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Research article

The willingness of healthcare workers to be vaccinated against monkeypox and their knowledge about monkeypox: A systematic review and meta-analysis

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ABSTRACT

Background: Vaccination is an important method to address the monkeypox epidemic. We aimed to analyze the knowledge of healthcare workers (HCWs) about human monkeypox and their attitudes toward vaccination.

MethodsWe searched PubMed, Embase and Web of Science for articles and performed a meta-analysis using Stata 14.0 with a random-effects model. This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Results: A total of 34 studies with 43,226 HCWs were included in this meta-analysis. The results showed that 54 % (95 % CI: 0.39–0.69) of the HCWs were willing to be vaccinated against monkeypox, and only 40 % (95 % CI: 0.29–0.50) of the HCWs had good knowledge of monkeypox. By analyzing the vaccination history of HCWs, we found that history of smallpox vaccination did not significantly affect the willingness of HCWs to receive another vaccination (OR = 0.53, 95 % CI: 0.23–1.26), whereas HCWs who had been vaccinated with the influenza vaccine (OR = 2.80, 95 % CI: 1.29–6.11) or COVID-19 vaccine (OR = 3.10, 95 % CI: 2.00–4.81) showed greater willingness to receive the monkeypox vaccine. In terms of income, low-income HCWs were less willing to be vaccinated against monkeypox (OR = 0.69, 95 % CI: 0.54–0.89), whereas middle-income HCWs were more willing (OR = 1.45, 95 % CI: 1.04–2.02). Notably, although HCWs with education related to monkeypox had better knowledge of monkeypox than HCWs without education related to monkeypox, the difference was not statistically significant (OR = 1.83, 95 % CI: 0.80–4.18).

Conclusions: Publicity and education on monkeypox should be strengthened so that more people, especially HCWs, can have a good understanding of monkeypox and be willing to be vaccinated.

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1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic had a great impact on people's quality of life and health [1]. With the gradual decline of the COVID-19 epidemic, the monkeypox virus reemerged, posing a new challenge to the healthcare system, especially when the infection prevention measures implemented during the COVID-19 pandemic were lifted. Monkeypox virus is a double-stranded DNA virus that belongs to the Orthopoxvirus genus together with Variola virus, which is the cause of smallpox. The genome of monkeypox virus is 96.3 % identical to that of Variola virus, but its mortality rate is not as high as that of smallpox [2]. In 1958, the virus was first isolated from colonies of monkeys used for research at the State Serum Institute in Copenhagen, Denmark, but human infection was first identified in 1970 in a 9-year-old boy in the Democratic Republic of the Congo [3]. This infection was mainly endemic to West Africa, such as the Democratic Republic of the Congo, Cote d'Ivoire, Gabon, Sierra Leone and Nigeria, and sporadic and self-limiting outbreaks were noted outside the African continent [4]. The first case of monkeypox reported outside Africa occurred in the United States in 2003 [5]. In May 2022, the World Health Organization (WHO) confirmed the first monkeypox epidemic outside epidemic areas on different continents worldwide, and on July 23, 2022, the WHO declared the ongoing human monkeypox multi-country outbreak a public health emergency of international concern [3,6]. According to statistics from the WHO, as of May 27, 2024, there were 95,859 confirmed cases and 186 deaths worldwide, involving 117 countries or regions (2022–2024) [7]. Monkeypox syndrome is characterized by a febrile prodrome that lasts for 1–4 days and is accompanied by headache and fatigue. This process is followed by the centrifugal development of deep, well-circumscribed maculopapular, vesicular, pustular, and finally crusted scab lesions [8]. However, during the monkeypox outbreak in 2022, several unusual presentations, including penile swelling and rectal pain that required hospitalization, were reported [9]. Vaccination is considered the best way to prevent monkeypox infection [10].

The smallpox vaccine is effective against monkeypox virus infection and can be used as a vaccine. Recently, the United Kingdom Health Security Agency announced that more than 20,000 doses of Imvanex, a smallpox vaccine, were purchased to vaccinate close contacts of monkeypox patients [11]. Although the WHO noted in the interim guidance on vaccines and immunization for monkeypox updated on August 24, 2022 that mass vaccination against monkeypox is not recommended or needed at present, it also advocated that HCWs be vaccinated first because they are at high risk of monkeypox infection [12]. Vaccination hesitancy, defined as the reluctance to be vaccinated despite the availability of vaccination services, is a major global public health challenge [13]. In 2019, just before the emergence of the COVID-19 pandemic, vaccination hesitancy was listed as one of the top ten global health threats by the WHO [14]. HCWs may also be hesitant to vaccinate against monkeypox. The WHO noted that one of the challenges in preventing a large-scale outbreak of monkeypox is the lack of knowledge about the disease, especially among HCWs [15].

