



Is Mexico's population hesitant towards COVID-19 vaccines? A 2021 survey on different levels of hesitancy and its determinants

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ABSTRACT

Vaccine hesitancy is a well-known phenomenon whereby individuals in a population reject or delay being vaccinated despite having access to vaccine services. This phenomenon is especially problematic in the current context of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) pandemic because vaccine hesitancy can decrease vaccination rates. In Mexico, vaccine hesitancy has been less thoroughly studied than in other countries such as the United States despite its importance and the potential impact of overlooking the problem. Understanding and effectively tackling this problem requires a more in-depth analysis of the defining characteristics of vaccination hesitancy. For this purpose, the World Health Organization's (WHO) Vaccine Hesitancy Determinants Matrix (VHDM in this study) is highly useful. In the present study, a digital survey was conducted using Google Forms to assess the level of vaccine hesitancy in the Mexican population and the vaccine determinants of the VHDM model associated with the respondents' different levels of vaccine hesitancy. The sample consisted of 1,195 people divided into four levels of vaccine hesitancy based on their answers. Tests for association were performed, identifying an association between some determinants of the VHDM model and the levels of vaccine hesitancy. Based on the analysis of the survey results, areas of opportunity for addressing COVID-19 vaccine hesitancy in Mexico were found and discussed; these included the importance of studying vaccine hesitancy as a complex and changing gradient, the high connectivity of people with high level of vaccine hesitancy to networks of people with vaccine hesitancy, the relatively high trust in physicians at all levels of vaccine hesitancy, the low trust in government authorities at high and moderate levels of vaccine hesitancy, and the strong association of the fear of suffering side effects and knowing people who have suffered them with the level of vaccine hesitancy.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has had drastic repercussions worldwide. In addition to the irreparable loss of human lives, the COVID-19 pandemic has impacted health systems, socioeconomic conditions, food security, and the quality of life of people in various countries around the world, including Mexico (World Health Organization, October 13, 2020; Shang et al., 2021; Sumner et al., 2020). By June 1, 2021, approximately 220,000 deaths and two million infections had been recorded in Mexico since the first case was

diagnosed in March 2020 (Subsecretaría de Prevención y Promoción de la Salud, 2021). The effects of the pandemic may be mitigated or even stopped thanks to the development of numerous vaccines against the virus, which have shown good efficacy against the disease (Fathizadeh et al., 2021; McDonald et al., 2021; Rodrigues & Plotkin, 2020). However, with the production of higher volumes of vaccines and the gradual increase of their availability to different population sectors, the ability to achieve high vaccination rates may be increasingly hampered by vaccine hesitancy and rejection, which can prolong the negative effects of the pandemic, as already studied in countries such as the United Kingdom

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(Olivera Mesa et al., 2021; Solís Arce et al., 2021).

Vaccine hesitancy is defined by the World Health Organization (WHO) Strategic Advisory Group of Experts (SAGE) as the “delay in acceptance or refusal of vaccines despite availability of vaccine services” (World Health Organization, 2014). This phenomenon has been identified as one of the main public health problems in the world since 2019 (World Health Organization, 2019; Scheres & Kuszewski, 2019). In the current context, the issue becomes even more serious because vaccine hesitancy may be heightened by the introduction of one or several new vaccines. As the disease continues to spread around the world, the rejection of preventive measures such as vaccination has had serious consequences (Cascini et al., 2021; Stoddard et al., 2021). Repercussions such as dose wastage or the high proportion of hospitalizations among unvaccinated people have already been observed in Mexico and other countries worldwide (Awasthi, 2021; Cunningham & Dow, 2021; Jabłońska et al., 2021; Rendall, 2021; Valencia, 2021; Warah, 2021). Thankfully, we are not completely in the dark on this issue. Last year, some population studies on COVID-19 vaccine hesitancy were conducted in Mexico at different time intervals, reporting different proportions of the population as unwilling to receive a COVID-19 vaccine (Carnalla et al., 2021; Center for Geospatial Information Science University of Maryland, June 25, 2021; Delgado-Gallegos et al., 2021; Lazarus et al., 2021; Ramonfaur et al., 2021; Sallam, 2021). However, more research that deepens our knowledge on this subject is necessary to effectively tackle this issue. Specifically, studies that contribute to further our understanding of the relationship between the population’s characteristics and their acceptance of vaccines, that is, of the vaccine hesitancy determinants for the population. In addition, there is a need for more attempts to study hesitancy as a spectrum and not a binary characteristic. This information will not only help address the issue of this pandemic, it could also allow us to have better tools for both present and future vaccine hesitancy problems.

Addressing vaccine refusal requires a deeper knowledge of the characteristics of a population’s vaccine hesitancy as well as those of the population itself. The complexity and multidimensionality of vaccine hesitancy are summarized in the Vaccine Hesitancy Determinants Matrix (abbreviated VHDM in this study), which indicates factors that help to understand the origin and characteristics of populations’ vaccine hesitancy. These factors are classified into 21 determinants organized into the following three domains: contextual influences, individual and group influences, vaccine and vaccination specific issues (Larson et al., 2014; WHO, 2014). At the time this study’s survey was conducted, there was already some evidence of the adverse effects of vaccine hesitancy in Mexico. On the date this article was finished (July 2022), the hesitancy of the Mexican population had changed, and around 70% of the population had already received the vaccine, it shows that hesitancy is an evolving phenomenon. Studying vaccine hesitancy in different time frames and understanding vaccine hesitancy determinants and the characteristics that differentiate the hesitant from the non-hesitant Mexican is crucial to understanding how VH works. In the present study, the degree of COVID-19 vaccine hesitancy and the opinions, demographic factors, and vaccine hesitancy determinants were recorded in a sample of the Mexican population in June of 2021.

2. Materials and methods

2.1. Study design

This cross-sectional study was conducted by anonymous survey using the Google Forms platform (Google, Mountain View, CA). Data were collected from June 1 to July 1, 2021. The survey was designed based on vaccine hesitancy determinants described by WHO SAGE, and it

consisted of 32 items, two of which were optional and the others necessary to record the respondents’ answers. Overall, the survey was divided into the following two sections: the first included demographic and socioeconomic characteristics, and the second addressed COVID-19 vaccine hesitancy-related aspects. Eight questions were open-ended or restricted only to numerical answers, and the others were multiple-choice. The questions of the survey as well as the answer options are available in supplementary material 1 and can also be accessed through this link (<https://forms.gle/rvgGD9YFQqvNjbD8>).

The demographic and socioeconomic characteristics section included 11 questions to determine the respondents’ nationality, state and place of residence, gender, age, education and socioeconomic levels, their type of settlement, and their ideology or religion and to assess whether they belonged to a socially vulnerable group. To determine the socioeconomic level, the questionnaire included two questions generated by simplifying the method proposed by the Socioeconomic Level Committee of the Mexican Association of Marketing Research and Public Opinion Agencies (*Asociación Mexicana de Agencias de Inteligencia de Mercado y Opinión – AMAI*) in its 2018 *Nota Metodológica* [Methodological Note]. This simplification was done to keep the survey concise. The first question referred to the head of the family’s educational level, which was scored as proposed by AMAI, and the second question asked about the home of residence, generating five categories, which were scored based on the score of several questions proposed by AMAI. These scores and their use to determine a socioeconomic level are available in supplementary material 2.

