Taylor & Francis
Taylor & Francis Group

Human Vaccines & Immunotherapeutics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/khvi20

COVID-19 vaccination intention among nursing, medical, and dental students: A systematic review and meta-regression analysis

Jongrim Choi & Jae Geum Ryu

To cite this article: Jongrim Choi & Jae Geum Ryu (2023) COVID-19 vaccination intention among nursing, medical, and dental students: A systematic review and meta-regression analysis, Human Vaccines & Immunotherapeutics, 19:2, 2253600, DOI: 10.1080/21645515.2023.2253600

To link to this article: https://doi.org/10.1080/21645515.2023.2253600

Published online: 21 Sep 2023.

HUMAN VACCINES & IMMUNOTHERAPEUTICS
2023, VOL. 19, NO. 2, 2253600
https://doi.org/10.1080/21645515.2023.2253600

Taylor & Francis
Taylor & Francis Group

REVIEW

OPEN ACCESS Check for updates

COVID-19 vaccination intention among nursing, medical, and dental students: A systematic review and meta-regression analysis

Jongrim Choi[a] and Jae Geum Ryu[b]

[a]College of Nursing, Keimyung University, Daegu, Republic of Korea; [b]College of Nursing, Chodang University, Muan, Republic of Korea

ABSTRACT
The introduction of the COVID-19 vaccine amidst the pandemic has heralded a paradigm shift. Healthcare students in nursing, medicine, and dentistry must have positive attitudes owing to their future role in vaccine recommendations to the public and patients. This meta-regression analysis assessed the differences in COVID-19 vaccination intention (VI) of nursing, medical, and dental students. Medline/PubMed, EMBASE, CINAHL, Cochrane Library, and Korean MBASE were searched for eligible studies. Quality was assessed by the Joanna Briggs Institute's quality appraisal. Forty-one studies were included in the final analysis, and the estimation of pooled prevalence (68%) and relevant factors were assessed. Dental students were found to have the lowest VI (57%), which significantly ($p = .018$) differed from that of nursing students (64%). Countries in South-East Asia and those with high income levels were found to have high VI. Therefore, global vaccine programs for healthcare students should be prepared considering their geographical and economic status.

ARTICLE HISTORY
Received 8 June 2023
Revised 21 August 2023
Accepted 28 August 2023

KEYWORDS
COVID-19; vaccination intention; health science; medicine; nursing; dentistry; meta-regression

Introduction

Concerns have persisted on whether a new pandemic surpassing COVID-19 (so-called "Disease X") would come up in the near future, even though the World Health Organization (WHO) declared that COVID-19 is no longer a public health emergency of international concern.[1–4] Regarding countermeasures, commitment to public health emergency preparedness for the post-COVID-19 pandemic period has been recommended by public health professionals and authorities,[5] especially for urgent pandemic vaccine development, distribution, and vaccination.[6] Upon experiencing the COVID-19 pandemic, herd immunity acquisition was appraised as the most important weapon to combat COVID-19 to reduce transmission and viral spread.[7]

Vaccination intention (VI) has been reported to be strongly related to actual vaccine uptake.[8] Regarding COVID-19 vaccine uptake, VI predicted future COVID-19 vaccine uptake, with a mediation effect between predisposing factors and vaccine uptake.[9] Notwithstanding this finding, COVID-19 vaccine coverage varies greatly across continents and countries from 8% to 70%.[10,11] For this reason, it is crucial to investigate VI and its influential factors to improve actual vaccine uptake.

While previous studies on VI among healthcare students have predominantly focused on medical students (MS), there has been limited research on nursing students (NS) and dental students (DS). To the best of our knowledge, only two studies[12,13] have previously investigated VI simultaneously among MS, NS, and DS. In 2022, Geng et al.[14] published the first systematic review and meta-analysis of college students' VI for COVID-19. Out of the 16 studies included, 11 were conducted among MS, with a pooled estimate of VI rate at 74%. Among NS (four studies) and DS (three studies), the pooled estimates for VI rates were both 60%. Furthermore, in 2022, Lin et al.[15] performed the first meta-analysis of three studies on VI for COVID-19 among DS, with pooled estimation of VI at 60.5%. While there have been more studies conducted on NS[16,17] and DS[12,13] in various continents with different economic statuses, no meta-analysis has been conducted to compare the levels and influential factors of VI among MS, NS, and DS.

According to studies on healthcare workers (HCW) and health science students, vaccine behavior is affected by various factors, such as demographic (gender, age, marital status, level of education, occupation), individual (knowledge, perceived efficacy/benefit, perceived harm, self-efficacy, prior vaccination experience, trust in government or media), and socio-economic (living country, economic status of country) characteristics.[14,18–23] In 2023, Yenew et al.[24] conducted a systematic review and meta-analysis based on the health belief model,[24] and concluded that susceptibility, perceived severity, perceived benefits, perceived barrier, and cues to action were predictors of VI among HCW. According to the 5C model, confidence and collective responsibility are the most important constructs in explaining students' COVID-19 VI.[25] In a qualitative study conducted in 2023, Ngaybe et al.[26] identified collective responsibility and pandemic attitudes as motivators for vaccination among HCW.

It is imperative that health science students develop a positive attitude toward vaccinations during their clinical training course.[12] These students will go on to become healthcare professionals at a high risk of exposure to infectious diseases while in close contact with patients, and also have

CONTACT Jae Geum Ryu jgryu21@cdu.ac.kr College of Nursing, Chodang University, 380 Muan Road, Muan 58530, Republic of Korea.
Supplemental data for this article can be accessed on the publisher's website at https://doi.org/10.1080/21645515.2023.2253600

a role in teaching and recommending that patients receive vaccines against infectious diseases.[14–16] Particularly, NS are destined to work in direct and close contact with infectious patients during their nursing practice.[13] This group has been reported to have high levels of vaccine hesitancy due to concerns regarding vaccine safety, efficacy, and a general mistrust of health authorities.[21] DS face the highest exposure to infectious agents during their clinical practice, particularly owing to frequent aerosol-generating procedures they encounter in their dental practice.[15]

Understanding the relevant factors influencing VI among MS, NS, and DS is crucial in developing targeted vaccine programs that reflect their unique characteristics and concerns. A systematic review would reveal how much the level of VI differs between MS, NS, and DS. Additionally, meta-analysis and meta-regression would help identify the determinants of VI among MS, NS, and DS.

For these reasons, this systematic review and meta-analysis aimed to examine the VI in regards to COVID-19 among MS, NS, and DS, and compare the factors affecting VI according to the health science disciplines of medicine, nursing, and dentistry, respectively. This will provide scientific evidence to develop future vaccination plans that consider the characteristics of health science students for VI, as well as prepare for newly emerging infectious disease pandemics.

