Demographic Factors and Structure of Vaccination Attitudes During the COVID-19 Pandemic in the Czech Republic

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Abstrakt Předchozí výzkum odhalil několik souvislostí mezi demografickými proměnnými a postoji k očkování. V této studii jsme zkoumali postoje k očkování během pandemie COVID-19 na vzorku 692 dospělých Čechů pomocí upravené verze Škály zkoumání postojů k očkování. Konkrétně bylo cílem studie 1) ověřit psychometrické charakteristiky škály a 2) ověřit souvislosti mezi dimenzemi Škály zkoumání postojů k očkování a vybranými demografickými charakteristikami. Zjistili jsme, že čtyři dimenze Škály zkoumání postojů k očkování spolu silně korelují a že nejlépe odpovídá adaptované škále pro COVID-19 v našem souboru hierarchická struktura se samostatným faktorem prvního řádu Výhody a faktorem druhého řádu Váhavost, který kombinuje faktory prvního řádu Obavy z budoucích dopadů, Obavy z komerčního zneužití a Preference přirozené imunity. Jak faktor Výhody, tak faktor Váhavosti se lišily mezi více demografickými skupinami. Další studium povahy a prediktorů seskupení různých postojových zdrojů váhavosti vůči očkování by mohlo vnést více světla do způsobů, jakými mohou lidé z různých sociodemografických a sociokulturních kontextů přijímat různá typy přesvědčení o očkování.

Klíčová slova: COVID-19 očkování, váhavost vůči očkování, postoje vůči očkování, demografické faktory, Škály zkoumání postojů k očkování

Extended abstract Vaccine hesitancy, defined as delay in acceptance or refusal of vaccination despite availability, emerged as a major public health challenge during the COVID-19 pandemic, fuelled by mistrust, misinformation and sociocultural factors. Understanding the structure and demographic predictors of vaccination attitudes is essential for designing effective communication strategies. This study examined attitudes toward COVID-19 vaccination in a representative sample of 692 Czech adults aged between 18 and 86 years (M = 45.2, SD = 16.8; 56.5% women) using an adapted Vaccination Attitudes Examination (VAX) scale. The Vaccination Attitudes Examination scale assesses four dimensions: Perceived vaccine benefits, Worries about unforeseen side effects, Concerns about commercial profiteering, and Preference for natural immunity. The scale was modified to refer specifically to COVID-19 vaccination. The main objectives of the study were 1) to validate the psychometric characteristics of the scale (internal consistency, factorial structure and measurement invariance) and 2) to examine the associations between Vaccination Attitudes Examination scale dimensions and selected demographic characteristics (age, gender, education, parental status, religion, vaccination status, and perceived physical health). Confirmatory factor analysis supported a hierarchical structure of the Vaccination Attitudes Examination scale: three dimensions (Worries about side effects, Commercial profiteering, and Preference for natural immunity) formed a second-order factor of Hesitancy, distinct from Perceived vaccine benefits. This structure demonstrated very good model fit, high internal consistency and scalar measurement invariance across gender, age, education, parenthood status, and religious affiliation, but not vaccination status, indicating that the structure of vaccination attitudes differs significantly between vaccinated and unvaccinated individuals. Demographic differences were mostly small but significant: group comparisons revealed that hesitancy was higher among people with children, people with less education and individuals without religious affiliation. Vaccinated participants reported greater perceived benefits and lower hesitancy than unvaccinated ones, with large effect sizes. Younger adults (18-29 years) showed the lowest hesitancy; and education level emerged as a consistent predictor on both perceived benefit and hesitancy scales. Perceived physical health had only a weak relationship with attitudes toward vaccination. These findings reflect universal and context-specific trends and underscore the importance of cultural, educational, and ideological factors in shaping vaccination attitudes. Tailored public health strategies should focus on increasing trust in vaccine safety and efficacy, especially among groups showing higher hesitancy. Efforts should include transparent communication, culturally sensitive messages, and education-based interventions to improve scientific literacy. The validated Czech version of the Vaccination Attitudes Examination scale offers a reliable tool for further cross-cultural and longitudinal research on vaccine acceptance.

Keywords COVID-19 vaccination, vaccine hesitancy, vaccination attitudes, demographics, Vaccination Attitudes Examination scale (VAX)

Introduction

Vaccine hesitancy, defined as "delay in acceptance or refusal of vaccines despite availability of vaccination services" (Strategic Advisory Group of Experts, 2014, p. 7), has been identified as one of the top ten threats to global health and a major threat to reverse the progress made in tackling vaccine-preventable diseases (WHO, 2021). Recently, the issue has become a subject of even more intense study in connection with the unprecedented outbreak of the COVID-19 disease in 2020 (Leonardelli et al., 2023). In an effort to mitigate the impact of the pandemic, government and health authorities across the globe issued strong vaccination recommendations as soon as the COVID-19 vaccines became available. However, in multiple countries, these were met with resistance and unwillingness on the part of various population groups. Frequently cited reasons for this identified by research included concerns about the vaccine's safety, its efficacy, and possible side effects (Babatope et al., 2023; Beleche et al., 2023; Leonardelli et al., 2023). Similar to pre-COVID studies on vaccination attitudes, research has indicated that COVID-19 vaccine hesitancy was largely linked to the spread of various types of misinformation regarding the COVID-19 pandemic and its management (Singh et al., 2022). It should also be mentioned, though, that compared to "traditional" vaccines, COVID-19 vaccines were based on novel vaccination systems that have not been widely used before, such as novel messenger RNA (mRNA) or viral vectors (Castrodeza-Sanz et al., 2023), and people's awareness of this fact might have aroused a sense of caution and skepticism even among those individuals who had never questioned the benefits of vaccination in general.

Even when vaccine hesitancy is closely associated with the endorsement of unfounded claims about vaccine safety or effectiveness, it would be inaccurate to assume a straightforward causal link between believing a specific claim and rejecting the related behaviour or recommendation. In fact, individuals may be more inclined to accept a range of questionable claims that justify their scepticism or refusal of vaccination because they are already motivated to reject it for other reasons (Hart et al., 2009), for example, perceiving vaccination as a threat to personal freedom, or feeling distrust or resentment toward the authorities promoting it.

