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Vaccination attitudes and intentions reported by Canadian children and their parents in the CHILD Cohort Study during the COVID-19 pandemic

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Abstract

Background Understanding if and how vaccination attitudes are shared among family members can help inform strategies to increase uptake. We assessed the correlation of self-reported COVID-19 vaccination attitudes and uptake among Canadian children and their parents, and investigated predictors of parents' attitudes in January 2021–2022.

Methods We studied a subset of 1458 CHILD Cohort Study households where children and parents self-reported their adherence to COVID-19 safety practices, vaccine attitudes and uptake, and health status during the pandemic. Vaccine hesitancy was defined as intending to not receive a COVID-19 vaccine. We identified predictors for vaccine hesitancy using regression and machine learning models and assessed agreement in vaccine intentions between parent–child responses.

Results About 4% of adults and 9% of children expressed hesitancy regarding the COVID-19 vaccine, with safety as the primary concern. By the end of the study (Winter 2022), 2% of parents and 13% of children remained unvaccinated. Children's intentions were largely aligned (over 95%) with their parents' vaccine uptake. COVID-19 vaccine hesitancy among children was much more common in families with unvaccinated parents (e.g. 48% vs. 5% hesitancy among children of unvaccinated vs. vaccinated mothers, respectively). Unvaccinated adults were less likely to follow COVID-19 safety recommendations and follow their doctor's vaccine recommendations, and more likely to have general concerns about vaccines.

Conclusion This is the first study to describe Canadian children's and parent's self-reported COVID-19 vaccine attitudes and intentions. Responses were highly concordant within families. Addressing vaccine hesitancy through understanding its root causes in both children and parents is important for pediatric immunization, both in general and in the context of novel vaccines.

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Keywords Pediatrics, Vaccine hesitancy, COVID-19 vaccines, Child health, Population health

Introduction

Vaccination is critical for individual and population-based health protection both in general and in the context of emergencies such as the COVID-19 Pandemic [49, 51]. Vaccine hesitancy is defined by the World Health Organization (WHO) as “a motivational state of being conflicted about, or opposed to, getting vaccinated, this includes intentions and willingness” [50]. Even before the COVID-19 pandemic, vaccine hesitancy was declared by the WHO to be one of the ten greatest global health threats [48].

Prior to the pandemic, global immunization efforts had averted approximately 154 million deaths over the past half-century [41]. A meta-analysis of parents with children aged 0–6 years found a global pooled prevalence of routine childhood vaccination hesitancy of 21.1% with hesitancy levels lowest in the Americas (13.3%) and highest in the Eastern Mediterranean (27.9%) [1]. Between 1980 and 2019, global coverage for the original Expanded Program on Immunization nearly doubled, for example, Diphtheria-Tetanus-Pertussis (DTP3) coverage rose from 39.6% to 80.9% [1, 17]. During the COVID-19 pandemic routine immunization coverage dropped [23, 28] and vaccine hesitancy gained greater prominence amidst changing vaccine mandates, skepticism toward public health recommendations and greater dissemination of online disinformation [15, 47]. The COVID-19 pandemic triggered the largest sustained decrease in childhood vaccinations in 30 years, reversing decades of progress [18, 50]. Global DTP3 coverage fell to 81% in 2021 from the pre-pandemic baseline of 86% and only partially recovered to 85% [3, 42, 52]. Skepticism towards COVID-19 vaccines has negatively impacted confidence in routine childhood immunization and the post-COVID period has resulted in vaccine rates slipping worldwide with outbreaks of vaccine preventable diseases like measles, meningitis and yellow fever in previously vaccinated populations [17, 27, 29, 38].

Canada has historically had stable childhood vaccination coverage but continued to trail behind international peers ranking 28 among 29 peer nations for childhood immunization rates going into the COVID-19 pandemic (e.g. 90% coverage for measles and 92% coverage for polio in 2019) [31, 40]. At the time it was unclear how willing parents would be to vaccinate their children particularly with the introduction of novel mRNA vaccines [2, 8, 46]. Children in Canada became eligible for COVID-19 vaccination in May 2021 (ages 12–17 years), November 2021 (age 5–11 years) and July 2022 (age 6 months–5 years). In 2026 these mRNA COVID-19 vaccines remain recommended for Canadian children and have favourable

safety and immunogenetic profiles reported [5, 11, 34]. Although Canada initially achieved high COVID-19 vaccine uptake among children, uptake was not universal and varied across age groups. Parent acceptance of vaccines were associated with the child's age [20] as well as other perceptions of safety and necessity [19, 45]. Uptake significantly declined as the pandemic progressed and post-pandemic rates of COVID-19 vaccine hesitancy have increased among parents [33]. Beyond the COVID-19 vaccine and mirroring the global trend of stagnation, the post-pandemic period has marked a decline in childhood immunization with up to 25% of Canadian parents reported delaying or missing a routine immunization since the pandemic [26].

Careful study of the factors that hinder routine childhood immunization internationally and the uptake of novel COVID-19 vaccines is essential to identifying barriers and improving vaccination rates moving forward. Study in this area has identified that global child immunization rates may be affected by concerns regarding the safety, effectiveness, or novelty of vaccines [12, 20, 53]. Other known determinants of childhood vaccination include context-specific individual or group related factors, such as parental socio-economic status, social and media influences, attitudes about vaccines, and scientific literacy [6, 13, 21, 25, 36]. A systematic review of childhood vaccine hesitancy among Canadian parents of preschoolers found that trust and access to providers was associated with vaccine uptake and may compensate for challenges related to SES and family dynamics [39]. It has also been shown that routine vaccination rates increase among adolescents when they are directly involved in decision making [14, 44]. Finally, an analysis of factors associated with timely routine vaccination found that new pandemic related barriers added additional logistical challenges to achieving vaccine coverage [26].

Most literature on vaccine hesitancy and challenges with childhood immunization has focused on cross-sectional parental vaccine hesitancy. Few studies have longitudinally explored vaccine hesitancy among Canadian children and factors affecting uptake during the COVID-19 pandemic. In particular, little is known about the alignment between parents and children's vaccine attitudes and how these attitudes influence immunization rates and evolve over time within families.

Thus our study explored pediatric vaccine hesitancy and uptake of novel COVID-19 vaccines among a cohort of Canadian parents and their children between January 2021 and March 2022. First, we examined the prevalence and longitudinal changes in COVID-19 vaccine uptake and intention among parents and children. Second, we

investigated the alignment between parent and child self-reported COVID-19 vaccine uptake and intentions to understand how vaccination attitudes are shared within families. Finally, we employed machine learning techniques to identify factors associated with general vaccine hesitancy among parents to identify possible strategies for outreach improving childhood immunization rates. Addressing this research gap may inform public health strategies that consider broader family-level dynamics rather than treating children and their parents as independent decision makers.