Method

This study was prospectively registered for a systematic review and meta-analysis in the International Prospective Register of Systematic Reviews (PROSPERO) (No: CRD42022342819). This study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline.

Search strategy

We searched MEDLINE, PubMed, EMBASE, CINAHL, the Cochrane Library, and KMBASE (Korean MBASE) for studies published from January 1, 2020, to February 10, 2023, after the first COVID-19 confirmed case. Control terms used included Medical Subject Heading (MeSH), EMTREE, and CINHAHL headings, to construct the search formula utilizing Boolean operators, phrase searching, and truncation for precision and specificity. Natural languages were also utilized, considering the publication time lag and increased sensitivity. The main search terms were as follows: ("covid 19"[MeSH Terms] OR "covid 19"[All Fields] OR "coronavirus infection"[All Fields] OR ("CoV-SARS-2"[All Fields] AND ("virus diseases"[MeSH Terms] OR ("virus"[All Fields] AND "diseases"[All Fields]) OR "virus diseases"[All Fields] OR ("virus"[All Fields] AND "infection"[All Fields]) OR "virus infection"[All Fields])) OR "coronavirus disease"[All Fields]) AND (("vaccination"[MeSH Terms] OR "vaccin*"[All Fields]) AND ("intention"[MeSH Terms] OR "inten*"[All Fields] OR "hesitan*"[All Fields] OR "cover*"[All Fields])) AND ("college"[All Fields] OR "colleges"[All Fields] OR "colleges"[All Fields] OR ("universiti"[All Fields] OR "universities"[MeSH Terms] OR "universities"[All Fields] OR "university"[All Fields] OR "university s"[All Fields]) OR "student"[All Fields]). Citation searches were performed and websites such as Google Scholar were used for a comprehensive search. We did not restrict the language to English, although we used only English search terms (see Table S1 for details).

Study selection and inclusion criteria

Two researchers independently performed the study selection process based on the inclusion and exclusion criteria. The inclusion criteria were 1) quantitative study designs, including cross-sectional and cohort studies; 2) studies conducted face-to-face or remotely, such as through telephone-based surveys or online surveys; 3) studies that investigated NS, MS, and DS in college or university; 4) studies providing sufficient proportional data of having an intention of COVID-19 vaccination when it became/was available; and 5) studies concerning participants who were not vaccinated during the survey period. The following studies were excluded: 1) conference abstracts, editorials, opinions, letters, and reports published solely as abstracts from conference proceedings and trial protocols; 2) any review including systematic reviews, scoping reviews, and meta-analyses; 3) qualitative studies; 4) studies with unavailable data on numerators and denominators regarding VI for COVID-19; 5) studies that did not provide specific data for the indented participants; 6) studies focused on HCW or faculty; and 7) studies investigating actual uptake or coverage rate of COVID-19. When discrepancies were discovered, the researchers checked and discussed them to reach an agreement (see Table S2 for details).

Quality assessment

According to the PRISMA guideline, two researchers independently assessed the quality of the included studies using the Joanna Briggs Institute (JBI)'s Critical Appraisal Checklist for Analytical Cross-Sectional Studies with eight questions and four possible answers ("yes = 1," "no = 0," "unclear," and "not applicable").[27] We checked for and discussed discrepancies while reviewing the papers in great detail. Finally, we reached a consensus without engaging a third party moderator. We summarized the quality score and categorized it into three groups: a score of less than three points indicated poor quality, a score between four and six points indicated moderate quality, and a score over seven points indicated good quality (see Table S3 for details).[21]

Data extraction

For each included study, two reviewers independently extracted information using a data extraction matrix and cross-checked the data. Data on the first author, publication year, country, study period (year and month), target population, study setting, sampling method, response rate, type of sample (NS, MS, or DS), effective sample size, measurements of VI and results, and demographic characteristics (sex and age) were extracted. Responses for COVID-19 VI were binary (yes or no) or multiple-choice (scored on a four, five, or eleven points Likert scale for agreement), which were categorized as having an intention to agree or strongly agree. The COVID-19 vaccine acceptance rate was assessed to evaluate the introduction of the COVID-19 vaccination program. Additionally, we collected data regarding COVID-19 cases, such as the daily average numbers of new, cumulative, new death, and cumulative death cases during the survey period for all studies from the WHO COVID-19 dashboard.[28] Socioeconomic data were also collected regarding country, income, and region classified from the World Bank group.[29] We used the four country income groups classified by the World Bank: low, lower-middle, upper-middle, and high income. Additionally, we combined the seven country regions on the WHO COVID-19 dashboard into four country regions: America, Africa, Europe and the Eastern Mediterranean, and South-East Asia and Western Pacific.[30]

Statistical analysis

A meta-analysis was conducted to evaluate the overall prevalence of the intention to administer the COVID-19 vaccine when it became available to MS, NS and DS. Pooled prevalence and the 95% confidence interval were estimated from each study using a random effects model using the *metaprop* Stata command. This was done owing the presumed high heterogeneity because of variations in country, region, availability of COVID-19 vaccines, medical system, adoption of mandatory vaccination program, and miscellaneous reasons.[31,32] Heterogeneity was tested using an I^2 statistic (high heterogeneity when it was over 75%).[33,34] Subgroup analysis and meta-regression (conducted when the number of studies was over 10) were conducted to investigate the heterogeneity.[35] The leave-one-out method was used for a sensitivity test. Funnel plots, trim and fill, and Egger's tests were used to assess publication bias. We used Stata 17.0 (StataCorp, Texas, US) for all meta-analyses. Two-tailed significance was tested statistically (<.05 for pooled prevalence and <.10 for heterogeneity).[34]

Results

Identification and selection of studies

The literature screening process was conducted according to the PRISMA 2020 statement[36] which is presented in Figure 1. A total of 19,640 records were identified at the initial literature review and 11,549 records were screened after removing 8103 duplicates. A total of 319 full-text articles were reviewed, and 278 articles were excluded because they did not include relevant participants (such as HCW or the general population), did not specify the discipline of participants or related data, and did not include relevant study types (such as editorial, commentary, and conference proceedings). Finally, 41 studies met the selection criteria and were included in the systematic review and meta-analysis.

