


Original Research

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Cross-Country Discrepancies in Monkeypox Vaccine Hesitancy Among Postgraduate and Undergraduate Medical Students

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Abstract

Background: Medical students hold significant importance, as they represent the future of healthcare provision. This study aimed to explore psychological antecedents towards the monkeypox (mpox) vaccines among postgraduate and undergraduate medical students across countries.

Methods: A cross-sectional survey was conducted among medical students aged 18 years old and above in 7 countries; Egypt, Romania, Malaysia, and Yemen, Iraq, India, and Nigeria. We used social media platforms between September 27 and November 4, 2022. An anonymous online survey using the 5C scale was conducted using snowball and convenience Sampling methods to assess the 5 psychological antecedents of vaccination (i.e., confidence, constraints, complacency, and calculation, as well as collective responsibility).

Results: A total of 2780 participants were recruited. Participants' median age was 22 years and 52.1% of them were males. The 5C psychological antecedents of vaccination were as follows: 55% were confident about vaccination, 10% were complacent, 12% experienced constraints, and 41% calculated the risk and benefit. Lastly, 32% were willing to be vaccinated for the prevention of infection transmission to others. The Country was a significant predictor of confidence, complacency, having constraints, and calculation domains ($P < 0.001$). Having any idea about the mpox vaccine was linked to 1.6 times higher odds of being more confident [OR = 1.58 (95% CI, 1.26–1.98), $P < 0.001$] Additionally, living in a rural area significantly increased complacency [OR = 1.42 (95% CI, 1.05–1.95), $P = 0.024$] as well as having anyone die from mpox [OR = 3.3 (95% CI, 1.64–6.68), $P < 0.001$]. Education level was associated with increased calculation [OR = 2.74 (95% CI, 1.62–4.64), $P < 0.001$]. Moreover, being single and having no chronic diseases significantly increased the calculation domain [OR = 1.40 (95% CI, 1.06–1.98), $P = 0.02$] and [OR = 1.54 (95% CI, 1.10–2.16), $P = 0.012$] respectively. Predictors of collective responsibility were age 31–45 years [OR = 2.89 (95% CI, 1.29–6.48), $P = 0.01$], being single [OR = 2.76 (95% CI, 1.94–3.92), $P < 0.001$], being a graduate [OR = 1.59 (95% CI (1.32–1.92), $P < 0.001$], having no chronic disease [OR = 2.14 (95% CI, 1.56–2.93), $P < 0.001$], and not knowing anyone who died from mpox [OR = 2.54 (95% CI, 1.39–4.64), $P < 0.001$], as well as living in a middle-income country [OR = 0.623, (95% CI, 0.51–0.73), $P < 0.001$].

Conclusions: This study underscores the multifaceted nature of psychological antecedents of vaccination, emphasizing the impact of socio-demographic factors, geographic location, and awareness, as well as previous experiences on individual attitudes and collective responsibility towards vaccination.

Introduction

Monkeypox virus (mpvx) is a double-stranded DNA virus belonging to the orthopoxviral genus.¹ It is a part of the Poxviridae family causing a zoonotic disease that was recorded for the first time in a child in the Democratic Republic of Congo (DRC).² The disease was mainly endemic in the central and western regions of Africa until 2003 when a major outbreak occurred in the United States of America (USA), due to the importation of animals such as the Gambian giant from Ghana which resulted in the infection of 53 patients according to the Centers for Disease Control and Prevention (CDC).^{3,4} After that, there were sporadic cases of the disease outside Africa. However, in May 2022, a major outbreak started to emerge which prompted the World Health Organization (WHO) to declare the disease a public health emergency of international concern (PHIC).⁵

The CDC recommends a range of measures including vaccination to prevent the disease including vaccination for healthcare providers (HCPs) and lab technicians exposed to the infection. Also, men who have sex with men (MSM), people who have multiple sex partners, or those newly diagnosed with a sexually transmitted disease, should be vaccinated.^{6,7} According to the CDC, there are 2 vaccines used in the vaccination program. The JYNNEOS vaccine is the first choice, administered as 2 doses of subcutaneous or intradermal injection. It is used in people who are over 18 years old. Then it received an emergency use to be used in a group lower than 18 years old. The ACAM2000 vaccine is the second choice, which is administered as a single-dose injection.^{3,8,9} A comprehensive systematic review encompassing 41 articles affirms the safety, immunogenicity, and efficacy of Mpox vaccines in effectively managing disease transmission.¹⁰

Vaccine hesitancy (VH) refers to the reluctance or delay in getting vaccinated despite its availability.¹¹ Different factors are associated with this phenomenon, such as false knowledge about vaccines and vaccination safety which are shared on social platforms.¹² Many of the recipients focus on vaccine safety and its associated side effects in the long term rather than focusing on the benefits of taking this vaccine in the prevention of the disease.¹³ The HCWs must be knowledgeable about the vaccines they introduce, to help in addressing any questions about the vaccines as the unanswered questions contribute to hesitancy and other factors based on the receivers' trust in the vaccine agencies.¹⁴ A point to consider is that there is a religion-based factor in accepting or refusing the vaccine based on the components and materials used in this vaccine, especially regarding the use of bovine or porcine raw materials.¹⁵ VH is considered a public health concern that needs to be monitored and eliminated. This attitude leads to spread in the vaccine's preventable diseases and new cases of incidence, such as in the case of the measles outbreak in 2011 and 2019 due to unvaccinated individuals.¹⁶

Investigating the factors that impact mpox-vaccination hesitancy among medical students holds significant importance as they represent the future of healthcare provision. Gaining an understanding of their perceptions and attitudes towards vaccines is crucial for ensuring their dedication to public health initiatives. Addressing these factors through education, building trust, and role modeling can help mitigate VH and promote vaccination among medical students, ensuring their active participation in controlling the spread of mpox. Furthermore, as prospective HCWs, they possess a considerable influence on patients' trust and acceptance of vaccines. Their attitudes and beliefs can shape the decisions made by their future patients. It is noteworthy that

medical students often have direct interaction with patients during their training, including vulnerable populations such as the elderly or immunocompromised individuals who may require protection against vaccine-preventable diseases like mpox. Lastly, the findings obtained from studying VH among medical students can have broader implications that extend beyond this particular population. By examining VH among medical students, we can gain insights into the underlying reasons for vaccine skepticism and develop strategies that can be applied to diverse populations.

To enhance the effectiveness of interventions that impact a person's decision to get vaccinated, the 5C scale was created.¹⁷ Unlike other instruments that focus solely on the 3C model, which considers constraints, complacency, and confidence, the 5C scale stands out by comprehensively evaluating 5 psychological antecedents. These include confidence that the vaccine is safe and effective, being complacent about important risk factors, logistical constraints, and calculating the amount of medical information that is available, as well as collective responsibility for public health.¹⁸ The 5C scale has already been widely used to assess the coronavirus disease (COVID-19),¹⁸ the seasonal influenza vaccination,¹⁹ and mpox.^{20,21} This study hypothesized that medical students either postgraduate or undergraduate exhibit a notable prevalence of hesitancy towards the mpox vaccine. Our aim was to explore the psychological antecedents related to mpox vaccines among medical students in various countries, utilizing the comprehensive 5C scale. Recognizing the factors influencing VH and customizing interventions to address specific concerns in diverse countries is imperative for enhancing disease prevention and control efforts.