Methods

Study population and data collection

The CHILD Cohort Study is a diverse prospective cohort of 3,454 children and their parents born in four Canadian provinces between 2008–12 [43]. Between October 2020 and May 2021, 1,458 CHILD Study households (5,377 individuals, 2,231 adults and 2,536 children) participated in the CHILD COVID-19 Add-on Study, including siblings ($n=1,427$) and other family members ($n=103$) not previously enrolled. Detailed methodology of the CHILD COVID-19 Add-on Study, including complete questionnaires, are available elsewhere [4]. Questionnaires were administered online to children and their parents at four time points: baseline (January–June 2021), follow-up 1 (August–September, i.e. Summer 2021), follow-up 2 (October–December, i.e. Fall 2021), and follow-up 3 (January–March; i.e. Winter 2022).

Vaccine attitudes and intentions were self-reported by children and their parents (Table S1). Vaccine attitudes were assessed using 4 questions from the World Health Organization Strategic Advisory Group of Experts (SAGE) 10-item Vaccine Hesitancy Scale (VHS). [24, 37], with modified wording for the version completed by children. Vaccine intention was assessed by asking individuals if they planned to get a COVID-19 vaccine when they became eligible. Hesitancy toward the COVID-19 vaccine was defined as responding ‘Somewhat Unlikely’, ‘Very Unlikely’, or ‘I don’t know’ to the question ‘When a COVID-19 vaccine becomes available, how likely is it that you will choose to get it?’. Children were required to be age 8 or older to fill out study questionnaires independently.

Descriptive analysis and vaccination rates

Demographic and vaccine-related variables are described by frequencies, percentages, means, and standard deviations. Responses of ‘prefer not to answer’ or ‘don’t remember’ were considered missing and excluded through listwise deletion, constituting a small proportion of overall responses. Participants who did not respond to skipped questionnaires were also excluded. Longitudinal changes in concerns about vaccine side effects

and vaccination intentions were visualized using alluvial plots. In this study, “vaccinated” refers to those receiving one or more COVID-19 vaccine doses. Vaccination rates were calculated by dividing participants reporting at least one dose by the total respondents, employing two approaches for the denominator: complete data (minimizing non-response bias) and carry-forward (maximizing sample size); see supplement for details.

Parent–child alignment of vaccine attitudes, intention, and uptake

Alignment of parent–child vaccination attitudes was explored by comparing child vaccination intentions with parent vaccination uptake in Summer 2021 (Follow-up 1), when most adults had been eligible for vaccination for several months, whereas most children were not yet eligible. Parents were considered vaccinated if they reported having received at least 1 COVID-19 vaccine dose. Children were considered hesitant toward the COVID-19 vaccine according to their reported intentions, as described above. We compared the proportion of hesitant children with vaccinated versus unvaccinated parents by chi-squared test, separately for mother–child and father–child pairs.

Globe analysis and chord diagram

We performed a spearman rank correlation analysis of child and adult participants across 1,844 variables (3,255 correlation tests) obtained from multiple sources including the pre-pandemic data from the CHILD Cohort Study and the Canadian Urban Environment (CANUE) Health Research Consortium [10], and new data from the CHILD COVID-19 Add-on Study, to explore associations between domains (see below). Data collected pre-pandemic included demographic and socioeconomic data linked to postal codes, mother’s mental health and parental stress [43]. Variables were grouped into higher-level domains representing similar concepts (e.g. mental health status, childcare impacts of the pandemic, employment status, COVID-19 exposures, etc.) (Table S2). Vaccine-associated variables fell into 3 categories: Vaccination status, Vaccination Beliefs and Vaccination Side Effects. Correlations were adjusted for multiple testing using the Benjamini Hochberg method. Only significant correlations above an absolute value of 0.25 between variables from different domains (where one variable is vaccine-associated) are presented in a chord dendrogram format and displayed on a globe. Detailed methodology can be found in the Supplementary Materials.

Machine learning analyses

We used a penalized multinomial logistic regression model to analyze longitudinal data from three questionnaires (baseline and follow-ups 1 and 2 as defined above)

in adult participants to predict attitudes toward vaccination (level of agreement with the statement "*Getting vaccines is a good way to protect myself from disease*" on a 1–4 scale, which was dichotomized into "Strongly Agree or Agree" or "Strongly Disagree or Disagree.") Questions with a low response rate (<70%) and participants who did not indicate their agreement or disagreement with the statement above in any of the questionnaires were excluded. All data from the third follow-up questionnaire were excluded from this analysis due to the small number of participants who indicated their agreement

Table 1 CHILD COVID-19 add-on study population at baseline (January–June 2021)

n (%) or mean $\pm$ SD	Adults N=2,256	Children N=2,536
Age, years	44.0 $\pm$ 6.2	10.1 $\pm$ 2.7 (0–17)
Relationship to CHILD Study child participant		
Mother	1290 (59.6)	-
Father	869 (39.0)	-
Step parent	18 (0.8)	-
Grandparent, aunt or uncle	35 (1.6)	-
Other adult household member	19 (0.8)	-
CHILD Study child participant	-	1342 (52.9)
Sibling	-	1188 (46.8)
Step Sibling	-	6 (0.2)
Sex assigned at birth		
Male	893 (40.0)	1315 (51.9)
Female	1323 (59.3)	1196 (47.2)
Intersex	0 (0.0)	2 (0.1)
Prefer not to answer	14 (0.6)	23 (0.9)
Prefer to self-describe	1 (0.0)	0 (0.0)
Educational attainment		
Bachelor's degree	890 (39.9)	-
Certificate or diploma	361 (16.2)	-
Graduate degree	587 (26.3)	-
High school or less	166 (7.4)	-
Trade, vocational or apprenticeship	138 (6.2)	-
Other	89 (4.0)	-
Total household income		
\$0–\$49 K	78 (3.5)	-
\$50–\$79 K	211 (9.5)	-
\$80–\$99 K	220 (9.9)	-
\$100–\$149 K	539 (24.2)	-
> \$150 K	696 (31.2)	-
Prefer not to say	111 (5.0)	-
Missing	376 (16.9)	-
Province of residence		
Alberta	360 (16.1)	413 (16.3)
British Columbia	569 (25.5)	708 (27.9)
Manitoba	675 (30.3)	672 (26.5)
Ontario	472 (21.2)	603 (23.8)
Other	155 (6.9)	140 (5.5)

or disagreement with the vaccination question in this questionnaire. Questions were categorized into domains (Table S2). Data were preprocessed by one-hot encoding categorical values, scaling with scikit-learn's StandardScaler [30], imputing missing values as median, and removing highly correlated variables. Recursive feature selection was used to select optimal features. Logistic regression models were built with balanced weights, hyperparameter tuning, and f1 macro metric evaluation (detailed in Supplementary Materials). The final models were trained and tested with stratified shuffle split cross-validation (10 repetitions) on 1,177 individuals' responses to 35 questions.

Results

Cohort description: demographic characteristics and vaccine uptake

The mean age of adults ($N=2,231$), and children ($N=2,536$) who participated in the CHILD COVID-19 Add-on Study was 44.0 (± 6.2 , range 18–86) and 10.1 (± 2.7 , range 0–17) years, respectively (Table 1). Participants came from diverse geographical ancestral origins, with the most common being European (77%), North American (9%), and Asian (9%). In the study, a high percent (68%) of adults had a bachelor's degree or higher education and most (84%) were employed during the baseline questionnaire period (January–June 2021), with 28% classified as essential workers (e.g., healthcare, delivery worker, store worker, security, building maintenance).