Characteristics of the included studies

The major characteristics of the 41 included studies are summarized in Table 1. In total, 29,563 participants were included in this systematic review. The number of participants and articles of NS, MS, and DS were 8601 participants in 14 articles, 13,066 participants in 29 articles, and 7896 participants in 6 articles, respectively. In total, 40 studies were conducted in specific continents; 2 in Africa,[37,38] 10 in America,[13,39–47] 18 in Europe and Eastern Mediterranean,[12,16,48–63] and 10 in South-East Asia and Western Pacific.[17,64–72] One study was conducted in various countries. The quality scores of the 41 included studies varied from 2 to 8 (M ± SD = 6.13 ± 1.57). Of these, 17 studies were of good quality, 21 were of moderate quality, and 3 were of poor quality (Table 1, Table S3). Twenty-nine studies were published in 2021 and the rest in 2022, of which 15 studies were surveyed in 2020 and the rest in 2021.

The percentage of participants who were willing to get vaccinated when the COVID-19 vaccine became available varied from 14.25% to 93.35%. The pooled percentages of NS, MS, and DS VI for COVID-19 VI ranged from 41.13% to 83.55, 14.25% to 93.35%, and 27.73% to 80.85%, respectively (Table 1).

Meta-analysis of vaccination intention

Regarding VI of NS, MS, and DS who were willing to administer the vaccine when available currently or in near future, the pooled percentage was estimated as 68.11% (95% CI = 61.76 ~ 74.14, heterogeneity I^2 = 99.21%, p < .001). The pooled percentage of having VI was 63.85% for NS (95% CI = 55.02 ~ 72.24, heterogeneity I^2 = 98.52%, p < .001), 72.30% for MS (95% CI = 61.47 ~ 81.95, heterogeneity I^2 = 99.42%, p < .001), and 56.71% for DS (95% CI = 45.88 ~ 67.23, heterogeneity I^2 = 96.91%, p < .001) (Figure 2).

Subgroup analysis and meta-regression

Owing to considerable heterogeneity in the estimation of the pooled percentages, subgroup analysis and meta-regression were performed. Subgroup analysis was conducted by sample size (≥1,000 vs <1,000), study quality (good, moderate, and poor), concurrent survey of COVID-19 vaccine acceptance (acceptance + intention vs intention only), year of data collection (2021 vs 2020), region (Africa, America, Europe and Eastern Mediterranean, South-East Asia and Western Pacific), country income (high, middle, low-middle, and low), and daily new COVID-19 cases during survey period (≥10,000 vs <10,000) (Figure 3).

For MS, country income (Q statistics = 25.49, p < .001), region (Q statistics = 12.29, p = .001), concurrent survey (Q statistics = 5.13, p = .002), and year of data collection (Q statistics = 4.64, p = .03) were statistically significant. For DS, study quality (Q statistics = 6.43, p = .01) was statistically significant. There were no statistically significant differences in the subgroup analysis of NS.

Meta-regression was performed on studies for NS and MS in which the number of included studies was over 10 following the recommendations of the Cochrane handbook (Table 2).[35] The univariate analysis revealed that the pooled proportion of participants was significantly higher in high income countries than low and middle-income countries (OR = 1.24, 95% CI:1.11 ~ 1.39, p < .001) and higher in surveying intention only than surveying concurrently with acceptance and intention (OR = 1.33, 95% CI:1.12 ~ 1.57, p = .001). There were no statistically significant differences in the pooled proportions of participants among the NS, MS, and DS groups in the univariate analysis.

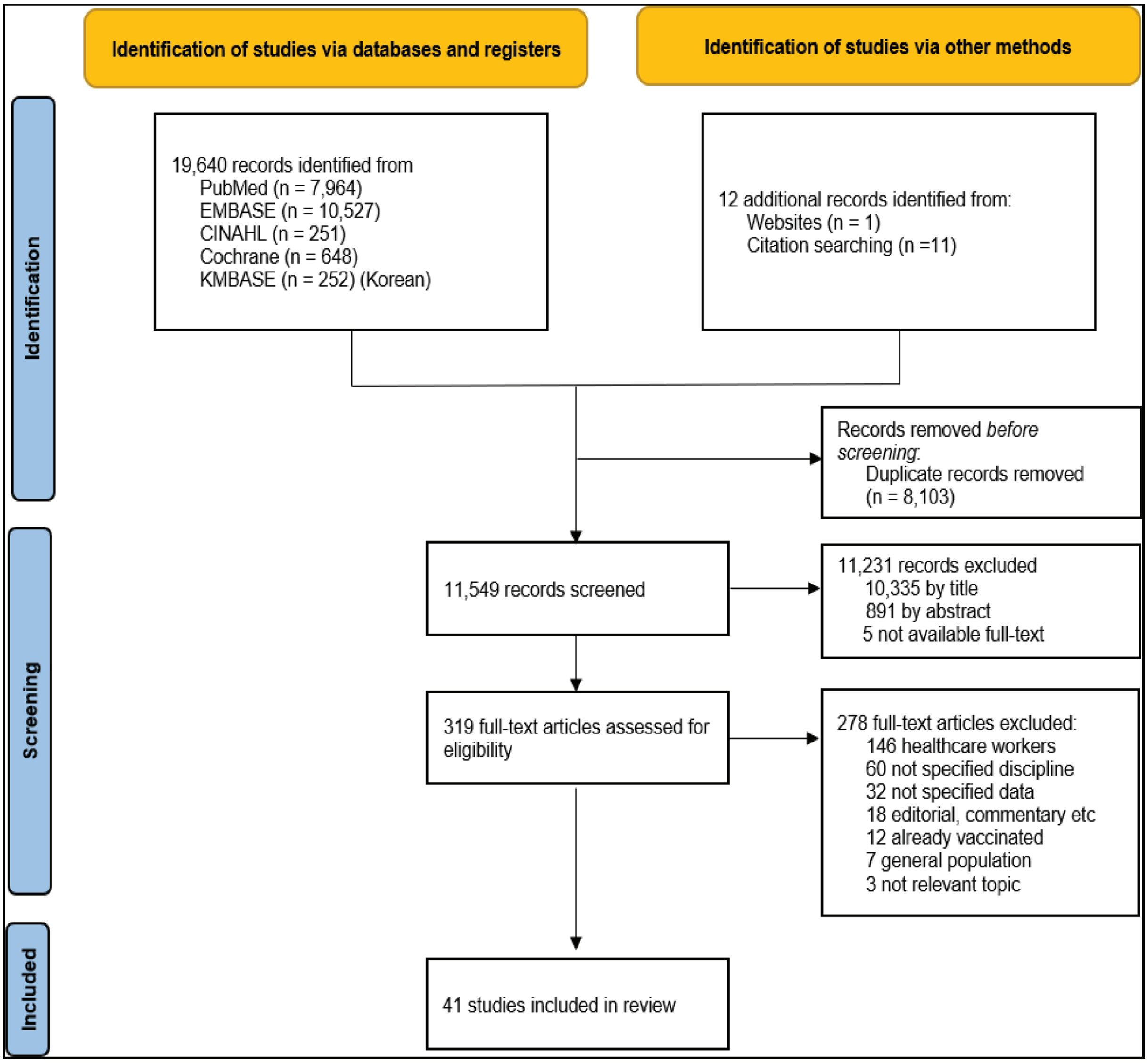

Figure 1. Flow chart depicting the literature screening process according to PRISMA 2020 statement.