The aim of this study was to analyze the knowledge of HCWs about monkeypox and their attitudes toward vaccination. This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

2. Materials and methods

2.1. Eligibility criteria

Articles that met the following criteria were included in this meta-analysis: 1) the study population included HCWs, including doctors, nurses, pharmacists, healthcare assistants and medical students; 2) the content of the study included HCWs' knowledge of human monkeypox or their attitude toward monkeypox vaccination; and 3) the article described the number of people who were willing to be vaccinated against monkeypox or who had good knowledge of monkeypox.

The exclusion criteria were as follows: 1) the participants were from the general population, children, or non-HCW occupations; 2) animal studies; 3) case reports; 4) abstracts; 5) reviews and comments; 6) studies contained duplicated data; 7) the study had a sample size less than ten; and 8) knowledge of monkeypox was based on HCWs' self-evaluation rather than statistical analysis.

2.2. Information sources and search strategy

We searched PubMed, Embase and Web of Science for articles published before May 25, 2024. We did not restrict the language of the article to allow for more useful information to be retrieved globally. The search strategies used for the PubMed, Embase and Web of Science databases are listed in **Supplementary File 1**.

2.3. Study selection process

All the articles identified from PubMed, Embase and Web of Science were imported into NoteExpress software. We first deleted duplicate articles by matching titles, authors and journals and then read titles and abstracts for preliminary screening to exclude articles irrelevant to our research. Finally, after the full texts were read, the remaining articles were further screened to determine which articles could be included in our meta-analysis.

2.4. Data selection process and items

Data extraction was performed independently by two authors to ensure the accuracy of the data. When the two authors encountered inconsistencies in the extracted data, disagreements were resolved by discussion, and the authors referred to the third author for

a final decision.

The extracted data included the following: the number of HCWs who were willing to receive the monkeypox vaccine, the number of HCWs who had good knowledge of monkeypox, the factors that affected the willingness to receive the monkeypox vaccine and the factors that affected the knowledge of monkeypox.

2.5. Study risk of bias assessment

The Newcastle–Ottawa quality assessment scale was used to assess the quality and risk of bias of the included articles. A total score of more than seven indicated that the risk of bias was low and that the quality of the study was high.

2.6. Reporting bias assessment

Given that the number of included articles in our studies was mostly less than 10, we did not use funnel plots. Instead, we used only Egger's test to evaluate reporting bias, and a p value > 0.05 indicated the absence of bias.

2.7. Statistical analysis

The data we included were all dichotomous variables; thus, we used odds ratios (ORs) for data analysis and evaluation and 95 % confidence intervals (CIs). The I^2 statistic was used to quantify heterogeneity: $I^2 \leq 50$ % indicated low heterogeneity, $50 < I^2 \leq 75$ % indicated moderate heterogeneity, and $I^2 > 75$ % indicated high heterogeneity [16]. We used subgroup analysis to explore the source of heterogeneity. A random-effects model was used to estimate the effect value. Stata 14.0 was used for statistical analysis, and a p value of the z test<0.05 indicated that the results were statistically significant.