Materials and Methods

Study Design

An online cross-sectional survey was anonymously conducted through commonly used social media platforms, including Facebook, WhatsApp, and Twitter. The questionnaire was created using Google Forms and distributed to postgraduate and undergraduate medical students from October 8, 2022, to December 13, 2022.

Study Population and Sample Size

The study's participants were medical students in 7 different countries around the world: Egypt, Nigeria, Romania, Malaysia, Yemen, Iraq, India. Medical students who were at least 18 years old and had internet access were also included.

The required sample size for the investigation was calculated using the following formula:

$$n = \frac{Z^2 * P(1 - P)}{e^2}$$

where P is the estimated prevalence rate from prior studies, n is the minimum number of respondents required, Z² is the relative value of 1.96 for the 95% confidence interval (CI), and e is the necessary precision of 5%. It was presumed that 50% of the medical students would be willing to receive the mpox vaccine due to the lack of prior research on their attitudes. Our calculations implied that the study required a sample size of at least 384 medical students from each country. To account for any inconsistent or incomplete data, the sample size was increased to 400 participants from each

country. The survey was distributed using convenience and snowball sampling methods.

Data Collection Tool

The questionnaire's initial part provided information about the study objectives, requested consent to participate, and guaranteed confidentiality of responses. The questionnaire consisted of several sections:

- 1) Section 1: The collected socio-demographic data includes information such as age, gender, nationality, and country, as well as marital status, living area, financial status, and education level, with occupation. Additionally, it features yes/ no questions about the presence of chronic diseases, previous experience with mpox infection, and awareness of mpox vaccination, as well as knowledge of someone who died from mpox.
- 2) Section 2: of the survey focused on measuring attitudes and perceptions using a 5C questionnaire. This questionnaire covered 5 domains: confidence, complacency, constraints, and calculations, as well as collective responsibility. Each domain had 3 questions, and participants were asked to rate their agreement or disagreement on a 5-point Likert Scale (ranging from 1: strongly disagree to 5: strongly agree). The questionnaire was provided in 3 different languages: English,¹⁷ German, and Arabic.²² The participants were allowed to choose a suitable language for them.

The cutoff points for each domain have been established as well in previous study.²³ The area under the curve of the 5 scales was 0.72, 0.60, 0.76, 0.66, and 0.66 for confidence, complacency, constraints, and calculation, as well as collective responsibility at cutoff values of 5.7, 4.7, 6.0, 6.3, and 6.2, respectively. To maintain data integrity, only 1 response per unique IP address was allowed. This measure was put in place to prevent any duplicate or fraudulent responses. The survey's opening page included information on the study's research goals, participation consent, and guarantees of anonymity. The time to answer the questionnaire ranged from 5 to 10 minutes. Before starting data collection, the research team performed a pilot study to test the feasibility and accessibility of their online tool. Each collaborator was asked to submit at least 2 responses, and necessary modifications were made to enhance the clarity and applicability of the questionnaires.

Operational Definitions

- 1) Confidence: This expression refers to public confidence in vaccinations, including their effectiveness and reliability, as well as their trust in the healthcare system and HCWs. When there is mistrust or lack of confidence in vaccinations, adoption rates may decrease. This can lead to a loss of trust in the healthcare system and an increase in the acceptance of misinformation. These statements were included in the survey's confidence domain questions: I have complete faith that vaccines are safe, complete faith that vaccine's function, and complete faith that public authorities will choose vaccines that are best for the population.^{17,24}
- 2) Constraints: Various barriers may hinder people from receiving vaccinations, both structural and psychological. These barriers could include limited access to vaccines, difficulties in finding time to get vaccinated, a lack of self-confidence or empowerment, and a sense of being unable to

control one's behavior. These obstacles could prevent someone from getting vaccinated, even if they have the intention to do so. Such barriers include access, time, self-efficacy, empowerment, and a lack of behavioral control.^{17,24}

- 3) Complacency: Some complacent people tend to underestimate the risks of diseases that can be prevented by vaccination, and therefore do not perceive vaccination as a necessary preventive strategy. The complacency section of the survey also addressed perceptions that vaccine-preventable diseases are uncommon, that a strong immune system may provide adequate defense, and that vaccine-preventable diseases are not serious enough to require immunization.^{17,24}
- 4) Calculation: It refers to gathering information to compare the risks of developing a disease vs. the hazards of having a vaccination to help 1 make an informed decision. This conduct, which is seen as a sign of risk aversion, could be harmful to vaccination strategies.^{17,24} The survey's questions in the calculation domain cover subjects including weighing advantages and risks, carefully evaluating the worth of each vaccination, and the need to understand the fundamentals of vaccination before receiving it.^{17,24}
- 5) Collective responsibility: is identified as the willingness to protect others by immunizing oneself through herd immunity. It refers to those who vaccinate themselves in order to safeguard others and gain a better understanding of how herd immunity limits transmission.^{17,24}

Statistical Analysis

The demographic characteristics and questionnaire responses of the respondents were expressed using numbers and percentages. The bivariate analysis evaluated the association between independent variables, such as demographic and sociological characteristics, and attitudes towards mpox vaccines. The variables that received a P -value < 0.05 in bivariate analysis were subjected to multivariate logistic regression analysis to determine the factors influencing their decision to receive mpox vaccines. The variables were described using odds ratios (OR) and 95% CI, with P -value < 0.05 considered statistically significant. To quantify how much each predictor contributed to the result, the multivariate analysis computed coefficients for each predictor included in the final model and adjusted them in relation to the other variables in the model. The likelihood ratio test and the omnibus test that demonstrated an improvement over the null model in the 5 fitted models were used to assess the overall model fit. SPSS version 16 (IBM Corp., Armonk, New York, USA) was used for all statistical analyses.

Ethics

This study was approved by the High Institute of Public Health Ethics Committee at Alexandria University (IRB No. 00012098/ FWA No. 00018699). The first page of the questionnaire contains complete information about the study objective, methods, the rights, and confidentiality of participation. Before starting the questionnaire, every participant provided online informed consent.

