European Journal of Pediatrics (2024) 183:3727–3738
https://doi.org/10.1007/s00431-024-05617-0

RESEARCH

Coverage and determinants of COVID-19 child vaccination in Munich, Germany in October 2022–January 2023: Results of the COVIP-Virenwächter study

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Received: 9 February 2024 / Revised: 13 May 2024 / Accepted: 16 May 2024 / Published online: 8 June 2024

Abstract

COVID-19 vaccination reduces the risk of severe disease, in children as well as adults. We studied COVID-19 vaccination coverage among children, parental COVID-19 vaccination intent for their children and determinants of vaccination among children to inform communication strategies. We invited parents of children aged 6 months–11 years in Munich, Germany, to an anonymous online survey between 13.10.2022 and 15.01.2023. Parents reported COVID-19 vaccination status and, for unvaccinated children, vaccination intent per child. We determined vaccination coverage (≥ 1 dose) and parental intent, and subsequently used logistic regression to identify determinants of vaccination, including the 5C psychological antecedents of vaccination (confidence, complacency, constraints, calculation, collective responsibility). In total, 339 parents reported on 591 children. Vaccination coverage was 7% (6/86) amongst 6-months–4-year-olds and 59% (295/498) amongst 5–11-year-olds. For unvaccinated 6-months–4-year-olds, 31% of parents reported high, 13% medium, 56% low vaccination intent; for 5–11-year-olds 8% reported high, 20% medium, 71% low intent. Positive determinants of vaccination were older child age, child belonging to a clinically vulnerable group, as well as parental COVID-19 vaccination, higher education level, country of birth Germany, and high level of trust in official guidelines; a negative determinant was previous vaccination refusal. For 5–11-year-olds, additional positive determinants were higher confidence and lower complacency.

Conclusion: While a substantial proportion of 5–11-year-olds were vaccinated against COVID-19, coverage was low among 6-months–4-year-olds. Parental vaccination intent for unvaccinated children was low. Vaccination communication should take into account parental socio-demographic characteristics and specifically address individual risks and benefits of child vaccination.

What is Known:
- *COVID-19 vaccination lowers severe disease risk in all ages.*
- *Germany recommends vaccination for 5–11-years-olds since December 2021 and for 6 months–4 year-olds since November 2022.*

What is New:
- *In Munich, vaccine uptake was high in 5–11-year-olds but parental intent for not yet vaccinated children was low; the opposite was the case for 6-months–4-year-olds; vaccination determinants were eligibility, parental education, birth country and general vaccination hesitancy; psychological antecedents were confidence and complacency.*
- *Tailored interventions should address guidelines, health literacy, cultural sensitivity, and boost confidence in vaccines and institutions while raising awareness of COVID-19 risks for children.*

Keywords COVID-19 · Vaccine · Paediatrics · Parents · Primary schools · Germany

Abbreviations

aOR	Adjusted odds ratio
CI	Confidence interval
OR	Odds ratio

Communicated by Tobias Tenenbaum

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PIMS-TS	Paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2
SD	Standard deviation
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
STIKO	German Standing Committee on Vaccination (Ständige Impfkommission)

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection can lead to severe COVID-19 and related death in children. Although these outcomes are relatively rare in younger age groups compared to older ones, COVID-19 represented a leading cause of death among children and adolescents in 2021 and 2022 [1]. While children with certain pre-existing comorbidities have an increased likelihood of severe outcomes [2–4], children without comorbidities can also experience severe outcomes, including paediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 (PIMS-TS) [5] and long COVID [6]. Moreover, children with a SARS-CoV-2 infection have an increased risk of new-onset type 1 diabetes mellitus compared to uninfected children [7, 8]. By March 2023, Germany reported 37,460 hospitalisations and 65 deaths related to COVID-19 among children under 18 years [9] and by April 2023, 926 cases of PIMS-TS [10].

COVID-19 vaccination significantly reduces the risk of severe outcomes in children [11]. In Germany, COVID-19 vaccination has been recommended for children aged 5–11 years since December 2021 and for children aged 6 months–4 years since November 2022, although recommendations for specific groups have been continuously adjusted in response to the evolving epidemiological landscape [12–15] (Table 1). However, based on available data, child vaccination uptake appears to be limited. By September 2023, only 22% of children aged 5–11 years and fewer than 3000 children aged 6 months–4 years had received at least one vaccine dose in Germany [16]. It is unclear whether parents whose children are not yet vaccinated intend to have them vaccinated in the future. A cross-sectional survey among 612 parents conducted in Germany in May 2020 found that half of the participating parents intended to have their children vaccinated [17]. A systematic review encompassing 98 studies across 69 countries, published by July 2022, showed that 57% of parents accepted child vaccination [18]. Factors positively influencing parental willingness to have their children vaccinated against COVID-19 included their own vaccination uptake and willingness, trust in vaccines, vaccine literacy, higher levels of perceived threat of COVID-19, trust in government and public health authorities, older parent and child age, male parent gender, higher socio-economic status, and higher educational level. Conversely, general vaccination hesitancy and concerns regarding the safety and efficacy of COVID-19 vaccines for children were negatively associated with parental vaccination willingness [18].