The section of questions related to COVID-19 vaccine hesitancy contained the remaining 21 questions. Two questions were used to understand the respondents’ vaccine hesitancy level: one asked the respondents whether they would get vaccinated when a vaccine became available, and the other asked them which vaccines they would be willing to receive. The latter was included in the questionnaire because the respondents could be more willing to accept specific vaccines and have a higher degree of vaccine hesitancy toward others, in line with the notion that vaccine hesitancy is a gradient and not a binary issue. The remaining questions referred to respondents’ opinions, sources of information, feelings, and other characteristics useful to identify vaccine hesitancy determinants. Questions from the three (contextual, individual or group, and vaccine- or vaccination-related) domains of determinants were included, but some determinants were not directly addressed by any question to avoid lengthening the survey, instead enabling the respondents to mention them in the open-ended questions.

2.2. Procedures and sampling

The respondents were recruited by non-probability convenience, quota, and snowball sampling (Stratton, 2019). The following three recruitment strategies were used: targeted Facebook advertising; promoting the survey in universities, which was requested from various faculties and institutes of the National Autonomous University of Mexico (*Universidad Nacional Autónoma de México – UNAM*) and a few other Mexican universities; and sharing the survey with Rotary International, which collaborated with this research by sharing the survey on networks and with acquaintances of various Rotaract Clubs in Mexico. The total sample consisted of 1,217 questionnaires. The inclusion criteria of the survey considered any person of Mexican nationality aged 18 or older who was able to read and write in Spanish and to use a device with internet access. Nineteen questionnaires were discarded and excluded from the tests because the corresponding respondents reported a nationality other than Mexican, their age was younger than 18 years, or they provided incongruous responses such as an age older than 200 years.

2.3. Statistical analysis

The data were processed and statistically analyzed in Excel 2017 and R version 4.0.3. The complete description of all changes made to the raw data to improve their processing in R and the original data are available in Supplementary Information 3. The strongest vaccine hesitancy determinants, the association of demographic and socioeconomic factors with vaccine hesitancy, and the differentiation between characteristics of populations with different degrees of vaccine hesitancy were described through the Chi-square test or a G-test depending on the case, setting the significance level at $p < 0.05$. To compare differences between groups, relative proportions at each vaccine hesitancy level were used, and the contribution of each category of variables to the differences of the tests was evaluated using the Chi-square standardized residuals. To make this analysis more robust, an ordinal logistic regression was performed through an AIC stepwise selection for best supported multivariate model to find the variables that best explain vaccine hesitancy in our data.

3. Results

3.1. Characteristics of the sample and degree of vaccine hesitancy

Of the 1,195 people surveyed, the ages were widely distributed (from 18 to 75 years), but the predominant age group ranged from 18 to 29 years (61%), with an average age of 31.5 years and a standard deviation of 13.74. Of the total number of respondents, 59% were women and predominantly people with high school (54%) and college (36%) degrees. The remaining sociodemographic characteristics of the sample are outlined in Table 1. The responses were sent from all Mexican states except for Zacatecas, Tabasco, and Nayarit. Most of the sample included Mexico City (42.2%) and State of Mexico (24.6%) residents.

The respondents' level of vaccine hesitancy (VH) was determined through two questions and assigned to one of four categories based on the combination of responses, as outlined in Fig. 1. People with confirmed rejection of all the vaccines available were assigned to the high level of VH (HVH) group (2.6%); respondents who are unsure whether they would want a vaccine were assigned to the moderate level of VH (MVH) group (8.4%); if they were willing to receive only specific vaccines and rejected others they were assigned to the low level of VH (LVH) group (37.1%); and finally, the ones who confirmed their willingness to receive any of all the vaccines available (51.9%), they were assigned to the no VH (NVH) group. The statistical tests were performed using these VH groups to find associations with other factors. It is noteworthy that the proposed ordinal variable for VH has limitations. Although it does not fully capture the intricacies of the VH spectrum and that its categories are not symmetrical in their increase of VH, it does allow for a simple categorization of VH that avoids the simplification of a "yes or no" question and takes into consideration the differences of opinion that a person can have concerning different vaccines.

In the open-ended questions, the most prevalent reasons why people did not want to be vaccinated or were unsure whether to do so included aspects of side effects, the safety of vaccine components, and adverse reactions (42%). Other frequently provided reasons included lacking information or confidence (17%), considering vaccines unnecessary (8%), or doubting their effectiveness (8%). Each of these points is shown in Fig. 2. In addition to COVID-19 vaccine hesitancy, the respondents were asked whether they considered each of the vaccines in the national vaccination card necessary or not; in all cases, VH was significantly associated with it ($p < 0.05$). Within the group of people who would be willing to receive only some vaccines, the Pfizer vaccine was the most popular (77%), and CanSino (18%) and Sinovac (6%) were the least popular.

Table 1
Sociodemographic factors and vaccine hesitancy

Table 1 shows the sociodemographic characteristics of the survey respondents divided by the hesitancy level categories used in this study. The sociodemographic factors are gender, age, education level, ideology, and type of settlement. The data is divided in three representations: the absolute frequency (Abs Freq), the relative frequency (%) in each hesitancy level, and the standardized residuals of chi-squared test. The final column shows the p-value of the G-test. P-values lower than 0.05 and standardized residuals higher than 2 or lower than -2 are highlighted in yellow.