Results

Participants' Demographics

In this multinational study, 2780 participants were recruited from 7 different countries: Romania (410), Iraq (403), India (400), and

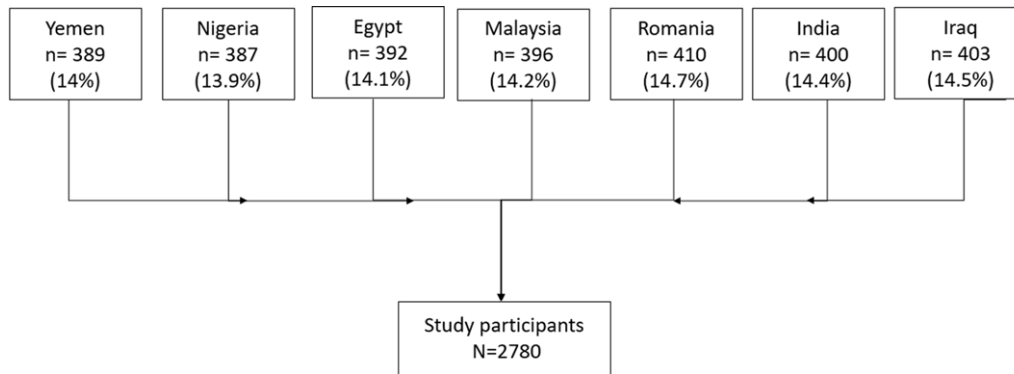


Figure 1. Consort flowchart for participation.

Malaysia (396), as well as Egypt (395), Yemen (389), and Nigeria (387). In total, 99.8% of the respondents agreed to answer the questionnaire. Of the participants, 60.6% utilized the English form, 39% opted for the Arabic version, and a small percentage (0.4%) utilized the German tool. Of the study participants, 52.1% (n = 1449) were males. The age range of participants was between 18–60 years old. Among the participants, 86.6% (n = 2408) were single, 81.7% (n = 2267) lived in urban areas, and 67.5% (n = 1876) had a middle-income, while 68% (n = 1890) were graduates, 12.8% (n = 355) reported chronic diseases, 3.8% (n = 105) had mpox, and 4.1% (n = 114) knew someone who passed away due to mpox (Figure 1, Table 1).

Overall Results of 5C Psychological Antecedents for MPX Vaccination

Of the sample under investigation, 55.1% expressed confidence in the mpox vaccination, 10.0% showed complacency towards the vaccine, 12.2% perceived constraints in the mpox vaccination, and 41.6% evaluated the risk and benefit of vaccination, while 32.1% consented to receive the mpox vaccination in order to protect others (Figures 2, 3).

Confidence

Regarding mpox vaccination, 76.3 % of participants from India were confident, compared to 57.1 % from Iraq, 53 % from Nigeria, and 40.1% from Yemen. They were also more confident participants from Egypt (37%), Romania (32.9%), and Malaysia (<20%). Females were more confident regarding mpox vaccination compared to males (48% vs. 42.4, $P = 0.007$). Higher confidence was noted in the age groups (18–30 and 31–45) by 45.1 % and 40.6%, respectively, compared with 0.0% in ages > 45 years old. Confidence was more common among single participants (46.6%) and married participants (43.8%) than among others who had a partner ($P < 0.001$). Residence was significantly associated with mpox vaccine confidence. People who were living in rural areas were more confident with vaccination than those living in urban areas (51.1% vs. 43.7%, $P = 0.015$). Graduated participants and postgraduates had a non-significant confidence of 45.6% compared to 43.3% of the undergraduates. Participants with the highest income or those who had an idea about various mpox vaccines had significantly higher vaccine confidence rates compared to others (50.9% and 51.9%, respectively). Having a history of chronic disease was inversely associated with mpox vaccine confidence; about 27.7% of the participants with chronic disease were confident regarding mpox vaccination compared to 47.5% among

those who did not report a history of chronic disease ($P = 0.001$). The previous infection with mpox significantly affected participant confidence, as only 40% of participants who experienced mpox were confident ($P = 0.001$) (Table 2).

Complacency

Among the variables studied, including gender, age, and marital status, as well as education, and financial status, none demonstrated a significant impact on complacency levels. Although trends indicated higher complacency among single individuals compared to married or partnered individuals (11.6%, 9.9%, and 10.0%, respectively), among those with high income compared to middle and low-income groups (11.2%, 10.4%, and 8.1%, respectively). However, these differences did not reach statistical significance (Table 2).

The level of complacency was notably influenced by the absence of chronic diseases or a lack of prior infection with mpox. Individuals without chronic diseases demonstrated lower complacency in comparison to those with chronic diseases (5.9% vs. 13.9%, $P = 0.007$). Similarly, a history of a confirmed mpox infection was associated with significantly lower complacency. Conversely, being acquainted with someone who had experienced passed out due to mpox was significantly associated with higher complacency ($P < 0.001$). (Table 2).

Constraints

High constraints were notably prevalent in 24.3% of participants from Egypt, followed by Romania and India with rates of 19.9% and 14.5%, respectively. In contrast, other countries showed rates of 10% or less ($P < 0.001$), indicating significantly lower levels of perceived constraints in those regions. Likewise, the presence of constraints was notably significant among individuals without any chronic diseases (12.8% vs. 7.7%). Additionally, 13.2% of participants who had not experienced mpox reported constraints, in contrast to those who had mpox (3.8%) or were uncertain about their mpox status (7.0%). On the contrary, constraints did not exhibit significant differences across various age groups, genders, or educational levels (Table 2).

Calculation

Participants from Iraq, Yemen, Nigeria, and Egypt significantly showed collective responsibility of 71.7%, 64.5%, 50.6%, and 45.8%, respectively. Of participants aged 31–45 years old, 43.8% of them showed calculation with a non-significant difference between different age groups ($P = 0.95$). Income level showed no association with calculation. Marital status, residence, and

Table 1. Demographics of the study participants

Characteristic	Frequency (%) (N = 2780)
Age	
Median	22 years (IQR: 20 - 23)
Range	18 - 60
Gender	
Male	1449 (52.1%)
Female	1331 (47.8%)
Nationality	
Iraqi	406 (14.6%)
Indian	404 (14.5%)
Romanian	410 (14.5%)
Malaysian	398 (14.31%)
Egyptian	392 (14.1%)
Nigerian	391 (14.06%)
Yemeni	385 (13.8%)
Country where you are living now	
Romania	410 (14.7%)
Iraq	403 (14.5%)
India	400 (14.4%)
Malaysia	396 (14.2%)
Egypt	395 (14.2%)
Yemen	389 (14%)
Nigeria	387(13.9%)
Questionnaire language	
English	1684 (60.6%)
Arabic	1084 (39%)
German	12 (0.4%)
Marital status	
Having a partner	251 (9%)
Married	121 (4.4%)
Single	2408 (86.6%)
Living area	
Urban	2267 (81.7%)
Rural	510 (18.3%)
Financial status	
Low-income	624 (22.4%)
Middle-income	1876 (67.5%)
High-income	280 (10%)
Education	
Undergraduate	811 (29.2%)
Graduate*	1890 (68%)
Postgraduate*	79 (2.8%)
Occupation	
Student	21 (0.7%)
Student in health or medical faculty	2759 (99.2%)
Chronic disease	
Yes	355 (12.8%)
No	2425 (87.2%)
Have you had monkeypox?	
Yes	105 (3.8%)
No	2389 (85.9%)
I don't know	286 (10.3%)

(Continued)

Table 1. (Continued)

Characteristic	Frequency (%) (N = 2780)
Has anyone that you know of died due to monkeypox?	
Yes	114 (4.1%)
No	2288 (82.3%)
I don't know	378 (13.6%)
Do you have any idea about various types of Monkeypox vaccinations?	
Yes	762 (27.4%)
No	2018 (72.6%)

*Graduate and postgraduate students refer to students who have completed their undergraduate (bachelor's) degree and are pursuing further education. The difference in terminology based on the educational system in the different countries included in the study.

education significantly affected the calculation, with the highest percentages in married, urban, as well as postgraduate groups. Having a chronic disease or knowing anyone who died from mpox significantly related inversely with the calculation (19.5% and 21.1% respectively) (Table 2).