It is unclear how uptake, parental vaccination intent and determinants of childhood COVID-19 vaccination have evolved since its recommendation in Germany. As evidence on vaccine effectiveness and safety accumulates, in combination with evolving COVID-19 epidemiology, parental

Table 1 Children eligible for COVID-19 vaccination in Germany from December 2021 to June 2023 according to recommendations by the German Standing Committee on Vaccination (Ständige Impfkommission, STIKO) [12–15]

Child age	Subgroup	2021										2022												2023						
		12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6										
5–11 years	Underlying conditions [12-15]																													
	Contact to persons at increased risk of severe COVID-19 [12-14]																													
	Healthy [13, 14]																													
6 months – 4 years	Underlying conditions [14, 15]																													
	Contact to persons at increased risk of severe COVID-19 [14]																													

Study period

vaccination intent and its associated factors are subject to change. The aforementioned review showed that parental willingness was lower in studies conducted at a later time [18]. Continuous monitoring of COVID-19 vaccination coverage among children and parental vaccination intent, alongside a comprehensive understanding of related determinants, is crucial to inform vaccination communication strategies. Therefore, we aimed to investigate child vaccination coverage, parental vaccination intent and predictors of vaccine uptake between October 2022 and January 2023 in Munich, Germany.

Methods

Study design, setting, population and procedures

We conducted the cross-sectional "COVID-19 Vaccination Intent among Parents (COVIP)-Virenwächter" study among parents of children attending primary schools in Munich, Germany, 13.10.2022–15.01.2023. We invited school administrations of the 17 primary schools that had previously participated in the "Münchner Virenwächter" study in 2021 [19], of which eight participated. The school administrations invited parents to our anonymous online survey on the platform LamaPoll (https://www.lamapoll.de) via email or internal digital platforms. Participation was anonymous and voluntary. To mitigate the potential for multiple entries, we implemented IP checking, although IP addresses were not retained for analysis for data privacy reasons. In addition, we explicitly instructed parents, in accompanying survey instructions, to complete only one questionnaire per parental set, and to consult with the other parent if necessary. Parents of children aged 6 months–11 years were eligible to participate.

Outcomes

Our main outcomes were childhood COVID-19 vaccination, and, for unvaccinated children, parental vaccination intent. Parents reported the COVID-19 vaccination status of each of their children aged 6 months–11 years and, for unvaccinated children, their vaccination intent. We considered children who had received ≥ 1 vaccine dose as vaccinated. We assessed parental vaccination intent via two questions on a 5-point Likert scale. We used separate sets of questions for children aged 6 months–4 years and 5–11 years, as at the start of the study, German guidelines recommended vaccination only for children aged ≥ 5 years [20]. For children aged 6 month–4 years, we assessed intent if vaccination was recommended, and if it was not. For each of the sets, we calculated the mean score after finding that Cronbach's α was > 0.9. We classified vaccination intent scores into three categories: high (≥ 4), medium (= 3), low (≤ 2).

Potential determinants

We included potential determinants [17, 21–23] of childhood COVID-19 vaccination in the survey, categorised into proximal, distal and intermediary factors (Online Resource 1).

We considered proximal factors as those factors with a direct causal relationship with vaccination, including the 5C psychological antecedents of COVID-19 vaccination described in Online Resource 2 [24] and child's fear of needles. Parents rated the 5C questions by child age group: for those aged 6 months–4 years, imagining vaccination was approved for that age group; for those aged 5–11 years considering recommendations at the time of the survey.

We considered factors hypothesized to indirectly influence vaccination via associations with proximal factors as distal factors, including parental and child sociodemographic characteristics.

We considered factors hypothesised to be on the causal pathway between distal and proximal factors as intermediary factors. For children, these comprised four items: belonging to a clinically vulnerable group (children at/ in contact with persons at increased risk of severe COVID-19 according to German guidelines [12]), relationship to the person completing the survey and previous SARS-CoV-2 infection. For parents, they comprised COVID-19 experience (4 items), parental COVID-19 vaccination status, knowledge of and attitudes towards COVID-19 (6 items), sources of trustworthy information on COVID-19 vaccination for children (10 items) as well as general vaccination hesitancy (4 items).

Online Resource 3 lists the survey items and respective options/scales. Outcome categories were combined or excluded in cases where subgroups were deemed too small for meaningful statistical analyses.

We summarised hypothesised causal relationships between the proximal, distal and intermediary factors and childhood COVID-19 vaccination in a causal framework (Online Resources 4 and 5).

Statistical analysis

We described socio-demographic characteristics of participating parents and their children. Among children, we determined vaccination coverage and, for unvaccinated children, parental vaccination intent stratified by age group and belonging to a clinically vulnerable group. We compared coverage between groups using a chi-square or Fisher's exact test, as appropriate.