The multivariate analysis showed that the pooled proportions of participants between NS, MS, and DS were significantly higher in NS than DS (OR = 1.24, 95% CI:1.04 ~ 1.47, $p = .018$) but not in MS. The pooled proportion of participants was significantly higher in high-income countries than low and middle-income countries (OR = 1.32, 95% CI:1.16 ~ 1.49, $p < .001$), and also higher in South-East Asia and Western Pacific (OR = 1.42, 95% CI:1.16 ~ 1.81, $p = .006$) than Africa. For MS, country income was significant in univariate (OR = 1.36, 95% CI:1.17 ~ 1.57, $p < .001$) and multivariate (OR = 1.34, 95% CI:1.14 ~ 1.59, $p = 0.001$) analyses. Additionally, surveying intention only was significant in the univariate (OR = 1.48, 95% CI:1.19 ~ 1.83, $p = .001$) and multivariate (OR = 1.28, 95% CI:1.04 ~ 1.58, $p = .024$) analyses (Table 2).

Sensitivity analysis

For sensitivity analysis, the leave-one-out forest plot was checked for considerable heterogeneity in the estimation of the pooled proportion (Figure 4). For NS, the pooled proportion increased by 2% points if the fourth,[50] tenth,[45] and thirteenth studies[12] were omitted. For MS, the pooled proportion increased by 1% points, if the third,[49] sixteenth,[57] and seventeenth[58] were omitted. For DS, the pooled proportion increased by 5% points if the sixth[12] study was omitted. Pooled proportion decreased by 2% points if three low-quality studies[40,44,73] were omitted, which were two for MS and one for DS.

Publication bias

Publication bias was checked using a funnel plot, trim-and-fill analysis, and Egger's test (Figure 5). The funnel plot showed that omitted publications were suspected in the area of lower VI for MS and in the area of upper VI for DS. Trim-and-fill analysis revealed that 11 virtual values of low intention of COVID-19 vaccination for MS were imputed, while two values of high intention for DS and one for NS were imputed. For MS, the difference in the pooled proportion decreased by 16.12% points, accounting for 22.87% of the initial pooled proportion after missing-value imputation, indicating a suspicious publication bias

Table 1. Characteristics of included studies regarding COVID-19 vaccination intention among nursing, medical, and dental students.

No.	1st author	Published year	Country	Survey period	Study participants and setting	Sampling method	Sample size, n	Vaccination intention, n (%)	Measurement of COVID-19 vaccination intention	Type	COVID-19 vaccine Acceptance (%)	Age, M ± SD or n (%)	Female, n (%)	Daily new COVID-19 cases*	Quality score
1	Al Janabi	2021	USA	October 2020	1,770 MSs of a college, 11% response rate, e-mail survey	Opportunity sampling	197	88 (44.67)	5-point Likert scale (strong disagree to strong agree)	MS	NA	20s: 172 (87.30) 30s: 15 (7.61) 40s: 6 (3.05)	114 (57.87)	58,584	7
2	Alshehry	2022	Saudi Arabia	November 2020 to December 2020	1,170 NSs of 10 universities, not report response rate, online survey	Convenience sampling	1,170	654 (55.90)	Yes/no/not sure	NS	NA	21.30 ± 1.88	639 (54.62)	258	8
3	Bolatov	2021	Kazakhstan	March 2021	888 MSs of a university, not report response rate, online survey	Opportunity sampling	870	199 (22.87)	Yes/no	MS	18/888 (2.03)	NR	679 (78.05)	1,078	8
4	Chaves	2021	Brazil	December 2020 to January 2021	250 MSs via social media, not report response rate, online opinion survey	Snowball sampling	250	210 (84.00)	Yes/no/not sure	MS	NA	18 ~ 25 yrs: 209 (83.60)	147 (58.80)	40,485	2
5	Fontenot	2021	USA	December 2020	2,085 NSs across 5 nursing schools, 37% response rate, online survey using Dillman's tailored method	NR	772	645 (83.55)	Primary intention/ secondary intention/ no intention	NS	NA	18–23 yrs 608 (78.8) 24–29 yrs 99 (12.8) 30+ yrs 65 (8.4)	676 (87.56)	199,093	8
6	Gala	2022	Sint Maarten, USA	March 2021 to April 2021	1,735 MSs at a medical school, 21.3% response rate, 62.4% female, online survey	NR	229	184 (80.35)	Yes/no	MS	NA	Not specified	Not specified	-	6
7	Gautier	2022	France	January 2021 to February 2021	4,927 healthcare students of a university, 29.7% response rate, online survey	Non-probability sampling	173 348	109 (63.01) 292 (83.91)	5-point Likert scale (no, certainly not to yes, definitely)	NS MS	NA	Not specified	Not specified	17,466	6
8	Gotlib	2021	Poland	March 2021 to April 2021	4,700 NSs of 12 universities, 16.9% response rate, 90.8% female, online survey	NR	162	68 (41.98)	5-point Likert scale (definitely no to definitely yes)	NS	612/793 (77.2)	Not specified	Not specified	17,769	7
9	Grochowska	2021	Poland	September 2020 to November 2020	419 medical professionals & MS of 2 university hospitals, no report response rate, online survey	NR	239	169 (70.71)	Yes/no/not sure	MS	NA	Mean 23 (19–31)	0 (0.00)	10,184	8
10	Han	2021	South Korea	April 2021	169 NSs of a college, not report response rate, online survey	Convenience sampling	169	140 (82.84)	5-point Likert scale (definitely no to definitely yes)	NS	NA	NR	124 (73.37)	631	5
11	Hosek	2022	USA	December 2020	3,439 students at an academic medical center, 30.0% response rate, web-based survey	NR	221 402 94	157 (71.04) 363 (90.30) 76 (80.85)	5-point Likert scale (very unlikely to very likely)	NS MS DS	NA	NR	1,027 (75.80)	199,093	8

(*Continued*)

Table 1. (Continued).