Collective responsibility

Participants from Iraq, India, Yemen, and Nigeria significantly showed collective responsibility 50.1%, 48.8%, 47.3%, and 46.5%, respectively. Of participants aged 31–45 years old, 43.8% showed collective responsibility, with non-significant differences between different age groups ($P = 0.18$). Marital and, financial status as well as education significantly affect collective responsibility, with the highest percentage in married, low-income, and graduate groups (34.3%, 40.1%, and 34.5%, respectively). Having a chronic disease or mpox infection or knowing anyone who died from mpox significantly related inversely with collective responsibility (16.1%, 21.9 %, and 12.3%, respectively) (Table 2).

The Determinants of 5C Antecedents of Mpox Vaccination in the Study Sample

The factors affecting the psychological antecedents of the participants about the mpox vaccine in 5 separate binary logistic regression models are shown in Table 3.

The difference in the country was a significant predictor in confidence, complacency, having constraints, and calculation domains ($P < 0.001$). Having any idea about mpox vaccine was associated with 1.6 times higher odds of being more confident [OR = 1.58 (95% CI, 1.26–1.98), $P < 0.001$] Additionally, living in a rural area significantly increased the OR of mpox complacency [OR = 1.42 (95% CI, 1.05–1.95), $P = 0.024$] as well as having anyone you know die from mpox [OR = 3.3 (95% CI, 1.64–6.68), $P < 0.001$]. The significant predictor of constraints, rather than country, was being a postgraduate with double OR than undergraduates [OR = 2.20 (95% CI, 1.24–3.92), $P = 0.007$]. Also, education level was a predictor for calculation domains [OR = 2.74 (95% CI, 1.62–4.64), $P < 0.001$]. Being single and having no chronic diseases significantly increased the calculation domain [OR = 1.40 (95% CI, 1.06–1.98), $P = 0.02$] and [OR = 1.54 (95% CI, 1.10–2.16), $P = 0.012$], respectively. Regarding having collective responsibility, predictors that were associated with increased OR were age 31–45 years old [OR = 2.89 (95% CI, 1.29–6.48), $P = 0.01$], being single [OR = 2.76 (95% CI, 1.94–3.92),

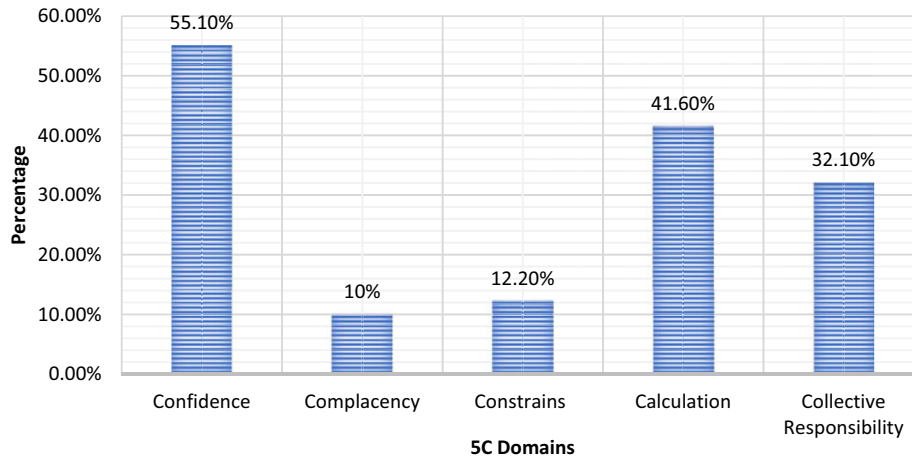


Figure 2. The 5C scale domains across different variables among the sample.

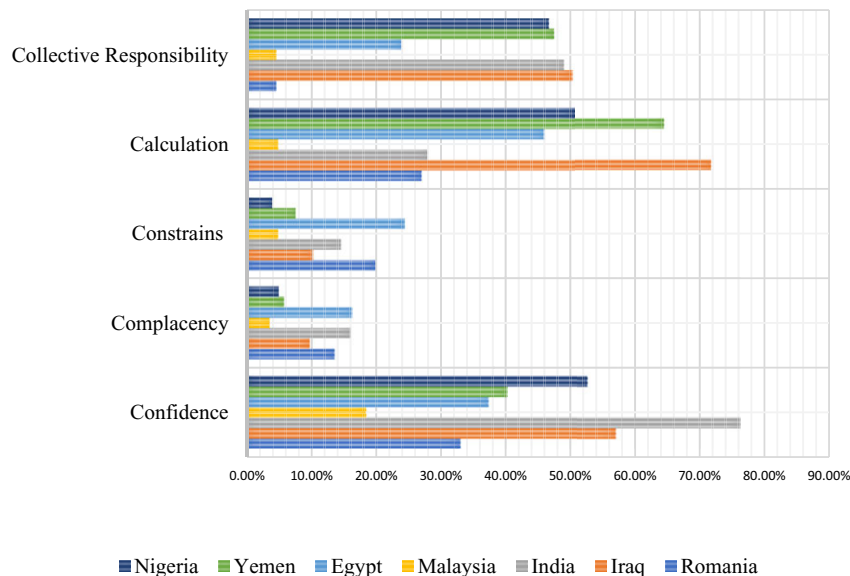


Figure 3. The 5C domains on the x-axis for each country.

$P < 0.001$], being graduate [OR = 1.59 (95% CI (1.32–1.92), $P < 0.001$], having no chronic disease [OR = 2.14 (95% CI, 1.56–2.93), $P < 0.001$], and not knowing anyone who died from mpox [OR = 2.54 (95% CI, 1.39–4.64), $P < 0.001$]. Middle income was significantly associated with decreased odds of collective responsibility [OR = 0.623, (95% CI, 0.51–0.73), $P < 0.001$].