This pattern can be more thoroughly understood through established psychological theories such as motivated reasoning and cognitive dissonance. Motivated reasoning suggests that people selectively process information in a way that protects their pre-existing beliefs or identity-consistent attitudes, leading them to favour information that justifies scepticism towards vaccination while dismissing contradictory evidence (Taber & Lodge, 2006). Cognitive dissonance theory further proposes that when individuals experience inconsistency between their attitudes (e.g., valuing autonomy or natural health) and recommended behaviours (e.g., complying with vaccination), they may resolve the discomfort by adopting beliefs that rationalise vaccine refusal (Festinger, 1957). These mechanisms help explain why misinformation often functions less as a cause of hesitancy and more as a post-hoc justification for an already motivated stance (Lewandowsky et al., 2012). Such psychological processes are strongly shaped by the broader social, cultural

and political environment in which individuals evaluate vaccination-related information. Therefore, identifying the shared foundations of vaccine hesitancy at a global level requires a careful exploration of its sociodemographic and psychosocial antecedents within diverse cultural settings.

Demographic variables as factors of vaccination intentions

In the light of the experience with high rates of vaccine rejection during the COVID-19 pandemic in 2020 and 2021, multiple studies have been conducted to examine its correlates at the population level, and several links with demographic variables have been found. Higher acceptance rates have been reported among older adults compared to young adults in countries such as South Korea (Kweon et al., 2022), Norway (Steinmetz, 2022), and the U.S. (Malik et al., 2020). Significant gender differences have also been reported, with women more vaccine hesitant than men (Enea et al. 2023, Gerretsen et al., 2021; Malik et al., 2020; Murphy et al., 2021; Riad et al., 2021). The level of education appears to be one of the strongest and most consistent demographic predictors of vaccine hesitancy. Using data on vaccination intentions from 20 countries, Enea et al. (2023) found that people with lower levels of education consistently reported lower vaccination intentions. Other studies suggest that various religious beliefs, especially among Muslims and Christians, could become sources of vaccine hesitancy due to moral objections to various aspects of vaccination (Enea et al., 2023; Garcia et al., 2021; Kibongani Volet et al., 2022).

Health status is considered another important factor of vaccine acceptance. Apart from the elderly, strong vaccination recommendations for COVID-19 were issued especially for people with certain pre-existing health conditions. However, whether people accepted these recommendations seems to depend on whether they also subjectively perceived the health risk associated with COVID-19 as high for them personally (Al-Amer et al., 2022). On the other hand, results of some studies suggest that overall better subjective health is a significant predictor of lower COVID-19 vaccine hesitancy (Wang et al., 2022), although this might not be applicable for people over 65 years of age (Khan et al., 2021).

As a systematic review by van Mulukom et al. (2022) has shown, demographic predictors in general – perhaps with the exception of education – do not seem to exhibit particularly strong and consistent associations with attitudes towards vaccination across all cultural contexts. This suggests that groups with highly similar demographic characteristics can develop very different ways of thinking depending on the specific socio-cultural and political context they are embedded in.

Present study

In summary, previous research has shown that adherence to recommendations during the COVID-19 pandemic, including willingness to receive vaccination, was associated with unsubstantiated beliefs about COVID-19 and COVID-19 vaccines. Furthermore, all of these variables were significantly related to trust in the authorities that issue recommendations and to various demographic characteristics. In the present study, we examined

the structure and demographic factors of COVID-19 vaccination attitudes in the adult Czech population using the four dimensions of the Vaccination Attitudes Examination Scale (VAX). To our knowledge, this was the first systematic investigation of vaccination attitudes in the Czech context using this instrument. The original VAX scale was developed by Martin and Petrie (2017) and validated in an adult population using exploratory and confirmatory factor analyses. Their research identified four distinct but interrelated dimensions of vaccination attitudes: (1) Mistrust of vaccine benefit, (2) Concerns about unforeseen future effects, (3) Concerns about commercial profiteering, and (4) Preference for natural immunity. The internal consistency of these dimensions, measured by Cronbach's alpha, ranged from 0.77 to 0.93, indicating good reliability.

Importantly, these dimensions can be meaningfully situated within established theoretical models of health behaviour. Although originally developed to explain a broad range of preventive and health-related behaviours, the Health Belief Model (HBM) has been applied to vaccination decisions in later research. Within this framework, perceived barriers play a central role (Rosenstock, 1974), and the VAX dimension "Concerns about unforeseen future effects" reflects precisely such perceived barriers, which may outweigh perceived benefits. Similarly, "Concerns about commercial profiteering" may reduce trust in the health system, a factor shown to influence health decision-making in HBM-based studies (Champion & Skinner, 2008). From the perspective of the Theory of Planned Behavior (TPB), the VAX dimensions can also be linked to key constructs: concerns about side effects contribute to negative attitudes, while worries about commercial motives may weaken subjective norms by undermining trust in the institutions promoting vaccination (Ajzen, 1991). Together, these theoretical frameworks illustrate how specific beliefs, as captured by the VAX scale, may shape vaccination intentions.

Since its development, the VAX scale has been widely applied and validated in studies investigating vaccination attitudes during the COVID-19 pandemic. For example, a recent Slovak study by Novák et al. (2025) reported strong internal consistency across subscales (α = 0.76–0.94) and the overall scale (α = 0.93), as well as high test–retest reliability (r = 0.57–0.82). Confirmatory factor analysis in this study supported the original four-factor structure, with factor loadings ranging from 0.56 to 0. 99. Furthermore, the VAX scale has been successfully adapted and validated in several other languages, including Arabic (Alansari et al., 2024), Italian (Bruno et al., 2022), Korean (Kim et al., 2023), and Spanish (Paredes et al., 2021). These validation studies consistently confirmed the solid psychometric properties of the scale in various linguistic and cultural contexts.

Therefore, the main objective of our study was to assess and verify the factorial structure of the VAX scale, which was adapted to specifically refer to the COVID-19 vaccination attitudes. In addition, because the resulting structure of the scale was a key assumption of the subsequent analyses, we also tested the measurement invariance of the scale across different demographic groups.