At baseline (Winter 2021), 17% of adult participants had received at least 1 dose of a COVID-19 vaccine (Fig. 1). The proportion of adult respondents receiving 2 or more vaccine doses was 6% at baseline, increasing to 93% at follow-up 1 (Summer 2021), 96% at follow-up 2 (Fall 2021) and 98% at follow-up 3 (Winter 2022). Children were not eligible for COVID-19 vaccination during the baseline questionnaire. By the first follow-up (Summer 2021), vaccines were authorized for children aged 12–17 and 18% of respondents in this age group had received at least 1 dose (Fig. 1), increasing to 21% by the second follow-up (Fall 2021). By the third follow-up (Winter 2022), vaccines had further been authorized for children aged 5–11, and 87% of all child respondents had received at least 1 dose.

General vaccine attitudes and COVID-19 vaccination plans among parents and children

The majority of respondents agreed or strongly agreed that in general, vaccination is important for the health of others in their community (95% of adults and 95% of children) and that vaccination is a good way to protect themselves from disease (97% and 97%) at follow-up 1 (Fig. 2 a&b). A large percentage of respondents reported that they generally follow their doctor or health care

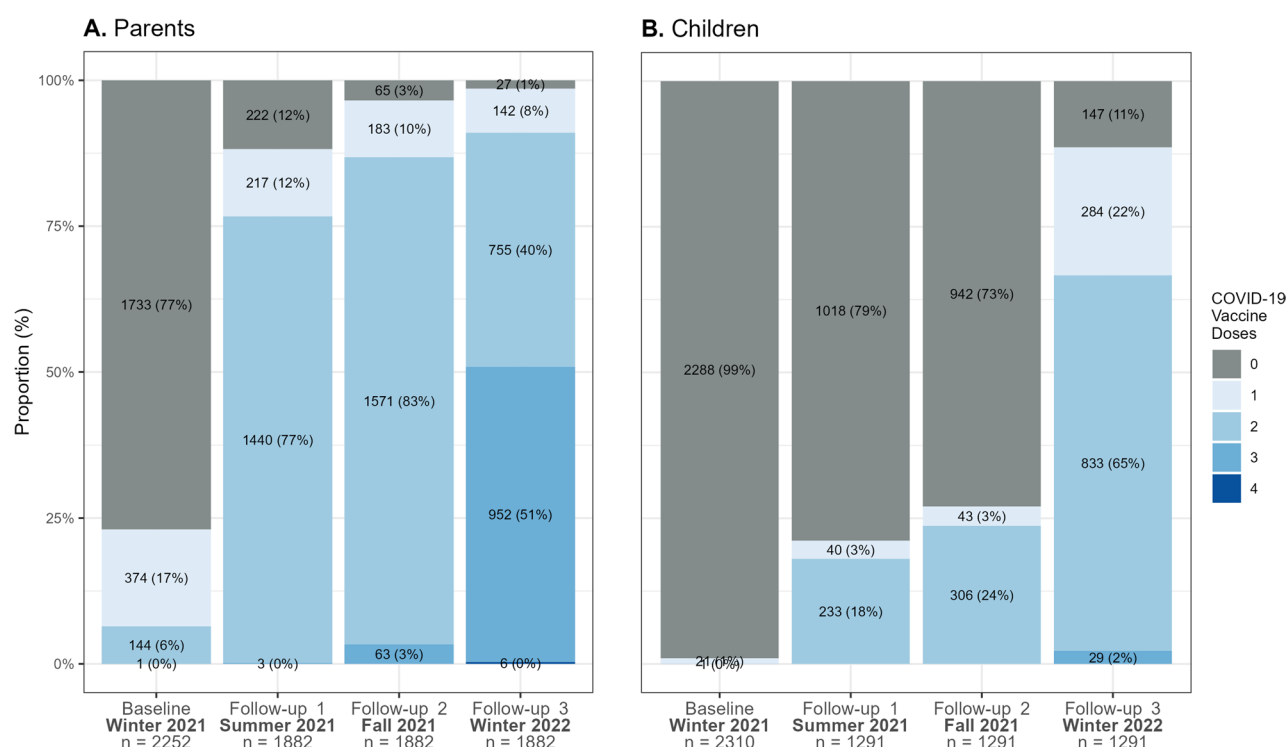


Fig. 1 COVID-19 vaccine uptake at each follow-up in the CHILD COVID-19 Add-on Study (January 2021 to March 2022). Self-reported vaccine uptake among (a) parents and (b) children, as a proportion of the total number of respondents at each follow-up. Vaccination rates may be overestimated as non-respondents were excluded at each follow-up, and respondents may be more compliant than non-respondents with respect to vaccine mandates. An alternative approach is presented in **Figure S1**. Data are also reported in **Table S3**

provider's vaccine recommendations (95% and 97%). Despite this high level of confidence in the general importance of vaccines and adherence to general vaccine recommendations, a substantial proportion of participants reported being generally concerned about the adverse side effects of vaccines (35% and 46%). These responses remained relatively consistent between the first (Summer 2021) and second (Fall 2021) follow-up questionnaires in both adult and child participants (Fig. 2 c&d).

Regarding COVID-19 vaccination intentions, the majority of child respondents at follow-up 1 (Summer 2021) reported that they were either already vaccinated (21%) or very or somewhat likely to get vaccinated when eligible (70%), leaving just 9% reporting they were somewhat or very unlikely to get vaccinated (Fig. 3b). No children were undecided ("I don't know"). At the same time point, over 95% of adult participants had already received 1 or more doses of a COVID-19 vaccine, with the remainder reporting they were very/somewhat likely (0.9%), undecided (0.9%) or very/somewhat unlikely (3.2%) to receive a COVID-19 vaccine in the future (Fig. 3a). Among this small unvaccinated adult population ($n=85$), 47% became vaccinated by follow-up 2 (Fall 2021) and only 18 individuals remained "Very Unlikely" to become vaccinated by the final follow-up (Winter 2022).

Of the relatively few adults ($n=85$, 4%) and children ($n=70$, 9%) who expressed hesitancy toward the COVID-19 vaccine at follow-up 1 (Summer 2021) (Fig. 3 a&b), the majority (59%) of reasons provided for not intending to be vaccinated were related to participants' safety concerns regarding the COVID-19 vaccine (Figure S2). Other reasons provided were that they "did not believe in vaccination" (4% of adults, 3% of children), "did not consider it necessary" (41%, 25%), "already had COVID-19" (12%, 12%), "have a pre-existing medical condition" (16%, 0%) and "have not yet decided" (16%, 8%).