To assess determinants of vaccination, we used multivariable logistic regression, accounting for potential cluster bias due to multiple children per parent using generalised estimating equations. First, we determined the univariable association of each proximal, distal and intermediary factor with vaccination. We then built three multivariable models with vaccination as the outcome: (1) a prediction model including only distal factors associated with vaccination, (2) a prediction model including distal as well as intermediary factors associated with vaccination, and (3) a causal model to determine independent associations of each of the 5C factors as proximal factors with vaccination.

For model 1, we first included all distal factors with a P-value ≤ 0.2 from the univariable analyses into a single multivariable model. We then assessed covariate distributions and collinearity and removed all factors with a P-value > 0.05 in a backward-stepwise fashion, unless they substantially influenced another exposure-outcome association (> 10% change in the estimate), to obtain a final model 1.

For model 2, we added intermediate factors with a P-value ≤ 0.2 from the univariable analyses to model 1. To avoid collinearity and data sparsity in the final model, we first generated multivariable models for each variable group (i.e., parent COVID-19 experience, knowledge of and attitudes towards COVID-19, general vaccination hesitancy and sources of trustworthy information on COVID-19 vaccination for children). In these models, we determined which intermediary variables with a P-value ≤ 0.2 from the univariable analyses were independently associated with vaccination after adjusting for the other variables in the respective group. We added only variables with a P-value ≤ 0.05 in their respective variable group model to model 1. After assessing the covariate distributions and collinearity, we removed all factors with a P-value > 0.05 in a backward-stepwise fashion, unless they substantially influenced another exposure-outcome association, to obtain a final model 2.

For model 3, we included each of the 5C variables as well as the child's fear of needles into a multivariable model. Based on our causal diagram, we considered all 5C variables as confounders for each other and identified fear of needles as an additional confounder. We stratified the third model a priori by age group.

All analyses were performed with R (Version 4.3.1) [25], using the tidyverse [26] and geepack [27] packages.

Legal and ethical aspects

We conducted the study in accordance with the Declaration of Helsinki. The Ethics Committee of the LMU Faculty of Medicine Munich has reviewed and approved the study (No.22-0487).

Results

In our survey, 339 parents reported on 591 children. Half of the parents (50%) reported on 2 children. Table 2 describes parent and child characteristics. The majority of parents was female (83%), aged 35–44 years (56%), born in Germany (79%) and had a higher education qualification (88%). The majority of children were aged 5–11 years (85%).

COVID-19 vaccination coverage among children

Of the 584 children for whom parents provided information on vaccination status and age, 301 (52%) were vaccinated (Table 3). Vaccination coverage was significantly higher among children aged 5–11 years (59%) as compared to those aged 6 months–4 years (7%). Among children belonging to a clinically vulnerable group, coverage was 59% (56/95); 7% (1/15) among those aged 6 months–4 years and 69% (55/80) among those aged 5–11 years.

Distal and intermediary determinants of childhood COVID-19 vaccination

Table 4 shows the results of the regression analyses for distal (model 1) and distal plus intermediary (model 2) determinants of vaccination. From model 1, distal factors positively associated with vaccination were child age 5–11 years, higher parental education level and parents born in Germany. The odds of vaccination for children aged 5–11 years were 18 times higher than for those aged 6 months–4 years, corrected for other distal factors. All variables from model 1 were retained in model 2 with the same direction of effect. From model 2, intermediary factors positively associated with childhood vaccination were child belonging to a clinically vulnerable group, parents having received a COVID-19 booster vaccination and parent's having high trust in official guidelines. A factor negatively associated were parents having ever refused a vaccination for themselves or their child because of doubts concerning usefulness and safety.

Proximal determinants of childhood COVID-19 vaccination

Figure 1 shows the mean scores for the 5C items by age group. Calculation was rated high (4.5 [SD: 0.7] for children aged 6 months–4 years and 4.5 [SD: 0.8] for those aged 5–11 years); constraints was rated low (1.4 [SD: 0.8] and 1.4 [SD: 0.7]). Table 5 shows the results of the regression analyses for

Table 2 Sociodemographic characteristics of parents ($N=339$) and children ($N=591$) participating in the "COVIP-Virenwächter" study, Munich, Germany, October 2022–January 2023

Characteristics	*N* (%)
Children	
Total	591 (100%)
Age group	
6 months–4 years	86 (15%)
5–11 years	499 (85%)
Gender	
Female	289 (49%)
Male	297 (50%)
Non-binary	2 (0.3%)
Living in the same household as person completing the survey	
Fully	567 (96%)
Partially	23 (3.9%)
Parents	
Total	339 (100%)
Number of children	
1	129 (38%)
2	168 (50%)
3	39 (12%)
4	3 (0.9%)
Age group	
< 34 years	24 (7.1%)
35–44 years	190 (56%)
> 44 years	124 (37%)
Gender	
Female	280 (83%)
Male	56 (17%)
Non-binary	0
Education	
No higher education qualification	40 (12%)
Higher education qualification	295 (88%)
Country of birth	
Germany	265 (79%)
Outside Germany	71 (21%)
Occupation in health sector	
Yes	43 (13%)
No	293 (87%)
Occupation in sector with close physical contact	
Yes	88 (26%)
No	249 (74%)