No.	1st author	Published year	Country	Survey period	Study participants and setting	Sampling method	Sample size, n	Vaccination intention, n (%)	Measurement of COVID-19 vaccination intention	Type	COVID-19 vaccine Acceptance (%)	Age, M ± SD or n (%)	Female, n (%)	Daily new COVID-19 cases*	Quality score
12	Jain	2021	India	February 2021 to March 2021	1,068 MSs via social network system, no report response rate, online survey	Snowball sampling	379	266 (70.18)	Yes/no/not sure	MS	NA	NR	NR	23,782	5
13	Jiang	2021	China	February 2021 to April	1,512 NSs of 2 medical universities, not report response rate, online survey	Convenience sampling, stratified sampling	1,488	1,240 (83.33)	1 ~ 8 score	NS	NA	<18 5 (0.34) 18 163 (10.95)19 326 (21.91) 20 293 (19.69)21 357 (23.99) 22 241 (16.20)23 103 (6.92)	1,254 (84.27)	31	7
14	Kateeb	2021	Palestine	February 2021 to March 2021	3500 DSs of 4 colleges social network, 11.9% response rate, online survey	NR	417	241 (57.79)	5-point Likert scale (strongly disagree to strongly agree)	DS	NA	≤22 yrs 359 (86.1) >22 yrs 58(13.9)	295 (70.74)	1,527	6
15	Katz	2022	Israel	December 2020	104 MSs of a medical school, not report response rate, online survey	NR	104	95 (91.35)	Yes/no	MS	NA	Average 29.2	64 (61.54)	2,709	5
16	Kausar	2021	India	July 2021	385 MSs of a medical school, 92.7% response rate, online survey	NR	356	297 (83.43)	Yes/no/maybe	MS	NA	18–19 54 (15.00) 20–21 131 (37.00) 22–23 113 (32.00) >23 58 (16.00)	213 (59.81)	77,177	4
17	Kaya	2021	Turkey	February 2020	980 MSs of a university,75.4% response rate, online survey	NR	739	444 (60.08)	Yes/no/hesitant	MS	NA	21.20 ± 2.68	427 (57.78)	7,938	6
18	Kelekar	2021	USA	September 2020 November 2020 to December 2020	494 MSs & 1481 DSs of a medical school & 3 dental schools, 34% (MS), 18% DS response rate, online survey	Opportunity sampling	163 245	126 (77.30) 135 (55.10)	4-point Likert scale (strongly disagree to strongly agree)	MS DS	NA	NR	NR	40,057	5
19	Le	2022	Vietnam	March 2021 to June 2021	1,000 students of a medical college, 91.1% response rate, online survey	Convenience sampling	228	180 (78.95)	Acceptance/ hesitancy/refusal.	NS	NA	Not specified	Not specified	75	8
20	Le An	2021	Vietnam	April 2021	1,040 health science students of a university, 82.1% response rate, online survey	NR	392	301 (76.79)	5-point Likert scale (none to absolutely certain)	MS	NA	Not specified	Not specified	4,694	8
21	Li	2021	China	March 2021	2,196 students of a medical university & a health school, online survey	Convenience sampling	1,414	845 (59.76)	Yes/no/undecided	NS	83/2,196 (3.8)	Not specified	Not specified	28	6

(*Continued*)

Table 1. (Continued).

No.	1st author	Published year	Country	Survey period	Study participants and setting	Sampling method	Sample size, n	Vaccination intention, n (%)	Measurement of COVID-19 vaccination intention	Type	COVID-19 vaccine Acceptance (%)	Age, M ± SD or n (%)	Female, n (%)	Daily new COVID-19 cases*	Quality score
22	Lindner-Pawłowicz	2022	Poland	December 2020	1976 students & professionals in nation, no response rate, online survey	NR	350	269 (76.86)	Yes/no/decision after more information	MS	NA	NR	NR	9,701	6
23	Moro	2022	Italy	November 2020 to February 2021	1,584 MSs of a University, 58.6% response rate, computer assisted web interview method	Convenience sampling	902	842 (93.35)	Yes/no/I don't know	MS	NA	Median age 24 yrs (IQR 23–26)	573 (63.53)	18,835	8
24	Lucia	2021	USA	2020	494 MSs of a medical school, 34% response rate, online survey	NR	167	126 (75.45)	Yes = agree	MS	NA	NR	95 (56.89)	53,796	3
25	Mahdi	2022	Iraq	2021	810 MSs of a medical college, not report response rate, online survey via social media	NR	702	100 (14.25)	Not specified	MS	108/810 (13.3)	16–19 yrs 314 (67.5) 20–25 yrs 235 (68.1)	326 (66.80)	4,107	5
26	Malygin	2021	Russia	June 2021	364 students of a medical university & a technical university, not report response rate, internet survey	NR	135	31 (22.96)	Refusal/monitoring the situation/ consent	MS	76/364 (20.9)	21.3 ± 2.4	119 (88.15)	11,774	5
27	Manning	2021	USA	August 2020 to September 2020	1,871 faculties & NSs of a university, response rates of 45.6% for faculties and 70% for NS, Dillman's survey technique	NR	1,029	465 (45.19)	Yes/no/don't know	NS	NA	30 and less 710 (69.1) 31 over 319 (31.9)	896 (87.07)	44,693	6
28	Mascarenhas	2021	USA	2020	1,481 DSs from dental schools from 3 states, 18 % response rate, online survey	NR	245	136 (55.51)	4-point Likert scale (strongly disagree to strongly agree)	DS	NA	26.3 ± 3.8	142 (57.96)	53,796	4
29	Mayan	2021	USA	February 2021 to March 2021	2,025 MSs of 212 medical schools, not report response rate, cloud-based survey	NR	1,899	1,772 (93.31)	5-point Likert scale (very reluctant to very willing)	MS	Not specified	Average 25.79 yrs	1,221 (64.30)	71,883	5
30	Mose	2022	Ethiopia	March 2021	420 students of a university, college of medicine and health science, 100% response rate, self-administered off line study	Simple random sampling	124 122	51 (41.13) 49 (40.16)	Yes/no	NS MS	NA	Not specified	Not specified	1,499	8

(*Continued*)

Table 1. (Continued).