Alignment of parent and child COVID-19 vaccination uptake and attitudes

We observed a high level of agreement between children and their parents regarding their COVID-19 vaccine intentions and uptake during the summer of 2021 (95% agreement with mothers, 96% agreement with fathers) (Fig. 3 c&d). Notably at this time, most adults had already been eligible for vaccination for several months, but most children were not yet eligible. COVID-19 vaccine hesitancy was 48% ($n=33/69$) among children whose mothers were unvaccinated, compared to just 5% ($n=41/754$) among those with vaccinated mothers ($p<0.0001$). A clear relationship was also observed when considering fathers' vaccination status, with 24%

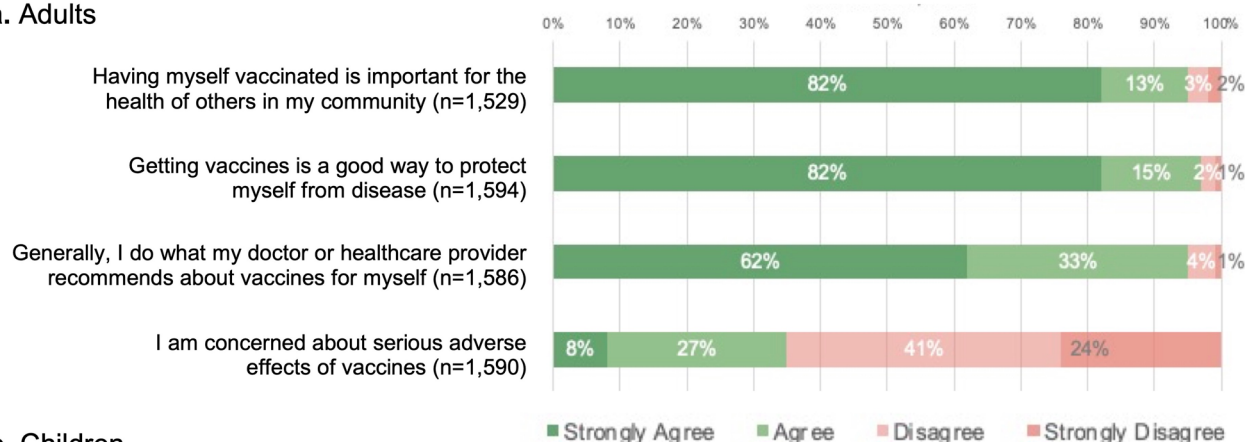
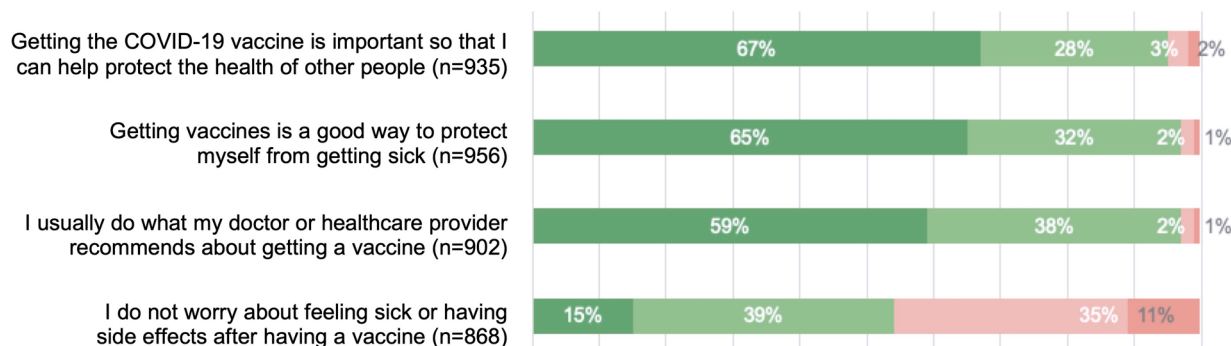
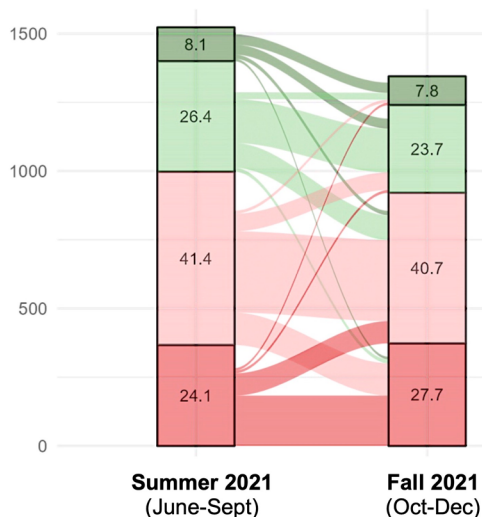
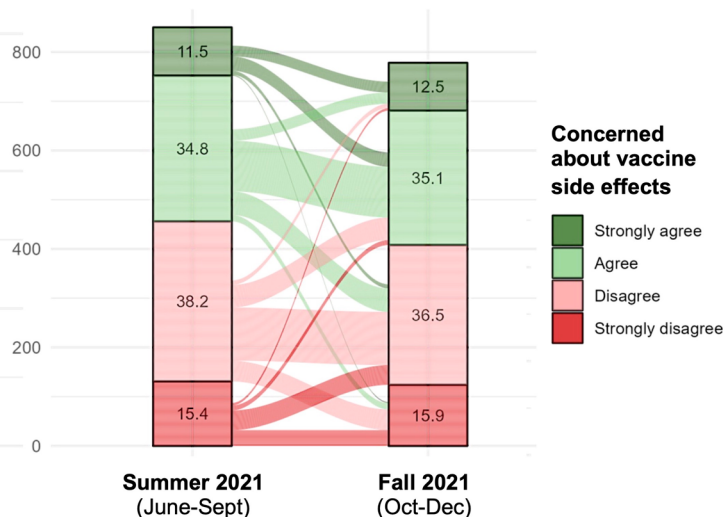
a. Adults**b. Children****c. Parents****d. Children**

Fig. 2 General vaccination attitudes of adults and children in the CHILD COVID-19 Add-on Study. Attitudes of (a) adults (n=2,231) and (b) children (n=2,536) at the second follow-up questionnaire (fall 2021), and temporal changes in (c) parent (n=1,523) and (d) child (n=850) concerns about vaccine side effects from summer to fall of 2021

hesitancy ($n = 27/109$) reported among children of unvaccinated fathers compared to 5% ($n = 25/533$) among those with vaccinated fathers ($p < 0.001$). When considering both parents' vaccination status in combination (Fig. 3e), children with two unvaccinated parents (a notably small

group) had the highest rates of hesitancy at 52% (16/31). Notably among families where parents' had discordant vaccination statuses ($n = 94$ families), it was more common for the mother to be the vaccinated parent ($n = 78$) than the father ($n = 16$ families). Overall, these results

