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Original Article

SARS-CoV-2 variants and the global pandemic challenged by vaccine uptake during the emergence of the Delta variant: A national survey seeking vaccine hesitancy causes

Fadi AlJamaan[a,1,13], Mohamad-Hani Temsah[b,c,*,2,13], Khalid Alhasan[b,d,3], Shuliweeh Alenezi[e,4], Ali Alhaboob[b,5], Abdulkarim Alrabiaah[b], Mohammed Batais[f], Fatimah Alshahrani[g,6], Rasha Asaad Assiri[h,7], Hind Bafaqih[i], Ali Alaraj[j,k], Bedoor Al Qadrah[b], Abdulilah Alhaidary[l], Khaled Saad[m], Basema Saddik[n,o,8], Rabih Halwani[o,p], Ali A. Rabaan[q,r,s,9], Sarah Al-Subaie[a,10], Mazin Barry[g,t,11], Jaffar A. Al-Tawfiq[u,v,w,12]

[a] Critical Care Department, College of Medicine, King Saud University, Riyadh, Saudi Arabia
[b] Pediatric Department, College of Medicine, King Saud University, Riyadh, Saudi Arabia
[c] Prince Abdullah Ben Khaled Celiac Disease Research Chair, Department of Pediatrics, Faculty of Medicine, King Saud University, Saudi Arabia
[d] Pediatric Kidney Transplant, Organ Transplant Center of Excellence, King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia
[e] Department of Psychiatry, King Saud University, Riyadh, Saudi Arabia
[f] Department of Family and Community Medicine, King Saud University Medical City, Riyadh, Saudi Arabia
[g] Division of Infectious Diseases, Department of Internal Medicine, College of Medicine, King Saud University and King Saud University Medical City, Riyadh, Saudi Arabia
[h] Department of Basic Medical Sciences, College of Medicine, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia
[i] Pediatric Critical Care Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia
[j] Department of Medicine, College of Medicine, Qassim University, Qassim, Saudi Arabia
[k] Dr Sulaiman Al Habib Medical Group, Riyadh, Saudi Arabia
[l] Nursing Department, King Saud University Medical City, Riyadh, Saudi Arabia
[m] Department of Pediatrics, Assiut University, 71516, Egypt
[n] Department of Family and Community Medicine, College of Medicine, University of Sharjah, Sharjah 27272, the United Arab Emirates
[o] Sharjah Institute of Medical Research, University of Sharjah, Sharjah 27272, the United Arab Emirates
[p] Department of Clinical Sciences, College of Medicine, University of Sharjah, Sharjah 27272, the United Arab Emirates
[q] Molecular Diagnostic Laboratory, Johns Hopkins Aramco Healthcare, Dhahran 31311, Saudi Arabia
[r] College of Medicine, Alfaisal University, Riyadh 11533, Saudi Arabia
[s] Department of Public Health and Nutrition, The University of Haripur, Haripur 22610, Pakistan
[t] Division of Infectious Diseases, Faculty of Medicine, University of Ottawa, K1H 8M5, Canada
[u] Specialty Internal Medicine and Quality Department, Johns Hopkins Aramco Healthcare, Dhahran, Saudi Arabia
[v] Infectious Disease Division, Department of Medicine, Indiana University School of Medicine, Indianapolis, IN, USA
[w] Infectious Disease Division, Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Abbreviations: CDC, Centers for Disease Control and Prevention; Covid-19, Coronavirus disease 2019; GAD7, Generalized Anxiety Disorder Assessment; HCWs, Healthcare workers; MOH, Ministry of Health; NHCS, Non-healthcare workers; SARS-CoV-2, Severe Acute Respiratory Syndrome Coronavirus 2; WHO, World Health Organization

