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Survival Analysis and Socio-Cognitive Factors in the Timing of COVID-19 Vaccination Among Mexican-Origin Youth

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Abstract

Objective The COVID-19 pandemic disproportionately affected ethnic minority populations and exacerbated preexisting health disparities. The current study aims to promote vaccine uptake among Mexican-origin youth from immigrant families by examining their time to COVID-19 vaccine uptake and assessing the influence of demographic, cognitive, and social factors on the incidence of COVID-19 vaccination.

Methods The study conducted Survival Analysis using a Cox proportional hazards model based on a sample of 202 Mexican-origin youth (61.39% female; $M_{age} = 20.41$) with data collected from August 2021 to January 2023 in central Texas.

Results The results show a critical time period for vaccine uptake (i.e., in the first six months after the vaccines were publicly available), evidenced by a surge decrease in COVID-19 unvaccination probability. In addition, more positive attitudes toward the COVID-19 vaccine (Hazard ratio/HR = 1.89, 95% Confidence Interval/CI = [1.64, 2.18]), greater motivation (HR = 2.29, 95% CI = [1.85, 2.85]), higher education levels (HR = 1.52, 95% CI = [1.24, 1.86]), and fewer general barriers to COVID-19 vaccine knowledge (HR = 0.75, 95% CI = [0.60, 0.94]) were associated with greater incidences of receiving COVID-19 vaccines at any given time point during the pandemic.

Conclusion The findings suggest that COVID-19 vaccine uptake among Mexican-origin youth occurred primarily within the initial months of vaccines being publicly distributed. To encourage vaccination among Mexican-origin youth, sustained COVID-19 vaccine promotion efforts are needed by targeting their motivation and positive attitudes and reducing barriers to vaccine information, particularly for youth with lower education levels.

Keywords COVID-19 · Vaccine · Mexican-origin · Youth · Survival analysis

Introduction

Swift vaccination on a wide scale against the coronavirus disease 19 (COVID-19) was urgent to curb the COVID-19 pandemic; however, specific segments of the U.S. population by age (i.e., young adults) and ethnic-minority status (i.e., Latinos) were at risk for slowed vaccine uptake. Delays in COVID-19 vaccine uptake have hindered the success of vaccination efforts, given greater chances of COVID-19 infection and transmission, as well as heightened risk of new variants emerging that are less responsive to existing vaccines. Young adults have been likely culprits in amplifying COVID-19 transmission because of greater socializing paired with decreased compliance with social distancing guidelines, yet delays in their COVID-19 vaccine uptake have been observed [1]. Simultaneously, Latinos have experienced disproportionate COVID-19 disease

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burden, as indicated by higher rates of infection and death compared to Whites, but they also exhibit greater endorsement of COVID-19 vaccine hesitancy as well as lower rates of COVID-19 vaccine coverage relative to Whites [2, 3]. Therefore, Latino young adults were an important subgroup for targeted COVID-19 vaccination efforts given the social characteristics of their age group and the higher rates of COVID-19 morbidity and mortality present within Latino populations. However, few studies have examined the COVID-19 vaccination behaviors of Latino young adults exclusively, and most research has been conducted on vaccine status as opposed to the duration of time to COVID-19 vaccination. Thus, the current study seeks to understand promotive and inhibiting factors (e.g., motivation, attitudes, general social and sociocultural barriers) related to the incidence of Latino young adults' COVID-19 vaccine uptake using data from Mexican-origin youth, which is crucial in order to ameliorate racial/ethnic COVID-19 disparities and safeguarding overall population health in future pandemics.

Extant work on health behaviors indicates that cognitive factors (e.g., motivation, attitude, and education status) are among the most robust predictors of health behaviors like COVID-19 vaccination [4], and evidence for these associations has been observed among Latinos and/or young adults. Motivation refers to the intention to implement a health behavior [4]. Decreased levels of motivation to become vaccinated have been noted among young adults because of a preference to "wait and see" until there is more evidence of COVID-19 vaccine safety [5]. Additionally, attitudes (i.e., positive or negative appraisals of a health behavior) exert an important influence on COVID-19 vaccination rates [6]. Greater COVID-19 vaccine hesitancy among Latinos arose, in part, due to negative perceptions regarding the vaccine's efficacy [3]. Moreover, reluctance towards COVID-19 vaccination was strengthened by medical mistrust, emanating from historical and contemporaneous discrimination within healthcare systems, which is more prevalent among racial/ethnic minority groups inclusive of Latinos [7]. Education status is also an important correlate of COVID-19 vaccine hesitancy and vaccine uptake among racial/ethnic minority groups particularly, as lower education levels have shown associations with stronger hesitancy towards the COVID-19 vaccine [8] and reduced vaccine uptake. While empirical support has been noted for the link between these cognitive factors and COVID-19 vaccine uptake among Latinos and/or young adults, we seek to assess the relevance of these predictors to the incidence of COVID-19 vaccination among Mexican-origin youth specifically.