Discussion

Due to the declaration of mpox as a PHIC concern by the WHO, there was great attention to the disease by different countries and research institutes to identify more about the disease characteristics, transmission, and preventive measures.²⁵ The JYNNEOS vaccine received FDA approval for mpox prevention, along with the ACAM2000 vaccine, which received expanded access to investigational new drug mechanisms.²⁶ Vaccination is recommended to a specific group of the population who are highly exposed to the infection, such as MSM, laboratory personnel who

are dealing with MPXV specimens, and HCPs who are in frontline contact with the infected patients.⁶

VH is a growing concern in the community (in children and adults) towards different vaccines, including the compulsory ones,²⁷ especially during COVID-19.²⁸ Medical students are not immune to this phenomenon. Medical students will be the future healthcare workers who will be dealing with mpox patients. Hence, they will be subjected to vaccination at that time based on the current recommendation from the CDC. Most studies are deficient in addressing the hesitancy in medical students. Cross-country discrepancies in VH among postgraduate and undergraduate medical students can have significant implications for public health, patient care, and medical education. Hence, this study aimed to identify the psychological factors affecting the VH in medical students. We focused more on the different domains included in the 5C questionnaire, and the study covered the participants' intentions toward mpox vaccination in 7 countries around the globe, which included Egypt, Romania, Iraq, and India, as well as Malaysia, Yemen, and Nigeria. More than 70% of the

Table 2. Factors associated with the domains of the 5C scale

Variables	Confidence		Complacency		Constraints		Calculation		Collective Responsibility	
	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)
Age										
18–30	1235 (45.1%)	1504 (54.9%)	274 (10%)	2463 (90%)	337 (12.3%)	2401 (87.7%)	1141 (41.7%)	1597 (58.3%)	877 (32%)	1861 (68%)
31–45	13 (40.6%)	19 (59.4%)	2 (6.5%)	29 (93.5%)	1 (3.1%)	31 (96.6%)	13 (41.9%)	18 (58.1%)	14 (43.8%)	18 (56.3%)
46–63	0 (0%)	3 (100%)	0 (0%)	3 (100%)	0 (0%)	3 (100%)	1 (33.3%)	2 (66.7%)	0 (0%)	3 (100%)
<i>P</i> -value	0.258		0.682		0.234		0.958		0.181	
Gender										
Male	614 (42.4%)	835 (57.6%)	146 (10.1%)	1302 (89.9%)	178 (12.3%)	1271 (87.7%)	551 (38%)	898 (62%)	434 (29.9%)	1015 (70.1%)
Female	636 (48%)	689 (52%)	130 (9.8%)	1201 (90.2%)	161 (12.1%)	1170 (87.9%)	602 (45.2%)	729 (54.8%)	465 (34.9%)	866 (65.1%)
<i>P</i> -value	0.007*		0.963		0.994		< 0.001*		0.008*	
Questionnaire language										
English	752 (44.7%)	932 (55.3%)	163 (9.7%)	1521 (90.3%)	188 (11.2%)	1496 (88.8%)	489 (29%)	1195 (71%)	450 (26.7%)	1234 (73.3%)
Arabic	490 (45.2%)	594 (54.8%)	112 (10.3%)	972 (89.7%)	146 (13.5%)	938 (86.5%)	662 (61.1%)	422 (38.9%)	441 (40.7%)	643 (59.3%)
German	6 (100%)	0 (0%)	1 (33.3%)	2 (66.7%)	4 (80%)	1 (20%)	4 (100%)	0 (0%)	0 (0%)	5 (100%)
<i>P</i> -value	0.024*		0.343		< 0.001*		< 0.001*		<0.001*	
Nationality										
Iraqi	232 (57.1%)	174 (42.9%)	39 (9.5%)	367 (90.5%)	41 (10.2%)	365 (89.8%)	289 (71.3%)	117 (28.7%)	205 (50.4%)	200 (49.6%)
Indian	309 (76.4%)	95 (23.6%)	64 (16%)	339 (84%)	60 (14.5%)	345 (85.5%)	112 (27.8%)	292 (72.2%)	198 (48.9%)	206 (51.1%)
Romanian	134 (33.2%)	270 (66.8%)	60 (13.6%)	349 (86.4%)	78 (19.2%)	326 (80.8%)	103 (25.4%)	301 (74.6%)	15 (3.8%)	389 (96.2%)
Malaysian	73 (18.3%)	325 (81.7%)	14 (3.6%)	384 (96.4%)	19 (4.8%)	379 (95.2%)	19 (4.8%)	379 (95.2%)	18 (4.6%)	380 (95.4%)
Egyptian	146 (37.2%)	246 (62.8%)	65 (16.5%)	327 (95.3%)	97 (24.8%)	295 (75.2%)	251 (46.0%)	212 (54.0%)	90 (23%)	302 (77%)
Nigerian	206 (52.8%)	184 (47.2%)	18 (4.7%)	373 (95.3%)	14 (3.6%)	376 (96.4%)	194 (49.5%)	197 (50.5%)	182 (46.6%)	209 (53.4%)
Yemeni	159 (41.3%)	226 (58.7%)	23 (6%)	362 (94%)	27 (7.1%)	358 (92.9%)	253 (65.8%)	132 (34.2%)	181 (47%)	204 (53%)
<i>P</i> -value	<0.001*		<0.001*		<0.001*		<0.001*		<0.001*	
Country where you are living now										
Romania	133 (32.9%)	271 (67.1%)	54 (13.5%)	347 (86.5%)	80 (19.9%)	323 (80.1%)	108 (26.9%)	294 (73.1%)	18 (4.5%)	385 (95.5%)
Iraq	230 (57.1%)	173 (42.9%)	39 (9.7%)	364 (90.3%)	41 (10.2%)	362 (89.2%)	289 (71.7%)	114 (28.3%)	202 (50.1%)	201 (49.9%)
India	305 (76.3%)	95 (23.8%)	64 (16%)	336 (84%)	58 (14.5%)	342 (85.5%)	111 (27.8%)	289 (72.3%)	195 (48.8%)	205 (51.2%)
Malaysia	73 (18.4%)	323 (81.6%)	14 (3.5%)	382 (96.5%)	19 (4.8%)	377 (95.2%)	19 (4.8%)	377 (95.2%)	18 (4.5%)	378 (95.5%)
Egypt	146 (37%)	249 (63%)	64 (16.2%)	331 (83.8%)	96 (24.3%)	299 (75.7%)	181 (45.8%)	214 (54.2%)	94 (23.8%)	301 (76.2%)
Yemen	156 (40.1%)	233 (60%)	22 (5.7%)	367 (94.3%)	29 (7.5%)	360 (92.5%)	251 (64.5%)	138 (35.5%)	184 (47.3%)	205 (42.7%)
Nigeria	205 (53%)	182 (47%)	19 (4.9%)	368 (95.1%)	15 (3.9%)	372 (96.1%)	196 (50.6%)	191 (49.4%)	180 (46.5%)	207 (53.5%)
<i>P</i> -value	<0.001*		<0.001*		<0.001*		<0.001*		<0.001*	
Residence										
Urban	988 (43.7%)	1275 (56.3%)	196 (8.7%)	2065 (91.3%)	258 (11.4%)	2005 (88.6%)	979 (43.3%)	1282 (56.7%)	742 (32.8%)	1520 (67.2%)
Rural	260 (51.1%)	249 (48.9%)	80 (15.7%)	428 (84.3%)	80 (15.7%)	428 (84.3%)	176 (34.6%)	333 (65.4%)	148 (29.1%)	361 (70.9%)
<i>P</i> -value	0.015*		<0.001*		0.055		0.002*		0.156	

