Acceptance of coronavirus disease 2019 (COVID-19) vaccines among healthcare workers: A meta-analysis

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Background: The coronavirus disease 2019 (COVID-19) pandemic has posed increasing challenges to global health systems. Vaccination against COVID-19 can effectively prevent the public, particularly healthcare workers (HCWs), from being infected by this disease.

Objectives: We aim to understand the factors influencing HCWs’ acceptance of COVID-19 vaccines.

Methods: We searched PubMed, Embase and Web of Science to collect literature published before May 15, 2022, about HCWs’ acceptance of COVID-19 vaccines. The Newcastle–Ottawa quality assessment scale was used to assess the risk of bias and the quality of the included studies. We utilized Stata 14.0 software for this meta-analysis with a random-effects model, and odds ratios (ORs) with 95% confidence intervals (CIs) were reported. This meta-analysis was conducted in alignment with the preferred reporting items for systematic review and meta-analysis (PRISMA) guideline.

Results: Our meta-analysis included 71 articles with 93,508 HCWs involved. The research showed that the acceptance of vaccines had significantly increased among HCWs compared to non-HCWs (OR = 1.91, 95% CI: 1.16–3.12). A willingness to undergo COVID-19 vaccination was observed in 66% (95% CI: 0.61–0.67) of HCWs. Among the HCWs involved, doctors showed a generally increased intention to be vaccinated compared with nurses (OR = 2.22, 95% CI: 1.71–2.89). Additionally, males were found to hold more positive attitudes toward vaccination than females (OR = 1.81, 95% CI: 1.55–2.12). When the effectiveness of COVID-19 vaccines was improved, the vaccination acceptance of HCWs was greatly increased accordingly (OR = 5.03, 95% CI: 2.77–9.11). The HCWs who were willing to vaccinate against seasonal influenza showed an increased acceptance of COVID-19 vaccines (OR = 3.52, 95% CI: 2.34–5.28). Our study also showed that HCWs who were willing to be vaccinated against COVID-19 experienced a reduced rate of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection (OR = 0.78, 95% CI: 0.66–0.92).
Conclusions: Our analysis revealed that the five factors of occupation, gender, vaccine effectiveness, seasonal influenza vaccines, and SARS-CoV-2 infection presumably affected the acceptance of COVID-19 vaccines among HCWs. It is essential to boost the confidence of HCWs in COVID-19 vaccines for the containment of the epidemic.

KEYWORDS
COVID-19, vaccines, meta-analysis, seasonal influenza, healthcare workers

Introduction

Rationale

On March 16, 2020, the first mRNA vaccine for coronavirus disease 2019 (COVID-19) developed by Moderna entered the clinical trial stage in the United States. Subsequently, various COVID-19 vaccines, including DNA-based vaccines, have been popularized throughout the world (1). Developing safe and effective vaccines to promote large-scale vaccination is probably the most effective way for humankind to fight against COVID-19 (2).

In 2022, millions of doses of COVID-19 vaccines are now administered each day globally (3). Surprisingly, numerous people showed distrust and concerns about COVID-19 vaccines (4). A large number of studies have shown that some healthcare workers (HCWs) remain skeptical about whether to receive COVID-19 vaccination (5). In one survey, approximately one-sixth of HCWs claimed that they would not choose to be vaccinated against COVID-19 even if mandated (6). The risk of the members of HCWs infected with COVID-19 was nearly three times that of the non-HCWs (7). In some countries, approximately 10% of HCWs are infected with SARS-CoV-2 (8). The acceptance of COVID-19 vaccines among non-HCWs can be easily affected by HCWs; in particular, HCWs with a negative attitude tend not to recommend vaccines to patients (9).

Objectives

We aim, through meta-analysis, to understand the factors influencing HCWs’ acceptance of vaccination against COVID-19. Our study may provide insights for promoting future immunization programs worldwide.

Materials and methods

Eligibility criteria

Studies meeting the following criteria were included in the meta-analysis: (1) the content must include the acceptance of HCWs about COVID-19 vaccines, (2) the number of HCWs who are willing and unwilling (including refusal and hesitation) to vaccinate should be recorded separately, and (3) the sample sizes of both the experimental group and the control group were more than 10.

Information from abstracts, comments, reviews, posters and case reports was excluded.

Search strategy

The method of “key words” + “free words” was adopted for retrieval. Search terms were limited to the titles and abstracts. Detailed strategies are listed in Supplementary File 1.

Study selection process

Literature collected from the database was imported into NoteExpress software for filtration. After deleting duplicated literature, we first read the titles and abstracts before we eliminated irrelevant pieces. Articles that did not meet the requirements were then further screened based on the abstracts or the full text. Articles that were fairly related were adopted for subsequent data selection.

Data selection process and items

Data extraction was completed independently by two authors. When those two authors disagreed on data selection, they would debate the problem before delivering it to a third author for the final conclusion.
The following data were recorded: the number of HCWs willing and unwilling to be vaccinated against COVID-19; the number of HCWs who had been vaccinated against seasonal influenza in 2019–2020 and who preferred to be vaccinated against the same disease in 2020–2021; the number of HCWs in favor of compulsory COVID-19 vaccination; the number of doctors and nurses willing to receive COVID-19 vaccines; the number of non-HCWs willing to be vaccinated with COVID-19; the number of HCWs willing to be vaccinated with different effective rates (bounded by 70%); the gender, age, and education level of HCWs; the number of HCWs afflicted with chronic diseases; the number of HCWs who contacted closely with COVID-19 patients; and the number of people vaccinated against influenza and the number of COVID-19 cases in the two groups of HCWs who were willing and unwilling to be vaccinated against COVID-19. If an article could extract several groups of data under different conditions, they were represented by “-A,” “-B” or “-C.”

Study risk of bias assessment

The quality and the risk of bias of the included studies were independently assessed using the Newcastle–Ottawa quality assessment scale. A low risk of bias and high quality were considered if the overall score was equal to or above seven. The assessment was completed by one author and reviewed by another.