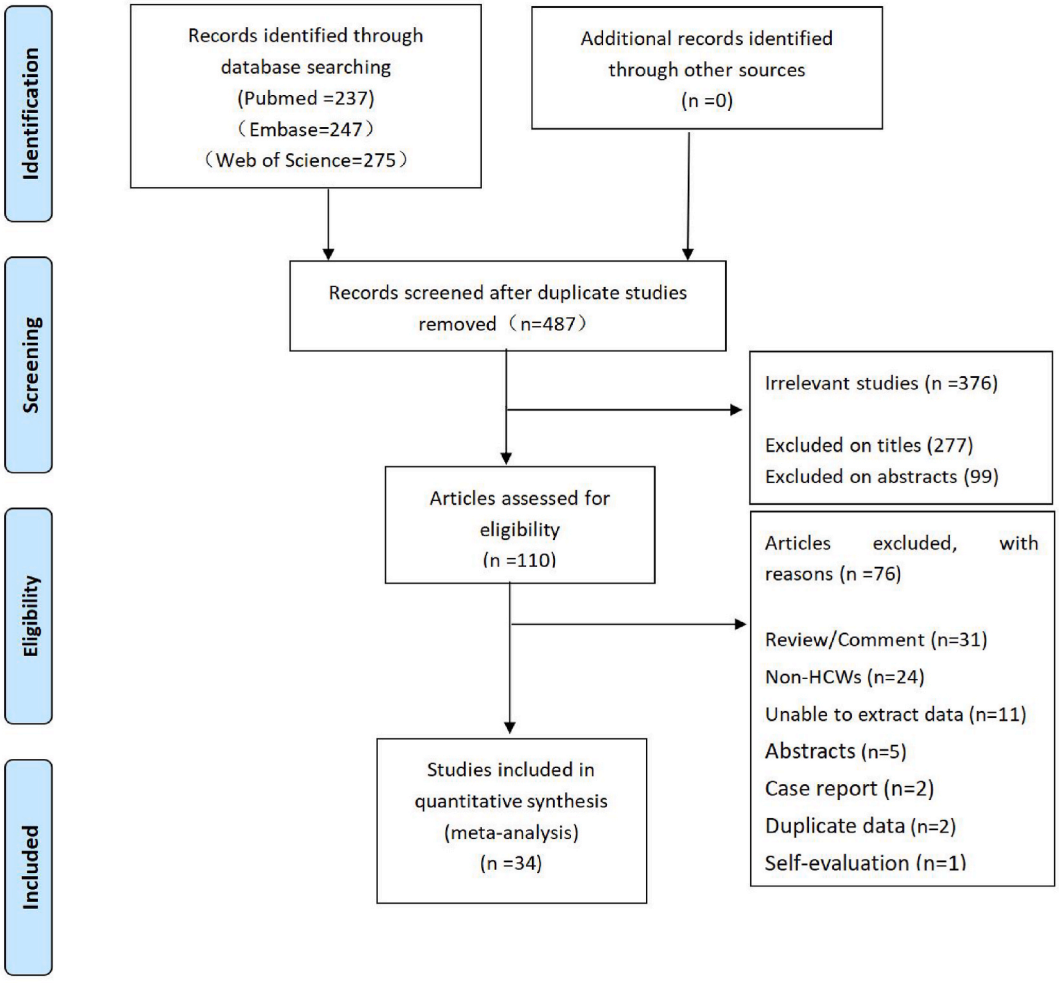

Fig. 1. Flow diagram of the article selection process.

3. Results

3.1. Study selection

We retrieved a total of 759 articles from PubMed, Embase, and Web of Science, 272 of which were duplicates. A total of 376 articles that were not relevant to our study were excluded after reading the titles and abstracts. Among the remaining 110 articles, 76 were further screened and excluded after reading the full text. The flow diagram of the article selection process is shown in Fig. 1.

3.2. Risk of bias in studies

The Newcastle–Ottawa quality assessment scale is described in Supplementary Table 1. All the articles included in the meta-analysis were of high quality and had a low risk of bias.

3.3. Characteristics and results of individual studies

A total of 34 studies with 43,226 HCWs were included in this meta-analysis. The data came from Asia, Africa, Europe, South America and North America. Nine articles focused on HCWs' willingness to receive the monkeypox vaccine, 20 articles focused on HCWs' mastery of monkeypox knowledge, and five articles focused on both areas.

The cutoff points for good knowledge were mainly based on the proportion of correct answers (50%–80 %) or other criteria (mean level, median value and mean + standard deviation). All the articles were published after 2020 and involved cross-sectional surveys. The details are provided in Table 1.

3.4. Results of syntheses

3.4.1. Willingness to vaccinate monkeypox

The results showed that 54 % (95 % CI: 0.39–0.69, $I^2 = 99.6$ %; Supplementary Fig. 1) of the HCWs were willing to be vaccinated against monkeypox. We focused on the factors that affected the willingness of HCWs to be vaccinated against monkeypox and compared several characteristics between the two types of HCWs, namely, those who were willing to be vaccinated and those who were unwilling to be vaccinated (Supplementary Table 2). We found that sex (OR = 0.97, 95 % CI: 0.86–1.09, $I^2 = 0.4$ %, p = 0.609; Supplementary Fig. 2), education level (OR = 1.03, 95 % CI: 0.74–1.44, $I^2 = 65.9$ %, p = 0.849; Supplementary Fig. 3) and hearing about monkeypox before (OR = 1.00, 95 % CI: 0.74–1.35, $I^2 = 39.2$ %, p = 0.994; Supplementary Fig. 4) had almost no influence on the willingness of HCWs to be vaccinated. HCWs who were younger (OR = 1.29, 95 % CI: 0.89–1.87, $I^2 = 78.6$ %, p = 0.176; Supplementary Fig. 5), had worked for fewer years (OR = 1.24, 95 % CI: 0.96–1.59, $I^2 = 58.2$ %, p = 0.097; Supplementary Fig. 6), and who had received monkeypox education (OR = 1.32, 95 % CI: 0.56–3.09, $I^2 = 75.7$ %, p = 0.521; Supplementary Fig. 7) were more likely to be vaccinated, whereas those who were married (OR = 0.81, 95 % CI: 0.62–1.06, $I^2 = 69.2$ %, p = 0.120; Supplementary Fig. 8) and who had chronic diseases (OR = 0.66, 95 % CI: 0.41–1.07, $I^2 = 39.5$ %, p = 0.095; Supplementary Fig. 9) were less likely to be vaccinated. However, the above differences were not statistically significant. By analyzing the vaccination history of HCWs, we found that history of smallpox vaccination did not significantly affect the willingness of HCWs to receive another vaccination (OR = 0.53, 95 % CI: 0.23–1.26, $I^2 = 79.6$ %, p = 0.152; Fig. 2A), whereas HCWs who had received the influenza vaccine (OR = 2.80, 95 % CI: 1.29–6.11, $I^2 = 76.1$ %, p = 0.009; Fig. 2B) and COVID-19 vaccine (OR = 3.10, 95 % CI: 2.00–4.81, $I^2 = 0.0$ %, p < 0.001; Fig. 2C) showed greater willingness to be vaccinated with the monkeypox vaccine. In terms of income, low-income HCWs were less willing to be vaccinated against monkeypox (OR = 0.69, 95 % CI: 0.54–0.89, $I^2 = 0.0$ %, p = 0.04; Fig. 3A), whereas middle-income HCWs were more willing (OR = 1.45, 95 % CI: 1.04–2.02, $I^2 = 0.0$ %, p = 0.029; Fig. 3B). Although high-income HCWs also showed greater willingness to be vaccinated against monkeypox (OR = 1.36, 95 % CI: 0.88–2.09, $I^2 = 7.8$ %, p = 0.161; Fig. 3C), the difference was not statistically significant. We also found that occupation as a doctor (OR = 1.32, 95 % CI: 0.82–2.13, $I^2 = 84.8$ %, p = 0.249; Supplementary Fig. 10) or nurse (OR = 0.86, 95 % CI: 0.55–1.35, $I^2 = 85.0$ %, p = 0.506; Supplementary Fig. 11) did not significantly affect the willingness of HCWs to be vaccinated against monkeypox.