Along with cognitive factors, aspects of Latino young adults' social environment (e.g., barriers to COVID-19 vaccine receipt) were also potent deterrents to vaccination. Barriers refer to tangible or perceived obstacles impeding health behaviors [9]. For example, lags in dissemination of information regarding the COVID-19 vaccine, due to the proliferation of vaccine misinformation in racial/ethnic minority communities or delayed health messaging around the COVID-19 vaccine available in Spanish, have strengthened COVID-19 vaccine hesitancy and/or hindered Latinos from becoming vaccinated [3, 7]. Thus, for Latino populations (including Mexican-origin adolescents), barriers to COVID-19 vaccination can be socially rooted, whether general social barriers or specifically related to their status as a racial/ethnic minority (i.e., sociocultural barriers).

Lastly, research has demonstrated that demographic characteristics, such as gender, are influential determinants of COVID-19 vaccination. For example, a national study of U.S. adults showed that males displayed higher odds of having received at least one dose of the COVID-19 vaccine relative to females [10]. Data across ten industrialized countries also suggests the presence of a "COVID-19 vaccine's gender paradox," where despite higher perception of COVID-19 infection risk and disease severity relative to men, empirical evidence suggests women display less agreement to be vaccinated compared to men [11]. Thus, examining the potential role of gender in the time to Mexican-origin adolescents' COVID-19 uptake is important to assess if similar gender differences exist, which may or may not manifest given unique gender norms and cultural values within Mexican-origin communities specifically, which has not been explored in prior studies.

While the relations between barriers, attitudes, motivation, and education status have been established with regards to COVID-19 vaccine uptake among Latinos or young adults more broadly, previous studies have been limited in two important ways. First, previous studies have primarily examined vaccine status: that is, whether individuals have received the COVID-19 vaccine or not. This approach ignores the duration of time until vaccination occurs, which, as previously described, is a critical factor in individual and societal immunity to the virus. Second, few studies have focused exclusively on Mexican-origin youth, despite the heightened risk profile of their age bracket in terms of COVID-19 transmission and the disproportionate disease burden within their ethnic group. The current study utilizes data from a Mexican-origin youth sample collected from a longitudinal study over multiple years of the pandemic, and is therefore uniquely positioned to estimate the time to becoming vaccinated as well as examine how key demographic, social, and cognitive factors (i.e., barriers to COVID-19 vaccine information, COVID-19 vaccine attitudes, motivation to become vaccinated, and education) may have influenced the *time to their COVID-19 vaccine uptake* (defined as first dose receipt). Taken together, the objectives of the current study are to (1) examine the time

to Mexican-origin young adults' COVID-19 vaccine uptake using survival analysis and (2) assess the effects of COVID-19 attitudes, COVID-19 vaccine motivation, educational level, and general social and sociocultural barriers on the incidence of COVID-19 vaccination among Mexican-origin adolescents specifically.

Methods

Participants

The current study adopted the last wave of data from a larger 4-wave longitudinal dataset spanning 11 years. The larger project was designed to study Mexican immigrant families. Covid-19-related questions were only included in Wave 4, which was collected from August 2021 to January 2023. In Wave 4, 202 Mexican-origin youth (61.39% female; M_{age} = 20.41) participated in the study. The median family income at Wave 4 fell in the $50,001-$60,000 range. The majority of participants were born in the U.S. (76.24%).

Procedure

Participants in the larger study were originally recruited in central Texas through school presentations and community recruitment. Middle school students were qualified for this study if they were from a Mexican immigrant family and translated for at least one of their parents between Spanish and English. Youth who agreed to participate provided informed consent or assent with parental consent. In Wave 4 data collection, youth reported their demographic information and answered COVID-19 vaccine-related questions during a Zoom home visit with bilingual research assistants. Each participant was compensated $70 for participating in Wave 4.

Measures

Cognitive Factors for Covid-19 Vaccine Uptake

COVID-19 Vaccine Uptake Motivation

Youth reported their motivation to take COVID-19 vaccines by responding to the item "I am motivated to take the COVID-19 vaccine" on a scale from 1 (*Not at all*) to 5 (*Extremely*).

COVID-19 Vaccine Positive Attitude

Youth reported their positive attitude toward COVID-19 vaccines using three items adapted from a previous study [12] on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The items were: "The COVID-19 vaccine can be trusted"; "It is beneficial to take the COVID-19 vaccine"; and "The COVID-19 vaccine is safe." Higher mean scores represent more positive attitudes toward COVID-19 vaccines (α = .91).

Educational Level

Youth reported their highest education attained by answering, "What is the highest level of education you have achieved in school?" The answers ranged from 1 (middle school) to 8 (finished graduate degree).

Social Factors for Covid-19 Vaccine Uptake

General Social Barriers to COVID-19 Vaccine

Youth reported their perceptions about general barriers to getting information on COVID-19 vaccines using two items adapted from a previous study [13] on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). The two items were, "Information about the COVID-19 vaccine is easy to access" (reverse coded) and "I am confident in my ability to find information about the COVID-19 vaccine" (reverse coded). Higher mean scores represent more barriers to getting COVID-19 vaccines (split-half reliability coefficient for the two-item measure = 0.83).