Method

Participants and data collection

The research sample consisted of 692 respondents, aged between 18 and 86 years (M = 45.2, SD = 16.8). A demographic breakdown of the sample is provided in Table 1. Data were collected throughout November and December 2021, about five months after the COVID-19 vaccines were made available to the entire adult population in the Czech Republic. An anonymous online questionnaire was used, with a substantial part of the data (n = 500; 72.3%) collected with the assistance of an external data collection company (MNFORCE, n.d.), who recruited participants from their online panel. These participants were rewarded in the form of credits provided by the data collection company. The final sample structure was representative to general population of the Czech Republic aged 18 years and over, with quotas set on age, gender, region, settlement size, and education. The sample size was determined primarily by practical reasons, in particular to achieve the most representative distribution possible of the demographic characteristics mentioned above to general adult population of the Czech Republic. Potential bias, however, might stem from the fact that the data only included Internet users, as they were collected exclusively online. This could have led to underrepresentation of seniors or less educated respondents without internet access. The participants agreed to the panel rules and privacy policy of the data collection company and received payment for their participation. An additional, smaller number of participants was recruited through social networks and announcements on university websites and conferences. These participants were recruited through convenience sampling and were not rewarded for the participation. All participants were informed that the data were collected for research purposes, and that they would be giving their consent with data processing by submitting the questionnaire. According to the local regulations in place at the time of data collection, formal approval from an Ethics Committee was not required for this type of non-interventional online anonymous survey study. This was subsequently confirmed in writing by the chair of the institutional Ethics Committee of the Faculty of Medicine of Masaryk University.

Instruments

The Vaccination Attitudes Examination (VAX) Scale (Martin & Petrie, 2017) is a brief, 12-item questionnaire created to assess general attitudes to vaccination. Four subscales evaluate four distinct but correlated vaccine attitudes: (a) perceived vaccine benefits (reverse scale, e.g., "*I feel safe when I am vaccinated against COVID-19.*"), (b) worries about unforeseen future effects (e.g., "*I worry about the unknown effects of COVID-19 vaccines in the future.*"), (c) concerns about commercial profiteering (e.g., "*Authorities promote COVID-19 vaccination for financial gain, not for people's health.*"), and (d) preference for natural immunity (e.g., "*Natural exposure to the virus gives the safest protection.*"). Each item is assessed using a 6-point Likert scale (1 = *strongly disagree*; 6 = *strongly agree*). Higher scores suggest stronger antivaccination attitudes, with the exception of the perceived vaccine benefits scale, in which lower scores signify stronger antivaccination attitudes (unless the scale

is reversed). In the present study, we modified the scale to directly address attitudes toward vaccination against COVID-19 by adding the word "COVID-19" or "coronavirus" to each item. The VAX scale was translated from English to Czech by two independent translators. Subsequently, the two translations were compared and evaluated by members of the research team. A back-translation was provided; these two back-translations were subsequently compared and evaluated by members of the research team. The final version was consulted with an expert working in the area of health psychology and medicine. The modified versions of the VAX scale in English and Czech are in the Appendix.

Demographic variables included in the present study, in addition to *gender* and *age*, included *education* (primary school / lower secondary – no school-leaving certificate / upper secondary – with a school-leaving certificate / college degree), *parenthood status* (children / no children), *religious group* (Catholic / Protestant / other Christian / Muslim / Jewish / Hindu / Buddhist / spiritual-unaffiliated – without religious affiliation / no religion or confession / other), and *vaccination status for COVID-19* (fully vaccinated / partly vaccinated / planning to get vaccinated / unvaccinated). We also asked about the respondents' *perceived physical health*, which they rated on a scale from 1 (*seriously ill*) to 6 (*perfectly healthy*). An overview of the individual demographic categories actually included in demographic analyses, with respective counts and VAX scores, is provided in Table 1. Age was treated as a categorical variable, with four age groups approximately representing four stages of general career development: education and career exploration (18 to 29 years), early productive age (30 to 45 years), late productive age (46 to 60 years), and end-of-career and retirement age, officially designated as a high-risk group of COVID-19 infection (61 years and older). All analyses involving education level, religion, and vaccination status as variables were only performed with those categories that contained sufficient numbers of participants (see Table 1). Vaccination status was treated as a binary variable: vaccinated (including partly vaccinated participants) vs. unvaccinated, with participants who reported an intention to get vaccinated later (n = 12) excluded from all analyses involving vaccination status.

Table 1
Demographic composition of the research sample with VAX scores

	n (% total)	% Vaccinated	% Un-vaccinated	% Planning to get vaccinated*	Total VAX score	
					M	*SD*
Gender						
Female	391 (56.5)	71.1	27.6	1.3	45.1	15.1
Male	301 (43.5)	76.4	21.3	2.3	42.3	13.7
Age group						
18-29	147 (21.2)	78.2	17.7	4.1	40.1	14.4
30-45	218 (31.5)	67.0	31.2	1.8	45.9	14.4
46-60	165 (23.8)	75.2	23.6	1.2	44.6	13.9
61+	162 (23.4)	75.9	24.1	0.0	43.8	15.0

Education level						
Some elementary*	1 (0.1)	0.0	100.0	0.0	33.0	-
Full elementary*	18 (2.6)	66.7	27.8	5.6	44.2	13.0
Lower secondary	221 (31.9)	63.8	34.4	1.8	47.8	13.8
Upper secondary	262 (37.9)	77.9	19.5	2.7	42.2	14.6
College	190 (27.5)	79.5	20.5	0.0	41.6	14.8
Parent						
No	261 (37.7)	72.8	24.5	2.7	42.4	14.5
Yes	431 (62.3)	73.8	25.1	1.2	44.8	14.5
Religion						
Christian	133 (19.2)	75.9	21.8	2.3	41.4	12.9
Spiritual unaffiliated	158 (22.8)	63.3	32.9	3.8	47.2	14.8
Atheist	350 (50.6)	78.0	21.4	0.6	43.0	14.8
Other*	51 (7.4)	66.7	31.4	2.0	45.8	14.6
TOTAL	**692 (100.0)**	**73.4****	**24.9**	**1.7**	**43.9**	**14.6**

*These participant categories were excluded from the analyses involving the respective demographic variables due to low numbers and/or poor category specification ("Other").
**Includes fully (70.7%) and partly (2.7%) vaccinated individuals.

Data analysis

All survey items in the online questionnaire were mandatory; therefore, the dataset contained no missing values, and no imputation procedures were required.