* Correspondence to: College of Medicine, King Saud University, PO Box 14135, Riyadh 11424, Saudi Arabia.
E-mail addresses: faljamaan@ksu.edu.sa (F. AlJamaan), mtemsah@ksu.edu.sa (M.-H. Temsah), kalhasan@ksu.edu.sa (K. Alhasan), salenizi@ksu.edu.sa (S. Alenezi), drhbooob@gmail.com (A. Alhaboob), alrabiaah@ksu.edu.sa (A. Alrabiaah), mbatais@ksu.edu.sa (M. Batais), Falshahrani1@ksu.edu.sa (F. Alshahrani), raassiri@pnu.edu.sa (R.A. Assiri), hbafagih13@gmail.com (H. Bafaqih), al_araj@hotmail.com (A. Alaraj), Bedoor29@gmail.com (B. Al Qadrah), aalhaidary1@ksu.edu.sa (A. Alhaidary), khaled.ali@med.au.edu.eg (K. Saad), bsaddik@sharjah.ac.ae (B. Saddik), rhalwani@sharjah.ac.ae (R. Halwani), arabaan@gmail.com (A.A. Rabaan), salsubaie@ksu.edu.sa (S. Al-Subaie), mbarry@ksu.edu.sa (M. Barry), jaltawfi@yahoo.com (J.A. Al-Tawfiq).
[1] https://orcid.org/0000-0001-8404-6652.
[2] https://orcid.org/0000-0002-4389-9322.
[3] https://orcid.org/0000-0002-4291-8536.
[4] https://orcid.org/0000-0002-7049-0960.
[5] https://orcid.org/0000-0003-2126-7874.
[6] https://orcid.org/0000-0002-4646-7488.
[7] https://orcid.org/0000-0001-8946-4618.
[8] 0000-0002-4682-5927.
[9] https://orcid.org/0000-0002-6774-9847.
[10] https://orcid.org/0000-0002-3128-5921.
[11] https://orcid.org/0000-0003-2274-007X.
[12] https://orcid.org/0000-0002-5752-2235.
[13] ‡These authors have contributed equally to this work

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ABSTRACT

Background: Herd immunity for COVID-19 is the ultimate goal to end the pandemic. Emergence of SARS-CoV-2 variants has been a subject of considerable debate regarding vaccines effectiveness. This ongoing discussion and other evolving variables contribute to the hesitancy toward vaccines and levels of vaccination acceptance among both the healthcare workers and the public. This study was conducted to assess COVID-19 vaccine uptake and hesitancy among the Saudi Arabian population during the emergence of SARS-CoV-2 Delta variant.

Methods: A national cross-sectional survey conducted between June 28 and July 5, 2021. The survey collected sociodemographic information, personal and family history of previous COVID-19 infection, adherence to precautionary measures, COVID-19 vaccination status, parental willingness to vaccinate their teenage children, and address variable associated with hesitancy to receive vaccination.

Results: Among the 4071 participants, 67 % were women, 86 % of the participants received COVID-19 vaccine, 70 % had very high or high commitment with COVID-19 precautionary measures. On multivariate analysis, vaccine hesitancy was less likely in men (OR 0.652, p-value < 0.001), those who had direct family members infected with COVID-19 (OR 0.455, p-value < 0.001), and those who reported using the Ministry of Health official channels as information sources (OR 0.522, p-value < 0.001), while those younger than 44 years had higher hesitancy to receive the vaccine (1.5–2.1 times). Of the participants, only 42 % showed willingness to vaccinate their teenage (12–18 years old) children.

Conclusions: The participants in this study had high COVID-19 vaccination rate; however, hesitancy was reported more commonly among women. Their willingness to vaccinate their teenage children was much lower. Participants relying on social media platforms were highly hesitant to receive vaccination. Public health officials should scale up their efforts targeting females, young population, and parents by vaccination awareness campaigns, and refute misinformation spread on social media, especially with the emergence of variants and the news burst that coincide with them.

Introduction

Several COVID-19 vaccines were developed and used during the past year, however, widespread vaccine uptake is needed in order to reach herd immunity and hence control the pandemic [1]. Multiple studies have demonstrated that vaccine acceptance varies significantly across different settings, with many individuals undetermined or unwilling to receive the vaccine [2–7]. Vaccine hesitancy (VH) is defined as "a behavior or attitude, influenced by several factors including confidence (mistrust in the vaccine or a provider), complacency (do not perceive a need for a vaccine or do not value the vaccine as effective method to prevent the disease or decrease its morbidity), convenience (access), and collective responsibility [8]. As of July 2021, there were 517,000 COVID-19 cases in the Kingdom of Saudi Arabia (KSA) and 8000 deaths; more than 25 million Saudis had received at least one dose of the vaccine, including approximately one million individuals aged 12–18 years; this accounts for more than 70 % of the population[9]. Meanwhile in Saudi Arabia, the B.1.617.2 (Delta) variant became the dominant variant by mid-April 2021.

