Innovation Department, Hospital Sant Joan de Déu, Universitat de Barcelona, Esplugues de Llobregat, Barcelona, Spain
[10]Facultat de Medicina i Ciències de la Salut, Universitat de Barcelona (UB), Barcelona, Spain
[11]ICREA, Pg. Lluís Companys 23, Barcelona 08010, Spain
[12]Paediatrics Department, Hospital Sant Joan de Déu, Universitat de Barcelona, Esplugues de Llobregat, Barcelona, Spain
[13]Centro de Investigação em Saúde de Manhiça (CISM), Maputo, Mozambique
[14]CIBER de Epidemiología y Salud Pública, Instituto de Salud Carlos III, Madrid, Spain

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