Sociocultural Barriers to COVID-19 Vaccination

Youth reported culturally specific barriers to getting COVID-19 vaccine information using two items adapted from a previous study [13] on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). Items included, "Getting the COVID-19 vaccine is difficult because I am Mexican" and "I have a hard time finding information in Spanish on how to get the COVID-19 vaccine." Higher mean scores represent more culturally specific barriers to getting COVID-19 vaccines (split-half reliability coefficient for the two-item measure = 0.64).

COVID-19 Vaccination Status and Date

Youth reported their COVID-19 vaccination status by answering, "Have you received the COVID-19 vaccine?" Answers included "yes" and "no." Youth reported the date

when they took the first dosage of their COVID-19 vaccine if they answered "yes" for vaccine status. The earliest date participants reported COVID-19 vaccine uptake in the current study (i.e., 12/23/2020) was considered as time zero for analysis.

Covariates

Youth age at time zero (i.e., 12/23/2020), gender, and nativity were included as covariates in the analysis, as these factors may be related to COVID-19 vaccine uptake [14].

Analysis Plan

Analyses were conducted in three steps in R 4.1.1 using packages "survival" and "survminer." First, descriptive statistics were examined to understand the average levels and variability of psychological experiences related to COVID-19 vaccine uptake for youth who had taken vaccines, versus those who had not, as well as the distribution of the censoring date (i.e., the date when data were collected for each participant) and the time to COVID-19 vaccine uptake for the survival analysis. For participants who had received COVID-19 vaccines, the time to COVID-19 vaccine uptake was calculated by subtracting the earliest date when COVID-19 vaccine uptake was reported in this dataset (i.e., 12/23/2020) from the date when they received the first dose of the COVID-19 vaccine. The censoring date was calculated by subtracting the earliest date when COVID-19 vaccine uptake was reported in this dataset (i.e., 12/23/2020) from the date when each participant had the interview. Second, survival analysis was conducted using the Kaplan-Meier estimator to assess the survival curve of the ***probability*** of being COVID-19 unvaccinated over time for the overall sample. Third, Cox proportional hazards regression models were conducted to examine the association between predictors and ***incidence*** (i.e., ***hazards;*** the probability of taking the vaccine at any time point given that the vaccine had not been taken yet) of COVID-19 vaccine uptake. Predictors, including vaccine motivation, positive attitude toward the vaccine, general social and sociocultural barriers to getting vaccine information, and education levels were modeled separately in five models. Demographic variables (i.e., age, gender, and nativity) were modeled together in a separate model and controlled in the five models for each predictor. Considering the relatively low reliability (0.64) for the measure of sociocultural barriers to COVID-19 vaccine knowledge, two additional models were conducted for the two items separately to test the robustness of the finding. Each model also included three covariates: gender, nativity, and age at time zero (i.e., 12/23/2020). Estimated hazard ratios (i.e., HRs), confidence intervals, and p-values are reported. Likelihood ratio tests were conducted to examine whether there were significant differences between the baseline model and the model with predictors and covariates. Assumptions for the Cox proportional hazards model were checked by examining whether the impact of each predictor was constant across time. For models with significant predictors, survival curves with confidence intervals were plotted for groups that reported one standardized deviation above and below the mean levels of the predictor.

Results

Descriptive statistics are presented in Table 1. Among 202 participants, there were 141 youth (69.80%) reporting having received at least one dosage of a COVID-19 vaccine on or before the interview date. Among youth who had not received COVID-19 vaccines, 13.1% of them had not finished high school, compared to 1.4% among youth who had received COVID-19 vaccines. On average, youth who had not received COVID-19 vaccines reported "strongly disagree" to "disagree" to questions about whether they were motivated to get COVID-19 vaccines, and reported "disagree" to "neutral" when rating items on positive attitudes toward COVID-19 vaccines and barriers to vaccine information; youth who had received COVID-19 vaccines reported "neutral" to "agree" when asked whether they were motivated to get COVID-19 vaccines and in terms of positive attitudes to vaccines, and reported "disagree" to "neutral" for items on barriers to vaccine information. Figure 1 shows the distribution of the censoring time and when the interview was conducted, and the distribution of the time when the vaccine was received, operationally defined as the time gap between time zero (i.e., 12/23/2020) and when the first dosage of a COVID-19 vaccine was taken.

The survival curve for being COVID-19 unvaccinated is shown in Fig. 2, along with the graph of weekly COVID-19 hospital admissions in Texas from Centers for Disease Control and Prevention [15]. There was a sharp decrease in the probability of being unvaccinated from around three months (i.e., March 2021) to nine months (i.e., August 2021) after time zero (i.e., 12/23/2020). This decrease in the probability of being COVID-19 unvaccinated aligns in time with a decline in weekly COVID-19 hospital admissions from March 2021 to July 2021. The decrease in the probability of being unvaccinated leveled off after August 2021. However, there were three waves of COVID-19 infections based on hospital admission data after August 2021. Despite another severe outbreak of COVID-19 in January 2022, there were no youth in the sample who received a first dosage of any COVID-19 vaccine after January 20, 2022.