Descriptive statistics were calculated using IBM SPSS Statistics software. Internal consistencies of VAX scale and its subscales were assessed based on McDonald's omega, which was computed using the psych package in R (Revelle, 2017). To examine the factorial structure of the VAX scale, a series of confirmatory factor analyses was conducted using the lavaan package in R (Rosseel, 2012), employing Satorra-Bentler robust maximum-likelihood estimation (Satorra & Bentler, 1994), which has been shown to provide unbiased standard error estimates with items rated on Likert-type scales with 5 points or more, while also performing relatively well when the assumption of normality is not met (Bovaird & Koziol, 2012). The package was also used to perform multiple-group confirmatory analysis to assess measurement invariance across different demographic groups, i.e.,

to see whether different demographic groups show significant differences in the structure of vaccine-related attitudes, including relationships between the individual factors. To assess model fit in all of the above analyses, robust Root Mean Square Error of Approximation (RMSEA) with 90% CIs (acceptable fit: UCI < 0.10), robust standardized root mean square residual (acceptable fit: SRMR < 0.08) (Hu & Bentler, 1999), robust Comparative Fit Index (CFI), and robust Tucker Lewis Index (TLI) were used. According to Hu and Bentler (1999), CFI and TLI values around 0.95 indicate good model fit. In the present study, therefore, we used the value of 0.90 as the cutoff criterion for minimum acceptable fit, and values 0.95 and above were considered as good fit. Relative adequacy of nested models, taking parsimony into account, was assessed based on the Bayesian Information Criterion (BIC) with smaller values indicating models with better fit.

Apart from using scalar invariance as a measure of group differences in VAX scores, demographic comparisons were performed using between-group *t*-tests with *df* modified to account for unequal variances, or one-way ANOVA when multiple groups were compared (the equality of variance assumption was not violated in this case). Hedge's *g* and eta squared were used as measures of effect sizes. The independence of the effects of the individual demographic predictors was additionally assessed using general linear modelling. The effects were compared based on partial eta squared. The relationship between the VAX total score and subjective physical health was tested using nonparametric correlation analysis (Spearman's rho) due to the severely skewed distribution of the latter variable. All these inferential analyses were conducted in IBM SPSS Statistics.

Results

Structure of the VAX scale

Results of the confirmatory factor analysis of the VAX scale are displayed in Table 2. First, we tested the original model (Model 1 in Table 2), in which all four dimensions were separate but correlated. The model exhibited a very good fit. Factor loadings across all dimensions ranged between 0.66 and 0.94, and the four factors were strongly correlated, with the strongest correlations, ranging between 0.71 and 0.85, observed between the dimensions Worries about unforeseen future effects, Concerns about commercial profiteering, and Preference for natural immunity. The correlations between these three dimensions and the positive Perceived vaccine benefits dimension ranged between -0.55 and -0. 63.

The strong correlations prompted us to test a more parsimonious model, in which all four dimensions were combined into a single factor. However, this model exhibited a very poor fit (Model 2 in Table 2). The model in which only the three negatively formulated dimensions – Worries about unforeseen future effects, Concerns about commercial profiteering, and Preference for natural immunity – were collapsed into a single factor, and the Benefits dimension remained separate (Model 3 in Table 2), exhibited considerably better fit than the unidimensional model; nevertheless, it was still substantially inferior to the original four-dimensional model. As the last step, therefore, we tested a hierarchical model, in which the first-order factors Worries about unforeseen future effects, Concerns

about commercial profiteering, and Preference for natural immunity, loaded on a second-order factor, named Vaccine Hesitancy, correlated with a separate first-order factor Benefits (Model 4 in Table 2). This model, displayed in Fig. 1, exhibited a very good fit, which was even superior to the original four-factor model.

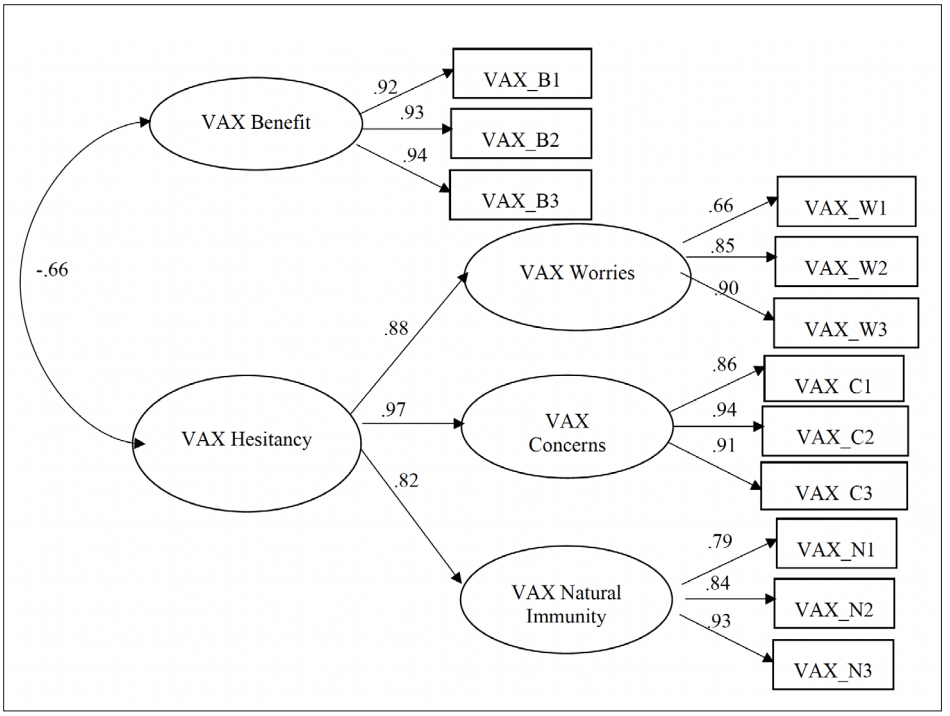

Fig. 1: Structure of the VAX scale (standardized parameters displayed

The descriptive statistics of the VAX scale and its subscales, including the results of the reliability analysis, are displayed in Table 3.