3.4.2. Knowledge of monkeypox

Because the cutoff points of good knowledge used by the included studies were not completely consistent, we used the cutoff point as the basis for subgroup analysis to conduct a detailed analysis of HCWs' knowledge of monkeypox (Supplementary Figs. 12–20). Our results showed that among the HCWs, only 40 % (95 % CI: 0.29–0.50, $I^2 = 99.8$ %) had good knowledge of monkeypox. By comparing HCWs with good knowledge of monkeypox to those without good knowledge (Supplementary Table 3), we found that sex (OR = 0.95, 95 % CI:0.82–1.10, $I^2 = 79.3$ %, p = 0.490), education level (OR = 0.82, 95 % CI: 0.45–1.49, $I^2 = 84.6$ %, p = 0.510), age (OR = 0.69, 95 % CI: 0.45–1.05, $I^2 = 86$ %, p = 0.082), working years (OR = 0.86, 95 % CI: 0.59–1.24, $I^2 = 84.9$ %, p = 0.419), marital status (OR = 1.12, 95 % CI: 0.76–1.67, $I^2 = 90.0$ %, p = 0.561) and occupation as a doctor (OR = 1.18, 95 % CI: 0.64–2.20, $I^2 = 92.4$ %, p = 0.597) or nurse (OR = 0.91, 95 % CI: 0.66–1.26, $I^2 = 67.8$ %, p = 0.584) did not significantly affect the knowledge level of HCWs regarding monkeypox. Notably, although HCWs with education related to monkeypox had better knowledge of monkeypox than HCWs without education related to monkeypox, the difference was not statistically significant (OR = 1.83, 95 % CI: 0.80–4.18; $I^2 = 97.7$ %, p = 0.151).

Table 1
Characteristics of individual studies.