Vaccines have been observed to be highly effective in controlling the disease spread and reducing its mortality and morbidity [10]. Still the Delta variant has been characterized by multiple mutations including those affecting its spike protein (T19R, Δ157–158, L452R, T478K, D614G, P681R, and D950N). Many of these mutations could affect the immune responses that are directed toward some key antigenic regions of the receptor-binding protein (452 and 478). P681R being at the S1–S2 cleavage site may have increased the viral replication, which could lead to higher viral loads and transmission. As information of COVID-19 vaccines effectiveness against this variant translated on clinical outcomes is still evolving [10,11], the most updated evidence is suggestive of variable response of this variant to the available vaccines with efficacy ranging from 60 % for Johnson and Johnson vaccine and up to 94 % for the Moderna, vaccine and the variation in efficacy was dependent on the time since vaccination and disease severity[12,13]. The aim of this study was to assess the level of COVID-19 vaccines hesitancy in KSA following the emergence and prevalence of the Delta variant.

Methods

Data collection

We used vaccination uptake survey tool for COVID-19 among healthcare workers that was previously validated, used and published, after being modified to accommodate questions related to the Delta variant, with additional question on travel to a country where the Delta variant has been recorded and specifying the questions on vaccines in regards to the Delta variant effectiveness [14]. The survey tool was developed by a panel of experts from infectious disease and epidemiology specialists. We modified the wording for the general population and so that the COVID-19 vaccine could be addressed among adults and children. To investigate potential causes of COVID-19 vaccine hesitancy and information sources about the vaccines, we adopted the previously published survey from KSA [9,15].

An initial pilot of the final bilingual questionnaire, which was completed by 52 individuals, found that the items were reliable and understood equally well by participants, with a 0.87 Cronbach's alpha.

Sampling technique

Snowball sampling was applied through social media platforms, WhatsApp, Twitter and Facebook as means of rapid subject recruitment for emergency health research during the rise of the Delta-variant wave [16]. The invitation to participate in the survey highlighted the inclusion criteria and voluntary nature of the survey, as well as privacy concerns. Data was collected between 28 June 2021 and 5 July 2021. Assuming that 50 % of the patients would have the desired outcome under study and with the intention to detect

the true prevalence of the patients with the intended study outcome with 95 % confidence and 5 % margin of error, the desired sample was calculated to be a minimum of 384 individuals.

Statistical analysis

Mean and standard deviation were used to describe continuous variables. Frequency and percentages were used for categorically measured variables. All completed response forms were included in the analysis. Variables that were collected included participants' sociodemographic characteristics and their COVID-19 vaccination status with their triggers if did not receive it, GAD 7 score, family history of COVID-19 infection and its severity, family commitment with COVID-19 infection prevention precautionary measures and participants' willingness to vaccinate their teenager (12–18 years old) children. The multiple response dichotomies analysis was applied to variables with more than one option. Histograms and the statistical Kolmogorov-Smirnov K-S tests were used to assess normality of continuous variables and Levine's test of homogeneity of variance to test the equality of variance. The Chi-squared ($\chi 2$)-test of independence was used to assess the correlations between categorically measured variables and One-way ANOVA test to assess the statistical significance of mean differences. Corrected Likelihood Ratio Chi-squared test was used when the statistical assumptions of the chi-squared test expected counts was violated and likewise a Welch's adjusted One-way ANOVA was applied when the equal variance statistical assumption was violated. The Generalized Anxiety score was computed according to the author's scoring manual and so the categorization of the GAD7 total score. The Multivariate Binary Regression analysis was used to assess the statistical significance of the predictors of adults' population odds of COVID19 vaccine reluctance expressed by odds ratio 95 % confidence intervals. The alpha significance level was considered at 0.050 level. The commercially available SPSS IBM statistical analysis program Version#21 was used.