Reporting bias assessment

Egger’s test was used for quantitative analysis. A p-value < 0.05 indicates the presence of bias.
| Reference | Region | Publication year | Study period | HCWs | The number of HCWs in favor of compulsory vaccination | Doctors | Nurses | Non-HCWs | Vaccine effectiveness (over 70%) | Willing to receive COVID-19 vaccines among HCWs | Willing to receive COVID-19 vaccines among doctors | Willing to receive COVID-19 vaccines among nurses | Willing to receive COVID-19 vaccines among non-HCWs | Vaccination against seasonal influenza in 2019–2020 among HCWs | Willing to receive seasonal influenza vaccines in 2020–2021 among HCWs |
|-----------|--------|-----------------|--------------|------|--------------------------------------------------|--------|-------|---------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Mascarenhas et al. (6) | America | 2021 | NA | 245 | 98 | NA | NA | NA | NA | 136 | NA | NA | NA | NA | NA | 148 | 178 |
| Qattan et al. (10) | Saudi Arabia | 2021 | 2020.12.8–2020.12.14 | 673 | NA | NA | NA | NA | NA | 340 | NA | NA | NA | NA | NA | 267 | 251 |
| Harapan et al. (13)-A | Indonesia | 2020 | 2020.3.25–2020.4.6 | 264 | NA | NA | NA | 1,095 | Yes | 252 | NA | NA | NA | NA | NA | 1,016 | NA |
| Harapan et al. (13)-B | Indonesia | 2020 | 2020.3.25–2020.4.6 | 264 | NA | NA | NA | 1,095 | No | 193 | NA | NA | NA | NA | NA | 718 | NA |
| Singhania et al. (14) | India | 2021 | 2020.1.20–2020.1.24 | 721 | NA | 615 | 56 | NA | NA | 572 | 496 | 32 | NA | NA | NA | 636 | NA |
| Nzaji et al. (12) | Congo | 2020 | 2020.3.20–2020.4.30 | 613 | NA | NA | NA | NA | NA | 170 | NA | NA | NA | NA | NA | 718 | NA |
| Harapan et al. (13)-A | Indonesia | 2020 | 2020.12.25–2020.12.31 | 5287 | NA | NA | NA | NA | NA | 3,032 | NA | NA | NA | NA | NA | 1,093 | NA |
| Kanyike et al. (15) | Uganda | 2021 | 2021.3.15–2021.3.21 | 600 | NA | NA | NA | NA | NA | 224 | NA | NA | NA | NA | NA | 810 | 1,364 |
| Chew et al. (16) | Asia-Pacific | 2021 | 2020.12.12–2020.12.21 | 1,720 | NA | 892 | 404 | NA | NA | 1,657 | 859 | 389 | NA | NA | NA | 1,025 | 1,325 |
| Papagiannis et al. (17) | Greece | 2020 | 2020.2.10–2020.2.25 | 461 | NA | 140 | 215 | NA | NA | 200 | 85 | 73 | NA | NA | NA | 636 | NA |
| Shaw et al. (18) | America | 2021 | 2020.12.22–2021.1.18 | 387 | NA | NA | NA | 1,913 | NA | 321 | NA | NA | NA | NA | NA | 1,093 | NA |
| Ledda et al. (20) | Italy | 2020 | 2020.9.1–2020.9.20 | 787 | NA | 324 | 357 | NA | NA | 593 | 261 | 251 | NA | NA | NA | 1,031 | NA |
| Verger et al. (21)-A | France | 2020 | 2020.10.1–2020.11.30 | 1,209 | NA | NA | NA | NA | NA | 910 | NA | NA | NA | NA | NA | 1,031 | NA |
| Verger et al. (21)-B | Belgium | 2020 | 2020.10.1–2020.11.30 | 434 | NA | NA | NA | NA | NA | 315 | NA | NA | NA | NA | NA | 347 | NA |
| Verger et al. (21)-C | Canada | 2020 | 2020.10.1–2020.11.30 | 1,055 | NA | NA | NA | NA | NA | 743 | NA | NA | NA | NA | NA | 636 | NA |
| Gennaro et al. (22) | Italy | 2020 | 2021.1.1–2021.1.31 | 385 | NA | 205 | 89 | NA | NA | 80 | 49 | 10 | NA | NA | NA | 636 | NA |
| Manning et al. (26) | America | 2020 | 2020.8.10–2020.9.14 | 1,212 | NA | NA | NA | NA | NA | 561 | NA | NA | NA | NA | NA | 3,363 | NA |
| Shekhar et al. (27) | America | 2020 | 2020.10.7–2020.11.9 | 3,479 | NA | NA | NA | NA | NA | 1,247 | NA | NA | NA | NA | NA | 3,363 | NA |
| Dzieciolowska et al. (28) | Canada | 2020 | 2020.12.15–2020.12.28 | 2,761 | NA | NA | NA | NA | NA | 2,233 | NA | NA | NA | NA | NA | 3,363 | NA |
| Theodore et al. (29) | America | 2020 | 2020.4.26–2020.7.22 | 121 | NA | NA | NA | NA | NA | 94 | NA | NA | NA | NA | NA | 3,363 | NA |
| Maraga et al. (30) | Palestine | 2020 | 2020.12.22–2021.1.6 | 1,157 | NA | 374 | 485 | NA | NA | 438 | 231 | 118 | NA | NA | NA | 636 | NA |
| Lucia et al. (31) | America | 2020 | 2020.9.24–2020.10.16 | 540 | NA | 201 | 207 | NA | NA | 447 | 187 | 147 | NA | NA | NA | 1,025 | 1,325 |
| Gadoth et al. (32) | America | 2020 | 2020.1.20–2020.1.24 | 1,571 | 1,299 | 480 | 607 | NA | NA | 803 | 343 | 261 | NA | NA | NA | 636 | NA |
| Janssens et al. (33) | Germany | 2021 | 2020.12.1–2020.12.31 | 2,302 | NA | 203 | 89 | NA | NA | 1,471 | NA | NA | NA | NA | NA | 1,025 | 1,325 |
| Ahmed et al. (35) | Saudi Arabia | 2020 | 2020.10.1–2020.10.31 | 236 | NA | 38 | 146 | NA | NA | 115 | 18 | 69 | NA | NA | NA | 636 | NA |
| Kwock et al. (36) | Hong Kong | 2020 | 2020.3.15–2020.4.30 | 1,205 | NA | NA | NA | NA | NA | 759 | NA | NA | NA | NA | NA | 590 | NA |
| Wang et al. (37) | Hong Kong | 2020 | 2020.2.26–2020.3.31 | 806 | NA | NA | NA | NA | NA | 322 | NA | NA | NA | NA | NA | 383 | 360 |
| Konopinska et al. (38) | Poland | 2021 | 2021.1.1–2021.1.31 | 126 | NA | NA | NA | NA | NA | 90 | NA | NA | NA | NA | NA | 90 | NA |
| El Hadji et al. (39)-A | Libya | 2021 | 2020.12.1–2020.12.18 | 3,967 | NA | 1,394 | 821 | NA | Yes | 3,174 | 1,386 | 643 | NA | NA | NA | 383 | 360 |
| El Hadji et al. (39)-B | Libya | 2021 | 2020.12.1–2020.12.18 | 3,967 | NA | 1,394 | 821 | NA | No | 1,552 | 494 | 314 | NA | NA | NA | 383 | 360 |