	High hesitancy			Moderate hesitancy			Low hesitancy			No hesitancy			P-value
	Abs Freq	(%)	Std Res	Abs Freq	(%)	Std Res	Abs Freq	(%)	Std Res	Abs Freq	(%)	Std Res	
Gender													0.09
Woman	22	73.30		63	64.28		276	62.59		351	57.17		
Man	8	26.60		35	35.71		165	37.41		263	42.83		
Age													0.01
18-29	16	51.61	-1.106	59	58.42	-0.594	248	55.98	-2.825	408	65.81	3.414	
30-39	4	12.90	0.224	16	15.84	1.379	57	12.87	1.022	62	10.00	-1.827	
40-49	4	12.90	0.133	14	13.86	0.556	59	13.32	0.962	68	10.97	-1.282	
50-59	4	12.90	0.485	12	11.88	0.549	55	12.42	1.853	52	8.39	-2.251	
+60	3	9.68	1.299	0	0.00	-2.351	24	5.42	0.806	30	4.84	0.116	
Education level													0.002
Postgraduate degree	6	19.35	1.021	9	8.91	-1.337	54	12.19	-0.808	89	14.35	1.201	
College or university degree	8	25.81	0.316	27	26.73	0.819	101	22.80	-0.396	144	23.23	-0.174	
Highschool diploma	15	48.39	-0.680	57	56.44	0.431	226	51.02	-1.799	352	56.77	1.716	
Vocational-technical degree	2	6.45	-0.494	8	7.92	-0.380	62	14.00	4.685	35	5.65	-4.160	
Socioeconomic level													0.021
A/B	17	54.84	1.843	45	44.55	1.216	145	32.73	-3.364	258	41.61	1.988	
C	10	32.26	-2.216	47	46.53	-1.124	247	55.76	2.057	316	50.97	-0.657	
D	3	9.68	0.399	7	6.93	-0.334	42	9.48	1.682	41	6.61	-1.567	
E	1	3.23	0.859	2	1.98	0.495	9	2.03	1.364	5	0.81	-1.868	
Ideology													0.0002
Catholicism	14	45.16	0.149	40	39.60	-0.899	222	50.11	3.349	248	40.00	-2.785	
Agnosticism	4	12.90	0.627	12	11.88	0.804	24	5.42	-3.784	75	12.10	3.010	
Other	3	9.68	0.195	12	11.88	1.184	49	11.06	2.220	40	6.45	-2.867	
None	8	25.81	-0.687	27	26.73	-1.070	121	27.31	-2.372	220	35.48	3.107	
Prefer not to answer	2	6.45	0.021	10	9.90	1.524	27	6.09	-0.288	37	5.97	-0.577	
Type of Settlement													0.64
Rural	2	6.45		6	6.00		32	7.29		28	4.52		
Suburban	3	9.68		12	12.00		41	9.34		61	9.84		
Urban	26	83.87		82	82.00		366	83.37		531	85.65		

		(a) If you were not vaccinated against COVID-19 and a vaccine was available, would you vaccinate?		
		Yes (1063)	Maybe/ I do not know (96)	No (36)
(b) Of the COVID-19 vaccines that are available in Mexico, check the ones you are willing to receive	Any of them (642)	NVH (620)	MVH (22)	--
	Only some of them (511)	LVH (443)	MVH (63)	MVH (5)
	None of them (42)	--	MVH (11)	HVH (31)

Fig. 1. Method for determining the level of vaccine hesitancy

The above figure shows the method for classification of vaccine hesitancy level used in this study according to the answers of two questions in the survey. The first question (a) is: If you were not vaccinated against COVID-19 and a vaccine was available, would you vaccinate? And the second question (b) is: Of the COVID-19 vaccines that are available in Mexico, check the ones you are willing to receive. NVH: No Vaccine Hesitancy; LVH: Low Vaccine Hesitancy; MVH: Moderate Vaccine Hesitancy; HVH: High Vaccine Hesitancy. The absolute frequency of each answer is shown in parenthesis.

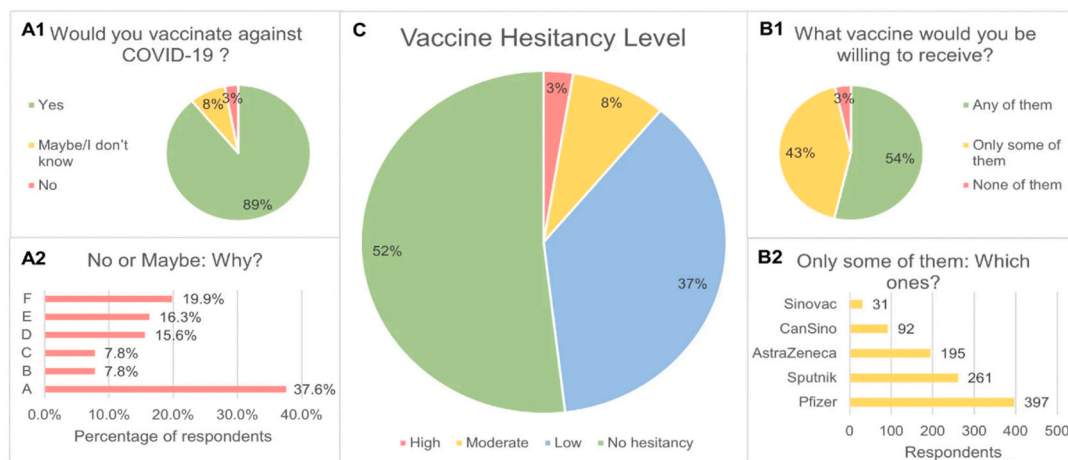


Fig. 2. Levels of Vaccine Hesitancy

The graphs represent the level of vaccine hesitancy in the survey respondents. A1) Answers to the question: If you were not vaccinated against COVID-19 and a vaccine was available, would you vaccinate? A2) Reasons for which the respondents answered "no" or "maybe/I do not know" to previous question (A: Safety and side effects B: They consider it unnecessary C: Vaccine efficacy D: Because of lack of complete information trustworthy information E: It depends on which vaccine F: Other reasons. B1) Answers to the question: Of the COVID-19 vaccines that are available in Mexico, which ones would you be willing to receive? B2) Absolute frequency of respondents that were willing to receive only certain vaccines that selected each vaccine. C) Level of vaccine hesitancy of respondents.

3.2. Sociodemographic characteristics and VH

The analysis of relationships between levels of VH and different sociodemographic variables showed significant associations with the variables of age, education and socioeconomic levels, and ideology but not with the variables of gender, type of settlement, and belonging to a socially vulnerable group. These results are summarized in Table 1. Younger ages were associated with the NVH category: the 18–29 year-old respondents accounted for more than 65% of the NVH group, while the 50–59 year-olds accounted for only 8% of the same VH group. Regarding educational level, only the subgroup of people without a high school diploma or with a vocational-technical degree showed a significantly high proportion of LVH and low proportion of NVH respondents.

The relationship between VH and socioeconomic level was shown by the large proportion of people from the LVH group with socioeconomic level C (55.7%) and the reverse for those in the HVH group (32.2%); in turn, a low proportion of LVH respondents belonged to socioeconomic level A/B (32.7%). Lastly, the strongest influence of ideology on VH was observed in the LVH and NVH groups.