Results

A total of 4071 participants completed the survey. The majority of participants were females (67.1 %), 94.2 % were married, and 76.9 % achieved university education. 65.4 % of participants had children in the age group approved for vaccinations at that time (12–18 years) (Table 1). Almost half of participants were aged 35–44 years. The majority (72.7 %) reported having had one of their direct family members previously developed COVID-19, mostly (84 %) reporting mild or moderate disease, and 6.4 % a severe to very severe disease. And 70 % of the participants had high to very high commitment to COVID-19 infection prevention precautionary measures while 24.7 % had medium commitment. (Table 1).

86 % of the participants had received at least one dose of the COVID-19 vaccine. While only 42 % of parents were willing to vaccinate their 12–18 years old children, parents who were willing to vaccinate their children were significantly more likely to have been vaccinated themselves and vice versa ($P < 0.001$) (Fig. 1). The assessment of trigger factors for those who did not receive the vaccine revealed that concern of vaccine adverse effects was the most common of 41.9 %, followed by assumption of adequate immunity from previous COVID-19 infection (34.1 %), their perception being not at risk to develop COVID-19 or serious disease or complication from it (35.7 %), concern of vaccines ineffectiveness against SARS-CoV-2 variants (12.2 %), and other reasons are detailed in Table 2.

Table 3 presents the Pearson's bivariate analysis of association between participants' characteristics and their COVID-19 vaccination status to evaluate how each contributed to their vaccination decision. Females were significantly more reluctant to receive the vaccine. Participants 45 years and older were high likely to receive the vaccine as compared to younger age group. There was no significant correlation between vaccination uptake and marital status, educational level, family size, or geographical location of residence.

Saudi nationals were significantly more likely to receive the vaccine compared to expatriates, $p = 0.014$. Unemployed or student participants were significantly more reluctant to receive the vaccine, while HCWs were significantly more likely to receive it. Participants or those whose relatives did not develop COVID-19 were

Table 1
Participants' sociodemographic characteristics. N = 4071.

Characteristic	Frequency	Percentage
Sex		
Female	2732	67.1
Male	1339	32.9
Marital state		
Married	3835	94.2
Divorced	156	3.8
Widow or Single parent	39	2
Educational Level		
High school or less	532	13.1
College/University degree	3132	76.9
Higher studies	407	10
Households' monthly income		
Prefer not to answer	879	21.6
Less than 5000 SR	290	7.1
5000–10,000 SR	684	16.8
More than 10,000 SR	2218	54.5
Do you have a child aged (12–18 years)?		
No	1340	34.6
Yes	2536	65.4
Nationality		
Saudi	3202	78.7
Non-Saudi	869	21.3
Employment		
Unemployed + students	147	3.6
Retired	201	4.9
Housewife	418	10.3
Freelance/owns job	414	10.2
Employed	1785	43.8
Healthcare workers	1106	27.2
COVID-19 vaccination status		
No	568	14
Yes	3503	86
Are you willing to vaccinate your (12–18 years) child		
No	2360	58
Yes	1711	42
Was anyone of the direct family members affected by the COVID-19		
No	1110	27.3
Yes	2961	72.7
Participants commitment with COVID-19 infection prevention precautionary measures		
Rarely committed	174	4.3
Slightly committed	41	1
Medium commitment	1005	24.7
Highly committed	242	5.9
Very Highly committed	2609	64.1
How severe were the symptoms of the affected persons, n = 995		
Very mild/asymptomatic	85	8.5
Mild	446	44.8
Moderate	390	39.2
Severe	61	6.1
Very severe	3	0.3
Death	10	1
Parents Generalized Anxiety GAD7 total score[a]	4.61 (3.0)	
Parents Generalized Anxiety GAD7 classification		
Very low: < 5 points	1476	58.7
Mild: 5–10 points	723	28.8
Moderate: 10–14 points	183	7.3
High: > 15 points	132	5.3

[a] Mean (SD) score of all the participants equivalent to low or minimal anxiety level.