(Continued)
| Reference | Region         | Publication year | Study period       | HCWs | The number of HCWs in favor of compulsory vaccination | Doctors | Nurses | Non-HCWs | Vaccine effectiveness (over 70%) | Willing to receive COVID-19 vaccines among HCWs | Willing to receive COVID-19 vaccines among doctors | Willing to receive COVID-19 vaccines among nurses | Willing to receive COVID-19 vaccines among non-HCWs | Vaccination against seasonal influenza in 2019–2020 among HCWs | Willing to receive seasonal influenza vaccines in 2020–2021 among HCWs |
|-----------|----------------|------------------|--------------------|------|------------------------------------------------------|---------|-------|----------|---------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------------------|------------------------------------------------|
| Szmyd et al. (40) | Poland | 2021 | 2020.12.22–2020.12.25 | 687   | NA | NA | NA | 1,284 | NA | 632 | NA | NA | 763 | NA | NA |
| Gonululu et al. (41) | Turkey | 2021 | 2020.11.1–2020.11.15 | 506 | 303 | NA | NA | NA | 420 | NA | NA | NA | 198 | NA | NA |
| Socarras et al. (42)-A | Columbia | 2021 | 2021.1.1–2021.1.31 | 1,066 | NA | NA | NA | NA | Yes | 821 | NA | NA | NA | NA | NA |
| Socarras et al. (42)-B | Columbia | 2021 | 2021.1.1–2021.3.1 | 1,066 | NA | NA | NA | NA | No | 967 | NA | NA | NA | NA | NA |
| Kuter et al. (43) | America | 2021 | 2020.11.13–2020.12.6 | 12,034 | NA | NA | NA | NA | NA | 7,284 | NA | NA | NA | NA | NA |
| Yu et al. (44) | China | 2021 | 2020.10.1–2020.11.30 | 2,264 | NA | 362 | 1,902 | NA | NA | 294 | 55 | 239 | NA | NA | NA |
| Hoke et al. (45) | America | 2021 | 2020.5.1–2020.5.31 | 350 | NA | NA | NA | NA | NA | 297 | NA | NA | NA | NA | NA |
| Giuseppe et al. (46) | Italy | 2021 | 2020.9.14–2020.11.30 | 779 | NA | 437 | 194 | NA | NA | 629 | 395 | 132 | NA | NA | NA |
| Kaplan et al. (47) | Turkey | 2021 | 2020.12.25–2020.12.31 | 1,574 | NA | 1,115 | 275 | NA | NA | 1,331 | 1,003 | 183 | NA | NA | NA |
| Kose et al. (48) | Turkey | 2020 | 2020.9.17–2020.9.20 | 1,138 | NA | 53 | 306 | NA | NA | 781 | 27 | 200 | NA | NA | NA |
| Sahle et al. (49) | Egypt | 2021 | 2021.1.1–2021.1.31 | 2,133 | 1,487 | NA | NA | NA | NA | 746 | NA | NA | NA | NA | NA |
| Droor et al. (50) | Israel | 2020 | 2020.3.19–2020.3.25 | 549 | NA | 338 | 211 | 1,112 | NA | 393 | 264 | 129 | 834 | NA | NA |
| Unroe et al. (51) | America | 2021 | 2020.11.14–2020.11.17 | 8,243 | NA | NA | NA | NA | NA | 5,705 | NA | NA | NA | NA | NA |
| Kukrejia et al. (52) | India | 2021 | 2020.9.24–2020.12.31 | 500 | NA | NA | 238 | NA | NA | 117 | NA | NA | 73 | NA | NA |
| Gubruka et al. (53) | France | 2021 | 2021.2.1–2021.2.28 | 61 | NA | NA | NA | NA | NA | 34 | NA | NA | NA | NA | NA |
| Wang et al. (54) | China | 2021 | 2020.9.15–2020.9.20 | 5,634 | NA | 1,123 | 1,841 | NA | NA | 2,874 | 929 | 1,400 | NA | NA | NA |
| Yourtis et al. (55) | Turkey | 2021 | 2021.4.1–2021.11.3 | 320 | NA | 113 | NA | 732 | NA | 168 | NA | 214 | NA | NA | NA |
| Noushad et al. (56) | Twelve countries | 2022 | 2022.1.2–2022.1.4 | 2,962 | NA | NA | NA | NA | NA | 2,038 | NA | NA | NA | NA | NA |
| Dikhar et al. (57) | India | 2022 | NA | NA | NA | NA | NA | NA | NA | 340 | NA | NA | NA | NA | NA |
| Aridj et al. (58) | South Africa | 2021 | 2020.11.10–2020.12 | 511 | NA | NA | NA | NA | NA | 511 | NA | NA | 511 | NA | NA |
| Ayole et al. (59) | Ethiopia | 2021 | 2021.3.1–2021.3.30 | 422 | NA | 60 | 148 | NA | NA | 191 | 39 | 52 | NA | NA | NA |
| Vignier et al. (60) | Gambia | 2021 | 2021.1.1–2021.1.30 | 529 | NA | NA | NA | NA | NA | 373 | NA | NA | 183 | 140 |
| Do et al. (61) | America | 2021 | 2020.12.10–2020.12.20 | 1,076 | NA | 63 | 275 | NA | NA | 563 | 52 | 144 | NA | NA | NA |
| Khan et al. (62) | Pakistan | 2022 | NA | NA | NA | NA | NA | NA | NA | 219 | NA | NA | NA | NA | NA |
| Wiysonge et al. (63) | South Africa | 2021 | 2021.3.20–2021.5 | 395 | NA | 49 | 191 | NA | NA | 233 | 44 | 97 | NA | NA | NA |
| Koh et al. (64) | Singapore | 2022 | 2021.5–2021.6 | 528 | NA | NA | NA | NA | NA | 501 | NA | NA | NA | NA | NA |
| Sharaf et al. (65) | Egypt | 2022 | 2021.8–2021.10 | 171 | NA | NA | NA | NA | NA | 112 | NA | NA | NA | NA | NA |
| Raju et al. (66) | Sudan | 2022 | 2021.6.30–2021.7.1 | 217 | NA | NA | NA | NA | NA | 121 | NA | NA | NA | NA | NA |
| Pal et al. (67) | America | 2021 | 2021.1.2–2021.3.31 | 1,358 | NA | NA | NA | NA | NA | 1,251 | NA | NA | NA | NA | NA |
| Saddik et al. (68) | United Arab Emirates | 2021 | 2020.11.20–2021.1.3 | 517 | NA | NA | NA | NA | NA | 312 | NA | NA | NA | NA | NA |
| Hara et al. (69) | Japan | 2021 | 2021.1.19 | 1,030 | NA | 120 | 369 | 6,180 | NA | 477 | 65 | 168 | 3,003 | NA | NA |
| Boche et al. (70) | Ethiopia | 2022 | 2021.3.1–2021.7.30 | 319 | NA | NA | NA | NA | NA | 232 | NA | NA | NA | NA | NA |
| Thomas et al. (71) | America | 2022 | 2021.3.1–2021.4.22 | 505 | NA | NA | NA | NA | NA | 457 | NA | NA | NA | NA | NA |
| Otiti-Sengeri et al. (72) | Uganda | 2022 | 2021.6–2021.8 | 300 | NA | NA | NA | NA | NA | 293 | NA | NA | NA | NA | NA |

(Continued)
## Synthesis methods

The $I^2$ statistic was used to quantify the heterogeneity among studies. An $I^2$ value $< 50\%$ indicated mild heterogeneity, while an $I^2$ value $\geq 75\%$ suggested significant heterogeneity. Moderate heterogeneity was considered if $50\% \leq I^2 < 75\%$. We conducted subgroup analysis to explore the source of heterogeneity. A random-effects model was used to estimate the effect value. Stata 14.0 software was applied for all analyses. A $p$-value of $z$ test $< 0.05$ was considered to be statistically significant.

## Effect measures and certainty assessment

In this study, the ratio and odds ratio (OR) were used for data analysis, and the confidence interval (CI) was $95\%$.

## Results

### Study selection

A total of 1,170 studies were searched in the database, of which 400 duplicated studies were deleted with NoteExpress software. According to the titles and abstracts, 578 articles irrelevant to this study were eliminated. Of the remaining 192 papers, 121 were excluded after further screening, including comments, reviews, case reports, and papers with insufficient data. Seventy-one articles were finalized for inclusion in our meta-analysis. The flow diagram of the study selection is shown in Figure 1.

### Study characteristics

The HCWs in our study came from various occupations, including doctors, nurses, paramedics, medical teachers, and students. The whole sample we extracted from the literature included 75,345 HCWs and 13,513 non-HCWs, covering 40 countries and regions.

### Risk of bias in studies

All the studies included in the Newcastle–Ottawa quality assessment scale indicated a fairly low risk of bias and high quality (Supplementary Table 1).

### Results of individual studies

The results of individual studies are presented in structured tables. The information of HCWs and non-HCWs is listed in...
### TABLE 2 The characteristics of HCWs who are willing and unwilling to receive coronavirus disease 2019 vaccines.