Variables with missing data were: child age group ($n=6$), gender ($n=2$), living in the same household as person completing the survey ($n=1$), parent gender ($n=3$), education ($n=4$), country of birth ($n=3$), occupation in health sector ($n=3$), occupation in sector with close physical contact ($n=2$)

proximal determinants (model 3). Due the low vaccination coverage among children aged 6 months–4 years, we built the model only for those aged 5–11 years. Confidence was positively (aOR = 2.7 [95% CI: 1.9–3.9]) and complacency negatively (aOR = 0.34 [95% CI: 0.24–0.49]) associated with childhood COVID-19 vaccination.

Parental vaccination intent for unvaccinated children

In total, 285 children had not yet been vaccinated against COVID-19: 80 among those aged 6 months–4 years, 203 among those aged 5–11 years; for 2 unvaccinated children no information on age was available. Table 6 shows parental vaccination intent for unvaccinated children by age group and clinically vulnerable group. Vaccination intent for children aged 6 months–4 years was high for 25/80 (31%) given the scenario that the vaccination was approved for that age group; compared to 5/80 (6%) given the scenario that vaccination was not yet approved. Vaccination intent was low for 145/203 (71%) of the children aged 5–11 years. For children aged 6 months–4 years belonging to a clinically vulnerable group, the proportion of parents with high vaccination intent was larger as compared to children aged 6 months–4 years not belonging to a clinically vulnerable group (14% vs. 5%).

Discussion

In this study, we examined the uptake of COVID-19 vaccination among children aged 6 months–11 years between October 2022 and January 2023, during the Omicron BA.5 wave of the SARS-CoV-2 pandemic. We found a 59% coverage among children aged 5–11 years. However, for unvaccinated children in this age group, parental vaccination intent was low. Conversely, vaccination coverage was significantly lower at 7% among children aged 6 months–4 years, but one-third of parents had a high vaccination intent should the vaccine be approved for this age group. We found multiple determinants of child vaccination, mostly related to child vaccination eligibility, parents' sociodemographic status, trust in COVID-19 vaccines for children and respective institutions, perceived necessity and general vaccination hesitancy.

Our estimates of vaccination coverage among children and parental vaccination intent differ from previous assessments. Among children aged 5–11 years, self-reported coverage was higher than German national estimates (22% as of September 2023) [16] and those of previous research in various countries (18% to 48%) [28–32], which may be due to differences in study setting and time. Conversely, parental vaccination intent for unvaccinated children was lower compared to previous research. Lower intent in studies conducted after our study has also been described [18]. Given that vaccination recommendations for children aged 5–11

Table 3 COVID-19 vaccination coverage (≥ 1 dose) stratified by age group and clinically vulnerable group among children participating in the "COVIP-Virenwächter" study for whom parents provided information on vaccination status and age ($N = 584$), Munich, Germany, October 2022–January 2023

Child age group and clinically vulnerable group	Total *n*	Vaccinated (≥ 1 dose) *n* (%)	Not vaccinated *n* (%)	*p*-value
Total	584	301 (52%)	283 (48%)	
6 months–4-year-olds				
Total	86	6 (7%)	80 (93%)	
Clinically vulnerable group	15	1 (7%)	14 (93%)	1**
Not clinically vulnerable group	71	5 (7%)	66 (93%)	
5–11-year-olds				
Total	498	295 (59%)	203 (41%)	< 0.001[a,*]
Clinically vulnerable group	80	55 (69%)	25 (31%)	0.060*
Not clinically vulnerable group	416	239 (57%)	177 (42%)	
Missing	2	1 (50%)	1 (50%)	

[a]Comparing COVID-19 vaccination coverage between age groups

**p*-value estimated using Pearson's Chi-squared test; ***p*-value estimated using Fisher's exact test

years have been in place since December 2021, parents have likely thoroughly considered their vaccination decision for children in this age group by the time of this study. Consequently, parents with high intent to vaccinate their children had likely already done so. Conversely, those who have not yet vaccinated their children may hold firm opposition to vaccination, reflecting a polarisation of attitudes mirroring the broader socio-political landscape surrounding COVID-19 vaccination [33]. To our knowledge, vaccination coverage among children aged 6 months–4 years has not been assessed previously and was expected to be comparatively low given the fact that vaccination recommendations for this group were introduced during the study, in November 2022.

Parental sociodemographic determinants of COVID-19 child vaccination identified in this study could be used to tailor interventions aimed at increasing uptake. Similar to previous studies, higher parental education level was associated with higher uptake [18, 29–31, 34] as was Germany being the country of birth. Interventions hence could be tailored to those with lower health literacy. A review of vaccination in migrant populations furthermore stressed the need for culturally-sensitive interventions [35]. As we did not assess specific migrant groups, further research with larger samples representing specific groups should be conducted to further investigate the role of country of birth, or cultural factors in vaccine decisions. Unlike other studies [18], we did not detect a significant effect of parental age. However, this may be attributed to the underrepresentation of younger parents in our study, which warrants consideration when interpreting our results.