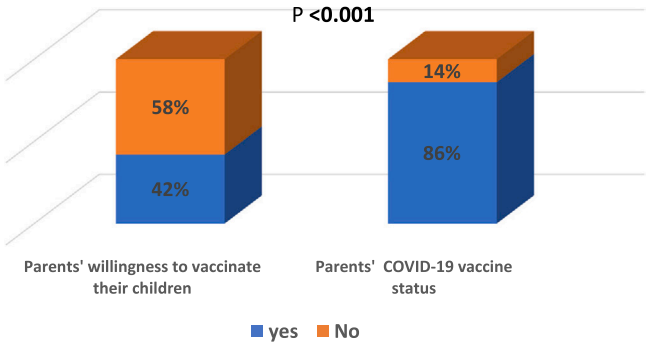

Fig. 1. Parents' vaccination status and their willingness to vaccinate their children.

significantly more reluctant to receive the vaccine compared to those who had developed the disease, while the severity of the disease developed by their relatives did not have any impact on their vaccination uptake decision. Participants' adherence to the COVID-19 precautionary measures had no significant impact on their vaccination uptake.

Having 12–18 years old children did not converge significantly with parents' hesitancy to COVID-19 vaccine uptake, p = 0.079, but parents who had children affected with chronic physical or mental illness were found to be significantly more predicted to take the vaccine themselves (p < 0.001). An independent samples t-test has shown that generalized anxiety score differed significantly among the participants, those who had taken the vaccine scored significantly higher mean GAD7 score (M = 4.61, SD = 4.83) compared to those who did not take the vaccine (Table 3).

A multivariate logistic binary regression analysis was performed to explore the variables associated interdependently with vaccination uptake hesitancy (Table 4). The yielded analysis model showed that males were 34.8 % less reluctant to receive the vaccine compared to females (OR.652, p < 0.001). Those aged between 25 and 34 years were 2.15 times more reluctant than those aged 45 years or above (p < 0.001), while those aged between 35 and 44 years were 1.55 times more reluctant compared to those aged 45 years and above (p < 0.001). Saudi nationals were also less reluctant compared to expatriates (OR 0.695 p 0.003). Unemployed or student participants were 1.60 times less inclined to take the vaccine than the others (p = 0.022).

The participants with family members who had previous COVID-19 infections were 55 % less hesitant to receive the vaccine than those who did not (p < 0.001). Sources of information about the COVID-19 and its vaccines also correlated with vaccine hesitancy. The participants who relied on the MOH website as a source were 48 % less hesitant compared to those who used other sources of information (p < 0.001). Conversely, those who relied on online videos and information shared on social media were 1.55–1.92 times more hesitant (p < 0.001), and those who used unidentified sources of information for COVID-19 were even much more hesitant (2.34 times more) compared to the rest of the participants (p < 0.001).

Discussion

Vaccination against COVID-19 became t the most imperative tool for recovering from this global pandemic. In many countries, infections caused by the Delta variant were responsible for most new cases at the time of this study, resulting in an increase in hospitalizations and mortality, particularly among the unvaccinated population [17–19]. The rapid development and roll-out of effective vaccines led to more than 10 billion vaccine doses administered worldwide [20]. There is evidence suggesting that vaccination effectiveness and immune response might drop over time, especially for those vaccinated early after the introduction of the vaccines; however, real-world data evaluations have shown that vaccines still provided significant protection, especially against severe diseases including emergent variants [21,22].

Therefore, optimizing vaccination rates is the most crucial and effective tool to combat the spread of the Delta, Omicron and other potentially emerging variants [23]. Many studies have revealed that countries with higher vaccination uptake have lower rates of severe illness and mortality related to COVID-19 [24–31]. In Saudi Arabia, vaccination acceptance rates for the COVID-19 vaccine varied significantly before and after COVID-19 vaccination campaign. Prior to the campaign, public reported rate of vaccine acceptance was 65 %; however, it dropped to 53 % after the campaign started (January–March 2021), that coincided with the second wave of the pandemic [32]. However, COVID-19 vaccination acceptance rate in KSA was considerably higher compared to neighboring countries such as Jordan (28 %) and Kuwait (24 %) [33]. Our most recent study had shown that despite the rapidly expanding global SARS-CoV-2 Omicron variant, only one-third of HCWs remained unsure whether vaccination offers the best protection against COVID-19 and its variants [34,35]. An international study was conducted Feb-Apr 2021 and involved 4630 participants from 91 countries and showed a hesitancy rate of 37 % towards COVID-19 vaccine(7). A systematic review of worldwide COVID-19 vaccine hesitancy published in 2021 February has shown that among adults representing the public, the highest COVID-19 vaccine acceptance rates were found in Ecuador (97.0 %), Malaysia (94.3 %). However, the lowest COVID-19 vaccine acceptance rates were found in Kuwait (23.6 %), Jordan (28.4 %), Italy (53.7), Russia (54.9 %), US (56.9 %), and France (58.9 %) (25). The global map of COVID-19 vaccine acceptance shows that the phenomenal vaccine hesitancy appeared more pronounced in the MENA, Europe and Central Asia, and Western/Central Africa (6).