| Reference | Region | Publication year | Study period | Reference | Region | Publication year | Study period | Reference | Region | Publication year | Study period | Reference | Region | Publication year | Study period | Reference | Region | Publication year | Study period |
|-----------|--------|-----------------|--------------|-----------|--------|-----------------|--------------|-----------|--------|-----------------|--------------|-----------|--------|-----------------|--------------|-----------|--------|-----------------|--------------|
| Mascarenhas et al. (6) | America | 2021 | NA | 136 | 109 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 120 | 58 | 100 | 49 | 7 | 18 |
| Qattan et al. (10) | Saudi Arabia | 2020.12.8–2020.12.14 | 340 | 333 | 227 | 225 | 306 | 287 | 228 | 177 | NA | NA | NA | NA | NA | NA | 183 | 144 | 70 | 61 | 234 | NA |
| Papagiannis et al. (11) | Greece | 2020.12.15–2020.12.22 | 267 | 73 | NA | NA | NA | NA | 142 | 31 | NA | NA | NA | NA | NA | NA | 110 | 202 | NA | NA | NA | 208 |
| Niaji et al. (12) | Congo | 2020.3.20–2020.4.30 | 170 | 443 | 118 | 303 | NA | NA | NA | NA | NA | NA | NA | NA | NA | 389 | 112 | NA | NA | NA | NA | NA | NA | 109 | 40 |
| Singham et al. (13) | India | 2021.1.20–2021.1.24 | 572 | 149 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 160 | 217 | NA | NA | NA | NA | NA | NA | NA | NA |
| Kanyike et al. (15) | Uganda | 2021.3.15–2021.3.21 | 224 | 376 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 138 | 146 | NA | NA | NA | NA | NA | NA | NA | NA |
| Chew et al. (16) | Asia-Pacific | 2021.9.12–2021.12.21 | 1,055 | 65 | NA | NA | NA | NA | 646 | 24 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Papagiannis et al. (17) | Greece | 2020.2.10–2020.2.25 | 700 | 261 | NA | NA | NA | NA | 69 | 89 | NA | NA | NA | NA | NA | NA | NA | 192 | 143 | NA | NA | NA | NA | NA | NA | NA | NA |
| Shaw et al. (18) | America | 2021.9.1–2021.12.20 | 593 | 194 | 259 | 70 | 423 | 164 | 312 | 56 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Fares et al. (25) | Egypt | 2021.9.1–2021.12.21 | 1,469 | 985 | NA | NA | NA | NA | 595 | 108 | 823 | 762 | 194 | 32 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Manning et al. (26) | America | 2020.9.1–2020.10.31 | 80 | 305 | NA | NA | NA | NA | 28 | 44 | 11 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Kuter et al. (43) | America | 2020.11.13–2020.12.6 | 7,284 | 4,750 | 3,835 | 2,296 | NA | NA | 4,000 | 461 | 618 | 893 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Manning et al. (26) | America | 2020.8.10–2020.9.14 | 1,758 | 939 | NA | NA | NA | NA | 595 | 108 | 823 | 762 | 194 | 32 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Maltezou et al. (33) | Greece | 2020.9.1–2020.10.31 | 136 | 109 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Ahmed et al. (35) | Saudi Arabia | 2020.12.8–2020.12.14 | 340 | 333 | 227 | 225 | 306 | 287 | 228 | 177 | NA | NA | NA | NA | NA | NA | 183 | 144 | 70 | 61 | 234 | NA |
| Wang et al. (37) | Hong Kong | 2020.2.26–2020.3.31 | 322 | 484 | 189 | 236 | 267 | 376 | 67 | 39 | NA | NA | NA | NA | NA | NA | 190 | 247 | 83 | 97 | NA | NA | NA | NA | NA | NA | NA |
| Gomella et al. (41) | Turkey | 2020.11.1–2020.11.15 | 420 | 86 | NA | NA | NA | NA | 184 | 25 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Socarras et al. (42)-A | Colombia | 2021.1.1–2021.1.31 | 821 | 245 | NA | NA | NA | NA | 440 | 123 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Socarras et al. (42)-B | Colombia | 2021.1.1–2021.1.31 | 1,055 | 65 | NA | NA | NA | NA | 646 | 24 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Kinter et al. (43) | America | 2020.11.13–2020.12.6 | 7,284 | 4,750 | 3,835 | 2,296 | NA | NA | 2,064 | 461 | 618 | 893 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Giuseppe et al. (46) | Italy | 2020.9.1–2020.10.31 | 629 | 350 | NA | NA | NA | NA | 474 | 104 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Kaplan et al. (47) | Turkey | 2020.12.25–2020.12.31 | 1,331 | 243 | 612 | 176 | 977 | 224 | 563 | 85 | NA | NA | NA | NA | NA | NA | 768 | 153 | 421 | 51 | 972 | 152 | 51 | NA | NA | NA | NA | NA |
| Nose et al. (48) | Turkey | 2020.9.17–2020.9.20 | 781 | 357 | NA | NA | NA | NA | 234 | 79 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Sisael et al. (49) | Egypt | 2021.1.1–2021.1.31 | 746 | 1,387 | NA | NA | NA | NA | 276 | 466 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Gokhio et al. (51) | France | 2020.11.1–2020.12.31 | 34 | 27 | NA | NA | NA | NA | 6 | 3 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Wang et al. (54) | China | 2020.9.15–2020.9.20 | 2,874 | 760 | NA | NA | NA | NA | 2,499 | 703 | 689 | 131 | 422 | 63 | 526 | 136 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

(Continued)
| Reference            | Region                  | Publication year | Study period                      | HCWs | Age < 40 | Age < 50 | Male | Less than bachelor's degree | Close contact with COVID-19 patients | Chronic diseases | Married | Willing to receive seasonal influenza vaccines in 2020–2021 | Vaccination against seasonal influenza in 2019–2020 | SARS-CoV-2 infection |
|----------------------|-------------------------|------------------|-----------------------------------|------|----------|----------|------|-----------------------------|-------------------------------------|-----------------|---------|------------------------------------------------|------------------------------------------------|------------------|
| Noushad et al. (56)  | Twelve countries        | 2022             | 2021.2–2021.4                     | 2,038 | 924      | NA       | 1,903 | 890                         | 853                   | 332            | NA      | NA                                          | NA                                          | 334              |
| Dikhar et al. (57)   | India                   | 2022             | NA                               | 340  | 171      | NA       | NA   | 132                         | 64                    | NA             | 139      | 84                | NA              | 206              |
| Adeniyi et al. (58)  | South Africa            | 2021             | 2020.11–2020.12                   | 1,179 | 129      | NA       | NA   | 223                         | 19                    | 352            | 22       | 906              | 103             | 767              |
| Ayele et al. (59)    | Ethiopia                 | 2021             | 2021.3.1–2021.3.30                | 191  | 231      | 146      | NA   | 202                         | NA                    | NA             | NA       | 53                | 39              | 112              |
| Vignier et al. (60)  | French                  | 2021             | 2021.1.22–2021.3.26               | 373  | 206      | NA       | NA   | 220                         | 165                   | 150            | 36       | NA                | NA              | 127              |
| Dev et al. (61)      | America                 | 2021             | 2020.12.10–2020.12.20             | 563  | 513      | NA       | NA   | NA                          | NA                    | NA             | NA       | NA                | NA              | 38               |
| Khan et al. (62)     | Pakistan                | 2022             | NA                               | 219  | 29       | NA       | NA   | 147                         | 12                    | NA             | NA       | NA                | NA              | 102              |
| Wijyongse et al. (63) | South Africa           | 2022             | 2021.3–2021.5                     | 233  | 162      | NA       | NA   | NA                          | NA                    | 100            | 95       | NA                | NA              | NA               |
| Koh et al. (64)      | Singapore               | 2022             | 2021.5–2021.6                     | 501  | 27       | NA       | NA   | 64                          | 1                     | NA             | 406      | 18                | NA              | 462              |
| Sharaf et al. (65)   | Egypt                   | 2022             | 2021.8–2021.10                    | 78   | 93       | 59       | 73   | 73                          | 89                    | 19             | 7        | NA                | 59              | 71               |
| Raja et al. (66)     | Sudan                   | 2022             | 2021.6.30–2021.7.11               | 121  | 96       | NA       | NA   | 57                          | 43                    | NA             | NA       | NA                | NA              | 57               |
| Pal et al. (67)      | America                 | 2021             | 2021.2.1–2021.3.31                | 1,251 | 107      | NA       | NA   | 258                         | 15                    | 503            | 64       | 691              | 56              | NA               |
| Thomas et al. (71)   | America                 | 2022             | 2021.3.12–2021.4.22               | 457  | 48       | 126      | 18   | NA                          | NA                    | 70              | 5        | NA                | NA              | 336              |
| Xu et al. (76)       | China                   | 2021             | 2021.4.16–2021.4.18               | 906  | 145      | NA       | NA   | 95                          | 16                    | 69             | 10       | NA                | NA              | NA               |
| Li et al. (78)       | China                   | 2021             | 2021.1.20–2021.2.20               | 1,670 | 109      | 1,388    | 88   | 1,621                       | 107                   | 202            | 8        | 255               | 14              | NA               |

HCWs, Healthcare workers; NA, not applicable; -A or -B, an article could extract several groups of data without intersection, or the data record research results under different condition; COVID-19, coronavirus disease 2019.
FIGURE 2
Forest plot of the acceptance of coronavirus disease 2019 vaccines by healthcare workers.
FIGURE 3
Forest plot of the acceptance of healthcare workers of compulsory vaccination.

Table 1. Among HCWS, information on people’s willingness to receive COVID-19 vaccines is shown in Table 2.

Reporting biases

We used Egger’s test for reporting bias analysis (Supplementary File 2). The study of the acceptance of HCWs with different education levels about COVID-19 vaccines showed a slight bias (p = 0.049), while other results carried no significant bias.

Certainty of evidence and results of syntheses

We considered the continent where the study was conducted as the basis of subgroup division and explored the source of heterogeneity through subgroup analysis (Figures 2–10). We found that the heterogeneity in some subgroups remained high.