No.	1st author	Published year	Country	Survey period	Study participants and setting	Sampling method	Sample size, n	Vaccination intention, n (%)	Measurement of COVID-19 vaccination intention	Type	COVID-19 vaccine Acceptance (%)	Age, M ± SD or n (%)	Female, n (%)	Daily new COVID-19 cases*	Quality score
31	Mubarak	2022	Saudi Arabia	March 2021 to May 2021	332 students of a university, not report response rate, online survey	NR	196	172 (87.76)	Yes/no	MS	NA	Not specified	Not specified	874	8
32	Nguyen	2021	Vietnam	April 2021	850 health science students of a university, 48.2% response rate, self-administered off line survey	Convenience sampling	219	178 (81.28)	Yes/no	MS	NA	Not specified	Not specified	11	6
33	Pastorino	2021	Italy	June 2020 to July 2020	559 students of a university, 78% response rate, online survey	NR	274	254 (92.70)	NR	MS	NA	Not specified	Not specified	238	6
34	Raja	2022	Sudan	June 2021 to July 2021	471 MSs of a university, 78% response rate, online survey	Simple random sampling	217	121 (55.76)	NR	MS	NA	≤24 161 (74.20) >24 56(25.80)	117 (53.92)	111	7
35	Riad	2021	Albania, Canada, Croatia, Ecuador, Estonia, Indonesia, Iran, Iraq, Italy, Latvia, Lebanon, Lithuania, Malaysia, Nepal, Pakistan, Palestine, Portugal, Russia, Sudan, Tunisia, Turkey, and US	February 2021	6,680 DSs of 22 countries, not report response rate, online survey	NR	6,639	4,220 (63.56)	5-point Likert scale (totally disagree to totally agree)	DS	NA	17–22 yrs 4,218(65.50) 23–40 yrs 2,421 (36.50)	4,682 (70.52)	-	3
36	Rosental	2021	Israel	August 2020 to September 2020	628 MSs & NSs via social media (several academic departments), not report response rate, online survey	Opportunity sampling	307 321	234 (76.22) 283 (88.16)	6-point Likert scale (strongly disagree to strongly agree)	NS MS	NA	26.04 ± 3.74 28.06 ± 3.33	257 (83.71) 161(50.16)	2,753	8
37	Saied	2021	Egypt	January 2021	27,715 students of 2 public universities, not report response rate, online survey	Convenience sampling	274 1,459 256	130 (47.45) 506 (34.68) 71 (27.73)	NR	NS MS DS	NA	Not specified	Not specified	928	6

(*Continued*)

Table 1. (Continued).

No.	1st author	Published year	Country	Survey period	Study participants and setting	Sampling method	Sample size, n	Vaccination intention, n (%)	Measurement of COVID-19 vaccination intention	Type	COVID-19 vaccine Acceptance (%)	Age, M ± SD or n (%)	Female, n (%)	Daily new COVID-19 cases*	Quality score
38	Shah	2021	India	February 2021	320 MSs of a medical school, 93.1% response rate, online survey	NR	274	193 (70.44)	Yes/no	MS	NA	19.6 ± 1.5	68 (24.82)	12,520	7
39	Sovicova	2021	Slovenia	March 2021	5,374 MSs of 3 universities, 23.1% response rate, online survey	NR	348	303 (87.07)	NR	MS	880/1,228 (71.7)	NR	249 (71.55)	826	5
40	Szmyd	2021	Poland	December 2020	1,971 medical & non-medical students of 2 university, not report response rate, online survey	NR	687	632 (91.99)	Yes/no/I don't know	MS	NA	Median 21 (20–24)	445 (64.77)	9,701	6
41	Zhou	2021	China	January 2021	1,070 NSs of 12 schools, online survey	NR	1,070	555 (51.87)	11-point Likert scale (extremely unlikely to extremely likely)	NS	NA	19.87 ± 1.89	879 (82.15)	136	8

NR = not reported; MS = medical student; NS = nursing student; DS = dental student; COVID-19 = coronavirus disease 2019; yrs = years.
*Data derived from WHO Coronavirus (COVID-19) Dashboard.

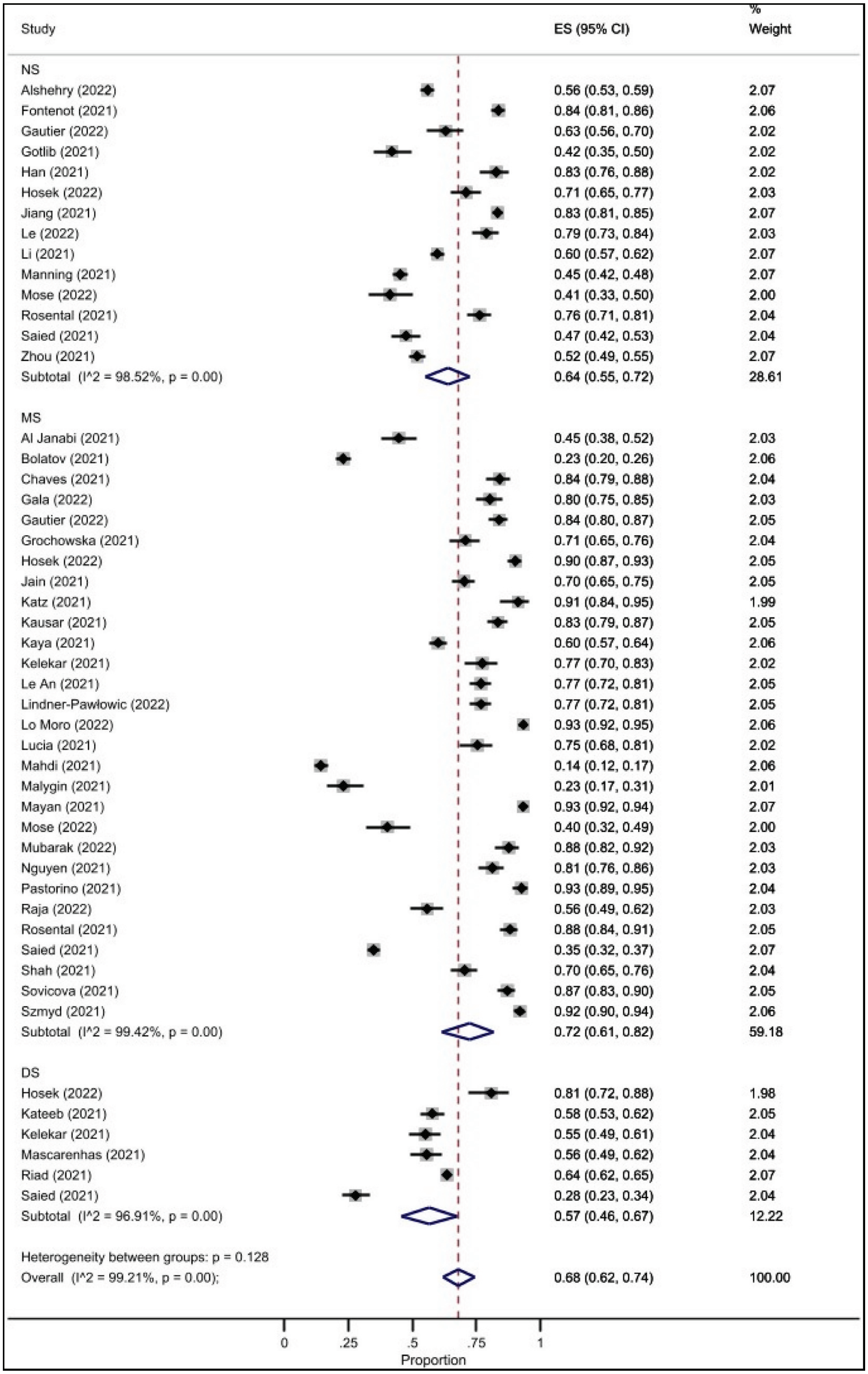

Figure 2. Forest-plot of COVID-19 vaccination intention of nursing, medical, and dental students (output generated by the Stata procedure *metaprop*, random effect model) (NS = nursing students; MS = medical student; DS = dental student; COVID-19 = coronavirus disease 2019).