In our current study conducted during the Delta wave surge, 86 % of the surveyed adults were in favor of accepting vaccination and received the vaccine already. In line with their healthy lifestyle behavior, 70 % of them had high to very high compliance with COVID-19 infection prevention strategies, while 24.7 % reported medium commitment. This is similar to the previous research conducted early in the pandemic, that reported high compliance levels with preventive measures and high willingness to self-isolate, while other studies in other settings showed poor compliance with those

Table 2
Participants triggers for not receiving COVID-19 vaccination.

Trigger	Frequency	Percentage
A concern of adverse effects of the vaccine	226	41.9
I already had a COVID19 infection	184	34.1
I am against vaccine in general	159	29.5
I perceive myself as not at high risk to develop COVID-19	99	18.4
I perceive myself as not at high risk to develop complications if I develop COVID-19	93	17.3
Other reasons	83	15.4
A concern of vaccine being ineffective for COVID-19 variants	66	12.2
A concern of acquiring COVID-19 from the vaccine itself	41	7.6
Prior adverse reaction to the vaccine	26	4.8

Table-3
Bivariate analysis of the parental hesitancy to COVID-19 vaccinate their children.

Variable	Participant' COVID-19 vaccine status			
	Yes N = 3503	No N = 568	Test statistic	p-value
Sex				
Female	2294 (65.5)	438 (77.1)	$\chi2$ (2) = 29.9	< 0.001
Male	1209 (34.5)	130 (22.9)		
Age group				
25–34 years	429 (15.1)	135 (23.8)	$\chi2$ (8) = 42.79	< 0.001
35–44 years	1582 (45.2)	274 (48.2)		
45–54 years	980 (28)	120 (21.1)		
55–64 years	352 (10)	32 (5.6)		
≥ 65 years	60 (1.7)	7 (1.2)		
Marital state			$\chi2$ (6) = 2.85	0.415
Educational Level			$\chi2$ (4) = 0.1	0.968
Household monthly income				
Prefer not to answer	764 (21.8)	115 (20.2)	$\chi2$ (6) = 30.1	< 0.001
Less than 5000 SR	229 (6.5)	61 (10.7)		
5000–10,000 SR	559 (16)	125 (22)		
More than 10,000 SR	1951 (55.7)	267 (47)		
Household size (family size with parents inclusive) [a]	6.02 (1.82)	6.16 (1.67)	t(3874) = 1.67	0.093
Geographical region			$\chi2$(4) = 4.53	0.338
Nationality				
Saudi	2733 (78)	469 (82.6)	$\chi2$(1) = 6.03	0.014
Non-Saudi	770 (22)	99 (17.4)		
Employment				
Unemployed + students	110 (3.1)	37 (6.5)	$\chi2$ (10) = 60.5	< 0.001
Retired	178 (5.1)	23 (4)		
Housewife	339 (9.7)	79 (13.9)		
Freelance/owns job	338 (9.6)	76 (13.4)		
Employed	1525 (43.5)	260 (45.8)		
Healthcare workers	1013 (28.9)	93 (16.4)		
Participants' family commitment to the precautionary measures against the COVID-19 virus [a]	4.25 (1.12)	4.23 (1.12)	t(4069) = 0.26	0.792
Participants' or their direct family member COVID-19 infection status				
No	873 (24.9)	237 (41.7)	$\chi2$(2) = 69.60	< 0.001
Yes	2630 (75.1)	331 (58.3)		
Severity of COVID-19 infection of the participants or their affected direct family member			$\chi2$ (2) = 10.43	0.064
Having children eligible for COVID-19 vaccine (12–18 years old)				
Yes	1145 (34)	195 (38)	$\chi2$ (2) = 3.10	0.079
No	2218 (66)	318 (62)		
Parents who have children diagnosed with an organic or psychological illness:				
Yes	1861 (53.1)	499 (87.9)	$\chi2$ (2)= 241.9	< 0.001
No	1642 (46.9)	69 (12.1)		
Participants' willingness to vaccinate their (12–18 years old) child				
No	1861 (53.1)	499 (87.9)	$\chi2$ (2)= 241.9	< 0.001
Yes	1642 (46.9)	69 (12.1)		
Parents Generalized Anxiety GAD7 score [a]	4.605 (4.83)	4.05 (4.59)	t(2512) = 2.10	0.036