Seventy-one articles were used to study the acceptance of HCWs about COVID-19 vaccines, which showed that a willingness to undergo COVID-19 vaccination was observed in 66% (95% CI: 0.61–0.67, I² = 99.7%, Figure 2) of HCWs. A recent study showed that up to 98% of HCWs in Uganda were willing to be vaccinated against COVID-19 (72). However, through subgroup analysis, we found that only 56% (95% CI: 0.42–0.70, I² = 99.8%, Figure 2) of HCWs in African countries were willing to receive COVID-19 vaccination, which was lower than that in Asian (ratio = 0.66, 95% CI: 0.56–0.76, I² = 99.8%, Figure 2) and European & American countries (ratio = 0.70, 95% CI: 0.64–0.75, I² = 99.5%, Figure 2).

Six articles were used to study the acceptance of HCWs about compulsory vaccination, showing that the proportion of HCWs who agreed with this was 59% (95% CI: 0.46–0.72, I² = 98.9%, Figure 3). We analyzed 24 articles to examine the variance in willingness to take the COVID-19 vaccine between doctors and nurses, and the results indicated that doctors showed a higher willingness to receive COVID-19 vaccination than nurses (OR = 2.22, 95% CI: 1.71–2.89, I² = 91.9%, Figure 4). Nine articles were used to compare the willingness of HCWs and non-HCWs to receive COVID-19 vaccination, and it was found that the willingness of HCWs was greatly increased compared to that of non-HCWs (OR = 1.91, 95% CI: 1.16–3.12, I² = 97.0%, p < 0.001, Figure 5). Additionally, by analyzing three other articles, we found that with an increased effectiveness of the vaccines in preventing COVID-19 (bounded by 70%), the willingness of HCWs to receive the vaccination also rose accordingly (OR = 5.03, 95% CI: 2.77–9.11, I² = 93.6%, p < 0.001, Figure 6). The research revealed that male members of HCWs showed a higher
Forest plot of the difference in the willingness between doctors and nurses to receive coronavirus disease 2019 vaccines.

The HCWs with a higher acceptance of COVID-19 vaccines were more inclined to receive seasonal influenza vaccines in 2019–2020 (OR = 3.44, 95% CI: 2.45–4.82, I² = 98.9%, p < 0.001, Figure 8) and 2020–2021 (OR = 3.52, 95% CI: 2.34–5.28, I² = 77.9%, p < 0.001, Figure 9). Furthermore, the rate of SARS-CoV-2 infection among HCWs willing to be vaccinated was significantly lower than that among HCWs who showed hesitancy (OR = 0.78, 95% CI: 0.66–0.92, I² = 65.4%, p < 0.001, Figure 10).

Nine articles were used to study the differences between the willingness of HCWs to receive COVID-19 vaccination and the 2020–2021 seasonal influenza vaccines (OR = 1.71, 95% CI: 0.83–3.52, I² = 98.9%, p = 0.145, Supplementary Figure 1). Seven articles were used to study the impact of the COVID-19 epidemic on seasonal influenza vaccination (2019–2020 and 2020–2021) (OR = 1.43, 95% CI: 0.81–2.53, I² = 98.2%, p = 0.214, Supplementary Figure 2), and no significant difference was observed in either study.

Some studies have shown that elderly HCWs are more willing to be inoculated with COVID-19 vaccines (20, 28, 51). Nevertheless, a study from Zhejiang Province, China, showed that a large number of HCWs aged over 50 years experienced SARS in 2003, influenza A (H1N1) in 2009 and avian influenza A (H7N9) in 2013. With the exception of H1N1, the other two were well contained without introducing vaccination, so some people would inevitably assume that vaccination against COVID-19 was probably not necessary (54). Married HCWs were remarkably more willing to be vaccinated for the protection of their families (47). However, a study from Uganda came to the opposite conclusion. Their study revealed that single HCWs showed a higher acceptance of COVID-19 vaccines (15). To solve similar contradictions, we compared the characteristics of HCWs from two groups, one with HCWs who were willing to
### FIGURE 5
Forest plot of the willingness of healthcare workers (HCWs) and non-HCWs to receive coronavirus disease 2019 vaccines.

| Study ID | OR (95% CI) | Weight |
|----------|-------------|--------|
| Harapan et al.-A (2020) | 1.63 (0.68, 3.04) | 8.96 |
| Harapan et al.-B (2020) | 1.43 (1.06, 1.93) | 10.09 |
| Dror et al. (2020) | 0.84 (0.67, 1.06) | 10.25 |
| Kukrel et al. (2021) | 0.69 (0.49, 0.97) | 9.97 |
| Yurttas et al. (2021) | 2.68 (2.04, 3.51) | 10.16 |
| Hara et al. (2021) | 0.91 (0.60, 1.40) | 10.40 |
| Kashif et al. (2021) | 2.92 (1.93, 4.41) | 9.76 |
| Yurttas et al. (2021) | 2.09 (1.60, 2.72) | 10.17 |
| **Subtotal (I-squared = 93.4%, p = 0.000)** | 1.44 (0.99, 2.09) | 79.77 |

#### Europe and America

| Study ID | OR (95% CI) | Weight |
|----------|-------------|--------|
| Szmyd et al. (2021) | 4.09 (3.09, 5.41) | 10.14 |
| Szmyd et al. (2021) | 7.85 (5.83, 10.56) | 10.09 |
| **Subtotal (I-squared = 89.8%, p = 0.002)** | 5.65 (2.98, 10.71) | 20.23 |

| **Overall (I-squared = 97.0%, p = 0.000)** | 1.91 (1.16, 3.12) | 100.00 |

NOTE: Weights are from random effects analysis

### FIGURE 6
Forest plot of the acceptance of healthcare workers of coronavirus disease 2019 vaccines with different effectiveness (bounded by 70%).

| Study ID | OR (95% CI) | Weight |
|----------|-------------|--------|
| Harapan et al. (2020) | 7.73 (4.07, 14.65) | 26.48 |
| Elhadi et al. (2021) | 6.23 (5.63, 6.69) | 37.77 |
| Socarras et al. (2021) | 2.91 (2.27, 3.75) | 35.75 |
| **Overall (I-squared = 93.6%, p = 0.000)** | 5.03 (2.77, 9.11) | 100.00 |

NOTE: Weights are from random effects analysis
be inoculated with COVID-19 vaccines and another with those who were not. The results showed that age \([\text{OR} = 0.91, 95\% \text{ CI: 0.75–1.12}, I^2 = 89.3\%, p = 0.145, \text{Supplementary Figure 3}]\) and \([\text{OR} = 0.85, 95\% \text{ CI: 0.63–1.14}, I^2 = 90.1\%, p = 0.288, \text{Supplementary Figure 4}]\), education level \([\text{OR} = 0.81, 95\% \text{ CI: 0.54–1.22}, I^2 = 94.2\%, p = 0.315, \text{Supplementary Figure 5}]\), marriage status \([\text{OR} = 0.96, 95\% \text{ CI: 0.75–1.23}, I^2 = 71.9\%, p = 0.758, \text{Supplementary Figure 6}]\), close contact with COVID-19 patients \([\text{OR} = 1.01, 95\% \text{ CI: 0.77–1.32}, I^2 = 94.1\%, p = 0.959, \text{Supplementary Figure 7}]\), and chronic diseases \([\text{OR} = 1.19, 95\% \text{ CI: 0.81–1.01}, I^2 = 94.2\%, p = 0.758, \text{Supplementary Figure 8}]\).
FIGURE 8
Forest plot of the acceptance of seasonal influenza vaccines by healthcare workers (2019–2020).