Table 1 Descriptive statistics for demographic information and study variables overall and by vaccine status

Vaccine status	No (N = 61)	Yes (N = 141)	Overall (N = 202)
Youth Age at Time Zero (i.e., 12/23/2020)			
Mean (SD)	19.3 (1.10)	19.1 (1.20)	19.2 (1.17)
Median [Min, Max]	19.2 [16.8, 21.9]	19.2 [16.2, 21.8]	19.2 [16.2, 21.9]
Youth Gender			
Male	27 (44.3%)	50 (35.5%)	77 (38.1%)
Female	34 (55.7%)	90 (63.8%)	124 (61.4%)
Youth Nativity			
U.S.	48 (78.7%)	106 (75.2%)	154 (76.2%)
Mexico	13 (21.3%)	35 (24.8%)	48 (23.8%)
Youth Education			
Finished middle school	1 (1.6%)	0 (0%)	1 (0.5%)
Some high school	7 (11.5%)	2 (1.4%)	9 (4.5%)
Finished high school	45 (73.8%)	100 (70.9%)	145 (71.8%)
Finished technical or vocational training after high school	4 (6.6%)	18 (12.8%)	22 (10.9%)
Finished a community college degree	3 (4.9%)	13 (9.2%)	16 (7.9%)
Finished a university degree/earned a bachelor's degree	0 (0%)	5 (3.5%)	5 (2.5%)
Vaccine Uptake Motivation			
Mean (SD)	1.82 (1.13)	3.59 (1.13)	3.05 (1.39)
Median [Min, Max]	1.00 [1.00, 5.00]	4.00 [1.00, 5.00]	3.00 [1.00, 5.00]
Vaccine Positive Attitude			
Mean (SD)	2.84 (0.829)	3.73 (0.763)	3.46 (0.883)
Median [Min, Max]	3.00 [1.00, 4.67]	3.67 [1.67, 5.00]	3.33 [1.00, 5.00]
Barriers to Vaccine Knowledge			
Mean (SD)	2.42 (0.857)	2.15 (0.756)	2.23 (0.795)
Median [Min, Max]	2.00 [1.00, 5.00]	2.00 [1.00, 4.00]	2.00 [1.00, 5.00]

Note Vaccine = COVID-19 vaccines

The Cox proportional hazards model for demographic variables only showed that age (HR = 0.99, 95% CI = [0.85, 1.16]), gender (HR = 1.35, 95% CI = [0.93, 1.95]), and nativity (HR = 0.96, 95% CI = [0.63, 1.47]) were not associated with the hazards of receiving COVID-19 vaccines. The results for cognitive and social predictors are shown in Table 2; Fig. 3. The likelihood ratio tests show that the models for vaccine motivation ($p < .001$), positive attitude towards vaccines ($p < .001$), and education levels ($p < .001$) all have significant increases in model fit compared to the null model with only an intercept. There was a marginally significant increase in model fit for the model for general social barriers to vaccine information ($p = .06$) compared to the null model. The assumptions for the Cox proportional hazards model held for all predictors in each model.

The results show that higher levels of vaccination motivation, positive attitude toward the vaccine, and education levels were significantly associated with an increased hazard (i.e., incidence) of receiving COVID-19 vaccines (i.e., the probability of receiving the COVID-19 vaccine at any time point given that the vaccine had not been received before). Holding covariates (i.e., age, gender, and nativity) constant, youth who were one unit higher in vaccination motivation, positive attitude toward the vaccine, or education levels had 1.89 (95% CI = [1.64, 2.18]), 2.29 (95% CI = [1.85, 2.85]), and 1.52 (95% CI = 1.24, 1.86) times the estimated hazard of COVID-19 vaccine uptake compared to those who were one unit less, respectively. Higher levels of general social barriers to getting vaccine information were significantly associated with a decreased hazard of receiving COVID-19 vaccines. Holding covariates (i.e., age, gender, and nativity) constant, having a one unit increase in general social barriers to getting vaccine information was associated with 0.75 (95% CI = 0.60, 0.94) times the estimated hazard of COVID-19 vaccine uptake. Sociocultural barriers to COVID-19 vaccine information were not associated with hazards of COVID-19 vaccine uptake. Additional analysis also showed that each item in the sociocultural barriers measure was not significantly associated with hazards of COVID-19 vaccine uptake.