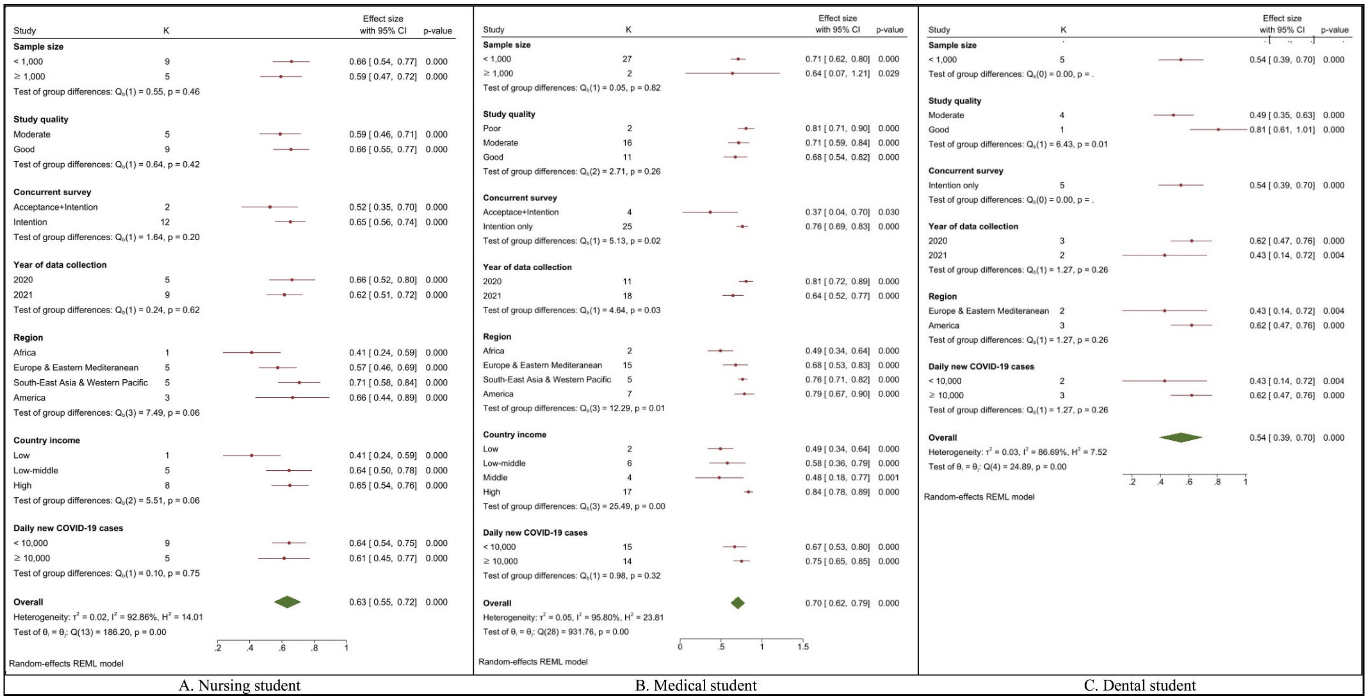

Figure 3. Subgroup analysis of COVID-19 vaccination intention of nursing, medical, dental students by study characteristics, socio-economic status, and daily new COVID-19 cases.

Table 2. Univariate & multivariate meta-regression analysis of COVID-19 vaccination intention among nursing and medical students by study characteristics, socio-economic status, and COVID-19 daily new cases.

Variables		Total		NS		MS	
		Univariate OR (95% CI)	Multivariate OR (95% CI)	Univariate OR (95% CI)	Multivariate OR (95% CI)	Univariate OR (95% CI)	Multivariate OR (95% CI)
Concurrent survey	Intention only	1.33 (1.12–1.57)**	1.21 (1.04–1.40)*	1.14 (0.88–1.49)	1.14 (0.77–1.69)	1.48 (1.19–1.83)**	1.28 (1.04–1.58)*
	Acceptance + Intention	Reference					
Year of data collection	2021	0.89 (0.79–1.00)	1.06 (0.95–1.19)	0.96 (0.78–1.17)	1.03 (0.76–1.36)	0.85 (0.71–1.02)	1.04 (0.88–1.24)
	2020	Reference					
Region	America	1.30 (0.98–1.72)	1.19 (0.90–1.58)	1.19 (0.83–1.98)	1.20 (0.56–2.60)	1.35 (0.91–2.01)	1.17 (0.78–1.71)
	South-East Asia & Western Pacific	1.32 (0.99–1.76)	1.42 (1.16–1.81)**	1.34 (0.89–2.04)	1.38 (0.80–2.36)	1.33 (0.88–2.01)	1.36 (0.95–1.94)
	Europe & Eastern Mediterranean	1.19 (0.91–1.55)	1.11 (0.87–1.40)	1.17 (0.77–1.78)	1.11 (0.61–2.02)	1.22 (0.83–1.77)	1.12 (0.81–1.55)
	Africa	Reference					
Country income	High	1.24 (1.11–1.39)***	1.32 (1.16–1.49)***	1.04 (0.86–1.26)	1.15 (0.81–1.65)	1.36 (1.17–1.57)***	1.34 (1.14–1.59)**
	Low & middle	Reference					
Daily new COVID-19 cases	≥10,000	1.07 (0.94–1.21)	0.92 (0.81–1.04)	0.97 (0.80–1.19)	0.94 (0.59–1.51)	1.07 (0.87–1.31)	0.93 (0.86–1.72)
	<10,000	Reference					
Discipline	MS	1.15 (0.87–1.32)	1.09 (0.90–1.31)				
	NS	1.07 (0.86–1.32)	1.24 (1.04–1.47)*				
	DS	Reference					

NS = nursing student; MS = medical student; DS = dental student; OR = odds ratio; CI = confidence interval; COVID-19 = coronavirus disease 2019.
*<.05; **<.01; ***<.001.

problem. The increase by 7.31% points for DS (accounting for 13.04% of the initial pooled proportion) and 1.40% points for NS (2.22%) after missing-value imputation, indicated the absence of publication bias.[74] Egger's test for NS, MS, and DS showed no publication bias ($p = .917$, $p = .604$, $p = .330$, respectively).