(Continued)

Table 2. (Continued)

Variables	Confidence		Complacency		Constraints		Calculation		Collective Responsibility	
	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)	Yes n (%)	No n (%)
Marital status										
Having a partner	75 (29.9%)	179 (70.1%)	25 (10.0%)	226 (90.0%)	35 (13.9%)	216 (86.1%)	81 (32.3%)	170 (67.7%)	42 (16.7%)	209 (83.3%)
Single	1121 (46.6%)	1287 (53.4%)	14 (11.6%)	107 (88.4%)	17 (14%)	104 (86%)	51 (42.1%)	70 (57.9%)	23 (19%)	98 (81%)
Married	53 (43.8%)	68 (56.2%)	238 (9.9%)	2169 (90.1%)	288 (12%)	2119 (88%)	1025 (42.6%)	1383 (57.4%)	826 (34.3%)	1582 (65.7%)
P-value	<0.001*		0.834		0.544		0.002*		<0.001*	
Income level										
Low	271 (43.7%)	349 (56.3%)	50 (8.1%)	570 (91.9%)	64 (10.3%)	556 (89.7%)	272 (43.9%)	348 (56.1%)	239 (38.5%)	381 (61.5%)
Middle	826 (44.4%)	1035 (55.6%)	194 (10.4%)	1665 (89.6%)	233 (12.5%)	1628 (87.5%)	769 (41.4%)	1090 (58.6%)	533 (28.7%)	1327 (65.5%)
High	141 (50.9%)	136 (49.1%)	31 (11.2%)	245 (88.8%)	38 (13.8%)	238 (86.2%)	106 (38.3%)	171 (61.7%)	111 (40.1%)	166 (60.0%)
P-value	0.087		0.179		0.240		0.269		<0.001*	
Educational level										
Undergraduate	351 (43.3%)	460 (56.7%)	79 (9.8%)	731 (90.2%)	101 (12.5%)	709 (87.5%)	313 (38.6%)	498 (61.4%)	220 (27.1%)	591 (72.9%)
Graduate*	862 (45.6%)	1028 (54.4%)	185 (9.8%)	1705 (90.2%)	219 (11.6%)	1671 (88.4%)	803 (42.5%)	1087 (57.5%)	652 (34.5%)	1238 (65.5%)
Postgraduate*	36 (45.6%)	43 (54.4%)	13 (16.5%)	66 (83.5%)	20 (25.3%)	59 (74.7%)	41 (51.9%)	38 (48.1%)	19 (24.1%)	60 (75.9%)
P-value	0.533		0.148		<0.001*		0.029*		<0.001*	
Chronic diseases										
Yes	98 (27.7%)	256 (72.3%)	21 (5.9%)	332 (94.1%)	27 (7.7%)	325 (92.3%)	69 (19.5%)	285 (80.5%)	57 (16.1%)	297 (83.9%)
No	1150 (47.5%)	1270 (52.5%)	332 (13.0%)	2163 (87.0%)	311 (12.8%)	2110 (87.2%)	1086 (44.9%)	1332 (55.1%)	834 (34.5%)	1585 (65.5%)
P-value	<0.001*		0.007*		0.006*		<0.001*		<0.001*	
Had confirmed monkeypox infection?										
Yes	42 (40%)	63 (60%)	4 (3.8%)	101 (96.2%)	4 (3.8%)	101 (96.2%)	27 (25.7%)	78 (74.3%)	23 (21.9%)	82 (78.1%)
No	1120 (47%)	1263 (53%)	260 (10.9%)	2120 (89.1%)	314 (13.2%)	2068 (86.8%)	1061 (44.6%)	1320 (55.4%)	822 (34.5%)	1560 (65.5%)
Not sure	86 (30.1%)	200 (70%)	12 (4.2%)	274 (95.8%)	20 (7.0%)	266 (93.0%)	67 (23.4%)	219 (76.6%)	49 (16.1%)	240 (83.9%)
P-value	<0.001*		<0.001*		<0.001*		<0.001*		<0.001*	
Know anyone who died from monkeypox										
Yes	41 (40%)	73 (64%)	17 (14.9%)	97 (85.1%)	14 (12.3%)	100 (87.7%)	24 (21.1%)	90 (78.9%)	14 (12.3%)	100 (87.7%)
No	1068 (46.8%)	1214 (53.2%)	225 (9.9%)	2054 (90.1%)	285 (12.5%)	1996 (87.5%)	1001 (43.9%)	1279 (56.1%)	798 (35%)	1483 (65%)
Not sure	139 (36.8%)	239 (63.2%)	34 (9%)	344 (91%)	39 (10.3%)	339 (89.7%)	130 (34.4%)	248 (65.6%)	79 (20.9%)	299 (79.1%)
P-value	<0.001*		<0.001*		0.488		<0.001*		<0.001*	
Having an idea about the types of monkeypox vaccines										
Yes	394 (51.9%)	365 (48.1%)	87 (11.4%)	674 (88.6%)	85 (11.2%)	674 (88.8%)	211 (27.2%)	548 (72.2%)	247 (32.5%)	513 (67.5%)
No	854 (42.4%)	1161 (57.6%)	189 (9.4%)	1821 (90.6%)	253 (12.6%)	1761 (87.4%)	944 (46.9%)	1069 (53.1%)	644 (32%)	1369 (68%)
P-value	<0.001*		0.111		0.328		<0.001*		0.798	

*Refers to students who have completed their undergraduate (bachelor's) degree and are pursuing further education at the master's or doctoral level. The difference between graduate and postgraduate students varies depending on the educational system and country.