Our analysis of determinants of vaccination further indicates that official vaccination guidelines and trust in the institutions issuing them are pivotal in shaping parental vaccination decisions. Child age 5–11 years and child belonging to a clinically vulnerable group were key determinants of childhood COVID-19 vaccination. This finding aligns with other studies [28, 34] but also with eligibility criteria according to national guidelines during the study [20]. Parents of unvaccinated children aged 6 months–4 years had a higher vaccination intent if vaccination were to be approved for this age group. As shown before [22, 36, 37], odds of vaccination were higher for children of parents with high trust in official guidelines. These findings underscore the importance of accessible guidelines and transparent communication, particularly when guideline revisions are frequent.

Our assessment of the 5C psychological antecedents of COVID-19 vaccination indicate that interventions to increase COVID-19 vaccination coverage among children should address confidence and complacency. Interventions aiming to increase confidence, i.e. trust in vaccine safety and effectiveness as well as system recommending and providing them, may aim to cultivate positive vaccination perceptions by ensuring stress-free vaccination, dispelling misinformation and heighten media awareness to avoid presenting "false balances" [38]. To target complacency, it is crucial to instil risk awareness by communicating the risks of COVID-19 for children [38]. Paediatricians may play an essential role in vaccination communication efforts, particularly in addressing confidence and complacency [39]. O'Leary et al. describe communication strategies tailored to varying levels of parental hesitancy, applying techniques such as motivational interviewing taking into account individual concerns [39]. Studies in other countries have also found that collective responsibility [40, 41] and calculation [41] were associated with vaccination and vaccination intent, respectively, highlighting the importance of setting-specific assessments of vaccination determinants.

Table 4 Univariable and multivariable regression analysis of distal and intermediary parent and child determinants of childhood COVID-19 vaccination among parent–child-dyads participating in the "COVIP-Virenwächter" study who provided information on child vaccination status ($N = 590$), Munich, Germany, October 2022–January 2023

Distal and intermediary factors	*N*	Vaccinated *n* (%)	Univariable analyses		Multivariable analyses model 1[a]		Multivariable analyses model 2[b]	
			OR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Total	**590**	**305 (52%)**						
Child factors								
Age group								
6 months–4 years	86	6 (7%)						
5–11 years	498	295 (59%)	19.38 (8.99–50.58)	< 0.001	18.11 (8.05–40.77)	< 0.001	63.32 (19.88–201.73)	< 0.001
Gender								
Female	289	148 (51%)						
Male	296	157 (53%)	1.08 (0.78–1.49)	0.658				
Living in the same household as person completing the survey								
Fully	566	297 (52%)						
Partially	23	8 (35%)	0.48 (0.19–1.13)	0.103	0.39 (0.14–1.07)	0.068	0.21 (0.02–2.23)	0.197
Previous SARS-CoV-2 infection	417	219 (53%)	1.11 (0.78–1.58)	0.578	n.c			
Clinically vulnerable group	97	58 (60%)	1.49 (0.96–2.33)	0.079	n.c		3.26 (1.45–7.35)	< 0.001
Parent factors								
Socio-demographic characteristics								
Age group								
< 45 years	394	188 (48%)						
≥ 45 years	194	115 (59%)	1.53 (1.00–2.35)	0.049				
Gender								
Female	493	255 (52%)						
Male	92	47 (51%)	0.88 (0.52–1.49)	0.638				
Higher education qualification	515	282 (55%)	2.73 (1.42–5.25)	0.003	3.14 (1.58–6.25)	0.001	2.75 (0.98–7.67)	0.054
Country of birth Germany	468	263 (56%)	2.57 (1.54–4.28)	< 0.001	2.81 (1.62–4.89)	< 0.001	1.92 (1.01–3.66)	0.048
Occupation in health sector	82	42 (51%)	1.08 (0.59–1.95)	0.811				
Occupation in sector with close physical contact	150	72 (48%)	0.81 (0.51–1.28)	0.374				
COVID-19 vaccination								
≤ 2 doses	125	20 (16%)						
≥ 3 doses	437	272 (62%)	8.41 (4.43–15.96)	< 0.001	n.c		4.92 (2.13–11.36)	< 0.001
COVID-19 experience								
Previous SARS-CoV-2 infection	459	247 (54%)	1.33 (0.75–2.34)	0.331	n.c			
SARS-CoV-2 infections among family/ friends	537	280 (52%)	1.05 (0.34–3.19)	0.936	n.c			
COVID-19 hospitalizations among family/ friends	64	29 (45%)	0.79 (0.41–1.52)	0.474	n.c			
COVID-19 deaths among family/ friends	40	21 (52%)	1.08 (0.47–2.44)	0.859	n.c			
Knowledge of and attitudes towards COVID-19								
Knowledge of STIKO recommendations on COVID-19 vaccination for children	523	270 (53%)	0.80 (0.37–1.75)	0.579	n.c			
Perceived knowledge								
Low / Medium	128	57 (45%)						
High	431	234 (54%)	1.48 (0.91–2.40)	0.117	n.c			
Perceived likelihood of infection								
Low	30	11 (37%)						
Medium	123	67 (54%)	2.19 (0.76–6.33)	0.146	n.c			
High	404	213 (53%)	1.76 (0.65–4.76)	0.269	n.c			
Perceived danger of infection								
Low	263	114 (43%)						