3.3. Characteristics and determinants of vaccine hesitancy

Most of the other variables were significantly associated with VH. To facilitate their interpretation, we divided them into five themes: 1) number of vaccine-hesitant personal contacts of the respondents (defined in this study as people the respondent knows personally,

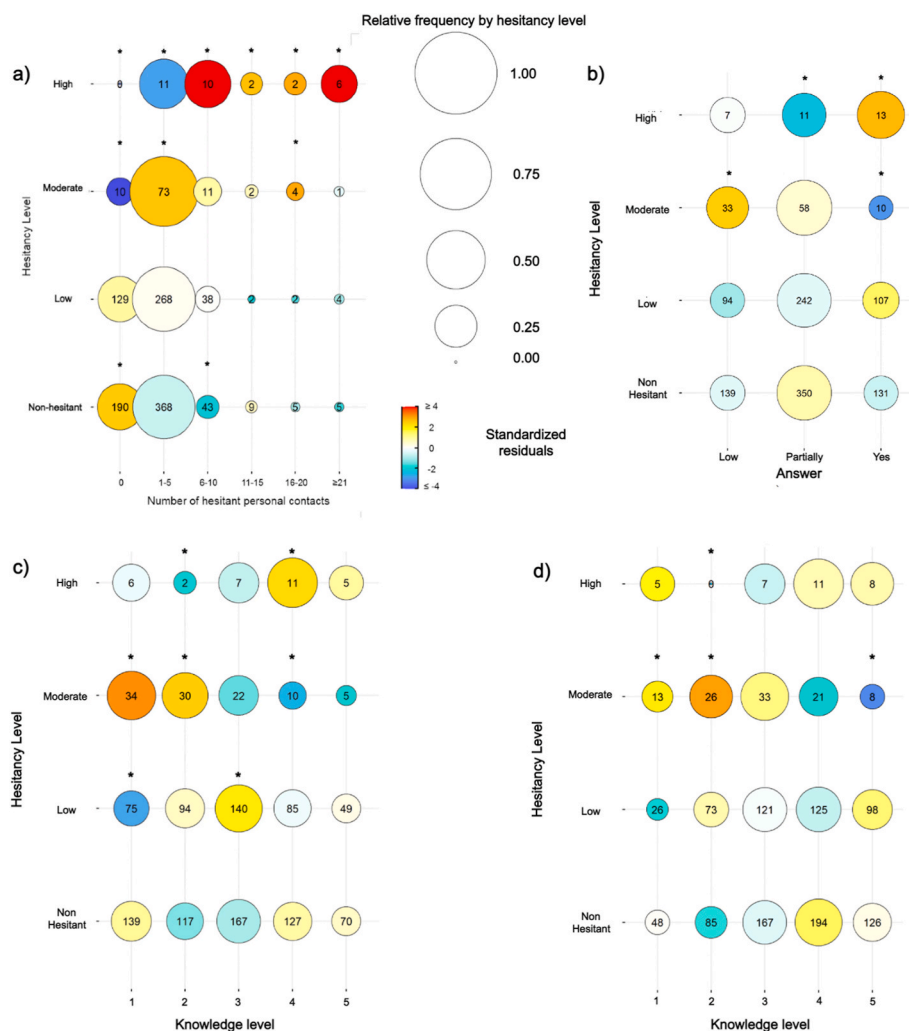


Fig. 3. Association between respondents' level of vaccine hesitancy, number of hesitant personal contacts, and self-perceived knowledge level. This figure shows three contingency tables that follow the scale in the higher central portion of the figure. a) Association between different levels of VH and the number of vaccine hesitant personal contacts that the respondents have b) Answers of the respondents to the question: Do you know the differences and how do each of the COVID-19 vaccines offered in Mexico work? c) Self-perceived knowledge level indicated by respondents regarding COVID-19 vaccine components. d) Self-perceived knowledge level indicated by respondents regarding the functioning of the COVID-19 vaccines. The numbers inside the circles show the absolute frequency, the size of the circle indicates the proportion relative to VHL, and the color of the circle shows the value of the standardized residuals of the Chi-squared for each cell. The standardized residuals whose value is higher than 2 or lower than -2 are considered as significant differences and are highlighted with an asterisk above the circle. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

including friends, family, and acquaintances), 2) self-perceived knowledge level, 3) sources of information, 4) confidence in different vaccination aspects, and 5) risk-benefit perception. Regarding the number of vaccine-hesitant personal contacts, significant differences were found in the proportions of VH (except for the LVH), as shown in Fig. 3a. NVH had a relatively high number of people with no vaccine-hesitant personal contacts (30%) and a low number with 11–15 vaccine-hesitant personal contacts (1.4%). HVH had a relatively low proportion of answers indicating 0 (0%) and 1–5 (35.4%) vaccine-hesitant personal contacts as well as a high proportion of the other groups, namely 6–10 (32%), 11–15 (6.4%), 16–20 (6.4%), and 21 or more (19.3%). Given these results, HVH is the group that differed most from the other groups.

The level of self-perceived knowledge of the vaccines was evaluated through two questions. The first one asked whether the respondent knew the differences between the COVID-19 vaccines available in Mexico, to which 54.9% of respondents answered “partially.” Significant differences were found between the answers of the HVH and MVH groups as shown in Fig. 3b. In the second question, respondents were asked to score their level of knowledge about the composition and functioning of vaccines from 1 to 5 (5 being the highest level of knowledge; Fig. 4c and Fig. 4d, respectively). In all cases, level of VH was significantly associated with the level of self-perceived knowledge, but most differences were derived from the MVH group, which had a relatively high proportion of respondents with a low level of knowledge (who answered 1 or 2).

The analysis of the respondents' sources of information and their

trust in them (Fig. 4) showed that many respondents reported having received content that questioned vaccine efficacy, need, and/or safety from the following sources of information: social networks (69%), newscasts, newspapers or news outlets (43%), and family and friends (42%). Conversely, the sources of information that the respondents trusted the most were academic sources (4.3 average in a 1 to 5 scale) and physicians or other healthcare professionals (4.1 average). VH was significantly associated with the level of trust in the news, academic sources, government authorities, and physicians as sources of information. These relative proportions were, in general, higher for distrust (answering 1 or 2) and lower for confidence (4 or 5) in the sources of information on the HVH group, and the reverse occurred in the NVH group.

Subsequently, the respondents were questioned about their level of confidence in different vaccination aspects, where the highest average confidence scores were found in evidence-based medicine (4.46), physicians and healthcare professionals (4.14), and in vaccine development by the pharmaceutical industry (3.85). The lowest scores, in turn, were found in alternative medicine (2.22), in the healthcare system and vaccine approval (3.29), and in the speed of vaccine development (3.47). Four of these aspects are shown in Fig. 5. In all cases, level of VH was significantly associated with the level of confidence in each aspect. For the most part, the higher VH, the lower the confidence in vaccination aspects. Despite significant differences between the VH categories, in all cases, more than 70% of respondents of each VH group scored 3 or higher in their level of confidence in physicians and evidence-based