Author	Year	Country	Continent	Study period	Sample size	Outcomes reported	Cutoff point of good knowledge
Sobaikhi et al. [4]	2023	Saudi Arabia	Asia	2022.11.4–2022.12.8	345	Knowledge of monkeypox	Good knowledge were defined at a level above 60 % correct responses
Alarif et al. [17]	2023	Saudi Arabia	Asia	2022.9.13–2022.11.13	743	Willingness to be vaccinated against monkeypox	NA
Harapan et al. [18]	2020	Indonesia	Asia	2019.5–2019.7	407	Willingness to be vaccinated against monkeypox	NA
Riad et al. [19]	2023	Belarus	Europe	2022.10.1–2022.10.31	100	Willingness to be vaccinated against monkeypox	NA
Sahin et al. [20]	2022	Turkey	Asia	2022.8.20–2022.9.2	283	Willingness to be vaccinated against monkeypox and knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Lounis et al. [21]	2023	Algeria	Africa	2022.6.28–2022.9.18	111	Willingness to be vaccinated against monkeypox and knowledge of monkeypox	Participants who scored above the mean level were considered to have good knowledge
Mahameed et al. [22]	2023	Jordan	Asia	2023.1.1–2023.1.31	330	Willingness to be vaccinated against monkeypox	NA
Ghazy et al. [23]	2022	Nigeria	Africa	2022.9.27–2022.11.4	389	Willingness to be vaccinated against monkeypox	NA
Ricco et al. [24]	2022	Italy	Europe	2022.5.24–2022.5.30	163	Willingness to be vaccinated against monkeypox	NA
Hong et al. [25]	2023	China	Asia	2022.5.30–2022.8.1	1032	Willingness to be vaccinated against monkeypox	NA
ElHafeez et al. [26]	2023	27 countries	More than one continent	2022.8.1–2022.8.15	11919	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge
Hasan et al. [27]	2023	Bangladesh	Asia	2022.5.26–2022.6.4	389	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Alshahrani et al. [28]	2022	Saudi Arabia	Asia	2022.3.26–2022.5.27	398	Knowledge of monkeypox	Good knowledge were defined at a level above 60 % correct responses
Harapan et al. [29]	2020	Indonesia	Asia	2019.5.25–2019.7.25	432	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Swed et al. [30]	2023	Arabic regions	More than one continent	2022.6.6–2022.6.25	5874	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Kaur et al. [31]	2022	India	Asia	2022.6.1–2022.6.30	253	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Scarinci et al. [32]	2023	Italy	Europe	2022.6–2023.4	204	Willingness to be vaccinated against monkeypox	NA
Ahmed et al. [33]	2023	Iraq	Asia	2022.11.1–2023.1.15	637	Willingness to be vaccinated against monkeypox and knowledge of monkeypox	Good knowledge were defined at a level above 80 % correct responses
Yang et al. [34]	2024	China	Asia	2023.7.24–2023.8.2	2155	Willingness to be vaccinated against monkeypox and knowledge of monkeypox	Good knowledge were defined at a level above 50 % correct responses

(*continued on next page*)

Table 1 (*continued*)

Author	Year	Country	Continent	Study period	Sample size	Outcomes reported	Cutoff point of good knowledge
Bates et al. [35]	2022	United States	North America	2022.9.2–2022.9.11	197	Willingness to be vaccinated against monkeypox	NA
Kumar et al. [36]	2022	Pakistan	Asia	2022.10.15–2022.10.30	946	Willingness to be vaccinated against monkeypox and knowledge of monkeypox	Participants who scored above "Mean + Standard Deviation" were considered to have good knowledge
Zhou et al. [37]	2023	China	Asia	2022.6.15–2022.6.21	2188	Knowledge of monkeypox	Good knowledge were defined at a level above 80 % correct responses
Nka et al. [38]	2024	Cameroon	Africa	2022.8–2022.10	342	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Yu et al. [39]	2024	China	Asia	2023.9.19–2023.11.1	8897	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge
Amer et al. [40]	2024	Egypt	Africa	2022.10–2022.12	1034	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge
Vellappally et al. [41]	2023	Saudi Arabia	Asia	2022.7–2022.9	159	Knowledge of monkeypox	Good knowledge were defined at a level above 80 % correct responses
Rony et al. [42]	2023	Saudi Arabia	Asia	2022.10–2023.3	1047	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Theban et al. [43]	2024	Saudi Arabia	Asia	2022.11.1–2022.12.31	195	Knowledge of monkeypox	Good knowledge were defined at a level above 70 % correct responses
Masood et al. [44]	2023	Pakistan	Asia	2023.5–2023.6	389	Knowledge of monkeypox	Good knowledge were defined at a level above 80 % correct responses
Raman et al. [45]	2023	Malaysia	Asia	2023.3.24–2023.6.1	138	Knowledge of monkeypox	Good knowledge were defined at a level above 80 % correct responses
Elsayed et al. [46]	2023	Egypt	Africa	2022.9.15–2022.10.15	710	Knowledge of monkeypox	Participants who scored above the mean level were considered to have good knowledge
Gonzales-Zamora et al. [47]	2023	Peru	South America	2022.8.10–2022.9.4	463	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge
Bhadra et al. [48]	2022	India	Asia	6 weeks	152	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge
Das et al. [49]	2023	Nepal	Asia	2022.10.1–2022.10.31	205	Knowledge of monkeypox	Participants who scored above the median value were considered to have good knowledge

3.5. Reporting biases

Egger's test was used for bias analysis (Supplementary Figs. 21–42); no reporting bias was noted in any of the studies.

3.6. Heterogeneity

We performed subgroup analysis using continent (Figs. 2 and 3, Supplementary Figs. 1–11 and Supplementary Figs. 43–51) and the cutoff point (Supplementary Figs. 12–20) as the basis for classification; unfortunately, we did not find an accurate source of heterogeneity.