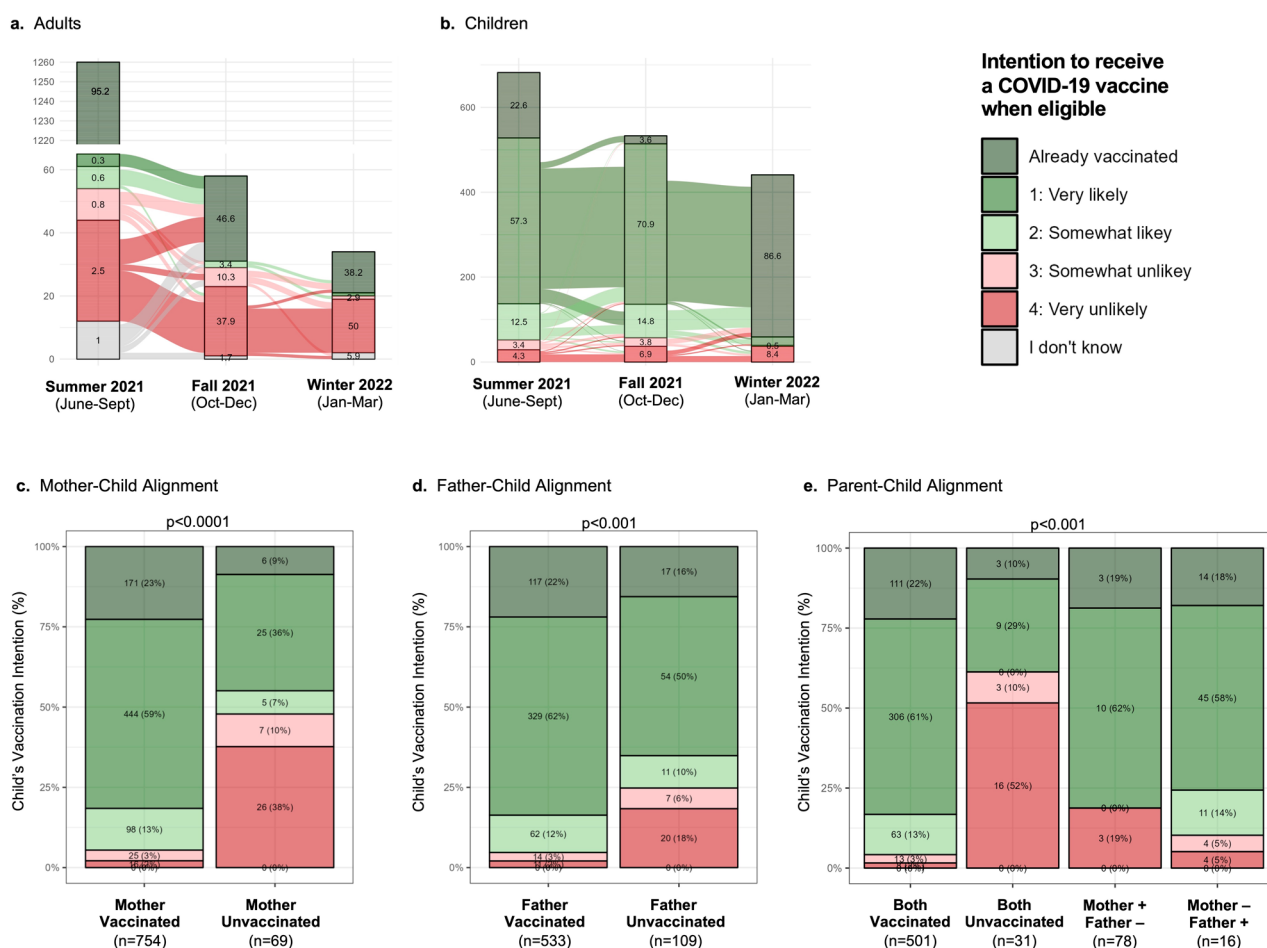


Fig. 3 Longitudinal changes (a & b) and parent-child alignment (c-e) of COVID-19 vaccination plans from Summer 2021 to Winter 2022 among parents and children in the CHILD COVID-19 Add-on study. Responses of parents (a) and children (b) to the question: "When a COVID-19 vaccine becomes available, how likely is it that you will choose to get it?" Relationship between mother's (c), father's (d) or both parents' (e) vaccination status and child vaccination intention, reported at Follow-Up 1 (Summer 2021, when adults had been eligible for vaccination for several months, but children were not yet eligible). Children with only 1 parent response ($n=261$) were excluded from the 'both parent' analysis. Number of responses are indicated on the y-axis and percent of respondents per response type are indicated inside stacked barplots

indicate that intention to receive the COVID-19 vaccine was frequently shared among children and their parents, with strongest parent-child alignment observed when both parents were either vaccinated or unvaccinated.

Globe analysis of vaccine-associated variables in children and adults

In an inter-domain correlation analysis of variables (globe analysis) of pre-COVID data from the CHILD Cohort and vaccine-related data from the CHILD COVID Add-on Study, we found that parents who believed in vaccinating themselves or their child for the benefit of the community also tended to believe that vaccines protect from disease ($r=0.764$ self, $r=0.804$ child), and follow doctor's vaccine recommendations ($r=0.543$ for self and $r=0.594$ for child) (Fig. 4). Parents who said they would vaccinate their child when eligible also believed in the benefits of vaccination for their community ($r=0.717$)

and child's health ($r=0.635$), and planned to follow their doctor's vaccine recommendations ($r=0.504$). Children who had received a flu vaccine had parents who were less concerned about COVID-19 vaccine side effects ($r=-0.266$).

Parents who lacked confidence in the safety of COVID-19 vaccines were also concerned about vaccine side effects ($r=0.759$) and were waiting for the safety to be confirmed ($r=0.557$), and/or did not believe that vaccines are necessary ($r=0.521$). Parents' reasons for their child not being vaccinated correlated with their reasons for themselves not being vaccinated, including concerns about risks and side effects ($r=0.474$), disbelief in vaccination ($r=0.816$), or having already had COVID-19 ($r=0.908$). A full correlation matrix of all significant relationships can be found in **Supplementary File 2**.