Discussion

The current study findings add to the growing body of COVID-19 research by depicting the change of the COVID-19 vaccine uptake rate over time and highlighting the effects of factors contributing to the incidence of COVID-19 vaccine uptake among Mexican-origin youth. While previous studies have investigated COVID-19 vaccine uptake, most did not consider the rate of COVID-19 vaccine uptake over a long period of time. The current study addressed this gap by observing the COVID-19 vaccine behaviors of Mexican-origin youth over multiple years of the pandemic (i.e., August 2021 to January 2023), which allowed for a long-term investigation of Mexican-origin youth vaccination behaviors. By utilizing survival analysis, the current study revealed that COVID-19 vaccine uptake among Mexican-origin youth mostly occurred within the first few months in the COVID-19 vaccine rollout. In addition, the current study was also unique in including the Cox Proportional Hazards model to identify multiple cognitive (i.e., motivation,

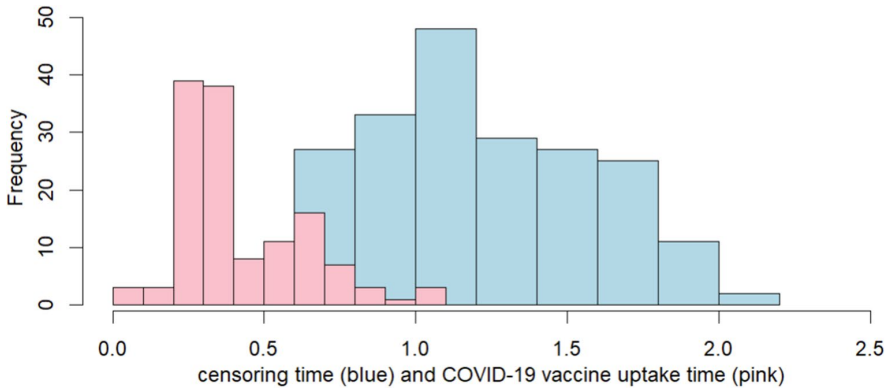

Fig. 1 Distribution of censoring time and COVID-19 vaccine uptake time. *Note* Censoring time is operationally defined as the time gap in years between time zero (i.e., the earliest date when a participant reported vaccine uptake in the sample: 12/23/2020) and the interview date; COVID-19 vaccine uptake time is operationally defined as the time gap in years between time zero and the date when participants take the first dosage of their COVID-19 vaccine

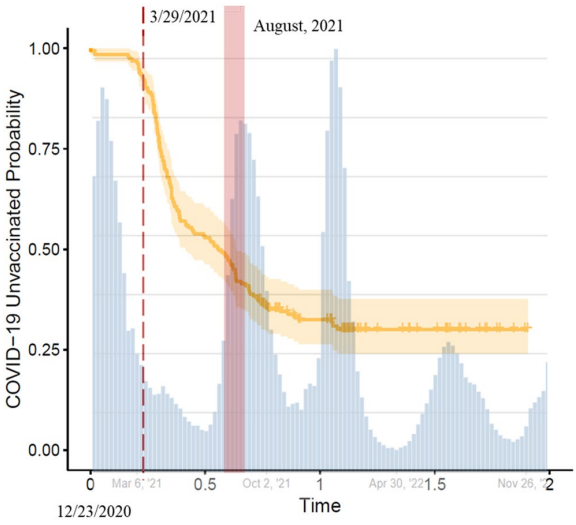

Fig. 2 Survival curve for being COVID-19 unvaccinated over time. *Note* Time 0 = 12/23/2020. The survival curve in orange depicts the change of COVID-19 unvaccinated probability over time with a 95% confidence interval. The censoring date is marked with small vertical lines (i.e., orange lines in the survival curve). The red dotted line indicates the date when vaccines were made publicly available in Texas (i.e., 3/29/2021) according to Texas Health and Human Services [37]. The red vertical bar represents the month (i.e., August 2021) after which the decrease in the probability of being unvaccinated levels off. The histogram in blue is the weekly COVID-19 new hospital admission data in Texas according to the Centers for Disease Control and Prevention [15]

positive attitudes toward COVID-19 vaccines, and education level) and social (i.e., general social and sociocultural barriers to COVID-19 vaccination) factors associated with the incidence of COVID-19 vaccine uptake among Mexican-origin youth. As Mexican-origin youth demonstrated a COVID-19 vaccine uptake rate that was relatively low and a hospitalization rate that was relatively high, compared to White youth [2, 15], increasing the COVID-19 vaccine uptake rate in this population may require a more tailored approach, one that considers sociocultural influences [16]. As such, the current study examined both general social and sociocultural barriers to COVID-19 vaccination. Results showed that Mexican-origin youth with higher motivation, more positive attitudes towards COVID-19 vaccines, a higher education level, and fewer general social barriers to COVID-19 vaccination had an increased incidence of COVID-19 vaccine uptake. However, sociocultural barriers to COVID-19 vaccination were not significantly associated with the incidence of Mexican-origin youth COVID-19 vaccine uptake. Moreover, there was no significant association between gender and the incidence of Mexican-origin youth COVID-19 vaccine uptake.