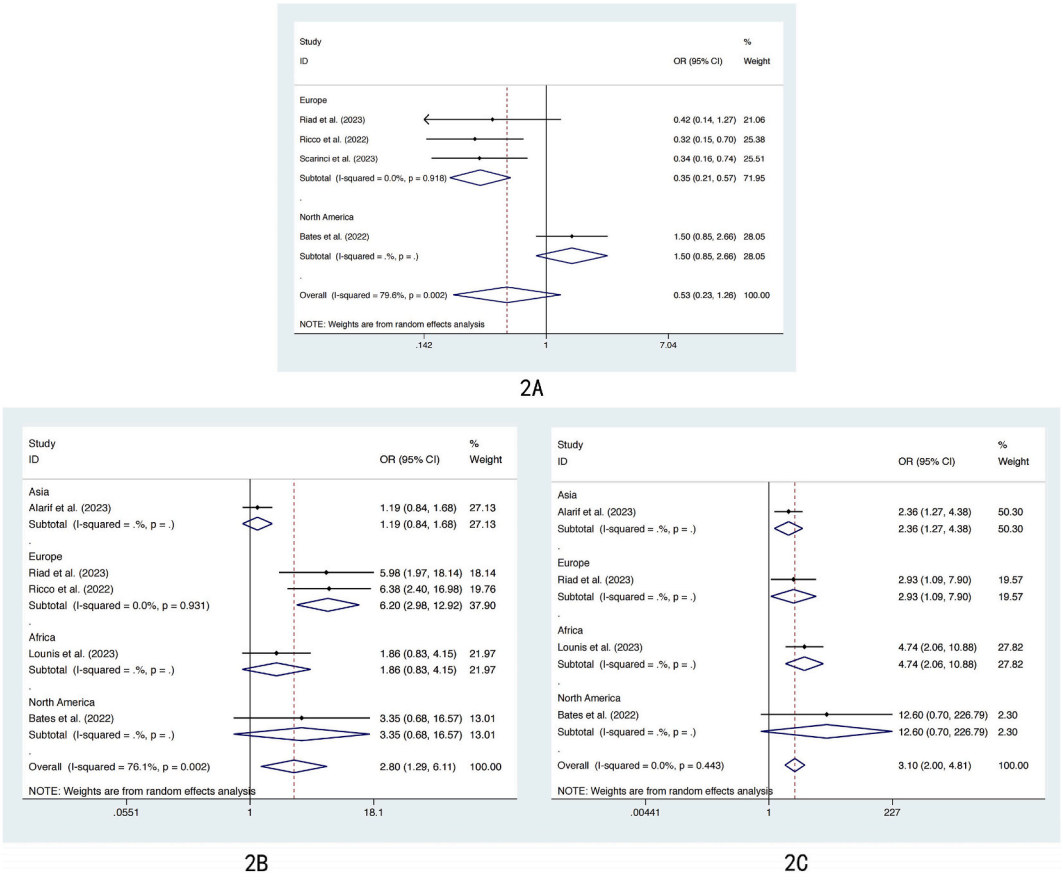

Fig. 2. Forest plot of factors affecting healthcare workers' willingness to be vaccinated against monkeypox: 2A) history of smallpox vaccination; 2B) history of influenza vaccination; and 2C) history of COVID-19 vaccination.

4. Discussion

To our knowledge, this is the first systematic review and meta-analysis focusing on the factors affecting HCWs' knowledge of monkeypox and their attitudes toward vaccination. Although the monkeypox epidemic in 2022 was mainly spread among men who have sex with men [50], other people, such as children, were the main victims of the previous regional monkeypox epidemic [51]. HCWs are a population worthy of special attention. A study from the Congo showed that the annual incidence of monkeypox among local HCWs was estimated to be 17.4/10,000, which was much greater than that in the general population [52]. A systematic review by Beer et al. revealed that the healthcare setting is an important source of transmission, and approximately one infection among HCWs was found among every 100 confirmed cases of monkeypox [53]. Strengthening vaccination with the monkeypox vaccine is beneficial for HCWs. Wolff et al. retrospectively analyzed 2054 Israeli adults with risk factors for monkeypox infection. They found that one dose of vaccine was associated with an 86 % reduction in the risk of monkeypox [54]. From July 31, 2022 to October 1, 2022, among vaccine-eligible men aged 18–49 years in 43 jurisdictions in the United States, the incidence of monkeypox among those who were not vaccinated was estimated to be 10 times greater than that reported for fully vaccinated people and seven times greater than that described for those who received only the first vaccine dose [55]. In the population infected with monkeypox, compared with those who have not been vaccinated, vaccinated individuals have a lower severity of monkeypox; furthermore, if the vaccine is administered within four days of infection, it can modify or prevent the onset of clinical disease [56,57].