[a] Mean (SD).

prevention measures and low levels of vaccinations acceptance at the same time [36–39].

On the other hand, our study showed only 42 % parental willingness to vaccinate their children, while those who already received the vaccine were significantly more inclined to accept vaccination for their children. The results in this study are consistent with studies from Germany and Turkey that reported low levels of parental acceptance of childhood COVID-19 vaccinations (30–50 %) [40–43], while studies from Korea, China, USA and other countries showed higher rates of parental acceptance (60–80 %) [40,44,45].

In our study, the most common participants' vaccination hesitancy triggers were inadequate information about the vaccine safety profile/adverse events and the assumption that they are immune/protected after having recovered from previous COVID-19 infection. Side effects and safety of the COVD-19 vaccines have been reported in most of the studies, with a systematic review of 63 surveys showing that ideas related to the rumors on infertility, concerns about the efficacy of the vaccines and side effects were the main triggers for vaccination hesitancy [46]. Another large metanalysis of 58,656 participants has shown that since the introduction of COVID-19 vaccines, national acceptance rates have been dropping and refusal rates increasing, with this finding indicating the need to re-address the pandemic after two years of its start, to implement strong guidelines regarding vaccine mandate, emphasizing the role of vaccination in ending the pandemic and augment future vaccination campaigns.

Developing natural immunity after infection was another factor reported in our study affecting vaccine hesitancy, as those who or their relatives developed the disease were less hesitant. Nevertheless, even in previously infected individuals, COVID-19 vaccination provides additional protection against SARS-CoV-2 infection, which is a strong recommendation from the CDC [47–49].

Female gender was independently associated with higher vaccine hesitancy. This observation has been consistent in multiple studies and was attributed to male eagerness to receive vaccines compared to females who might also have additional fear from vaccines due to current or planned pregnancy [24,50–52]. A significant correlation has also been demonstrated between age and vaccination behavior; younger populations had less willingness to receive vaccinations. This has also been notably observed with influenza vaccines [53]. That contradicts the attitude from neighboring countries that showed those older than 35 years were significantly more reluctant to accept vaccination [54]. The perception of older age being a risk factor for severe infections or strong beliefs in vaccine effectiveness

Table 4
Multivariate Binary Logistic regression analysis of the participants' characteristics and their COVID-19 vaccine uptake hesitancy.

Variable	Multivariate adjusted Odds Ratio (OR)	OR[a]		p-value
		Lower 95 % CI	Upper 95 % CI	
Sex Male	.652	.523	0.813	< 0.001
Age 25–34 years	2.154	1.652	2.809	< 0.001
Age 35–44 years	1.550	1.247	1.925	< 0.001
Residential Region	.960	.903	1.021	.194
Employment status Unemployed/ students	1.600	1.069	2.395	.022
Participants with family member developed COVID-19	.455	.376	0.549	< 0.001
Nationality Saudi	.695	.545	0.887	.003
Source of information MOH website	.5220	.426	0.636	< 0.001
Source of information Videos	1.923	1.441	2.568	< 0.001
Source of information Formal media channels	1.556	1.245	1.944	< 0.001
Source of information Other sources	2.342	1.477	3.713	< 0.001

[a] Odds ratio.

may explain such an attitude. Furthermore, young people are frequent users of social media, which may serve as a rich source of negative attitudes toward vaccination [24,51,53,55].

Educational level and employment status also affected vaccination behavior, those with a lower level of education and unemployed were more hesitant to take the vaccine [24]. Such behavior was explained in the literature because of low disease risk complacency, perhaps lack of scientific knowledge background, and unhealthy habits [53,56].