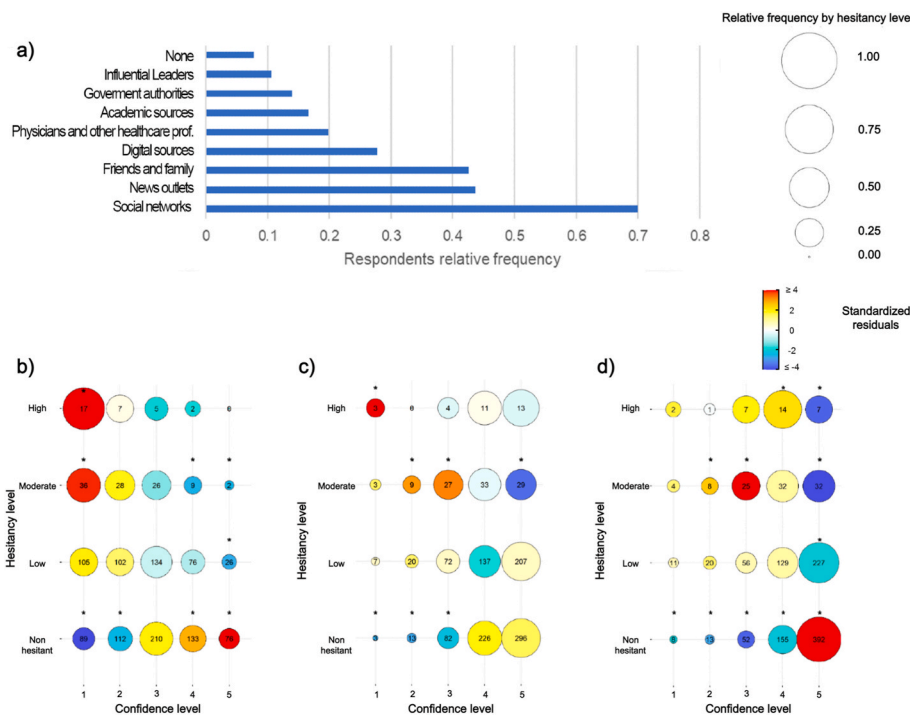


Fig. 4. Vaccine hesitancy and Information sources. This figure shows a bar graph and 4 contingency tables that follow the scale located in the upper right section of the figure. a) Relative frequency of the respondents that reported having received content that questioned vaccine efficacy, need, and/or safety from each of the sources of information. b) Confidence level towards government authorities as sources of information. c) Confidence level towards physicians and health professionals as sources of information. d) Confidence level towards academic sources as sources of information. e) Confidence level towards news-casts, newspapers, or news outlets. The numbers inside the circles show the absolute frequency, the size of the circle indicates the proportion relative to the level of VH, and the color of the circle shows the value of the standardized residuals of the Chi-squared for each cell. The standardized residuals whose value is higher than 2 or lower than -2 are considered as significant differences and are highlighted with an asterisk above the circle. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

medicine.

To understand vaccine risk perception (Fig. 6a–b), the respondents were asked whether they were worried about vaccine side effects, with 50.7% answering yes. Similarly, 41% of the respondents reported knowing someone who had experienced an adverse reaction to a vaccine or having had one themselves. Significant associations were found between the answers to these questions and with the level of VH. The higher the level of VH, the higher the proportion of people who answered yes to both questions. Prior experience (personal or acquaintance) with an adverse reaction is also significantly associated with concern about side effects as 60.9% of people with prior experience were concerned about side effects.

In addition, the respondents were asked three questions assessing how they rated COVID-19 risks and the risk-benefit of COVID-19 vaccines for most of the population on Fig. 6c and d, the data specific to benefit of COVID-19 vaccines is not shown being that it was mostly inverse of perceived risk of the vaccine. As expected, level of VH was significantly associated with these assessments. Most HVH respondents rated COVID-19 as a low-risk disease and COVID-19 vaccines as low-benefit, high-risk vaccines. LVH and NVH respondents had similar responses to each other and contrary to those of HVH. MVH respondents provided slightly more variable answers, especially regarding vaccine risk, with most proportions varying between those of HVH and NVH.

Lastly, the ordinal logistic regression multivariate analysis showed that the best model to explain the VH variable was $VH = \text{Age} + \text{trust in academic sources and government authorities} + \text{confidence in evidence-based medicine, alternative medicine, speed of vaccine development, vaccine components, safety and efficacy} + \text{fear of side effects} + \text{perceived benefit and risk of the vaccine}$, with only age and trust in academic sources being non significant.

4. Discussion

4.1. Vaccine hesitancy in Mexico

As in previous studies, our research identified a subpopulation of vaccine-hesitant people in Mexico (Fig. 2C), albeit markedly smaller than those of other countries such as the United States (52.1%) or Russia

(55.1%; Carnalla et al., 2021; Delgado-Gallegos et al., 2021; Ramonfaur et al., 2021; Sallam, 2021). The percentage of people with no VH (51.9%) was lower than that reported in other studies, such as those by Delgado-Gallegos et al. (87.8%) or by Ramonfaur et al. (85%; Delgado-Gallegos et al., 2021; Ramonfaur et al., 2021). To understand this discrepancy, we must consider that all of them—including the present study—have limitations; for example, those studies were conducted before the vaccine rollout in Mexico and only considered VH as absent or present. In the study by Carnalla et al. (2021), three levels of VH were described, and the acceptance was 62.3%—a value much closer to the percentage found in our study. In addition, in our data, we found a significant association between the level of VH towards COVID-19 vaccination and whether the respondents considered each of the vaccines offered in the Mexican vaccination card necessary or not. This association had already been reported for the influenza vaccine but not for the other vaccines (Carnalla et al., 2021; Delgado-Gallegos et al., 2021; Ramonfaur et al., 2021). This information may be problematic because it could indicate that an increased COVID-19 vaccine rejection could translate into decreased rates of vaccination against other diseases in new generations; therefore, this issue should be monitored carefully.

Dividing the surveyed population into four levels of VH enabled us to identify people who want to be vaccinated but would not do so with any vaccine. This group is a characteristic phenomenon of the current pandemic because different vaccines were developed, produced, and eventually became accessible to the population. When differentiating these people with selective VH (referred to as LVH in this study), the percentage of people with no VH becomes lower than otherwise reported in other studies with a simpler VH categorization (Center for Geospatial Information Science University of Maryland, June 25, 2021; Delgado-Gallegos et al., 2021; Lazarus et al., 2021; Sallam, 2021). This difference in the level of VH as a function of the vaccine depends on many factors that affect each person’s perception of a vaccine, including differences in efficacy, as reported by Ramonfaur et al., who found that the acceptance of a hypothetical vaccine changes drastically with its efficacy, decreasing from 85% to 46% acceptance when its efficacy decreases from 90% to 50% (Ramonfaur et al., 2021). These data indicate the existence of population sectors that should not be overlooked as ignoring these low or selective levels of VH could lead to a lower