FIGURE 9
Forest plot of the acceptance of seasonal influenza vaccines by healthcare workers (2020–2021).
Discussion

The vaccine is metaphorically known as the “seatbelt against the disease,” which can effectively protect people against infectious diseases at the lowest cost (79). In improving public health, vaccination functions as one of the most important advances. It successfully promoted the elimination of smallpox worldwide and the control of numerous infectious diseases (e.g., rubella, diphtheria, polio) (80). It is estimated that approximately two to three million deaths can be avoided each year by vaccination (81). Despite this, public distrust of vaccines is widespread. The most typical example is the boycott of polio vaccination in northern Nigeria in 2003–2004 (82). Frontline HCWs are frequently and closely exposed to highly contagious patients with COVID-19, posing them at highly increased risk of infection and transmission. Therefore, they became the primary concern of authorities around the world when they formulated COVID-19 vaccination policies (19). Our research showed that approximately 66% of HCWs were willing to receive COVID-19 vaccines, which might vary among different regions. A report showed that only 21% of HCWs in Egypt held a positive attitude toward COVID-19 vaccines (25). A survey on the Asia Pacific region showed that the acceptance of COVID-19 vaccines by HCWs in six countries, including China and India, approached nearly 96% (16). Since a compulsory vaccination program can
TABLE 3 The factors associated with COVID-19 vaccine acceptance of HCWs.

| Variables                                      | Included studies                                                                 | OR   | 95% CI   | P-value | $I^2$ |
|------------------------------------------------|----------------------------------------------------------------------------------|------|----------|---------|-------|
| Occupation (doctors and nurses)                | [14, 16, 17, 20, 23, 24, 30, 32, 33, 35, 39, 44, 46–48, 50, 54, 58, 59, 61, 63, 69, 73, 78] | 2.22 | 1.71–2.89| <0.001  | 91.90%|
| Occupation (HCWs and non-HCWs)                 | [13, 19, 40, 50, 52, 55, 65, 74, 79]                                             | 1.91 | 1.16–3.12| 0.01    | 97.00%|
| Vaccine effectiveness                          | [13, 39, 42]                                                                     | 5.03 | 2.77–9.11| <0.001  | 93.60%|
| Gender                                         | [10–12, 15–18, 20, 22, 23, 25–27, 33, 37, 41–43, 47–49, 53, 54, 56, 57, 58, 60, 62, 64, 65–67, 71, 76, 78] | 1.81 | 1.55–2.12| <0.001  | 89.50%|
| Seasonal influenza vaccines (2019–2020)        | [6, 23, 27, 37, 41, 49, 60]                                                     | 3.44 | 2.45–4.82| <0.001  | 81.30%|
| Seasonal influenza vaccines (2020–2021)        | [6, 11, 23, 41, 49, 60, 64]                                                     | 3.52 | 2.34–5.28| <0.001  | 77.90%|
| SARS-CoV-2 infection                           | [6, 14, 22, 25, 27, 30, 31, 41, 47, 49, 56, 57, 58, 59, 60, 61, 62, 65]           | 0.78 | 0.66–0.92| <0.001  | 65.40%|
| Age (bounded by 40)                            | [10, 12, 20, 22, 26, 27, 33, 37, 43, 47, 59, 65, 71, 78]                         | 0.91 | 0.75–1.12| 0.145   | 89.30%|
| Age (bounded by 50)                            | [10, 20, 22, 26, 27, 30, 33, 37, 46, 47, 54, 56, 60, 65, 78]                    | 0.85 | 0.63–1.14| 0.288   | 90.10%|
| Education level                                | [16, 23, 25, 27, 43, 54, 58, 63, 67, 76, 78]                                   | 0.81 | 0.54–1.22| 0.315   | 94.20%|
| Marriage status                                | [10, 12, 15, 16, 46, 47, 57, 59, 78]                                            | 0.96 | 0.75–1.23| 0.758   | 71.90%|
| Close contact with COVID-19 patients           | [10, 14, 18, 23, 25, 27, 33, 37, 41, 46, 47, 54, 57, 58, 64, 65, 67, 71]        | 1.01 | 0.77–1.32| 0.959   | 94.10%|
| Chronic diseases                               | [10, 16, 20, 27, 33, 35, 37, 41, 46, 47, 48, 56, 58, 59, 65]                   | 1.19 | 0.90–1.59| 0.222   | 90.60%|

HCWs, Healthcare workers; COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; OR, odds ratio; CI, confidence interval.

effectively increase the overall vaccination coverage rate (83), we considered the views of HCWs on this measure, and the results showed that approximately 59% of HCWs agreed with it. We additionally studied the impact of the COVID-19 epidemic on vaccination against seasonal influenza and the association between the two. The prior experience gained from seasonal influenza vaccination provides a reference and guidance for COVID-19 vaccination. It was noticed that the COVID-19 epidemic did not significantly affect the seasonal influenza vaccination of HCWs; however, interestingly, HCWs who showed a stronger intention to vaccinate against COVID-19 were more likely to receive seasonal influenza vaccination. The experience of influenza vaccination has been known as one of the drivers of accepting COVID-19 vaccines (64). It was also discovered that when the effectiveness of the vaccines changed, the acceptance of the vaccines by HCWs varied accordingly. In our meta-analysis, HCWs demonstrated a higher acceptance of COVID-19 vaccines than non-HCWs. Even in HCWs, the acceptance of COVID-19 vaccines varied among individuals with different occupations. In particular, doctors showed significantly higher acceptance of COVID-19 vaccines than nurses.

It was comparatively found that males were more willing to be vaccinated against COVID-19 than females among HCWs. The higher willingness of males to receive COVID-19 vaccination could be attributed to social and cultural differences and males’ risk-taking tendency (85). Some reports indicated that males were at a higher risk of experiencing COVID-19 complications, infections, and even deaths (86). Our study showed that HCWs willing to be vaccinated against COVID-19 experienced a lower risk of infection, probably owing to a high level of protection awareness among them.

The HCWs who remained skeptical about vaccination against COVID-19 were mainly concerned about the efficacy and safety of the vaccines due to the short duration of vaccine development (18, 22, 25, 33). The rapid spread of misleading information about COVID-19 vaccines on various media platforms has aggravated HCWs’ doubts about them (10). Since the acceptance of HCWs directly affects the trust of non-HCWs in COVID-19 vaccines, it is necessary to boost their confidence.

Limitations

The data were collected from various countries and regions in the world. Due to the different severities of the outbreak, various prevention and control measures, and cultural and cognitive differences, the heterogeneity of our results was generally high. People’s intention to vaccinate against COVID-19 will change with the epidemic situation (37). Even in the same region, there will be certain variations in the statistical data at different periods.

Conclusions

Our research revealed that a considerable percentage of HCWs remained skeptical about COVID-19 vaccines. Five factors: occupation, gender, vaccine
effectiveness, seasonal influenza vaccines, and SARS-CoV-2 infection; significantly affected the willingness of HCs to be vaccinated against COVID-19. Herein, it is essential to boost the confidence of HCWs in COVID-19 vaccines for the containment of the epidemic.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Project administration and data curation: JL. Writing-original draft preparation: LW and YW. Writing-review and editing: XC and XL. Software: YY. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.881903/full#supplementary-material