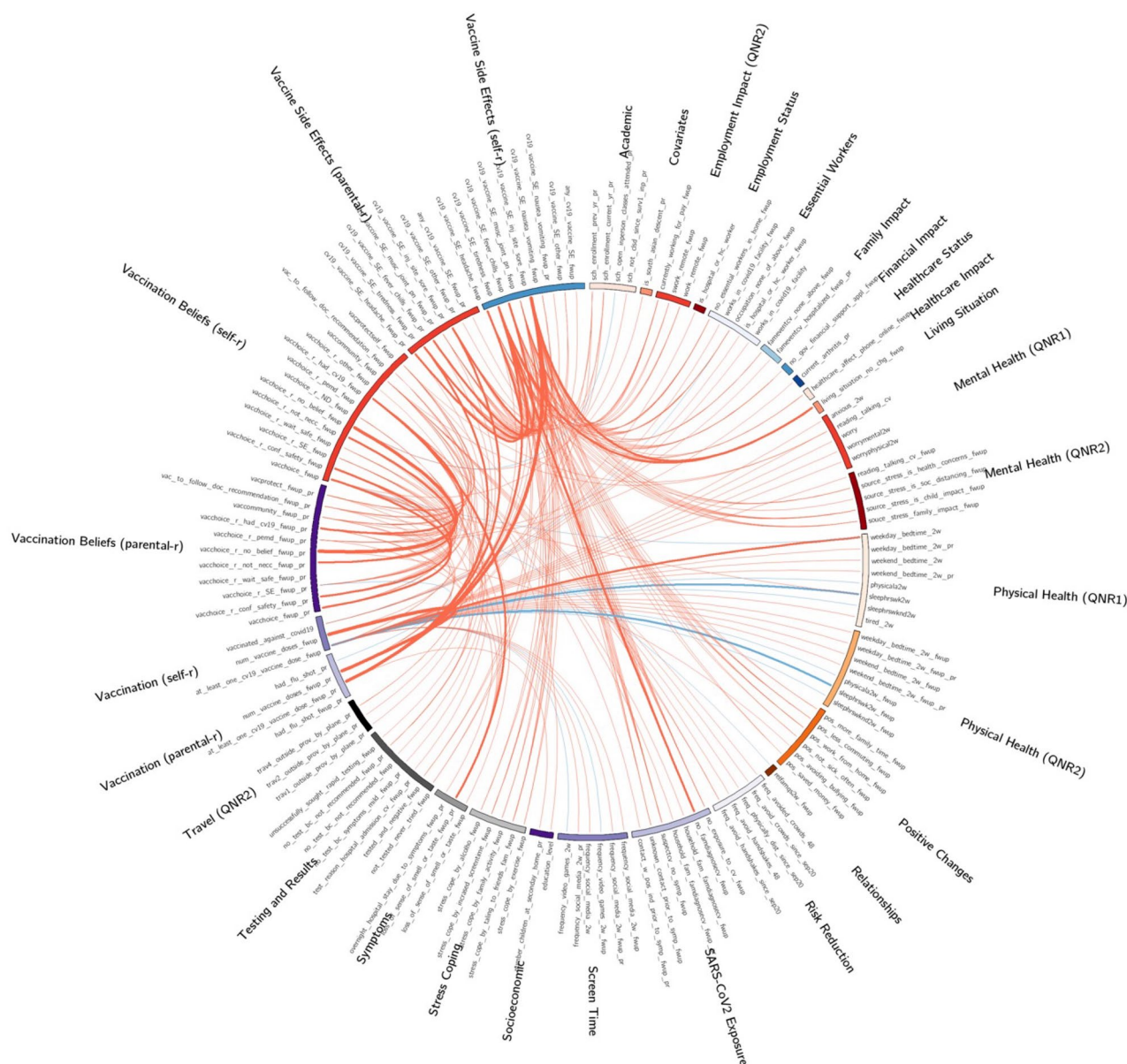


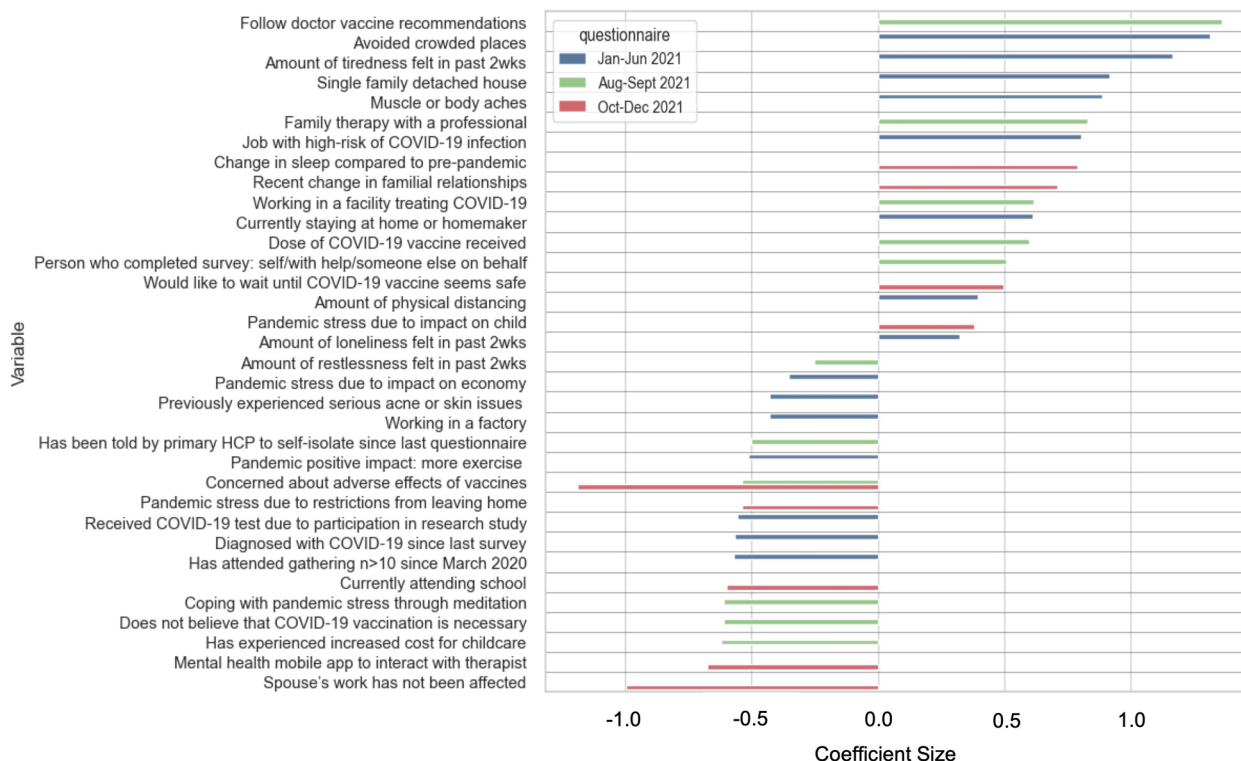
Fig. 4 Cord dendrogram highlighting 333 statistically significant correlations between vaccine-associated variables and other variables collected at baseline (Winter 2021, QNR1), follow-up questionnaire 1 (Summer 2021, QNR2) and pre-pandemic CHILD variables. Variables are grouped into higher level domains representing similar concepts (see Table S2). Domains ending in "self-r" distinguish questions answered by adults or children directly while domains ending in "parental-r" are for questions answered by parents on behalf of the child. Correlations were adjusted for multiple testing using Benjamini Hochberg method. Significant correlations above absolute value 0.25 with $p < 0.05$ are included in this figure. Only those correlations between variables from different domains where one variable is vaccine-associated are shown. Red lines indicate a positive correlation coefficient. Blue lines indicate a negative correlation coefficient. Thinnest line = ≥ 0.25 , medium lines ≥ 0.5 and thick lines ≥ 0.75