Table 4 (continued)

Distal and intermediary factors	*N*	Vaccinated *n* (%)	Univariable analyses		Multivariable analyses model 1[a]		Multivariable analyses model 2[b]	
			OR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Medium	231	138 (60%)	1.72 (1.11–2.65)	0.015	n.c			
High	65	39 (60%)	1.90 (0.96–3.78)	0.066	n.c			
Perceived susceptibility to infection								
Low	172	91 (53%)						
Medium	308	158 (51%)	1.01 (0.64–1.61)	0.961	n.c			
High	79	42 (53%)	1.06 (0.55–2.06)	0.858	n.c			
Perceived ease avoiding infection								
Low	224	134 (60%)						
Medium	271	132 (49%)	0.66 (0.43–1.03)	0.067	n.c			
High	64	25 (39%)	0.47 (0.24–0.96)	0.037	n.c			
Perception that measures currently being taken are greatly exaggerated								
Low	305	195 (64%)						
Medium	144	72 (50%)	0.62 (0.38–1.03)	0.062	n.c		1.03 (0.50–2.15)	0.930
High	105	23 (22%)	0.15 (0.08–0.30)	< 0.001	n.c		0.43 (0.16–1.12)	0.085
General vaccination hesitancy								
Children received all the recommended vaccinations for their age	475	274 (58%)	5.64 (2.66–11.98)	< 0.001	n.c		2.55 (0.91–7.17)	0.076
Ever refused a vaccination for yourself or your child because you thought it was not useful or dangerous	160	50 (31%)	0.30 (0.19–0.48)	< 0.001	n.c		0.46 (0.22–0.96)	0.039
Ever postponed a vaccination recommended by your doctor for reasons other than health	166	77 (46%)	0.69 (0.44–1.08)	0.102	n.c			
Generally refuse vaccinations	6	2 (33%)	0.45 (0.04–5.09)	0.521	n.c			
Sources of trustworthy information on COVID-19 vaccination for children								
Personal contacts								
Low	358	172 (48%)						
Medium/High	174	102 (59%)	1.55 (0.99–2.43)	0.056	n.c		1.47 (0.68–3.17)	0.331
Teachers								
Low	193	81 (42%)						
Medium/High	275	156 (57%)	1.87 (1.20–2.93)	0.006	n.c			
Official guidelines								
Low/Medium	227	59 (26%)						
High	329	228 (69%)	6.61 (4.16–10.50)	< 0.001	n.c		6.03 (3.11–11.68)	< 0.001
Influencers on social media								
Low	496	262 (53%)						
Medium/High	56	20 (36%)	0.48 (0.28–0.99)	0.048	n.c			

aOR adjusted odds ratio, *CI* confidence interval, *m* months, *n.c.* not considered, *OR* odds ratio, *STIKO* German Standing Committee on Vaccination (Ständige Impfkommission)

Variables with missing data were: child age group ($n=6$), gender ($n=5$), living in the same household as person completing the survey ($n=1$), previous SARS-CoV-2 infection ($n=1$), child in clinically vulnerable group ($n=3$), parent gender ($n=5$, including 2 non-binary children who were excluded from the analyses), education ($n=8$), country of birth ($n=5$), occupation in health sector ($n=5$), occupation in sector with close physical contact ($n=5$), COVID-19 vaccination ($n=28$), knowledge of STIKO recommendations ($n=24$), previous SARS-CoV-2 infection ($n=42$), SARS-CoV-2 infections among family/ friends ($n=31$), COVID-19 hospitalizations among family/friends ($n=32$), COVID-19 deaths among family/ friends ($n=35$), perceived COVID-19 knowledge ($n=31$), perceived likelihood of infection ($n=33$), perceived danger of infection ($n=31$), perceived susceptibility of infection ($n=31$), perceived ease avoiding infection ($n=31$), perception that measures currently being taken are greatly exaggerated ($n=36$), children received all the recommended vaccinations for their age ($n=45$), ever refused a vaccination for yourself or your child because you thought it was not useful or dangerous ($n=54$), ever postponed a vaccination recommended by your doctor for reasons other than health ($n=68$), generally refuse vaccinations ($n=40$), sources of trustworthy information on COVID-19 vaccination for children personal contacts ($n=58$), teachers ($n=36$), official guidelines ($n=34$), influencers on social media ($n=38$)