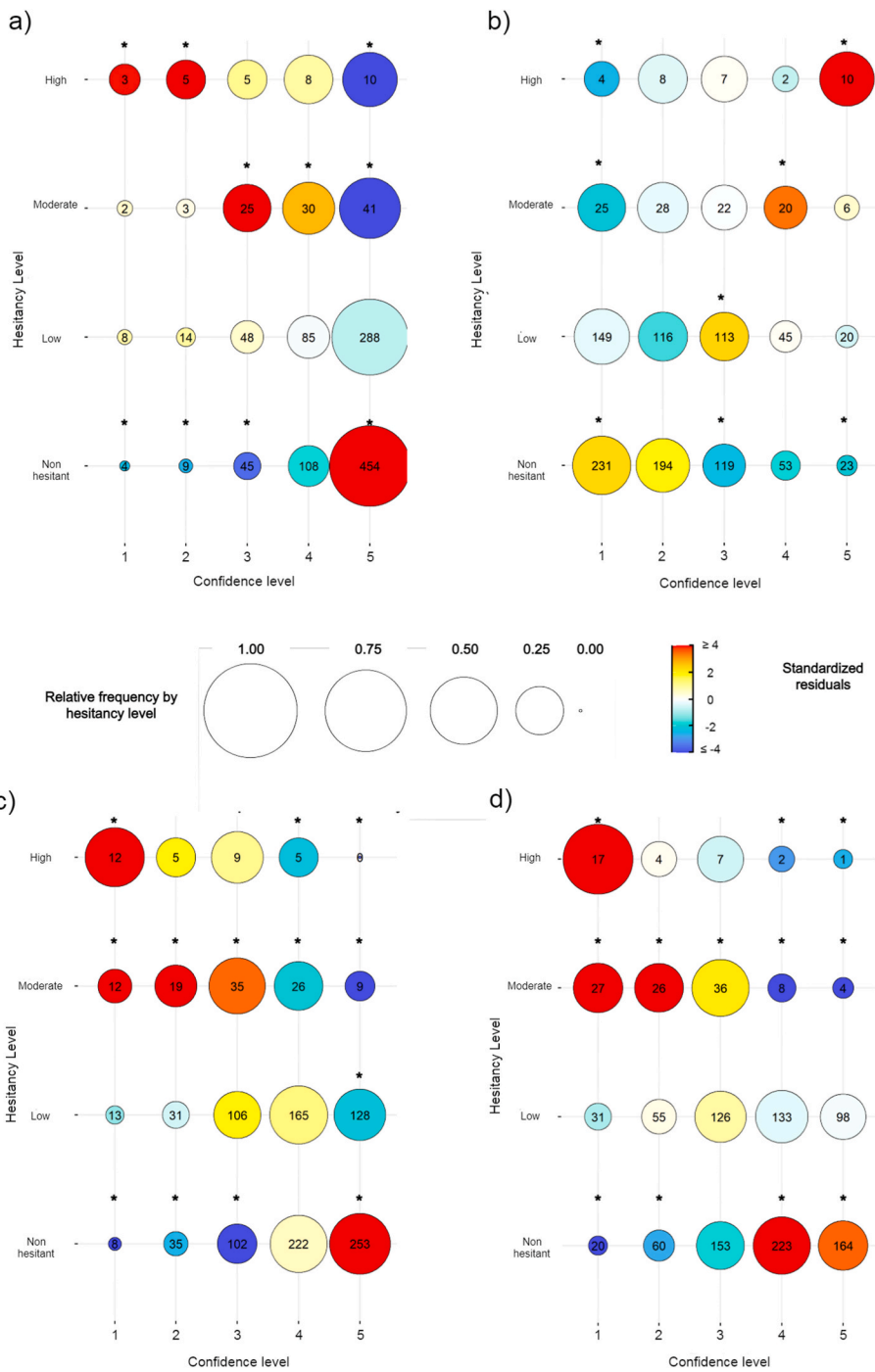


Fig. 5. Vaccine hesitancy and confidence toward vaccine related aspects
 This figure shows 6 contingency tables that follow the scale located in the central portion of the figure. a) Confidence level of the respondents towards evidence-based medicine. b) Confidence level of respondents towards alternative medicine. c) Confidence level of respondents towards the pharmaceutical industry. d) Confidence level of respondents towards the speed of COVID-19 vaccine development. The numbers inside the circles show the absolute frequency, the size of the circle indicates the proportion relative to the level of VH, and the color of the circle shows the value of the standardized residuals of the Chi-squared for each cell. The standardized residuals whose value is higher than 2 or lower than -2 are considered as significant differences and are highlighted with an asterisk above the circle. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

vaccination rate if these people are not offered the vaccines that they are willing to receive. Furthermore, these findings also enabled us to identify the most (Pfizer and Sputnik) and least (Sinovac and CanSino) accepted vaccines among the respondents of the sample, as shown in Fig. 2B2.

These differences in VH would not have been found had the respondents' categorization of vaccine hesitancy been simplified into vaccine hesitancy and acceptance, which shows the importance of not binarily characterizing the level of vaccine hesitancy. In addition to this caveat, four predominant reasons were identified to justify VH based on the open-ended questions of the survey (Supplementary Information 1): component safety, side effects, and adverse reactions; lack of information or mistrust of available information; vaccines considered as

unnecessary; and vaccines' efficacy being questioned. With this information and categorization of vaccine hesitancy among the population, we were able to find associations between the respondents' characteristics and their levels of VH, identifying the most important determinants.

4.2. Vaccine hesitancy determinants

The analysis of the survey highlighted various WHO VHDM determinants in the population studied. These belong to three domains, and we mention the determinants with the strongest impact as they were significantly associated with the level of VH.