Table 2

Results of Confirmatory Factor Analysis of VAX Scale

	χ^2	df	p	CFI	TLI	RMSEA	SRMR	BIC
Model 1	235.25	48	<.001	.97	.96	.09 [.08.10]	.04	23531.76
Model 2	1646.62	54	<.001	.71	.64	.25 [.24.26]	.11	25530.07
Model 3	704.11	53	<.001	.89	.86	.15 [.14.16]	.06	24111.20
Model 4	237.44	50	<.001	.97	.96	.08 [.07.10]	.04	23520.44

Note. Model 1 = Four correlated factors; Model 2 = Single factor; Model 3 = Two correlated factors – Benefit (positive attitudes) and Hesitancy (negative attitudes); Model 4 = Hierarchical (second-order Vaccine Hesitancy factor correlated with first-order Vaccine Benefit factor; see Fig. 1)

Table 3
Descriptive statistics and internal consistencies of VAX scale (total sample)

	M	**SD**	**Skewness**	**Kurtosis**	**McDonald's ω total**
VAX					
Benefits	10.06	4.47	-0.15	-1.03	.95
Worries	12.26	3.73	-0.07	-0.66	.86
Concerns	10.34	4.81	0.14	-1.13	.93
Natural Immunity	10.33	4.16	0.26	-0.75	.89
Total Hesitancy*	32.92	11.42	0.20	-0.96	.94
TOTAL	43.86	14.55	0.32	-0.84	.94

*Total VAX score excluding the Benefits subscale

The effect of demographic variables and the overall VAX score on the structure of the VAX scale

The results of the multiple-group CFA to determine the level of measurement invariance of the VAX scale across different demographic groups in our sample, conducted on the hierarchical model, which exhibited the best fit in the general CFA, are displayed in Table 4. The table shows indicators of fit for models assuming configural invariance (Model 1; structure equivalent, but with parameters estimated freely across groups), metric invariance (Model 2; with factor loadings constrained to equality across groups, but intercepts, variances and covariances freely estimated), and scalar invariance (Model 3; with both factor loadings and intercepts constrained to equality across groups, but variances and covariances freely estimated).

Table 4
Results of measurement invariance testing of VAX scale

	χ^2	df	*p*	CFI	TLI	RMSEA	SRMR	BIC
Gender								
Model 1: Configural	278.03	100	<.001	.97	.96	.08 [.07.09]	.04	23750.57
Model 2: Metric	297.54	110	<.001	.97	.96	.08 [.07.09]	.05	23700.22
Model 3: Scalar	330.16	117	<.001	.97	.96	.08 [.07.09]	.05	23689.78
Age group (18-29 / 30-45 / 46-60 / 61+)								
Model 1: Configural	399.43	200	<.001	.97	.96	.09 [.07.10]	.05	24074.22
Model 2: Metric	452.25	230	<.001	.97	.96	.08 [.07.09]	.06	23925.10
Model 3: Scalar	538.74	251	<.001	.96	.95	.09 [.08.10]	.06	23875.47
Education level (college/secondary with leaving certificate/lower)								
Model 1: Configural	355.31	150	<.001	.97	.96	.09 [.08.10]	.04	23119.99
Model 2: Metric	387.90	170	<.001	.97	.96	.08 [.07.09]	.06	23015.32
Model 3: Scalar	414.79	184	<.001	.96	.96	.08 [.07.09]	.06	22951.36

Children (yes/no)								
Model 1: Configural	276.72	100	<.001	.97	.96	.08 [.07.09]	.04	23782.45
Model 2: Metric	296.37	110	<.001	.97	.96	.08 [.07.09]	.05	23730.91
Model 3: Scalar	321.94	117	<.001	.97	.96	.08 [.07.09]	.05	23711.89
Religion (Christian/ Spiritual-Unaffiliated/ Atheist)								
Model 1: Configural	322.23	150	<.001	.97	.96	.08 [.07.10]	.04	22186.79
Model 2: Metric	353.19	170	<.001	.97	.96	.08 [.07.09]	.05	22085.18
Model 3: Scalar	364.71	184	<.001	.97	.97	.08 [.07.09]	.05	22004.72
Vaccinated (yes/no)								
Model 1: Configural	234.99	100	<.001	.97	.96	.07 [.06.09]	.04	22736.06
Model 2: Metric	274.18	110	<.001	.96	.95	.08 [.07.09]	.06	22711.43
Model 3: Scalar	344.08	117	<.001	.95	.94	.09 [.08.10]	.07	22751.36

As seen in Table 4, in all analyses involving demographic groups but one, the most parsimonious (i.e., most constrained) Model 3 showed superior fit compared to Models 1 and 2 as indicated by the values of BIC. This means that no evidence of inter-group model variance was detected across different demographic indicators. The only exception was found with the vaccination status, in which Model 3, assuming scalar invariance, showed poorer fit than either Model 1 or Model 2, in which intercepts were allowed to vary freely.

The association between vaccination attitudes and demographic variables and physical health

Because the results of the CFA revealed that the correlation between the three "Hesitancy" subscales of the VAX scale were very close to 1.0, we performed all subsequent analyses separately for the Benefit subscale score and the total "Hesitancy" score, obtained by adding up the Worries about unforeseen future effects, Concerns about commercial profiteering, and Preference for natural immunity scores.

Table 5
Between-group comparisons (t-test) – VAX total score (more reasons to not get vaccinated)

VAX Benefit				
	t	df	*p*	*g*
Gender	3.62	655.77	< 0.01	.28
Children yes/no	-0.09	566.17	0.93	.01
Vaccinated yes/no	-25.88	407.30	< 0.01	1.95
VAX Hesitancy				
	t	df	*p*	*g*
Gender	-1.86	664.17	0.06	.14
Children yes/no	**-2.77**	**554.79**	**< 0.01**	.22
Vaccinated yes/no	17.34	282.95	< 0.01	1.57

Table 5 shows the results of group comparisons (between-group *t*-tests) for gender, parenthood status (parent vs. non-parent) and COVID-19 vaccination status. There was

a small difference in VAX Benefit scores between women (n = 391) and men (n = 301), with women (M = 9.52, SD = 4.50) showing somewhat lower Benefit scores compared to men (M = 10.75, SD = 4.35; Hedge's g = 0.28). Women also scored higher in Hesitancy (M = 33.62, SD = 11.71) than men did (M = 32.01, SD = 10.97), but the very small difference (Hedge's g = 0.14) did not reach significance. On the other hand, participants with children (n = 431) showed significantly higher Hesitancy (M = 33.85, SD = 11.42) compared to participants without children (n = 261, M = 31.39, SD = 11.26; Hedge's g = 0.22), but the difference in Benefit scores was negligible (With children: M = 10.07, SD = 4.54; No children: M = 10.04, SD = 4.36; Hedge's g = 0.01). The greatest difference, unsurprisingly, was found between the participants who had received at least one dose of vaccine against COVID-19 (n = 508) and those who had not been vaccinated (n = 172), with unvaccinated participants scoring substantially higher in Hesitancy (M = 44.00, SD = 9.78; Hedge's g = 1.57) and substantially lower in Benefit (M = 5.07, SD = 2.63; Hedge's g = 1.95) compared to vaccinated participants (Hesitancy: M = 29.22, SD = 9.30; Benefit: M = 11.75, SD = 3.65).