[a]Logistic GEE regression model including only distal factors

[b]Logistic GEE regression model including distal and intermediary factors

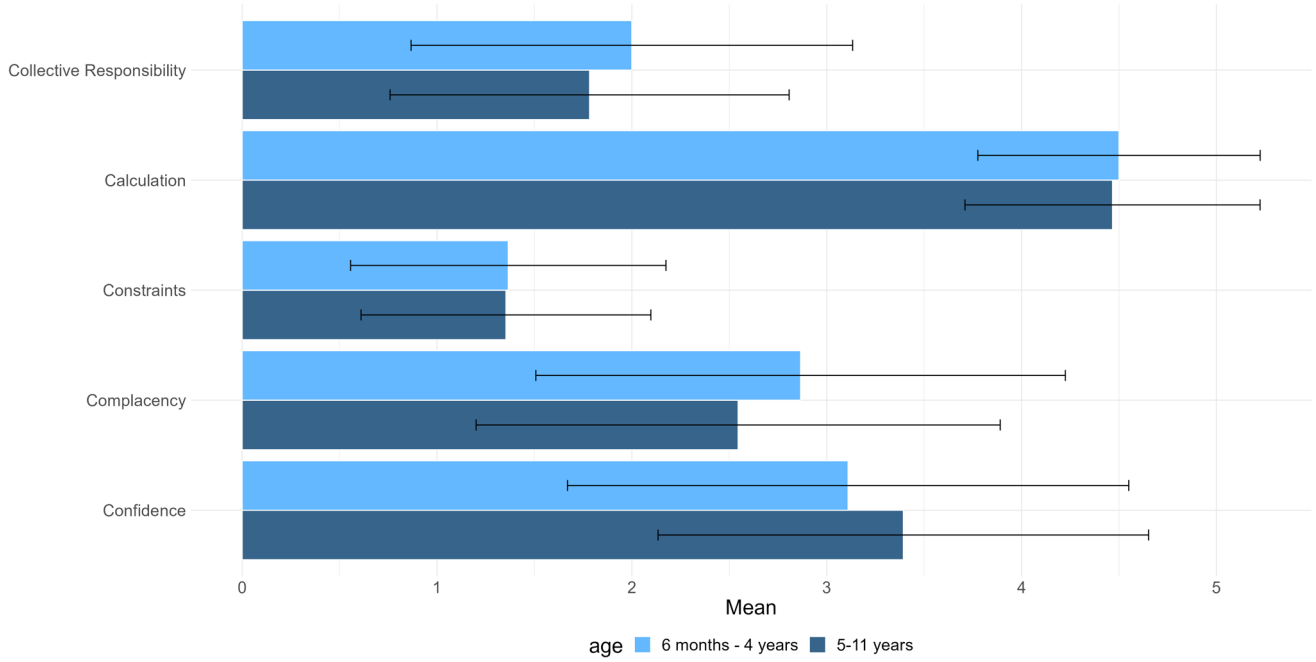

Fig. 1 Mean scores for 5C psychological antecedents of childhood COVID-19 vaccination by child age group among parent-child-dyads participating in the "COVIP-Virenwächter" study who provided information on child age ($N = 585$), Munich, Germany, October 2022–January 2023

Interventions concerning COVID-19 child vaccination may further need to address parents' general vaccination hesitancy. We observed lower odds of vaccine uptake among children whose parents had a lower number of COVID-19 vaccinations, and whose parents had previously declined vaccinations for themselves or their children due to concerns about usefulness or safety. Previous studies have already shown that parental COVID-19 vaccination is an important predictor of childhood COVID-19 vaccination [28–31, 34, 42, 43]. Furthermore, studies have found that child influenza vaccination is a predictor of childhood COVID-19 vaccination [28, 42]. These findings suggest that parental hesitancy to vaccinate their children against COVID-19 is not isolated but to a certain extent rooted in a general reluctance to vaccinate stemming from the same underlying psychological determinants. Conversely, parents' hesitancy towards the COVID-19 child vaccination may also have affected attitudes towards other child vaccinations [44]. As the COVID-19 landscape evolves, particularly when the potential inclusion of COVID-19 vaccination in routine childhood immunization becomes clearer, continued vigilance in monitoring these associations will be important.

Our study has some limitations. Our results may not be representative of all children aged 6 month–11 years and their parents in Munich. Possibly, respondents were more polarized in their vaccination attitudes, as compared to non-respondents. We were unable to compare respondents with non-respondents, as we did not have information on non-respondents. To prevent

Table 5 Univariable and multivariable regression analysis of proximal determinants of childhood COVID-19 vaccination among parent–child-dyads of children aged 5–11 years participating in the "COVIP-Virenwächter" study who provided information on child vaccination status ($N = 498$), Munich, Germany, October 2022–January 2023