Contextual influences: two main determinants were strongly

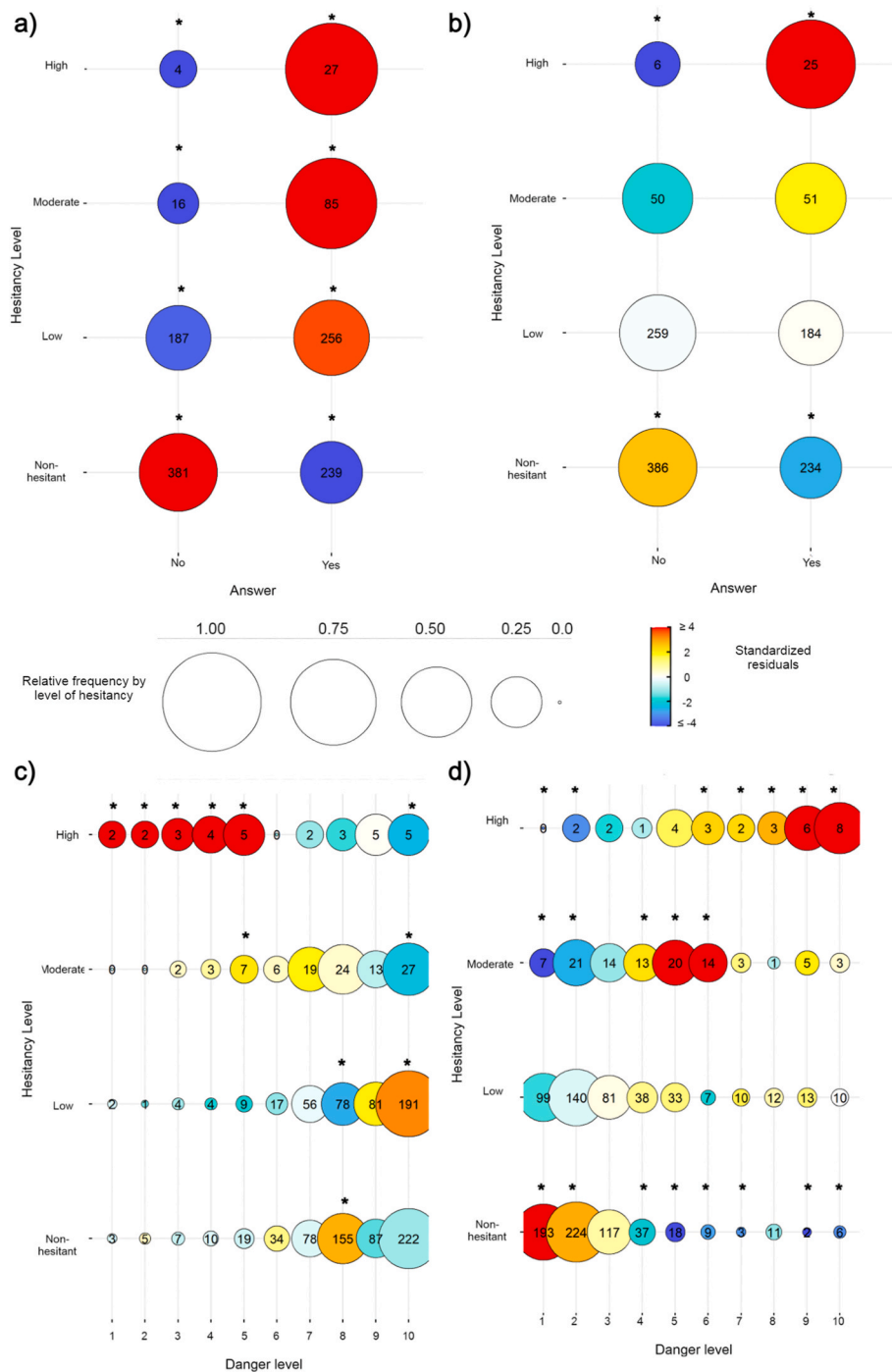


Fig. 6. Vaccine hesitancy and risk-benefit perception towards vaccines
 This figure shows 6 contingency tables that follow the same scale showed in the central part of the figure. a) Answers to the question: Are you worried about the COVID-19 vaccine side effects? b) Answers to the question: Have you, or anyone you know personally, ever had an adverse reaction to any vaccine? c) Danger associated to COVID-19. d) Danger associated to COVID-19 vaccines. The numbers inside the circles show the absolute frequency, the size of the circle indicates the proportion relative to level of VH, and the color of the circle shows the value of the standardized residuals of the Chi-squared for each cell. The standardized residuals whose value is higher than 2 or lower than -2 are considered as significant differences and are highlighted with an asterisk above the circle. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

associated with VH, namely (i) the media and communication environment and (ii) the perception of the pharmaceutical industry, as shown by significant and marked differences in VH between answers to the questions on sources of information, on trust in these sources, and in the pharmaceutical industry. No significant associations were found between VH and the determinants of religion, culture, gender, and socioeconomic factors—albeit some noticeable differences in proportions can be found in these variables with respect to VH, mostly in the NVH and LVH groups. The factor “influential leaders” was evaluated but not found to be significant, while the other determinants of this domain were not directly evaluated.

Individual and group influences: all determinants of this domain showed a significant association with the level of VH—especially the

determinants of experiences with prior vaccinations, knowledge and awareness, risk-benefit perception, and trust in the healthcare system.

Vaccine and vaccination-specific issues: the determinants that stood out in this domain were evidence-based risk-benefit perception, the introduction and formulation of a new vaccine, and the role of healthcare professionals. The vaccine administration method was identified as a key factor in a few respondents’ answers to the open-ended questions.

Finding associations, or the lack of them, with each determinant can affect the design of strategies for increasing vaccine acceptance because this information allows us to understand which actions have the highest potential to generate the desired impact on the population and which ones do not. It is to be noted that finding associations through a Chi-square or G test is not an infallible way to ensure a determinant is

present in the population, but it does provide a good approximation. Adding the multivariate ordinal logistic regression allowed us to consider the interaction between variables, which showed that, for the most part, the important variables were already identified in the individual Chi-square tests. Similarly, previously published studies in which the characteristics of vaccine hesitancy in a population have been studied using the VHDM model show that the importance and effect of each determinant varies with the population (Larson et al., 2014). This information allows us to visualize vaccine hesitancy by applying the VHDM model to the Mexican population.

4.3. Implications of associations

When observing all the results of the sociodemographic factors, in line with other studies (Carnalla et al., 2021; Delgado-Gallegos et al., 2021; Ramonfaur et al., 2021), we found that the level of VH is significantly associated with the variables of age, education and socioeconomic levels, and ideology; nevertheless, most proportions are not noticeably different from each other (Table 1). Likewise, when analyzing the standardized residuals, we found that most of the significant differences were identified in the NVH and LVH groups. The only exceptions were the low proportions of people of socioeconomic level C in the HVH group and of those older than 60 years in the MVH group. These results show that, although the sociodemographic groups could be further divided when a higher prevalence of vaccine hesitancy is found (for example, among people older than 29 years), the different VH populations of the study sample are socio demographically diverse. In conclusion, the strategies proposed to reduce VH should focus on more than one sociodemographic group to broaden the desired effect.

The number of VH personal contacts was also a determining factor. Unsurprisingly, most respondents knew one or more vaccine hesitant person (83%). A differentiating feature of VH—specifically at the high and moderate levels—is the higher prevalence and number of VH personal contacts (Fig. 3a). These results show that people with a higher level of VH, and who therefore are more prone to lower vaccination rates, are more connected to networks of VH people. This association, in turn, complicates the situation because this high connectivity could generate a feedback loop of disinformation and promotion of vaccine hesitancy, but it could also be used as an opportunity for spreading information among VH people. Furthermore, if this connectivity produces a network of contacts who avoid getting vaccinated, the same connective could generate groups particularly susceptible to COVID-19 due to the low immunization rates in the group, as previously modeled and discussed for other vaccines (Centola, 2010, 2020). Studying connectivity and information flows promoted by VH may open communication channels for more effectively targeting and disseminating content designed to address VH.

When asked about their level of knowledge, the respondents of the MVH group considered that they had lower levels of knowledge on all topics, while the HVH group had a self-reported level of knowledge equal to or higher than that of other VH groups (Fig. 3b–d). These differences could exemplify the Dunning-Kruger effect, as previously observed in other cases of VH (Motta et al., 2018), but because only self-perceived knowledge was evaluated, this assertion cannot be confirmed. What can be suggested from these results of self-perceived knowledge is that the MVH group has a higher potential than that of any other group for being approached using strategies based on dialogue and awareness campaigns. Increasing the information available to this group utilizing adequate models of communication like dialogue model and participation model could generate behavioral change (Hetland, 2016), thereby increasing the number of vaccinated people.