Table 3. Determinants of the 5C psychological antecedent of monkeypox vaccine among the participants

Variables	OR	95% CI	P-value
Confidence			
Gender			
Male	1		
Female	1.15	(0.97-1.37)	0.108
Country			<0.001*
Romania	1		
Iraq	2.57	(1.91-3.45)	<0.001*
Malaysia	5.45	(3.86-7.69)	<0.001*
Egypt	0.36	(0.24-0.53)	<0.001*
Yemen	1.36	(1.01-1.83)	0.046
Nigeria	1.49	(1.09-2.02)	0.011
India	2.41	(1.77-3.29)	<0.001*
Financial status			0.213
Low income	1		
Middle income	1.2	(1.20-0.98)	0.079
Upper income	1.164	(1.16-0.85)	0.344
Marital status			0.151
Partnered	1		
Married	1.51	(0.94-2.44)	0.09
Single	1.31	(0.97-1.77)	0.081
Living area			
Urban	1		
Rural	0.96	(0.77-1.21)	0.749
Suffer from chronic disease			
Yes	1		
No	1.28	(0.95-1.72)	0.101
Have you had monkeypox?			
Yes	1.38		
No/don't know	1	(0.86-2.19)	0.182
Has anyone died from monkeypox you know?			0.215
Yes	1		
No	0.67	(0.42-1.06)	0.084
I don't know	0.72	(0.44-1.17)	0.178
Have an idea about the types of monkeypox vaccines?			
Yes	1.58		
No	1	(1.26-1.98)	<0.001*
Complacency			
Country			<0.001*
Romania	2.29	(1.30-4.06)	0.004
Iraq	1.7	(0.903-3.19)	0.1
Malaysia	2.5	(1.356-4.61)	0.003
Egypt	0.48	(0.209-1.09)	0.08
Yemen	3.3	(1.817-5.99)	<0.001*
Nigeria	1.05	(0.537-2.07)	0.879
India	1		
Highest education			0.278
Undergraduate	1		
Graduate	1.12	(0.76-1.64)	0.578
Postgraduate	1.72	(0.88-3.36)	0.112
Financial status			0.075
Low income	1		
Middle income	1.42	(1.01-2.00)	0.047
Upper income	1.05	(0.635-1.73)	0.856
Living area			
Urban	1		
Rural	1.43	(1.05-1.95)	0.024*
Suffer from chronic disease			
Yes	1		
No	1.61	(0.94-2.75)	0.082
Have you had monkeypox?			
Yes	0.51		
No/ don't know	1	(0.18-1.48)	0.219

(Continued)

Table 3. (Continued)

Variables	OR	95% CI	P-value
Has anyone died from monkeypox you know?			
Yes	3.3		<0.001*
No	0.91	(1.64-6.68)	0.001
I don't know	1	(0.612-1.36)	0.65
Have an idea about the types of monkeypox vaccines?			
Yes	1.31	(0.93-1.84)	0.126
No	1		
Constraints			
Country			<0.001*
Romania	5.8	(5.80-3.25)	<0.001*
Iraq	2.87	(2.87-1.49)	0.002
Malasyia	4.19	(4.19-2.25)	<0.001*
Egypt	1.5	(1.50-0.70)	0.293
Yemen	8.06	(8.06-4.36)	<0.001*
Nigeria	2.05	(2.05-1.04)	0.037
India	1		<0.001*
Highest education			0.020*
Undergraduate	1		
Graduate	0.99	(0.69-1.41)	0.939
Postgraduate	2.2	(1.24-3.92)	0.007*
Living area			
Urban	1		
Rural	1.05	(0.790-1.40)	0.736
Suffer from chronic disease			
Yes	1		
No	1.35	(0.87-2.12)	0.184
Have you had monkeypox?			
Yes	1		
No/ don't know	1.62	(0.57-4.58)	0.365
Calculation			
Gender			
Male	1		
Female	1.01	(0.84-1.20)	0.945
Country			<0.001*
Romania	1		
Iraq	7.61	(5.21-11.10)	<0.001*
Malasyia	1.21	(0.83-1.76)	0.334
Egypt	0.17	(0.09-0.30)	<0.001*
Yemen	2.67	(1.86-3.83)	<0.001*
Nigeria	5.44	(3.75-7.89)	<0.001*
India	2.77	(2.02-3.81)	<0.001*
Highest education			0.001*
Undergraduate	1		
Graduate	0.97	(0.76-1.25)	0.823
Postgraduate	2.75	(1.63-4.64)	<0.001*
Marital status			0.065
Partnered	1		
Married	1.36	(0.82-2.27)	0.237
Single	1.45	(1.061-1.98)	0.02*
Living area			
Urban	1		
Rural	0.91	(0.72-1.15)	0.441
Suffer from chronic disease			
Yes	1		
No	1.54	(1.10-2.16)	0.012*
Have you had monkeypox?			
Yes	1		
No/ don't know	0.73	(0.41-1.31)	0.291
Has anyone died from monkeypox you know?			0.615
Yes	1		
No	0.77	(0.43-1.37)	0.377
I Don't know	0.83	(0.44-15)	0.546

(Continued)

Table 3. (Continued)

Variables		OR	95% CI	P-value
Have you had monkeypox?	Yes	1		
	No	1.14	(0.89-1.44)	0.305
Collective responsibility				
Gender	Male	1		0.004*
	Female	1.28	(1.08-1.51)	
Highest education				<0.001*
	Undergraduate	1		
	Graduate	1.59	(1.32-1.92)	<0.001*
Marital status				0.801
	Postgraduate	1.08	(0.60-1.93)	
				<0.001*
Financial status				<0.001*
	Partnered	1		
	Married	1.14	(0.63-2.06)	0.675
Suffer from chronic disease				<0.001*
	Single	2.76	(1.94-3.92)	
				<0.001*
Have you had monkeypox?				<0.001*
	Low income	1		
	Middle income	0.62	(0.51-0.76)	<0.001*
Has anyone died from monkeypox you know?				0.878
	Upper income	1.02	(0.76-1.38)	
				<0.001*
Suffer from chronic disease	Yes	1		
	No	2.14	(1.56-2.93)	<0.001*
Have you had monkeypox?	Yes	1		
	No/ don't know	1.04	(0.62-1.73)	0.889
Has anyone died from monkeypox you know?				<0.001*
	Yes	1		
	No	2.54	(1.39-4.64)	0.002
				0.255
	I don't know	1.45	(0.77-2.74)	

OR = Odds Ratio, *significant.

participants declared that they didn't know the various available types of mpox vaccination. That complied with the findings from another study conducted in Saudi Arabia, in which most of the participants had poor knowledge about the disease.²⁹ Another study in Jordan declared that most of them had insufficient knowledge regarding vaccination.²⁰ Using the 5C model for measuring the different aspects of the vaccination, which include confidence, complacency, constraints, and calculation, as well as collective responsibility, 55% of the participants declared that they were confident in the vaccination's effectiveness, safety, and health authorities. Ten percent of the participants showed complacency, which indicates a positive intention toward vaccine-preventable diseases. Twelve percent of the participants had barriers and constraints to being vaccinated. Thirty-two percent were willing to be vaccinated to prevent the transfer of the infection to others, which translated into a positive attitude. Forty-one percent of the participants were still calculating, weighing the benefits and risks of getting the vaccines to be able to decide.