References

1. Lurie N, Saville M, Hatchett R, Halton J. Developing Covid-19 vaccines at pandemic speed. N Engl J Med. (2020) 382:1969–73. doi: 10.1056/NEJMoa2005630
2. Omer SB, Yildirim I, Forman HP. Herd immunity and implications for SARS-CoV-2 control. JAMA. (2020) 324:2095–6. doi: 10.1001/jama.2020.20892
3. Coronavirus (COVID-19) Vaccinations. https://ourworldindata.org/covid-vaccinations (accessed May 15, 2022).
4. Vergara RD, Sarmento PID, Lagman JDN. Building public trust: a response to COVID-19 vaccine. J Public Health. (2021) 43:e291–2. doi: 10.1093/pubmed/fdaa282
5. Verger P, Fresslard L, Collange F, Gautier A, Jéstin C, Launay O, et al. Acceptability of a COVID-19 vaccine among dentists: an evaluation of dentists’ willingness to participate in the vaccination program. J Dent Educ. (2021) 85:1504–1510. doi: 10.1002/jdd.12632
6. Mascarenhas AK, Lucia VC, Kelekar, Afonso NM. Dental students’ attitudes and hesitancy toward COVID-19. J Dent Educ. (2021) 2:891–7. doi: 10.1016/j.ebiom.2015.06.018
7. Nguyen LH, Drew DA, JoshAD, Joshi AD, Gao CG, Ma W, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health. (2020) 5:6475–83. doi: 10.1016/S2468-2667(20)30164-X
8. Centers for Disease Control and Prevention. Coronavirus. Available online at: https://www.cdc.gov/coronavirus/about/index.html (accessed March 29, 2020).
9. Arda B, Durusoy R, Yamanaz T, Sipahi OR, Taşbakan M, Pullukçu H, et al. Did the pandemic have an impact on influenza vaccination attitude? a survey among health care workers. BMC Infect Dis. (2011) 11:87. doi: 10.1186/1471-2334-11-87
10. Qattan AMN, Alshareef N, Alsharqi O, Rahahleh NA, Chirwa GC, Al-Hanawi MK. Acceptability of a COVID-19 vaccine among healthcare workers in the kingdom of Saudi Arabia. Front Med. (2021) 8:644300. doi: 10.3389/vaccines9030218
11. Papagiannis D, Fradelos EC, Malli F, Papathanasiou IV, Danail Z, et al. Assessment of knowledge, attitudes, and practices towards new coronavirus vaccine among medical students in Greece. Trop Med Health. (2021) 49:37. doi: 10.1186/s41182-021-00331-1
12. Chew NWS, Cheong C, Kong G, Phua K, Ngiam JN, Tan BYQ, et al. Acceptance of the coronavirus disease-2019 vaccine among medical students in Uganda. Trop Med Health. (2021) 5:e475–9. doi: 10.1016/j.tropmed.2021.03.008
13. Harapan HW, Wagner AL, Yufika A, Winardi W, Anwar S, Gan AK, et al. Acceptance of a COVID-19 vaccine in southeast asia: a cross-sectional study in Indonesia. Front Public Health. (2020) 8:381. doi: 10.3389/fpubh.2020.00381
14. Singhania N, Kathivaran S, Pannu AK. Acceptance of coronavirus disease 2019 vaccine among health-care personnel in India: a cross-sectional survey during the initial phase of vaccination. Clin Microbiol Infect. (2021) 27:1064–6. doi: 10.1016/j.cmi.2021.03.069
15. Kanyike AM, Olimu R, Kajimba J, Ojyong D, Akech GM, Nassiri DR, et al. Acceptance of the coronavirus disease-2019 vaccine among medical students in Uganda. Trop Med Health. (2021) 49:37. doi: 10.1186/s41182-021-00331-1
16. Chey NWS, Cheong C, Kong G, Phua K, Ngiam JN, Tan BYQ, et al. An Asia-Pacific study on healthcare workers’ perceptions of, and willingness to receive, the COVID-19 vaccination. Int J Infect Dis. (2021) 106:52–60. doi: 10.1016/j.ijid.2021.03.069
17. Papagiannis D, Malli F, Raptis DG, Papathanasiou IV, Fradelos EC, Danail Z, et al. Assessment of knowledge, attitudes, and practices towards new coronavirus (SARS-CoV-2) of health care professionals in Greece before the outbreak period. Int J Environ Res Public Health. (2020) 17:4923. doi: 10.3390/ijerph17144925
18. Shaw I, Stewart T, Anderson KB, Hanley S, Thomas SL, Salmon DA, et al. Assessment of U.S. health care personnel (HCP) attitudes towards COVID-19 vaccination in a large university health care system. Clin Infect Dis. (2021) 73:1776–83. doi: 10.1093/cid/ciaa554
19. Szymczyk R, Karuga FF, Bartoszek A, Staniecka K, Radek M. Attitude and behaviors towards SARS-CoV-2 vaccination among healthcare workers: a cross-sectional study from Poland. Vaccines. (2021) 9:218. doi: 10.3390/vaccines9030218
20. Ledda C, Costantino C, Cuccia M, Maltezou HC, Rapsissard V. Attitudes of healthcare personnel towards vaccinations before and during the COVID-19 pandemic. Int J Environ Res Public Health. (2021) 18:2703. doi: 10.3390/ijerph18052703
21. Verger P, Scrononis D, Daubry N, Adzedi KA, Gobert C, Bergeat M, et al. Attitudes of healthcare workers towards COVID-19 vaccination: a survey in France and French-speaking parts of Belgium and Canada. 2020. Euro Surveill. (2021) 26:2002347. doi: 10.2807/1560-7917.ES.2021.26.3.202047
22. Gennaro FD, Murri R, Murri FV, Cerruti L, Abdelle A, Saracino A, et al. Attitudes towards Anti-SARS-CoV-2 vaccination among healthcare workers: results from a national survey in Italy. Viruses. (2021) 13:371. doi: 10.3390/v13030371

23. Bauerfeind S, Hittenbichler F, Huppertz G, Zeman E, Koller M, Schmidt B, et al. Brief report: attitudes towards Covid-19 vaccination among hospital employees in a tertiary care university hospital in Germany in December 2020. Infection. (2021) 49:1307–11. doi: 10.1007/s10152-021-01622-9

24. Abouwen A, Ellis T, Miller J, Davidson R, Rachwala Q, Medeiros M, et al. COVID-19 vaccination intention among London healthcare workers. Occup Med. (2021) 71:211–4. doi: 10.1093/occmed/kuab057

25. Fares S, Elmmyer MM, Mohamed SS, Elsayed R. COVID-19 vaccination perception and acceptance among healthcare workers in Egypt. J Prim Care Community Health. (2021) 12:1–9. doi: 10.1177/17538487211113303

26. Manning ML, Geroliamis AM, Marino MA, Hansen-Zalef M, Pogorzelska-Maziarz M. COVID-19 vaccination readiness among nurses faculty and student nurses. Nurs Outlook. (2021) 69:565–73. doi: 10.1016/j.outlook.2021.01.019

27. Sekhar R, Sheikh AB, Upadhay S, Singh M, Kottwar S, Mir H, et al. COVID-19 vaccine acceptance among health care workers in the United States. Vaccines. (2021) 9:119. doi: 10.3390/vaccines9021199

28. Dzieciolowska S, Hamel D, Gado L, Dionne M, Gagnon D, Robitaille L, et al. COVID-19 vaccine acceptance, hesitancy and refusal among Canadian healthcare workers: a multicenter survey. Am J Infect Control. (2021) 49:1552–7. doi: 10.1016/j.ajic.2021.05.009

29. Maraka R, Nazal Z, Rabi R, Sarhan N, Al-Shakhra M, Al-Shakhra M, et al. COVID-19 vaccine hesitancy among health care workers in Palestine: a call for action. Prev Med. (2021) 149:106618. doi: 10.1016/j.ymp Ava.2021.106618

30. Lucia VC, Kelekar A, Afonso NM. COVID-19 vaccine hesitancy among medical students. J Public Health. (2020) 43:445–9. doi: 10.1093/pubmed/fdaa230

31. Gadoth A, Halbrook M, Blais RM, Gray A, Tobin NH, Ferbas KG, et al. Cross-sectional assessment of COVID-19 vaccine acceptance among health care workers in Los Angeles. Am J Infect Control. (2021) 174:882–8. doi: 10.1016/j.ajic.2021.05.007

32. Maltzoe HC, Pavli A, Dedoulou X, Georgakoulos T, Rafopoulos V, Drositis I, et al. Determinants of intention to get vaccinated against COVID-19 among healthcare personnel in hospitals in Greece. Infect Dis Health. (2021) 26:189–97. doi: 10.1016/j.idh.2021.03.002

33. Iannons U, Kluge S, Marx G, Hermes C, Salabber R, Karagianndis C. Einstellung zur impfung gegen SARS-CoV-2 umfrage unter mitarbeitenden in krankenhäusern vor und nach beginn der impfung in Deutschland. Med Klin Intensivmed Notfmed. (2021) 49:1152–4. doi: 10.1007/s00063-021-00821-4

34. Ahmed G, Almoosa Z, Mohamed D, Ramj I, Minaezi O, Khurma IA, et al. Healthcare provider attitudes toward the newly developed COVID-19 vaccine: a cross-sectional study. Nurs Rep. (2021) 31:187–94. doi: 10.3390/nursrep11030018

35. Kwok KO, Li KH, Wei WI, Tang A, Wong SY, Lee SS, et al. Influenza vaccine uptake, COVID-19 vaccination intention and vaccine hesitancy among nurses: a survey. Int J Nurs Stud. (2021) 114:103854. doi: 10.1016/j.ijnurstu.2020.103854

36. Wang K, Wang ELY, Ho KE, Cheung AWL, Chan EYY, Yeoh EL, et al. Intention of nurses to accept coronavirus disease 2019 vaccination and change of intention to accept seasonal influenza vaccination during the coronavirus disease 2019 pandemic: a cross-sectional survey. Vaccine. (2020) 38:7049–56. doi: 10.1016/j.vaccine.2020.09.021