Probability of COVID-19 Vaccine Uptake Over Time

Timing can be an essential factor to consider in promoting youth health behaviors. The current study illustrated that Mexican-origin youth were more likely to receive the COVID-19 vaccine upon its initial availability rather than delaying their vaccination over an extended period of time. From March 2021 to November 2022, there were three peaks of hospitalization due to COVID-19 infection in Texas (see Fig. 2). The current study showed that there was a surge decrease in the probability of Mexican-origin youth being COVID-19 unvaccinated in the first six months of the COVID-19 vaccine rollout (i.e., from March 2021 to August 2021) after the first peak of hospitalization. It is possible that Mexican-origin youth who received the vaccine within the first six months were motivated to get a COVID-19 vaccine because of the high hospitalization rate. However, no Mexican-origin youth in the current study took their first dose of the COVID-19 vaccine after January 20, 2022 (data collection ended in January 2023), even though there was another peak in COVID-19 hospitalization in January 2022. This finding might imply that a high hospitalization rate due to COVID-19 infection may only motivate youth to seek out vaccination for a certain duration of time. Therefore, COVID-19 vaccine uptake primarily occurred immediately

Table 2 Cox proportional hazards model results

Model	predictors	coefficient	hazard ratio	95% confidence interval		*p*
				lower	upper	
1	Vaccine motivation	0.637	1.890	1.638	2.181	< 0.001
	Gender (1 = female)	0.136	1.146	0.789	1.663	0.474
	Nativity (1 = Mexico)	-0.243	0.784	0.514	1.196	0.259
	Age	0.038	1.039	0.901	1.198	0.598
2	Positive attitude to vaccine	0.829	2.291	1.845	2.846	< 0.001
	Gender (1 = female)	0.413	1.512	1.043	2.189	0.029
	Nativity (1 = Mexico)	-0.310	0.734	0.474	1.135	0.164
	Age	0.094	1.098	0.948	1.272	0.211
3	General social barriers to vaccine	-0.289	0.749	0.597	0.941	0.013
	Gender (1 = female)	0.340	1.405	0.971	2.034	0.071
	Nativity (1 = Mexico)	-0.089	0.915	0.596	1.404	0.683
	Age	0.010	1.010	0.867	1.176	0.900
4	Sociocultural barriers to vaccine	0.063	1.065	0.836	1.357	0.608
	Gender(1 = female)	0.286	1.331	0.918	1.930	0.132
	Nativity (1 = Mexico)	-0.060	0.942	0.613	1.448	0.785
	Age	-0.008	0.992	0.851	1.156	0.915
5	Education level	0.416	1.516	1.236	1.860	< 0.001
	Gender (1 = female)	0.235	1.265	0.874	1.833	0.213
	Nativity (1 = Mexico)	-0.093	0.912	0.591	1.406	0.675
	Age	-0.029	0.971	0.829	1.138	0.720

Note Vaccine = COVID-19 vaccine

following the COVID-19 vaccine rollout for Mexican-origin youth, as there was no subsequent uptick in their COVID-19 vaccine receipt. Sustained COVID-19 vaccine promotion efforts are needed to encourage Mexican-origin youth who currently *refuse* the vaccine to become *adopters* of the vaccine.

Cognitive Factors Contributing to Incidence of COVID-19 Vaccine Uptake

Cognitive factors (i.e., attitude toward COVID-19 vaccines, motivation, and education level) are strongly and consistently associated with health behaviors, such as vaccine uptake [4]. The current study found that attitudes toward vaccines and motivation could be influential for youth vaccine uptake: youth with less positive attitudes toward vaccines and low motivation had a lower incidence of receiving COVID-19 vaccines at any given time. This finding was supported by previous literature showing that positive attitudes and higher motivation were associated with higher vaccine uptake [17, 18], but the current study went further to focus on different cognitive factors related to the incidence of COVID-19 vaccine uptake in order to identify the relative influence of these predictors. Findings suggest that it is important to increase youth motivation and positive attitudes to raise youth incidence of COVID-19 vaccine uptake. Youth motivation and positive attitudes could be increased by providing clearer information about vaccination and emphasizing that it is every individual's responsibility to protect others by receiving the COVID-19 vaccine [19]. Youth may also be motivated to become vaccinated to avoid the criticism of not taking vaccines [20], leading to higher incidence of COVID-19 vaccine uptake. Furthermore, youth educational level was found to be associated with the COVID-19 vaccine uptake [21]. The current study showed that Mexican-origin youth with higher education levels had a higher incidence of COVID-19 vaccine uptake. Youth with higher educational levels may have more access to COVID-19-related information and more comprehensive understanding of the benefits of receiving COVID-19 vaccines, resulting in higher incidence of vaccine uptake [22]. With more COVID-19-related information, youth are less likely to believe COVID-19 vaccine-related myths and misinformation, making them more likely to trust the COVID-19 vaccines and receive them [23, 24]. Future studies can empirically test for such mechanisms to explain the association between youth educational level and incidence of COVID-19 vaccine uptake.