Analyzing the absolute frequencies in the factor of sources of information showed that trust in physicians was high in all VH groups and that trust in government authorities was especially low in the high and moderate VH groups (Fig. 4). These findings could have important implications for strategies aimed at reducing VH because this information

indicates that the physicians' communication strategies with their patients could have a strong impact, as previously reported in other interventions, and that messages directed through clearly governmental media could have a weak effect on the highest levels of VH (Brewer, 2020; Jarrett et al., 2015). This association between VH and distrust in the government was detected in another study (Ramonfaur et al., 2021). The level of confidence, in combination with the other factors, helps to identify VH determinants as well as the issues that people with the highest levels of VH distrust the most, which were vaccine safety, their speed of development, the healthcare system and vaccine approval, and vaccine efficacy (Fig. 5).

Lastly, the risk-benefit perception and fear of vaccines' side effects were highlighted as key issues for most respondents (Fig. 6). The associations between VH and fear of vaccines' side effects and having had or knowing someone who had an adverse reaction to a vaccine indicate the strong impact of this topic on COVID-19 VH. This association corroborates that observed in the study conducted in 2020 (Ramonfaur et al., 2021). The strong relationships between all these vaccine safety factors and VH flag a demographic sector that must be addressed: people who have suffered vaccines' side effects and their families. Providing an adequate follow-up for clarifying doubts, helping people understand the procedures to take care of their own health, as well as studying the adverse reactions to vaccines and their role in the development of VH could be a key element of strategies to avoid VH. In addition, the risk-benefit perception showed more noticeable differences in vaccine perception than in the risk of COVID-19, which indicates that strategies for changing vaccine perception could be more effective than those aimed at increasing the perception of danger of the disease, as observed in previous campaigns addressing VH (Brewer, 2020; Parsons et al., 2018).

4.4. Limitations

The characteristics of the sample allow us to perform the desired statistical analysis, but several study limitations must be considered. Among other limitations, the survey was conducted online, without supervision, which in turn prevented us from calculating the participation rate. Another limitation was the selected sampling method, which was the most reasonable given the context of the study but limited the control over the demographic characteristics of the sample, thereby leading to the overrepresentation of younger age groups (from 18 to 29 years) and populations from the center of the country (especially Mexico City and State of Mexico), which may introduce some biases into the study. Although this survey helped to further our understanding of COVID-19 VH in Mexico, the conclusions of the analysis may be more applicable to the population of the Metropolitan Zone of the Valley of Mexico and may serve as a good example for further studies. Lastly, as with any survey that works with the opinions and behavior linked to people's world view, there is no way to ensure that respondents have not resorted to motivated reasoning or confirmation bias which could affect their answers.

5. Conclusion

VH is one of many global issues whose visibility (and possibly even severity) has increased during the COVID-19 pandemic. To avoid its potential negative effects, this phenomenon must be carefully studied to design effective strategies for reducing its impact. In the present study, we worked with a sample of the Mexican population, which was divided into four VH levels to find associations between them and the respondents' different characteristics. This division into four VH levels is a key contribution of this study because, thanks to this categorization, we were able to identify potential problems, such as the high percentage of people who accept only some of the vaccines (37.1%) and areas of opportunity for addressing VH. Similarly, various VHDM determinants were identified. Some determinants (such as trust in the healthcare

system) seem to describe the vaccine-hesitant population under study, while others (such as influential leaders) do not seem to have much influence on VH. These findings could be useful when designing awareness campaigns.

Various areas of opportunity for addressing VH were identified in Mexico. Given the nature of this study, these areas of opportunity could be more applicable to young populations in the Metropolitan Area of the Valley of Mexico, although subsequent studies may indicate that they are also useful in other subpopulations. Among these areas of opportunity, sociodemographic diversification stands out when addressing the population, taking advantage of the high trust in physicians that seems to exist at all levels of VH as well as carefully assessing the strong negative impact that messages coming from physicians promoting VH could generate; moreover, awareness messages from governmental authorities ought to be reduced because the low confidence of vaccine-hesitant people in them indicates their ineffectiveness. Furthermore, conducting direct awareness campaigns aimed at people from the MVH group and addressing issues related to vaccine safety, the speed of its development, the healthcare system and vaccines' approval, and the vaccines' effectiveness, as well as monitoring people who suffer from adverse reactions to vaccines and their relatives, could help reduce vaccine rejection since a large proportion of vaccine-hesitant people indicate having had or knowing someone who suffered an adverse reaction to a vaccine.

This study adds to the small pool of covid-19 vaccine hesitancy studies conducted in Mexico (less than 20) in comparison with other countries like the United States (more than 400) according to a quick Scopus bibliographic search. This study is also, to the best of our knowledge, the first attempt to describe the vaccine hesitancy determinants in Mexico according to the VHDM model, which helps deepen our understanding of how hesitancy works in this population. Lastly, this research holds valuable information because, according to the information we could gather and up to July of 2022, there is no published VH research that took place in Mexico after february of 2021, and there is only one published study whose survey included the earliest months of that year. These types of studies can help paint the picture of VH and its evolution, which in turn could allow us better understand the VH phenomenon and be better prepared for future issues regarding vaccine acceptance.

VH is an evolving phenomenon; therefore, this study, together with previous and subsequent studies, helps to provide a more comprehensive view of VH in Mexico. These observations could be useful, but further studies must be conducted at state and local levels in various populations of Mexico, Latin America, and worldwide to gather complete information and to subsequently apply these data to design and implement truly effective strategies for reducing VH, increasing vaccination rates, and improving public health.

Ethical statement

With this, the authors of this manuscript consciously assure that for the manuscript titled "Is Mexico's population hesitant towards COVID-19 vaccines? A 2021 survey on different levels of hesitancy and its determinants." the following is fulfilled:

- 1) This material is the authors' original work, which has not been previously published elsewhere.
- 2) The paper is not currently being considered for publication elsewhere.
- 3) The paper reflects the authors' research and analysis wholly and truthfully.
- 4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
- 5) The results are appropriately placed in the context of prior and existing research.

- 6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated by using quotation marks and giving proper reference.
- 7) All authors have been personally and actively involved in substantial work leading to the paper and will take public responsibility for its content.

Likewise, this study, as is specified in the survey's welcome message that appears in [Supplementary Material 1](#), was done under complete anonymity, and no personal or identification data was gathered from respondents.

Author statement

Diego Alonso Echánove-Cuevas: Conceptualization, methodology, formal analysis, investigation, data curation, writing - original draft, writing-review & editing, visualization. **Nancy R. Mejía-Domínguez:** Methodology, software, validation, formal analysis, writing-review & editing, visualization. **América Nitxin Castañeda-Sortibrán:** Conceptualization, methodology, validation, writing-review & editing, supervision, project administration.

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Declaration of competing interest

None.

Data availability

We have attached the data of our study in supplemental material 3.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2022.101207>.

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