The attitude of HCWs and medical students toward mpox vaccination was reported in other studies. A study conducted in Pakistan by Kumar et al. showed that 67.7% of the students were willing to be vaccinated if the vaccine was available.³⁰ Another study conducted by Wang et al.³¹ among the science population reported that 68.8% of them were willing to be vaccinated against mpox. Aljamaan et al.³¹ conducted a cross-sectional study among the Saudi Arabian HCWs which included medical students and reported that 69.8% of them believed that they should be vaccinated. Among Czech, including medical students, it was reported that 46.3 % of the participants were vaccine-hesitant

toward mpox vaccination.³² Of Italian physicians, 64.4% had a favorable attitude towards receiving the mpox vaccines.³³ Pan et al.³⁴ conducted a study among Chinese HCWs which reported that 85.27% of the HCWs were willing to be vaccinated if they had sufficient information about the vaccine. Sahin et al.³⁵ reported that 31.4% of Turkish physicians were willing to receive the mpox vaccine while 38.5% were hesitant to get mpox vaccine. Interestingly, a systematic review reported that vaccine acceptance among HCWs was estimated to be equal to 63%.³⁴

The factors that were reported to be associated with high confidence were being single, living in rural area, those with a high income, and not having a previous history of chronic disease, as well as those with prior knowledge about the different types of vaccines. However, that was consistent with another study which reported that the participants who were knowledgeable about COVID-19 were more willing to be vaccinated against the disease.³⁶ These findings need to be taken into consideration when designing a program for increasing vaccine acceptance. Providing the participants with sufficient knowledge about the importance of the vaccine, and the infection risk of the non-infected individuals besides other factors that should be taken into consideration, will assist in overcoming VH.

Constraints are considered obstacles toward vaccination acceptance, such as in cases of being required to pay for the vaccine as well as inappropriate time and place of vaccination services. Among the participants of our study, it was reported that the constraints were significantly correlated with the absence of prior mpox infection and a history of chronic disease. Therefore, 12.2% of the total participants reported constraints toward mpox

vaccination. Recommended measures to overcome constraints which in turn will increase vaccine acceptance are providing the vaccine for free and making it available to be taken at any time.^{19,37}

Complacency means that the participants thought that their immunity was strong enough to fight the infection which indicates that they do not need to get vaccinated. It is an important barrier against acceptance. Complacency was among the factors that significantly affected vaccine acceptance among HCWs.^{38,39} In our study, there was high complacency among the participants who were free from chronic disease and mpox.

The calculation part of the 5C questionnaire, in which the participants weighed the benefits versus risks of getting the vaccine, was reported to be significantly correlated with single participants and those who are free from chronic disease and mpox. We should focus on identifying the importance of vaccination for medical students, giving an insight into the safety of the vaccines, and describing the minimal risks associated with using them.^{38,39}

Collective responsibility means that the participant is interested in being vaccinated for the protection of others from infection transmission as the disease is vaccine preventable.⁴⁰ A high collective responsibility was associated with single participants, those with low income, and being among the highly educated graduate group.

Cross-country discrepancies in VH among medical students can vary widely, with some countries reporting high levels of VH and others reporting low levels. One factor that contributes to cross-country discrepancies in VH among medical students is differences in vaccine education and training. Medical students in some countries receive more comprehensive vaccine education and training than others, which can influence their attitudes and beliefs about vaccines. In countries where vaccine education is lacking, medical students may be more susceptible to anti-vaccine sentiment and misinformation. Cultural norms and beliefs can also contribute to cross-country discrepancies in VH among medical students. In some cultures, vaccines may not be seen as a priority or may be viewed with suspicion. This can lead to medical students in these countries being less likely to receive or recommend vaccines. Another factor that can contribute to cross-country discrepancies in VH among medical students is the influence of social media and other forms of media. Medical students in countries where anti-vaccine sentiment is prevalent on social media may be more likely to be influenced by this sentiment and may be more likely to be vaccine hesitant. New strategies may effectively improve vaccine acceptance and coverage, like combining mpox vaccine with other well-known vaccines like seasonal influenza. This strategy was proven to be effective in reducing VH in countries with low COVID-19 vaccination coverage.⁴¹

The impact of cross-country discrepancies in VH among medical students can be significant. Medical students who are vaccine-hesitant may be less likely to recommend vaccines to their patients, which can have negative implications for public health. Additionally, medical students who are vaccine-hesitant may be less prepared to respond to outbreaks of vaccine-preventable diseases.

Strengths and Limitations

This study provides evidence about the status of mpox VH among medical students who are future healthcare workers dealing with patients. The study used validated tools and was conducted in different countries across the globe with different income levels.

We tried to create a guideline targeted to fill the gap in their attitude toward vaccination. However, the limitations of this study include the non-random sampling which can affect the external validity of the results, and the nature of the cross-sectional studies as being observational studies so we can't confirm a causality relationship, and the results represent the attitude of the participants at a single time point that may change with time.

Conclusions

Cross-country discrepancies in VH among medical students are a complex issue arising from factors such as differences in vaccine education, training, cultural norms, and media influence. This study provides valuable insights into the current state of mpox VH among medical students. Nearly 50% of the participants expressed confidence in the effectiveness, safety and trustworthiness of the vaccine, as well as health authorities' recommendations. However, a small percentage displayed complacency, potentially underestimating the risk posed by mpox. Barriers and constraints may hinder vaccination decisions, and measures such as providing the vaccine free of charge and ensuring availability at any time are recommended to address these challenges.

Many participants expressed a willingness to be vaccinated for their protection and to prevent transmission of the infection to others, highlighting a sense of collective responsibility towards public health, additionally, about two fifths of participants engaged in a thoughtful assessment of the benefits and risks associated with MPOX vaccination before deciding. Addressing these discrepancies requires a multi-faceted approach that includes improving vaccine education and training, addressing cultural barriers to vaccine acceptance, and countering anti-vaccine sentiment on social media. By working together, medical students can provide the highest quality of care and promote public health.

Availability of data and material. All data are available upon request from the first author.

Authors' contribution. MH, RMG, AS: Methodology, Writing—Review and Editing, Visualization; HI, NM: Data Analysis; DE, MN, AH, JA, MO, MR, TS, SY, CL: Data Curation; MH, AS, NM: Writing—Original Draft Preparation. All the authors have read and agreed to the published version of the manuscript.

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Competing interests. Authors declared that they have no conflict of interest.

Ethics approval. This study was approved by the High Institute of Public Health Ethics Committee at Alexandria University (IRB No. 00012098/FWA No. 00018699).

Consent to participate. Ethical consent was presented as a required beginning item within the questionnaire, with optional choices for the participant to complete or reject to participate in the study. The personal information of the participants was fully confidential and anonymous. Informed consent was obtained from all the subjects involved in the study. The survey cover page had an "agree" option, where eligible parents who accessed the electronic survey could click on it before accessing the survey questions.

Consent for publication. All authors confirm that this manuscript has not been published elsewhere or submitted to any other journal. The final version of the manuscript has been approved by all authors, and they have agreed to its publication. Additionally, all authors have declared that they have no conflicts of interest related to this work.

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