Machine learning model of adult vaccination skepticism

To better understand the factors that are strongly associated with general vaccine hesitancy, we used a penalized multinomial logistic regression model to predict agreement with the statement "getting vaccinated is a good way to protect myself from disease" using data from the adults' baseline survey and first two follow-up questionnaires (Fig. 5). Factors that were associated with agreement (i.e. vaccine acceptance) included (Fig. 5a):

following doctor's vaccine recommendations, adherence to COVID-19 safety practices (e.g. avoiding crowded places and practicing physical distancing), having a job that leads to increased risk of contracting COVID-19/working in a facility that treats COVID-19 patients, and feeling lonely. Factors that predicted disagreement (i.e. vaccine hesitancy) included: adverse feelings about vaccines in general, having been diagnosed with COVID-19,

a. Significant predictors of vaccine acceptance in machine learning models



b. Highest contributing variable domains

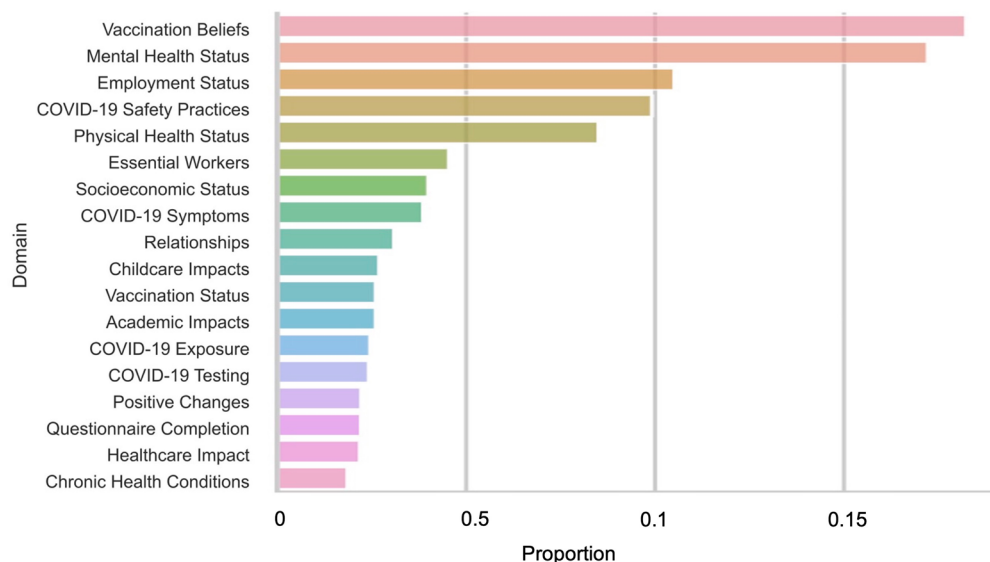


Fig. 5 Longitudinal machine learning model identifying factors associated with vaccine acceptance among adults in the CHILD COVID-19 Add-on Study. Penalized multinomial logistic regression model using l2 regularization, maximum 100 iterations, and lbfgs solver (average macro f1 score of 0.95). A) Variables with absolute coefficients > 0.2 in modelling the response to the statement "Getting vaccines is a good way to protect myself from disease" by logistic regression. Bars are colored based on the questionnaires from which they are derived. Variables with coefficients > 0 are associated with agreement, while variables with coefficients < 0 are associated with disagreement. **a** Proportion of significant variables (**b**) belonging to various domains. 26 domains were present in the original dataset (Table S2), while 18 are represented in the model. Coefficients for each variable are given in Supplementary Data File 2

working in a factory, attending gatherings with more than 10 people since the pandemic began, and feeling restless.

Both those who agreed and those who disagreed with the statement that vaccines are protective experienced stress from the pandemic, but from different sources. Individuals who were vaccine hesitant indicated that they experienced stress due to their inability to leave home and the impact of the pandemic on the economy, while those who were accepting of vaccines felt stress due to the impact of the pandemic on their child(ren). Both groups of individuals were willing to seek help for mental health concerns. Vaccine hesitant individuals were more likely to use a mental health mobile app to interact with a therapist, while vaccine accepting individuals were more likely to engage in family therapy with a professional.

Overall, the most important variables in the prediction model centered around vaccination beliefs, mental health status (including stress) and employment status (Fig. 5b). Notably, the proportion of variables selected from each domain for the model was not related to the proportion of variables in each domain in the entire dataset (Table S2), indicating that the predictive ability of each type of variable was not influenced by its frequency in the questionnaires.

Discussion

Our study of families in the Canadian CHILD Study found strong parent–child alignment in COVID-19 vaccine intentions and vaccine uptake during a dynamic period of the pandemic. Most parents (98%) and children (87%) received at least one COVID-19 vaccine dose by the end of the study period in Spring 2022. Lower uptake among children reflects the later approval of vaccines for this age group, but could also indicate higher hesitation around pediatric COVID-19 vaccination. Overall, 4% of adults and 9% of children in this study reported hesitancy about receiving the COVID-19 vaccine, with safety concerns as the primary reason. Within families, parents and children were strongly aligned regarding COVID-19 vaccine intention and uptake, with much higher rates of hesitancy reported among children with unvaccinated parents. While true for all parents, this alignment was particularly strong for mothers where we observed 48% hesitancy among children of unvaccinated mothers compared to just 5% among those with vaccinated mothers.

The high COVID-19 vaccination rates among children in our study (87% in Spring 2022) align with other Canadian studies performed around the same time. For instance, a longitudinal study from Quebec in 2021 reported that 86% of parents intended to vaccinate their children [32], while a study from Toronto in Summer 2021 found that 69% of parents with children aged over 11 years reported their children had received at least one

dose of the vaccine, while 7% did not plan to vaccinate their children, and 19% were undecided [22].

Although alignment between parents and children is not unexpected, our study is novel in capturing children's own self-reported attitudes and intentions longitudinally during an active vaccine rollout. Children's perspectives are rarely included in family studies, which typically rely only on parent report, and vaccine attitudes are seldom examined for newly introduced vaccines. Study designs that use questionnaires reported by only one party create falsely high concordance rates. We mitigated this risk by separately asking parents and children to self-report their intentions. However the strong concordance between parent and child vaccine intentions aligns with established theories of social learning, family systems, and health socialization, all of which predict close similarities in parent–child health beliefs and behaviors. Consistent with these frameworks and our findings, prior research also shows substantial parent–child alignment across health domains such as diet and physical activity [16]. However, no prior studies to our knowledge have evaluated parent–child concordance of vaccine uptake and self-reported vaccine hesitancy during a global pandemic. Our findings contribute new evidence to show that such concordances persist even under extreme circumstances. Further research is warranted to understand how parents and children's vaccine decision-making influence each other. It is also possible that children influence their parents' vaccine decision-making. In which case, strengthening public health education about vaccines in schools could be beneficial in multiple ways.

Our exploratory analysis also indicates that parents' vaccine decisions are shaped by broader beliefs, social networks and trust in institutions. Pandemics may intensify safety concerns, misinformation exposure and polarization. Parents who believed in vaccination for protecting the health of their community also believed in the personal protection provided by vaccines and followed doctors' vaccination recommendations. Hesitant parents lacked confidence in vaccine safety, were concerned about side effects, and did not see its necessity. Parents who did not vaccinate their child reported similar reasons for not vaccinating themselves. These results mirror a cross-sectional national survey of Canadian parents' perception of COVID-19 vaccination for their children where parents' low vaccination intention was associated with children not receiving an influenza vaccine pre-pandemic, parents having low COVID-19 vaccination intention for themselves, and concerns about COVID-19 vaccine safety and use in children without prior testing [20]. Taken together, these results suggest that parents' vaccine hesitancy and concerns for their children are not limited to the novelty of COVID-19 vaccines. Given that parent–child alignment on vaccine hesitancy persisted

in the unique context of a novel pandemic, future studies should closely examine the roles and potential unintended consequences of vaccine mandates and mass-media in public health messaging and organizational strategy. Hospital-based strategies could have potential for improving childhood immunization coverage [35].