Social Factors Contributing to Incidence of COVID-19 Vaccine Uptake

The current study found that more general social barriers to COVID-19 vaccination were associated with a lower incidence of COVID-19 vaccine uptake among Mexican-origin youth. The finding was consistent with studies showing that

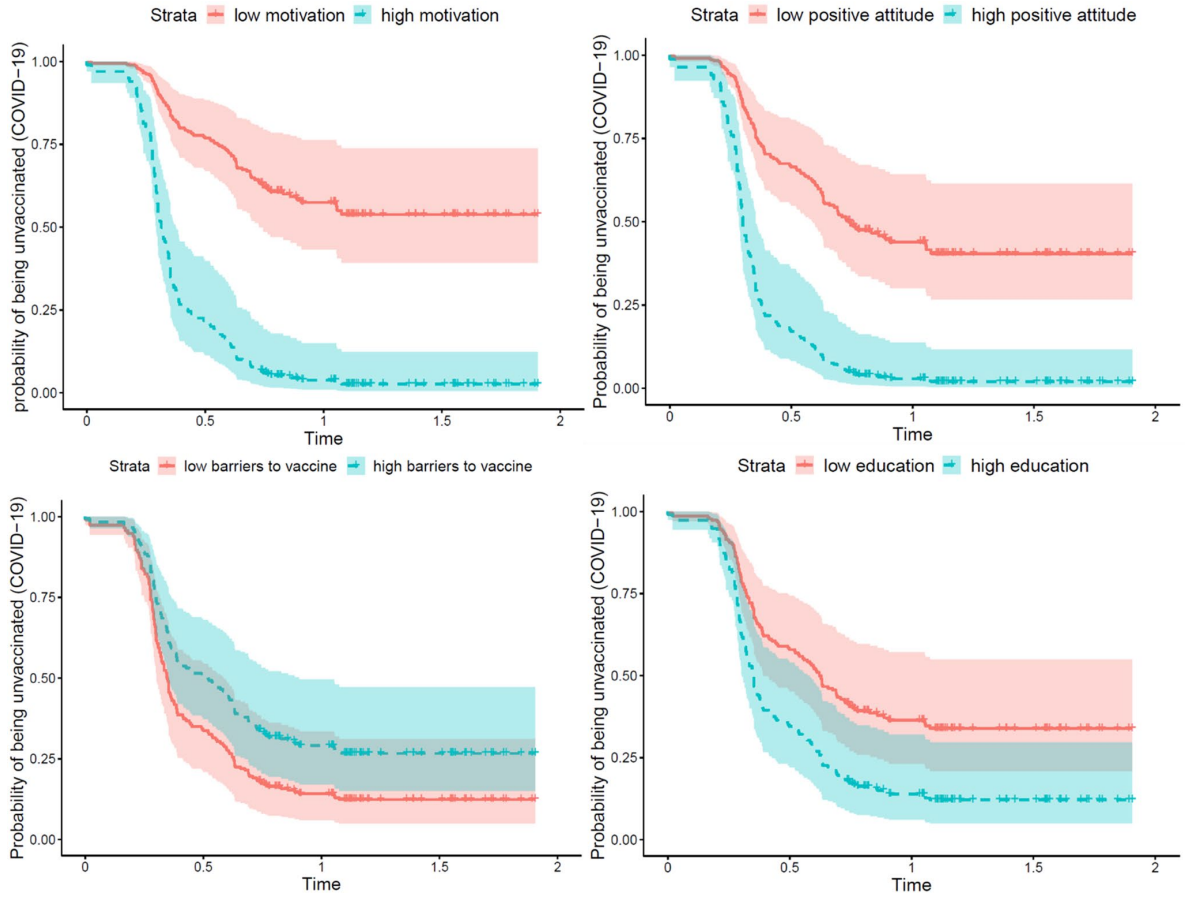

Fig. 3 Cox proportional hazards models. *Note* The censoring date is marked by small vertical bars in both pink and blue lines. High levels are defined as one standard deviation above the mean, while low levels are defined as one standard deviation below the mean. Youth who had high motivation to get COVID-19 vaccines, high (versus low) positive attitude toward COVID-19 vaccines, perceived low (versus high) general social barriers to COVID-19 vaccines, and had high (versus low) education levels showed a steeper decline in the probability of being unvaccinated over time

youth with access to more information about vaccines were more likely to take vaccines for protection [25]; the current study goes beyond past studies by focusing on how social factors (both general social and sociocultural) are related to the incidence of COVID-19 vaccine uptake in Mexican-origin youth. Concerns about vaccine safety could be a major deterrent to COVID-19 vaccine uptake [26]. If youth have less access to COVID-19 vaccine-related information, they may have more safety concerns regarding vaccines and subsequently be less likely to get vaccinated. Indeed, youth tend to want more information about vaccines, such as potential long-term side effects and compatibility with personal health conditions, before they agree to receive vaccines [27]. Although previous literature has investigated the association between barriers to vaccination and vaccine uptake, there is a critical need to understand the sociocultural barriers to vaccination [18], particularly among Mexican-origin youth who are a large and growing ethnic minority group in the U.S. The current study filled this gap by testing the association between sociocultural barriers to COVID-19 vaccination and the incidence of vaccine uptake among Mexican-origin youth. However, the current study did not find a significant association between sociocultural barriers to COVID-19 vaccination and the incidence of COVID-19 vaccine uptake among Mexican-origin youth. Sociocultural barriers to COVID-19 vaccination in the present study were examined mainly by measuring language barriers. Previous literature has illustrated that English language proficiency is positively associated with vaccine uptake in the United States [28]. Because the majority of the participants (97.5%) in the current study were socialized in the United States and reported high proficiency in speaking and understanding English, they were less likely to experience language barriers. The results may be interpreted as