Our study showed that 54 % of HCWs were willing to be vaccinated against monkeypox, and some HCWs still showed resistance to vaccination. These results can be attributed to several factors: 1. People are often more worried about diseases such as COVID-19 than about monkeypox [58]. Ricco et al. conducted a survey among HCWs to evaluate the potential threat represented by monkeypox. The participants ranked monkeypox far below other infectious diseases, including not only COVID-19 but also more common conditions, such as tuberculosis, acquired immune deficiency syndrome and hepatitis B virus infection [24]. 2. Some HCWs did not know about monkeypox and even misunderstood it. Previous studies have shown that a good understanding of an infectious disease is related to the acceptance of vaccines against the disease [59–61]. 3. Concerns about vaccines can also cause HCWs to hesitate to receive a vaccine. In the United States, obstacles to vaccination against COVID-19 among HCWs include concerns about its effectiveness (37.1 %), safety (55.0 %) and long-term side effects (57.1 %) [62]. In Hong et al.'s study, 67.15 % of participants expressed concern about the

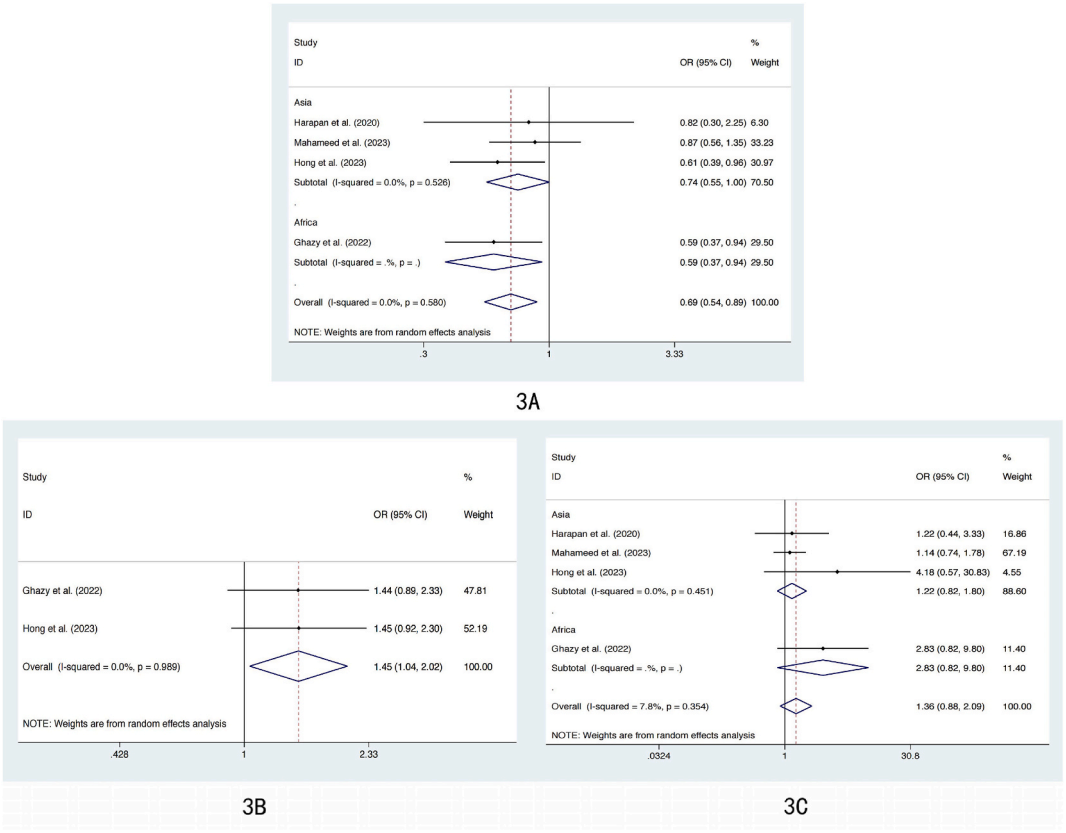

Fig. 3. Forest plot of factors affecting healthcare workers' willingness to be vaccinated against monkeypox: 3A) low-income; 3B) middle-income; and 3C) high-income.

effectiveness of the monkeypox vaccine, and 68.90 % of participants expressed concern about its safety. 4. Given that monkeypox is self-limiting, symptoms usually disappear within 14–21 days [3,63]. Some HCWs may be complacent about this disease and believe that even if they are infected with the monkeypox virus, vaccination is unnecessary.

A history of vaccination with various types of vaccines may affect people's willingness to be vaccinated in the future [64]. HCWs who were vaccinated with the COVID-19 vaccine and influenza vaccine had a greater likelihood of accepting the monkeypox vaccine, which might be attributed to their positive experience with the benefits of vaccination. After large-scale vaccination with the COVID-19 vaccine was achieved worldwide, there was a decline in mortality worldwide [65]. Moreover, the minor side effects of previous vaccination also dispelled some HCWs' fears about the safety of the monkeypox vaccine. We also found that low-income HCWs were less willing to be vaccinated against monkeypox, which might be related to their concerns about the cost of the vaccine.