Table 6
Between-group comparisons (ANOVA) – VAX total score (more reasons to not get vaccinated)

VAX Benefit					
	F	df_1	df_2	p	H^2
Age group	4.42	3	688	< 0.01	.02
Education level	5.48	2	670	< 0.01	.02
Religion	7.51	2	638	< 0.01	.02
VAX Hesitancy					
	F	df_1	df_2	p	H^2
Age group	6.46	3	688	< 0.01	.03
Education level	13.04	2	670	< 0.01	.04
Religion	5.10	2	638	< 0.01	.02

Table 6 shows the results of one-way ANOVA conducted with demographic variables with more than one group. With respect to age, as with the multiple-group CFA, participants were divided into four groups: 18-to-29-year-olds (n = 147, Benefit: M = 10.25, SD = 4.44; Hesitancy: M = 29.31, SD = 11.07), 30-to-45-year-olds (n = 218, Benefit: M = 9.21, SD = 4.29; Hesitancy: M = 34.15, SD = 11.54), 46-to-60-year-olds (n = 165, Benefit: M = 10.28, SD = 4.39; Hesitancy: M = 33.84, SD = 10.82), and participants aged 61 and older (n = 162, Benefit: M = 10.80, SD = 4.47; Hesitancy: M = 33.61, SD = 11.58). As shown in Table 6, one-way ANOVA revealed significant effects of age group for both variables. A Tukey post-hoc test revealed that the group of 18-to-29-year-olds showed significantly less Hesitancy than all of the older groups (overall Hedge's g = 0.41). However, in the case of Benefit, the main difference was between the lowest-scoring group of 30-to-45-year-olds and all three other groups (overall Hedge's g = 0.28).

A similar effect was found with religious affiliation. In this analysis, three groups were compared: Christians (n = 133, Benefit: M = 10.89, SD = 4.10; Hesitancy: M = 31.29, SD = 10.46), atheists (n = 350, Benefit: M = 10.32, SD = 4.50; Hesitancy: M = 32.33, SD = 11.53),

and participants who identified themselves as spiritual but unaffiliated (n = 158, Benefit: M = 9.01, SD = 4.32; Hesitancy: M = 35.21, SD = 11.39). The spiritual-unaffiliated group was found to score significantly higher in Hesitancy (overall Hedge's g = 0.28) and significantly lower in Benefit (Hedge's g = 0.33) than both of the other groups, which did not differ significantly in either of the variables.

Finally, significant differences were also found with respect to education. Specifically, participants who only completed secondary vocational education without a school-leaving certificate (n = 221) showed significantly higher Hesitancy (M = 36.07, SD = 11.06) than either participants with fully completed secondary education with a school-leaving certificate (including college students; n = 262; M = 31.76, SD = 11.21), or participants with completed college education (n = 190; M = 30.97, SD = 11.37). The overall difference was of medium size (Hedge's g = 0.41). An expected difference in the opposite direction was found with Benefit (Secondary without certificate: M = 9.28, SD = 4.55; Secondary with certificate: M = 10.56, SD = 4.50; College: M = 10.36, SD = 4.27; overall Hedge's g = 0.27).

The effects of all demographic variables except vaccination status were compared using partial H^2 estimated through general linear modelling. The results, shown in Table 7, almost fully mirrored the results of the piecewise analyses in terms of group differences. The strongest demographic predictor of both VAX Benefit and VAX Hesitancy was education level, while the effect of parenthood on VAX Hesitancy was completely explained by the other variables. For VAX Benefit, the effects of the other predictors were comparable. For VAX Hesitancy, the effect of education was followed by the effects of age and religious affiliation, with gender differences only playing a minor role.

Table 7
Prediction of VAX total scores from demographic variables

Model 1: VAX Benefit						
	F	df_1	df_2	*p*	par. H^2	*R*2
Gender	5.62	1	604	0.02	.01	.10
Age group	4.66	3	604	< 0.01	.02	
Education level	15.02	2	604	< 0.01	.05	
Children yes/no	0.56	1	604	0.45	.00	
Religion	5.45	2	604	< 0.01	.02	
Model 2: VAX Hesitancy						
	F	df_1	df_2	*p*	par. H^2	*R*2
Gender	9.64	1	604	< 0.01	.02	.08
Age group	2.85	3	604	0.04	.01	
Education level	9.02	2	604	< 0.01	.03	
Children yes/no	0.01	1	604	0.93	.00	
Religion	5.22	2	604	< 0.01	.02	

Regarding perceived physical health, Spearman correlation analysis revealed a very weak, yet significant negative correlation with Hesitancy (ρ = -0.12, p < 0.01), and a non-significant weak negative relationship with Benefit (ρ = -0.07, p = 0.08).

Discussion

High rates of vaccine hesitancy and general unwillingness to get vaccinated despite official recommendations and pleas voiced by the medical and government authorities were perceived as a major challenge to public health in countries around the world during the COVID-19 pandemic. Predictors of vaccination willingness and hesitancy have been examined in numerous studies. In the present study, we examined vaccination attitudes during the COVID-19 pandemic in the Czech population using a version of the VAX scale (Martin & Petrie, 2017) modified to assess the four principal groups of vaccination attitudes – (lack of) perceived benefit of vaccines, worries about unforeseen future effects, concerns about profiteering, and preference for natural immunity – with respect to COVID-19 vaccines specifically. We assessed the factorial structure of the modified Czech translation of the scale and its measurement invariance across different demographic groups.