Source of information is a significant factor in vaccine hesitancy, and has varying effects on different population groups, depending on their education level, employment status, age and even gender. A national cross-sectional study found that the most reported information sources about the COVID-19 crisis were the internet/social media (85.8 %), health practitioners (54.7 %), TV/Radio (35.7 %), family/friends (29.5 %), and other sources (7 %) [57]. Similarly, the most widespread social media platforms used among HCWs and non-HCWs during the early stages of the pandemic in KSA were WhatsApp (51.6 %), Twitter (27.6 %) and Snapchat (13.8 %) [58]. Other commonly reported information sources used among HCWs are health care providers and the World Health Organization (WHO) [59], as well as hospital announcements, MOH official statements among other sources [60]. Social media platforms are a likely source of negative vaccine attitude, and this could be explained by the unverified information they deliver, due to the non-skeptical, non-critically appraised information they deliver and promotion of conspiracy theories about the COVID-19 vaccines such as microchip implantation with vaccinations or vaccine's unproven association with infertility [61]. Such platforms are highly accepted among certain groups of the society, and unidentified media and information sources carry greater impact on vaccine hesitancy than the formal social media platforms. Similar results have also been reported with respect to booster dose anxiety and acceptance [11,62,63]. Nevertheless, refusal to receive a booster dose might be expected to be observed in individuals who experienced significant side effects following earlier COVID-19 vaccinations and who had suffered anxiety as a result [63].

Positive correlations have been observed between perceptions of COVID-19 severity as a disease and vaccine acceptance. Among the participants in our study, more than two-thirds had close family members who were infected with COVID-19; however, only 6.4 % experienced severe or critical course and 1 % died. Studies found that the perceived severity of COVID-19 and the worry of contracting the virus were strongly associated with increased intention to accept the vaccine, though these tend to change during the course of the pandemic [64]. We found that having a direct family member with COVID-19 had a positive effect on their relatives to receive the vaccine. This has also been reported in other populations [65–67]. This may be an expected intuitive behavior based on the perceived psychological risk they feel and experience of contracting the disease or the morbidity/mortality they observe, especially if the disease outcome of their relative was poor, which would influence them even more to receive the vaccine. This positive attitude can be seen as a protective measure by them to protect the other family members from contracting the disease from themselves as part of their feeling of collective responsibility [68].

Study limitations and strengths

Our study has several strengths and limitations. The relatively large sample size provides further insight into perceptions and vaccine acceptance of newly emerging variants. Nonetheless, there are limitations. Being a self-reported, cross-sectional survey, it is subject to recall bias and changing perceptions over time. Another limitation of the study was that we did not address all potential factors that contributed to the individual's hesitancy for the COVID-19 vaccine, such as the national trend of the reported cases and their severity. In addition, the snowball sampling through social media platforms may limit its representativeness; however, this research provides a guide for similar studies in other populations and serves as baseline information for future research.

Conclusions

This study found that the COVID-19 vaccine has been well accepted by Saudi adults during the emergence of SARS-CoV-2 Delta variant. In contrast, parental willingness to vaccinate their children was much lower, but parental self-vaccination correlated significantly with parental willingness to vaccinate their children. Additionally, COVID-19 vaccine reluctance was highest among females and young population. Although participants had high adherence to infection prevention precautionary measures, those who relied on social media and unidentified sources of information about COVID-19 and its vaccines were significantly less likely to receive the vaccine. Our results highlight the importance of promoting reliable and verified sources that promote positive proven information about the vaccines, in order to reach the desired targets of vaccination rates.

Ethics approval and consent to participate

The study was approved by the institutional review board of King Saud University (approval # 21/0529/IRB).

CRediT authorship contribution statement

FAlJamaan, MHT, KA, SA, MBarry, and JAA conceptualized the research, conducted the research and wrote the manuscript. AAlhaboob, AAlrabiaah, MBatais, FAlshahrani, RAA, HB, AAlaraj, BAQ, AAlhaidary, KS, BS, AAR, and RH collected the data and edited the

manuscript. All authors contributed to the finalization of the manuscript.

Data Availability Statements

The data underlying this article will be shared on reasonable request to the corresponding author.

Conflict of interest

None declared.

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