In our study, only 40 % of the HCWs had good knowledge of monkeypox, which is a worrying result. We believe that three reasons explain this finding: 1. The global program for smallpox vaccination ended after 1980 [66], which means that many HCWs lived in the "smallpox-free" era, and it is not surprising that their attention to the monkeypox virus has decreased. Moreover, in daily medical practice, many HCWs never treat monkeypox patients or even see them, which also leads to a lack of clinical experience. Reports from Indonesia showed that local HCWs were much more aware of common infectious diseases (such as dengue) than emerging infectious diseases (such as Zika) [67,68]. 2. Our results showed that whether HCWs had received monkeypox education did not significantly affect their knowledge of monkeypox either because there were few courses related to monkeypox or because most HCWs did not study monkeypox knowledge seriously. Harapan et al. noted that fewer than 20 % of general practitioners had heard of monkeypox during their medical education, highlighting the lack of monkeypox education in academic courses [29]. 3. Studies have shown that the main source of information about monkeypox in HCWs is social media rather than scientific journals or medical institutions [25,27]. Misinformation on social media not only prevents HCWs from having correct knowledge about monkeypox but also affects their willingness to be vaccinated. The most representative fallacy is the proliferation of conspiracy ideas on social media, including "viruses are biological weapons created by superpowers to control the world" and "lockdowns in response to emerging infections are designed to conduct mass surveillance and control every part of our lives". Moreover, studies have shown that some HCWs in many countries, including Jordan, Kuwait and Nigeria, support the idea of conspiracy promoted through social media [69–71].

Although the outbreak of monkeypox has been less severe than that of COVID-19 and has not affected people's daily lives, we are worried that the virus will mutate and may cause more serious consequences. Studies have shown that the adaptability of monkeypox virus to the human body is evolving [72]. Isidro et al. compared the genome of monkeypox virus in 2022 with those of its relatives in

2018–2019 and reported that the average difference between the genomes was 50 single-nucleotide polymorphisms, far exceeding the expected mutation rate of Orthopoxviruses [73]. There is no doubt that preventing disease among healthy people is much better than treating disease among patients who are already sick. One of the most significant global accomplishments was the eradication of smallpox, which was achieved through effective vaccination programs [36]. Multiple studies have shown that the general population considers HCWs to be the most trusted source of information about monkeypox. Moreover, HCWs are quite effective at promoting vaccine acceptance in the general population. Unfortunately, when HCWs are affected by vaccine hesitancy, they may also transmit this attitude to the people for whom they care [24,74,75]. Therefore, we propose the following suggestions. For medical students, we should teach monkeypox courses and add related topics to their academic assessment; continuing education related to monkeypox should be provided to HCWs who have already completed their studies, and the continuity of education should be maintained. An awareness-raising campaign in Brazil encouraged HCWs to receive the influenza vaccine, which successfully increased the vaccination rate to 34.4 %. However, due to the lack of continuous education and intervention, the proportion decreased to 20.2 % in the second year and to 12.75 % two years later [76]. In terms of acquiring knowledge, scientific journals should be more prominently regarded as regular information sources for HCWs and as an important strategy for improving their knowledge of monkeypox [77] so that HCWs can have a clearer understanding of the side effects and safety of the monkeypox vaccine and improve their willingness to receive it.

5. Limitations

There are several limitations in our study. The study designs of all the included articles were cross-sectional surveys. The cross-sectional design was designed to measure associations between the explanatory variables and the different outcomes of interest, and it was impossible to determine causal relationships. For cross-sectional studies, it is important to control the time span of the survey, and HCWs' knowledge of monkeypox may change over time. The time span was quite different among the studies we included. Ricco et al. and Zhou et al. have the shortest time spans, with only a week to complete the survey [24,37]. Scarinci et al. reported the longest time span, nearly one year [32], and the long time span may have affected the quality of the research. Most of the information in the article came from online questionnaires, and some answers might be obtained after searching for correct answers online. When investigating the knowledge of HCWs about monkeypox, the questionnaires used in each study were different, which could have impacted the consistency of the results.

6. Conclusions

Some HCWs have shown resistance to vaccination against monkeypox, and it is particularly noteworthy that most HCWs do not have good knowledge of monkeypox. Publicity and education on monkeypox should be strengthened so that more people, especially HCWs, can have a good understanding of monkeypox and be willing to be vaccinated.

Ethical statement

An ethics statement is not applicable because this study is based exclusively on published literature.

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Data availability statement

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Yingying Han: Writing – original draft, Data curation, Conceptualization. **Xin Wang:** Writing – review & editing. **Xingzhao Li:** Methodology, Data curation. **Zhuan Zhong:** Writing – original draft, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e35196.

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