The results of the psychometric analysis provided evidence for good construct validity of the adapted Czech version of the VAX scale, although the factor loadings for the Benefit subscale were considerably high (>.90), which may indicate excessive homogeneity of some items. A similar result was found also in a recent study by Novák et al. (2025) validating the Slovak version of the VAX scale. Overall, the Czech version of the VAX scale displayed measurement invariance across different demographic groups. The four factors were even more strongly correlated than in the original validation study by Martin & Petrie (2017), which might have been related to the fact that our adapted version was specifically focused on COVID-19 vaccination attitudes measured during November and December 2021. The three subscales representing antivaccination attitudes – worries about unforeseen future effects, concerns about profiteering, and preference for natural immunity – were more strongly related to each other than to the remaining, perceived benefit dimension. As a result, a hierarchical solution, with Worries about unforeseen future effects, Concerns about commercial profiteering, and Preference for natural immunity loading on a second-order factor we referred to as "Hesitancy", produced a better fit for the data when model parsimony was taken into account. This merging of the three antivaccination subscales as opposed to the positively formulated Benefits scale may reflect distinct mechanisms for the formation of two sets of attitudes. For example, information regarding positive aspects of vaccination and that regarding potential negative aspect can come from different sources, which makes it possible for these two dimensions to co-exist without being explicitly in contradiction.

The results of the CFA, pointing at two rather than four main dimensions in the scale, prompted us to conduct the subsequent analyses of predictors separately for the Benefit score and the total Hesitancy score, obtained by summing up the three remaining subscale scores. The results of demographic group comparisons confirmed several significant, albeit mostly rather small differences, most of which were already documented in previous studies conducted both in the Central European and worldwide context (e.g., Malik et al., 2020; Murphy et al., 2021; Riad et al., 2021). Specifically, women scored higher on the VAX scale than men, although the difference was very small and only significant for the Benefit

subscale, indicating that women were somewhat less confident than men in the benefit of the COVID-19 vaccine. In contrast, parenthood was only associated with the Hesitancy score, with participants with children showing slightly but significantly stronger antivaccination attitudes compared to childless participants. According to research conducted by Rozbroj et al. (2020), attitudes towards vaccination tend to be at least partly influenced by establishing one's own family, though this does not apply to all parents, but rather particularly to originally vaccine-refusing or vaccine-hesitant parents, who may be even more concerned about possible side effect of vaccination after establishing a family. It should be noted that, in our sample, the significant difference held particularly for Worries about unforeseen future effects and Preference for natural immunity, which seems to be consistent with Rozbroj et al.'s explanation, as is the fact that the effect of parenthood was virtually eliminated when other predictors were added to the regression equation.

Age was another factor that played a significant, albeit small role in the attitudes towards vaccination in general. Specifically, young participants in emerging adulthood (aged 18 to 29) scored significantly lower on Hesitancy than the older groups, and the group of young working adults (aged 30 to 45) scored lower on Perceived vaccine benefit than the other three groups, especially the oldest group (60+). These results are not entirely in line with previous studies, several of which linked greater vaccine acceptance in general with older adulthood (Kweon et al., 2022; Malik et al., 2020). It must be noted, however, that we did not test for a linear relationship in our study, and the differences might have thus arisen from the use of different analytical approaches, as well as different age distributions in the research samples. Our results may have also been partly influenced by the fact that all participants in our study were Internet users and by the composition of the sample, specifically the high proportion of university students and graduates in the youngest group (76.9%) compared to the older groups (62.2%). Another possible explanation is the so-called "post-communist syndrome", which seems to be associated with generally lower levels of vaccine willingness (Enea et al. 2023), especially in people over 50 years of age (Berniell et al., 2021).

Regarding education level, previous research relatively consistently suggests that education is an important factor of vaccine hesitancy, with highly educated people displaying stronger willingness to get vaccinated than people with lower education levels (Enea et al., 2023). Our results showed more-or-less the same pattern: Participants who had completed secondary education with a school-leaving certificate and those who had a college degree showed a less strong endorsement of antivaccination attitudes compared to participants with a lower level of education (i.e., secondary school without a school-leaving exam).

Another demographic factor we examined was religious affiliation. According to previous studies (Garcia et al., 2021; Kibongani Volet et al., 2022), religiosity may be an important source of vaccine hesitancy because some aspects of vaccinations might clash with various religious beliefs. Consistent with this idea, in our study religious affiliation played a significant role in Benefit and Hesitancy subscales; however, the difference is not explainable by the universal religiosity dimension, as Christians actually scored lowest of all the three compared groups. The highest levels of antivaccination attitudes

were observed with the spiritual-unaffiliated group, who scored significantly higher than Christians or atheists. One explanation for this result may be that the Czech Republic is very specific in terms of religious affiliations compared to other European and non-European countries. During the 1990s, significant changes occurred in the religious beliefs in the Czech society, with many people distancing themselves from religious institutions and developing a non-institutional approach to religious beliefs, spirituality, or so-called 'alternative religiosity' (Spousta, 2002). Affiliation to Christianity, therefore, might not be necessarily associated with stronger religious beliefs, but might rather be the continuation of cultural traditions within the family. Therefore, the religious beliefs associated with vaccine hesitancy described in previous studies may not be so distinctive among Czech Christians as compared to other countries.

Subjectively perceived physical health was another factor included in our study for two reasons: First, some of previous studies presented subjective health status as one of the most important factors of COVID-19 vaccine hesitancy (Khan et al., 2021; Wang et al., 2022); second, due to the policy of the Czech Ministry of Health, preferential vaccination in the course of the pandemic was based not only on age, but also on health status (Ministry of Health CR, 2021a, b). However, our results did not reveal subjective physical health as a particularly important predictor of attitudes towards vaccination. A very weak negative relationship was only found between subjective physical health and Hesitancy, which means that participants who perceived themselves as less healthy were somewhat more vaccine hesitant.

Taken together, the demographic patterns observed in this study suggest several avenues for more targeted public health communication. Although most effects were small, they nonetheless point to specific groups for whom tailored content may be particularly relevant. Individuals with lower levels of education showed stronger antivaccination attitudes, indicating that communication strategies should prioritise clarity, avoidance of technical jargon, and the provision of accessible explanations of vaccine development, safety monitoring, and expected side effects. Parents, who were slightly more hesitant than non-parents, may benefit from messages that directly address concerns about long-term effects and provide evidence-based reassurance regarding vaccine safety for families. The spiritual-unaffiliated group displayed the highest levels of hesitancy; for this group, transparent, and autonomy-respecting communication, focusing on the practical benefits of vaccination and the reliability of scientific processes, may be more persuasive than appeals framed through institutional or moral authority. Age differences were small and somewhat inconsistent, but the relatively lower hesitancy among emerging adults suggests that social media-based interventions using peer communication or participatory formats could be effective for younger audiences. Overall, communication efforts should not rely solely on broad, population-wide messaging; instead, they would benefit from adapting tone, emphasis, and format to the specific concerns and informational needs of these demographic subgroups.