37. Kosopotiska I, Obuchowaska L, Lisowski L, Dub N, Kosera M, Bekas M, et al. Intention to get COVID-19 vaccinations among ophthalmology residents in Poland: a cross-sectional survey. Vaccines. (2021) 9:373. doi: 10.3390/vaccines9040371

38. Elhadi M, Alosafi A, Alhaiadi A, Himeda A, Alsharaea E, Dokali M, et al. Knowledge, attitude, and acceptance of healthcare workers and the public regarding the COVID-19 vaccine: a cross-sectional study. BMC Public Health. (2021) 21:955. doi: 10.1186/s12889-021-10987-3

39. Szym B, Bartoszek A, Karuga FF, Staniecza K, Błaszczzyk M, Raddek M. Medical students and SARS-CoV-2 vaccination: attitude and behaviors. Vaccines. (2021) 9:128. doi: 10.3390/vaccines9020128

40. Gonullla E, Soysal A, Atici E, Engin M, Yelilbas O, Kasp S, et al. Pediatricians’ COVID-19 experiences and views on the willingness to receive COVID-19 vaccines: a cross-sectional survey in Turkey. Hum Vacc Immunother. (2021) 17:2389–96. doi: 10.1177/2041133721990874
62. Khan S, Uddin A, Imran M, Ali Y, Khan S, Salman Khan M, et al. COVID-19 vaccine acceptance and hesitancy among health care workers (HCWs) in two major urban centers in Khyber Pakhtunkhwa, Pakistan. Asia Pac J Public Health. (2022) 34:580–2. doi: 10.1177/10105395221083832

63. Wiyongse CS, Alobwee SM, Katoto PMC, Kidzere EB, Lumingwe EN, Cooper S, et al. COVID-19 vaccine acceptance and hesitancy among healthcare workers in South Africa. Expert Rev Vaccines. (2022) 21:549–59. doi: 10.1080/14760584.2022.2023355

64. Koh SWC, Liow Y, Loh VWK, Liew SJ, Chan YH, Young D. COVID-19 vaccine acceptance and hesitancy among primary healthcare workers in Singapore. BMC Prim Care. (2022) 23:81. doi: 10.1186/s12875-022-01693-z

65. Sharaf M, Taqa O, Mousa H, Radran A. COVID-19 vaccine acceptance and perceptions among dental teaching staff of a governmental university in Egypt. J Egypt Public Health Assoc. (2022) 97:9–6. doi: 10.1101/2022.07.02.22247222

66. Raja SM, Osman ME, Musa AO, Hussien AA, Yusuf K. COVID-19 vaccine acceptance, hesitancy, and associated factors among medical students in Sudan. PLoS ONE. (2022) 17:e0266670. doi: 10.1371/journal.pone.0266670

67. Pal S, Shekhkar R, Kotrewar S, Upadhyay S, Singh M, Pathak D, et al. COVID-19 vaccine hesitance and attitude toward booster doses among US healthcare workers. Vaccines. (2021) 9:1358. doi: 10.3390/vaccines9121389

68. Sadiq B, Al-Buwli N, Shukla A, Barqawi H, Alsayed HAH, Sharif Akari NS, et al. Determinants of healthcare workers perceptions, acceptance and choice of COVID-19 vaccines: a cross-sectional study from the United Arab Emirates. Hum Vaccin Immunother. (2022) 18:1–9. doi: 10.1080/21645515.2021.1994300

69. Hara M, Ishibashi M, Nakane A, Nakano T, Hirotta Y. Differences in COVID-19 vaccine acceptance, hesitancy, and confidence between healthcare workers and the general population in Japan. Vaccines. (2021) 9:1389. doi: 10.3390/vaccines9121389

70. Boche B, Kebede O, Damessa M, Gudeta T, Wakiuja D. Health professional's COVID-19 vaccine acceptance and associated factors in tertiary hospitals of south-west Ethiopia: a multi-center cross- sectional study. Inquiry. (2022) 59:4695802221083181. doi: 10.1177/00201485221083181

71. Thomas CM, Searle K, Galvan A, Liebman AK, Mann EM, Kirsch JD, et al. Healthcare worker perspectives on COVID-19 vaccines: Implications for increasing vaccine acceptance among healthcare workers and patients. Vaccine. (2022) 40:2612–8. doi: 10.1016/j.vaccine.2022.03.011

72. Ottiti-Sengeri J, Andrew OB, Luusoya RC, Atukunda I, Nalukengwe C, Kalinaki A, et al. High COVID-19 vaccine acceptance among eye healthcare workers in Uganda. Vaccines. (2020) 10:609. doi: 10.3390/vaccines10040609

73. Rosenthal H, Shmueli L. Integrating health behavior theories to predict COVID-19 vaccine acceptance: differences between medical students and nursing students. Vaccines. (2021) 9:783. doi: 10.3390/vaccines9070783

74. Kashif M, Fatima I, Ahmed AM, Ali SA, Memon RS, Afzal M, et al. Perceptions, willingness, barriers, and hesitancy towards COVID-19 vaccine in Pakistan: comparison between healthcare workers and general population. Cureus. (2021) 13:e19106. doi: 10.7759/cureus.19106

75. Kateeb E, Danadneh M, Pokorna A, Klugaroa J, Abdulqader H, Klugar M, et al. Predictors of willingness to receive COVID-19 vaccine: cross-sectional study of Palestinian dental students. Vaccines. (2021) 9:954. doi: 10.3390/vaccines9090954

76. Xu B, Gao X, Zhang X, Hu Y, Yang H, Zhou YH. Real-world acceptance of COVID-19 vaccines among healthcare workers in perinatal medicine in China. Vaccines. (2021) 9:704. doi: 10.3390/vaccines9070704

77. Yilmaz D, Mohammed B, Abdela SG, Enbiale W, Seifu F, Pareyn M, et al. COVID-19 vaccine acceptability among healthcare workers in Ethiopia: do we practice what we preach? Trop Med Int Health. (2022) 27:418–25. doi: 10.1111/tmi.15742

78. Li XH, Chen L, Pan QN, Liu J, Zhang X, Yi J, et al. Vaccination status, acceptance, and knowledge toward a COVID-19 vaccine among healthcare workers: a cross-sectional survey in China. Hum Vaccin Immunother. (2021) 17:4065–73. doi: 10.1080/21645515.2021.1957415

79. Giubilini A, Savulescu J. Vaccination, risks, and freedom: the seat belt analogy. Public Health Ethics. (2019) 12:237–49. doi: 10.1093/phe/phz014

80. Dubé E. Addressing vaccine hesitancy: the crucial role of healthcare providers. Clin Microbiol Infect. (2017) 23:279–80. doi: 10.1016/j.cmi.2016.11.007

81. Immunization WHO. Available online at: http://www.who.int/topics/imunization/en/ (accessed December 29, 2020).

82. Ghinaii I, Willott C, Dadian I. Listening to the rumours: what the northern Nigeria polio vaccine boycott can tell us ten years on. Glob Public Health. (2013) 8:1138–50. doi: 10.1080/17441692.2013.859720

83. Schumacher S, Garcia JS, Corneley OA, Mellinghoff SC. Increasing influenza vaccination coverage in healthcare workers: a review on campaign strategies and their effect. Infection. (2019) 49:387–99. doi: 10.1007/s15010-020-01555-9

84. Hassan L, Kazmi SK, Tahir MI, Ullah I, Royan HA, Fahriani M, et al. Global acceptance and hesitancy of COVID-19 vaccination: a narrative review. Naraa J. (2021) 1:e57. doi: 10.52225/narra.v1i3.57

85. Friedli A, Ponderfieh A, Schmidt U. Gender differences in social risk taking. J Econ Psychol. (2020) 77:102182. doi: 10.1016/j.jeap.2019.06.005

86. Nasiri MJ, Haddadi S, Tahvildari A, Farsi Y, Arhah M, Hasanadeh S, et al. COVID-19 clinical characteristics, and sex- specific risk of mortality: systematic review and meta- analysis. Front Med. (2020) 7:459. doi: 10.3389/fmed.2020.00459

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