Our longitudinal machine learning model found that adults who were more accepting of vaccines were more likely to follow doctor's recommendations, adhere to COVID-19 safety practices, and work in high-risk environments. Factors that predict adults' vaccine hesitancy included adverse feelings about vaccines in general, having been diagnosed with a SARS-CoV-2 infection, and attending gatherings with more than 10 people since the pandemic began. These results suggest that vaccine-hesitant adults in the study represent a unique group that may be more willing to take risks related to COVID-19 and do not perceive the benefits of vaccination. Tailored public health messaging aimed at this group, based on their lifestyle factors, may be an effective strategy to increase vaccination rates along with motivational interviewing by health care providers [7, 9].

Our study has limitations, including potentially limited generalizability due to the demographics of participants (predominantly Caucasian with relatively high socioeconomic status) and high attrition rates that made it challenging to accurately report vaccination rates, potentially introducing non-response bias. It is also possible that some vaccine hesitant participants were not captured here due to reluctance to report their negative vaccination attitudes and intentions, particularly as these became highly divisive social issues during the COVID-19 pandemic.

Furthermore, due to the urgency of the pandemic, our modified SAGE 10-item Vaccine Hesitancy Scale for children was not validated or previously tested for age-related variations prior to its rollout and children's age may affect their comprehension and independence in answering questions. To minimize this concern, only children above age 8 were given the opportunity to independently fill out questionnaires given the literacy skills required. We were also unable to ensure all child responses were filled out completely independently due to children and parents both being home during lockdown when questionnaires were completed. There is also potential for parental presence in the home to influence child responses. Additionally, it is possible that other factors not directly assessed in the questionnaires affected vaccine hesitancy (e.g. fear of needles). Limitations to our regression modeling were the inability to include pre-pandemic CHILD data, assumption of unidirectional relationships, and reliance on an imbalanced dataset only 2% expressing vaccine hesitancy. Finally, correlation analyses and dendrograms relied on subjective interpretation.

Despite these limitations, this study allowed the investigation of vaccine uptake and attitudes among children and parents, using longitudinal data from a dynamic period of the pandemic.

The implications of this research extend beyond the COVID-19 pandemic and the Canadian context. Understanding how vaccine attitudes and uptake are shaped within families provides critical insights for any immunization program whether for routine childhood immunization, seasonal influenza, or future vaccines for emerging pathogens. Parent-child alignment in health behaviors is a global phenomenon, and our data underscore the importance of family-level dynamics in shaping vaccine decisions. As vaccine hesitancy is one of the greatest threats to global health, evidence on predictors of hesitancy and family influence can guide tailored approaches that strengthen confidence, improve uptake, and ultimately enhance population-level protection against infectious diseases.

Conclusion

Our study offers a unique analysis of vaccine hesitancy, intentions and uptake among Canadian children and their parents during the COVID-19 pandemic, which can inform future vaccine rollouts and pandemic preparedness. Overall, we found that children and their parents shared similar beliefs about vaccines, though discordance was observed in some families, suggesting that strengthening public health education for both children and parents is valuable. Further research is needed to identify how parents and children reciprocally influence each other's vaccination intentions, and to better understand the unique aspects of vaccine hesitancy within the context of pandemics and novel vaccines.

Abbreviations

WHO	World Health Organization
COVID-19	Coronavirus (SARS-CoV-2) disease 2019
CANUE	Canadian Urban Environment Consortium
SAGE	Strategic Advisory Group of Experts on Immunization (SAGE)

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-026-27115-8>.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

Acknowledgements

We are grateful to all the families who took part in this CHILD COVID-19 Add-on Study and the entire CHILD Study team, which includes study site coordinators, research assistants, nurses, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, and receptionists at the following institutions: McMaster University, University of Manitoba, University of Alberta, SickKids, and University of British Columbia. We acknowledge Jay Onysko (Public Health Agency of Canada) who served on

the CHILD COVID-19 Add-on Study Knowledge User Committee. We thank the main CHILD Cohort Study participant families for their dedication and commitment to advancing health research.

Authors' contributions

M.V.M., E.E.G., G.L.W., R.A., L.C.L., S.G., R.M.H., D.M., D.M.P., S.B., J.B., S.E.M., E.S., S.E.T., T.J.M., P.S., F.S.L.B., M.B.A. all contributed to manuscript conceptualization and approved the final manuscript. Data analyses were performed by M.V.M., E.E.G., G.L.W. and S.G. with supervision and guidance of F.S.L.B. and M.B.A. The first draft of the manuscript was written by M.V.M. and M.B.A. with all authors reviewing, editing and approving the manuscript.

Funding

This work was supported by funding from the Canadian Institutes of Health Research and the Canadian COVID-19 Immunity Task Force [VR5-172658] and Research Manitoba [4494]. Core funding for the CHILD Cohort Study was provided by the Canadian Institutes of Health Research [CIHR; AEC-85761, PJT-148484, FDN-159935, and EC1-144621], the Allergy, Genes and Environment Network of Centres of Excellence (AllerGen NCE) [12CHILD], BC Children's Hospital Foundation, Don & Debbie Morrison, and Genome Canada/Genome BC [274CHI]. This research was supported, in part, by the Canada Research Chairs program: MBA holds a Tier 2 Canada Research Chair in the Developmental Origins of Health and Disease; SET holds a Tier 1 Canada Research Chair in Pediatric Precision Health; PS holds Tier 1 Canada Research Chair in Pediatric Asthma & Lung Health. FSLB is an SFU Distinguished Professor. MVM has received doctoral support from Canadian Institutes of Health Research, Canadian Lung Association and the SickKids Foundation. The funding agencies had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication. In alignment with the call from the Canadian Chief Science Advisors, this COVID-19 related publication will be open access.

Data availability

Existing CHILD researchers and CHILD COVID-19 Knowledge Users will be given rapid access to study data on request. New researchers interested in developing or collaborating on a project using CHILD data are encouraged to contact the Study's National Coordinating Centre for a formal request. Data request and access details are outlined on the CHILD website: <https://childstu dy.ca/for-researchers/study-data/>

Declarations

Ethics approval and consent to participate

All relevant ethical guidelines have been followed, and any necessary IRB and/or ethics committee approvals have been obtained. This study received approval for the research described by the Ethics committee/IRB of the University of British Columbia (H20-02324), University of Alberta (Pro00102524), University of Manitoba (HS24250), The Hospital for Sick Children (1000071220) and McMaster University (1108). Freely given informed consent to participate was obtained from all participants in this study including the use for scientific publication.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 16 March 2025 / Accepted: 18 March 2026

Published online: 26 May 2026

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