Limitations and future directions

In the present study, we attempted to shed some initial light on the demographic factors of and (lack of) differentiation between different types of COVID-19 attitudes towards vaccination. Although we believe our findings point in some relevant directions, they are limited both in scope and interpretability and serve mainly as an inspiration for a more systematic investigation of the indicated issues.

First, the present study was limited to the Czech context, and while we attempted to obtain a sample representative of the general population, the number of participants in the individual demographic categories was too small to reliably investigate the interaction effects of various combinations of demographic indicators. It is also important to examine which of these factors and associations are universal to different socio-political and cultural contexts, and which macrosocial factors may serve as moderators of these relationships. Such questions can only be addressed through carefully designed cross-cultural studies.

Another potential limitation of our study arises from the use of the VAX scale, which was originally designed as a general measure of attitudes toward vaccination outside the context of COVID-19. Although the scale captures many of the most common arguments against vaccination, certain items may be less relevant to the COVID-19 situation (e.g., concerns about unexpected side effects in children). At the same time, some beliefs that became prominent during the COVID-19 pandemic, such as the idea that vaccination programmes serve as tools of political control over specific groups, may not be adequately represented.

In addition, some items in the adapted scale, such as "*I feel safe when I am vaccinated against COVID-19.*", presuppose that respondents have been vaccinated. While unvaccinated participants could answer these items in a hypothetical manner, this may nonetheless affect response accuracy and contribute to differential item interpretation. This limitation should be taken into account when using the scale in mixed samples, and future versions may benefit from neutral phrasing that does not assume prior vaccination.

Furthermore, the hierarchical structure of the VAX scale observed in our data may not necessarily be generalised to all the language versions or cultural contexts in which it has been applied during the COVID-19 pandemic. Because our research addressed the 'clustering' of COVID-19 vaccination attitudes in a rather broad manner, the results - especially when considered alongside these limitations - raise more questions than provide definitive answers.

A central question that emerges is whether certain universal 'core' beliefs exist that, once adopted, predispose people to embrace a broader set of scientifically unfounded views about vaccination. If these core beliefs can be identified, future research could focus on understanding the individual and contextual factors that make people more likely to adopt and maintain them. The insights of such studies could help bridge the gap between scientifically grounded recommendations and public doubts, fears, and concerns about vaccination, ultimately supporting more effective communication between health authorities and the public.

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APPENDIX

The Vaccination Attitudes Examination (VAX) Scale – modified English version

(*Original version:* Martin, L. R., & Petrie, K. J. (2017). Understanding the dimensions of anti-vaccination attitudes: The Vaccination Attitudes Examination (VAX) scale. *Annals of Behavioral Medicine, 51*(5), 652–660. https://doi.org/10.1007/s12160-017-9888-y)

These questions are designed to help us better understand people's beliefs about COVID-19 vaccinations. Please mark the choices that most accurately reflect your feelings or beliefs. There are no right or wrong responses.

1. I feel safe when I am vaccinated against COVID-19. (-)
2. I can rely on vaccines to stop COVID-19. (-)
3. I feel protected after getting vaccinated against COVID-19. (-)
4. Although the COVID-19 vaccines appear to be safe, there may be problems that we have not yet discovered.
5. COVID-19 vaccines can cause unforeseen problems in children.
6. I worry about the unknown effects of COVID-19 vaccines in the future.
7. COVID-19 vaccines make a lot of money for pharmaceutical companies, but do not do much for regular people.
8. Authorities promote COVID-19 vaccination for financial gain, not for people's health.
9. The COVID-19 vaccination program is a big con.
10. Natural immunity lasts longer than the COVID-19 vaccination.
11. Natural exposure to the virus gives the safest protection.
12. Being exposed to COVID-19 naturally is safer for the immune system than being exposed through vaccination.

Response scale: 1 = Strongly disagree; 2 = Disagree; 3 = Somewhat disagree; 4 = Somewhat agree; 5 = Agree; 6 = Strongly agree

VAX subscales: 1, 2, 3: *Mistrust of vaccine benefit* (reversed items); 4, 5, 6: *Worries about future effects*; 7, 8, 9: *Concerns about commercial profiteering*; 10, 11, 12: *Preference for natural immunity*.

The Vaccination Attitudes Examination (VAX) Scale – modified Czech version

Následující otázky jsou navrženy tak, aby nám pomohly lépe porozumět názorům lidí na očkování proti COVID-19. Označte prosím možnosti, které nejpřesněji odrážejí vaše pocity nebo přesvědčení. Neexistují žádné správné nebo špatné odpovědi.

1. Po očkování proti COVID-19 se cítím bezpečně. (-)
2. Když se chci ubránit koronaviru, mohu se spolehnout na vakcíny. (-)
3. Po očkování proti COVID-19 se cítím být chráněný/á. (-)

4. Přestože se vakcíny proti COVID-19 zdají být bezpečné, mohou nastat problémy, které jsme dosud neobjevili.
5. Vakcíny proti COVID-19 mohou způsobit nepředvídané problémy u dětí.
6. Mám obavy z neznámých budoucích účinků vakcín proti COVID-19.
7. Vakcíny proti COVID-19 vydělávají velké peníze pro farmaceutické společnosti, ale nedělají moc pro běžné lidi.
8. Úřady propagují očkování proti COVID-19 za účelem finančního zisku, nikoli pro zdraví lidí.
9. Očkovací program proti COVID-19 je velký podfuk.
10. Přirozená imunita trvá déle než účinky očkování proti COVID-19.
11. Přirozené vystavení se koronaviru poskytuje nejlepší ochranu.
12. Přirozené vystavení se koronaviru je pro imunitní systém bezpečnější než očkování.

Odpověďová škála: 1 = Rozhodně nesouhlasím; 2 = Nesouhlasím; 3 = Spíš nesouhlasím; 4 = Spíš souhlasím; 5 = Souhlasím; 6 = Rozhodně souhlasím

VAX subškály: 1, 2, 3: *Nedůvěra v přínosy vakcíny* (obrácené položky); 4, 5, 6: *Obavy z budoucích dopadů*; 7, 8, 9: *Obavy z komerčního zneužití*; 10, 11, 12: *Preference přirozené imunity*.

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