follows: for immigrant-origin youth who are proficient in English, it may be that cognitive factors, such as motivation, attitudes toward vaccines, education level, as well as general social barriers to COVID-19 vaccination, are more salient than sociocultural factors in shaping their health behaviors. For immigrants who are not proficient in English, cultural factors may be more important in influencing their health behaviors, but future studies are needed to test this idea empirically. The non-significant result in the current study may also be due to the fact that there were too few sociocultural items to fully represent the sociocultural barriers Mexican-origin youth may face. For instance, Mexican-origin families may refuse to use the U.S. health care system (e.g., taking the COVID-19 vaccine) because of the fear of deportation [29, 30]. Future studies may want to include more socio-culturally relevant measures to measure the sociocultural barriers to COVID-19 vaccination experienced by Mexican-origin youth more comprehensively.

Lastly, the study did not show a consistent pattern that gender was associated with Mexican-origin youth COVID-19 vaccine uptake. Specially, among five models, only one model demonstrates that females were more likely to take the COVID-19 vaccine than males. This result contradicted previous literature showing that males have a higher COVID-19 vaccine uptake rate than females [10, 31]. The contradiction may be because females in the Mexican-origin population espouse cultural values such as familism, which may motivate them to take the COVID-19 vaccine to protect other family members [32]. Future studies may want to consider cultural influences when comparing vaccine uptake rates among different gender groups.

Limitations

Despite the current study's contributions, there are several limitations that should be noted. First, the findings point to social and cognitive factors enhancing COVID-19 vaccine rates among Mexican-origin youth; however, the survival analysis demonstrates that after a specific period of time a significant contingent of the sample still refused to get the vaccine. More research is needed to identify factors, beyond those identified in this study, that can encourage Mexican-origin youth who are COVID-19 vaccine-refusers to become adopters of the vaccine. Second, the results of the current study may not be able to be generalized to all Latino groups. The current study focuses on Mexican-origin youth from the state of Texas in the United States, but Latino youth from other states or countries, or who belong to other ethnic groups, may have different experiences and characteristics. Thus, interpretations of the results should be made with caution to avoid over-generalization. Third, most study constructs are measured by one or a few items, which may not fully represent the constructs the current study aims to test. Fourth, the present study did not examine whether the COVID-19 vaccination among Mexican-origin youth occurred voluntarily or due to mandates from schools and employment settings. Future research could explore how vaccine mandates influence the uptake of the COVID-19 vaccine among Mexican-origin youth. Lastly, the current study did not consider the impact of religious belief on the incidence of Mexican-origin youth COVID-19 vaccine uptake. Latinx people with stronger religious beliefs are more likely to have mistrust in science because they consider the Bible as the ultimate source of authority in determining their lives, which contributes to lower motivation to become vaccinated and more COVID-19 vaccine hesitancy [33–35]. More spiritual Mexican-origin youth may also be less likely to engage in COVID-19 preventative behaviors (i.e., vaccination, mask-wearing, social distancing, etc.) and at higher risk of COVID-19 infection [36]. Therefore, future studies should examine how one's degree of spirituality may inform Mexican-origin youth's COVID-19 preventative behaviors and their motivation for COVID-19 vaccine uptake.

Conclusion

Increasing COVID-19 vaccine uptake rates in the early period of a pandemic was critical to prevent the spread of the virus, particularly for ethnic minority populations, such as Mexican-origin youth, who demonstrate high COVID-19 infection rate, but limited health resources [2, 3]. The study findings suggest that COVID-19 vaccine uptake among Mexican-origin youth was predominantly observed following the initial rollout of the vaccine. The current study also revealed that cognitive and social factors, including attitudes toward COVID-19 vaccines, motivation, youth education status, and general barriers to COVID-19 knowledge, are significantly related to Mexican-origin youth incidence of receiving COVID-19 vaccines. Thus, public health efforts to educate Mexican-origin youth about COVID-19 related information aimed at increasing their positive attitude, motivation, and COVID-19-related knowledge is essential to increase vaccine uptake rates in the event of a future pandemic. Although the current study identified cognitive and social factors that motivated Mexican-origin youth to accept COVID-19 vaccines, those factors did not universally motivate every youth to become vaccinated. Future studies should go beyond the predictors we examined in this study to investigate factors that motivate unvaccinated youth to get vaccines.

Author contribution Su Yeong Kim: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing - original draft, Writing - review and

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Declarations

Ethical Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Review Board at the University of Texas at Austin, protocol number 2015-01-0006.

Consent to Participate Informed consent was obtained from all individual participants included in the study.

Competing Interests The authors report there are no competing interests to declare.

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