Proximal factors	Mean (SD)	Mean (SD) among vaccinated	Univariable analyses		Multivariable analysis (model 3[a])	
			OR (95% CI)	*p*-value	aOR[b] (95% CI)	*p*-value
Confidence	3.4 (1.3)	4.0 (0.8)	3.79 (2.79–5.16)	< 0.001	2.73 (1.93–3.88)	< 0.001
Complacency	2.5 (1.3)	1.9 (0.9)	0.28 (0.21–0.38)	< 0.001	0.34 (0.24–0.49)	< 0.001
Constraints	1.4 (0.7)	1.3 (0.6)	0.70 (0.52–0.95)	0.020	0.70 (0.46–1.07)	0.098
Calculation	4.5 (0.8)	4.4 (0.8)	0.90 (0.66–1.22)	0.483	1.47 (0.97–2.22)	0.070
Collective responsibility	1.8 (1.0)	1.6 (0.9)	0.55 (0.42–0.71)	< 0.001	1.08 (0.75–1.55)	0.067
Needle fear	2.3 (1.2)	2.2 (1.2)	0.98 (0.87–1.11)	0.741		

aOR adjusted odds ratio, *CI* confidence interval, *OR* odds ratio

[a]Logistic GEE regression model including proximal factors, needle fear was excluded from the multivariable model due to data sparsity issues

[b]Adjusted for the 5C variables

Table 6 Parental childhood COVID-19 vaccination intent stratified by child age group and clinically vulnerable group for unvaccinated children participating in the COVIP-Virenwächter study ($N = 283$), Munich, Germany, October 2022–January 2023

Child age group and clinically vulnerable group	Total *N*	Vaccination intent			*p*-value[a]
		Low *n* (%)	Medium *n* (%)	High *n* (%)	
6 months–4 years					
Scenario COVID-19 vaccination approved for 6 months–4-years-olds					
Total	80	45 (56%)	10 (13%)	25 (31%)	
Clinically vulnerable group	14	9 (64%)	1 (7.1%)	4 (29%)	0.843
Not clinically vulnerable group	66	36 (55%)	9 (14%)	21 (32%)	
Scenario COVID-19 vaccination not approved for 6 months–4-years-olds					
Total	80	68 (85%)	7 (8.8%)	5 (6.2%)	
Clinically vulnerable group	14	9 (64%)	3 (21%)	2 (14%)	0.049
Not clinically vulnerable group	66	59 (89%)	4 (6.1%)	3 (4.5%)	
5–11 years					
Total	203	145 (71%)	41 (20%)	17 (8.4%)	
Clinically vulnerable group	25	18 (72%)	5 (20%)	2 (8.0%)	1.000
No clinically vulnerable group	177	126 (71%)	36 (20%)	15 (8.5%)	
Missing	1	1	0	0	

[a]Estimated using Fisher's exact test

multiple entries per child, the instructions accompanying the questionnaire explicitly requested parents to submit only one questionnaire per parental set. However, due to the anonymous nature of the survey, we cannot entirely eliminate the possibility of multiple entries from parents accessing the survey from different IP addresses. Furthermore, German COVID-19 vaccination guidelines changed during our study period, which could have altered parents' vaccination decisions.

Conclusion

A substantial proportion of children aged 5–11 years and children belonging to or in contact with risk groups in Munich were vaccinated against COVID-19 in late 2022/early 2023 and parents of unvaccinated children had a low intent to vaccinate their child in the future. For children aged 6 months–4 years, coverage was lower but intent higher. To address parental vaccination intent and increase vaccine uptake, interventions should be culturally sensitive, tailored to reduced health literacy, encompass clear guidelines and address parents' confidence in vaccines and the institutions providing them as well as parents' awareness of COVID-19-related risks for their children. Depending on national recommendations, these findings could be used to inform targeted, small-scale interventions, particularly for parents of clinically vulnerable children or more expansive vaccination campaigns. This study may provide a baseline for a longitudinal assessment monitoring vaccination uptake and determinants in light of emerging SARS-CoV-2 variants, new COVID-19 vaccines and updated recommendations on COVID-19 child vaccination allowing rapid adjustments of vaccination communication strategies. Such monitoring should be extended to encompass future novel vaccines for children early on in vaccine-rollout in order to design appropriate interventions in timely fashion.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00431-024-05617-0.

Acknowledgements The authors would like to gratefully acknowledge all COVIP-Virenwächter study participants for their contribution. They would also like to thank the administration of the participating schools for their support in inviting the study participants, Tanja Charles and Aftab Jasir for their supervision as part of the PAE/EPIET fellowship and the GI-TFI2 team for piloting the survey.

Authors' contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Liza Coyer and Sarah van de Berg. The first draft of the manuscript was written by Sarah van de Berg and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability Datasets generated and analysed during the current study can be made available upon reasonable request.

Declarations

Human ethics and consent to participate We conducted the study in accordance with the Declaration of Helsinki. The Ethics Committee of the LMU Faculty of Medicine Munich has reviewed and approved the study (No.22-0487). Participation was anonymous and voluntarily. Therefore, no informed consent was obtained.

Competing interests The authors declare no competing interests.

Disclosure The author Liza Coyer is a fellow of the ECDC Fellowship Programme, supported financially by the European Centre for Disease Prevention and Control. The views and opinions expressed herein do not state or reflect those of ECDC. ECDC is not responsible for the data and information collation and analysis and cannot be held liable for conclusions or opinions drawn.

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