Discussion

This systematic review and meta-regression analysis was conducted to evaluate COVID-19 VI and the factors influencing it among NS, MS, and DS. Forty-one studies were eligible for inclusion and 29,563 participants were included in this meta-analysis. In particular, we assessed the estimated pooled proportion by health science discipline (nursing, medicine, and dentistry) and conducted subgroup analysis (sample size, year of data collection, study quality, region, country income, daily new COVID-19 cases during the study period), meta-regression, and tested for publication bias using various methods (funnel plot, trim-and-fill, and Egger's test) owing to considerable heterogeneity.

In our study, the pooled proportion of VI for COVID-19 was estimated to be of moderate level (68.11%), which was

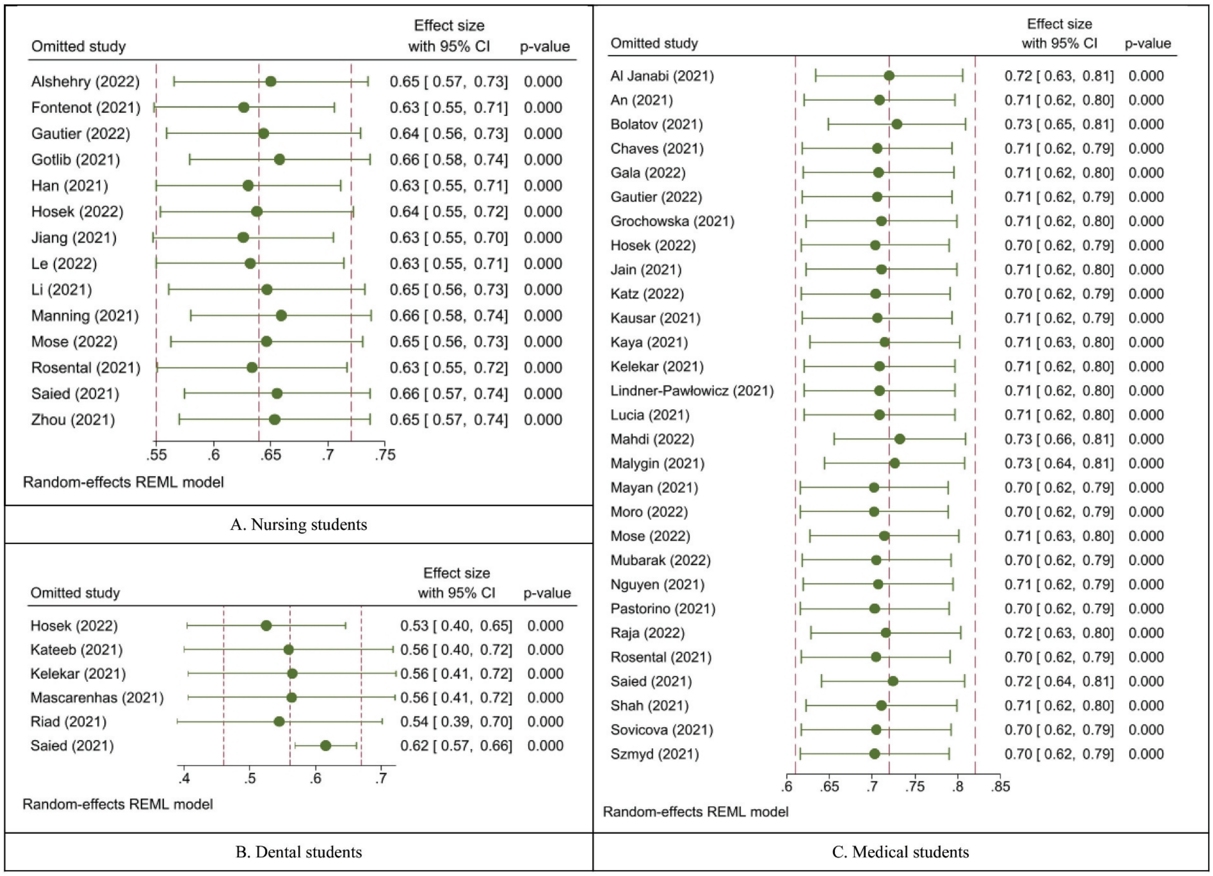

Figure 4. Leave-one-out method in sensitivity analysis. The three vertical dotted lines denote the pooled random effect of prevalence of vaccination intention among nursing, medical, and dental students. The horizontal lines and the circles indicate the pooled effect size and 95% CIs applying the leave-one-out-method.

higher than that of Swiss university students (49%) in January 2021,[75] similar to that of German students (67.8%) from June to August 2021,[76] and lower than that of Italian students (81.5%)[60] from June to July 2020 during the lockdown in Italy. Healthcare students such as NS, MS, and DS were reported to have a 2.75 times higher intention than non-health science students.[14] Higher trust in the efficacy and safety of the COVID-19 vaccine was observed among healthcare students compared to non-healthcare students,[77] which would have contributed to their willingness and intention to receive the COVID-19 vaccine.[51,76,78] As future HCW, healthcare students tend to express more collective responsibility than non-healthcare students, which may result in them being more willing to be vaccinated against COVID-19 to protect their families or the public.[75,79] Wismans et al.[25] explained students' VI for COVID-19 using a 5C model consisting of five constructs: confidence, calculation, complacency, constraints, and collective responsibility, in which confidence and collective responsibility were mediating factors in the relationship between VI and preconditions (perceived effectiveness, perceived risk, trust in government and health authorities, altruism, and need to belong). Confidence refers to the trust in the efficacy and safety of vaccines and the system that delivers it, and collective responsibility is defined as the willingness to protect others by one's vaccination.[25,80] These were found to be related to the willingness to accept to be vaccinated among university students.[60]

The pooled proportion (68.11%) of VI for COVID-19 of healthcare students was lower than that (77.3%) of HCW reported in the meta-analysis.[21] In one study,[21] physicians had the highest VI level (83.6%) followed by nurses (77.4%). Another study found the pooled prevalence of VI for COVID-19 among dental professionals to be significantly higher (81.1%).[15]

In the subgroup analysis, the level of VI for COVID-19 was the highest in the MS (72.30%) group, followed by the NS (63.85%) and DS (56.71%) groups, although this difference was not statistically significant. This finding aligns with the levels reported for MS (74%) and NS (60%), but not the level reported for DS (60%), in a previous meta-analysis study.[14] It was similar to the results of a previous study presenting high VI levels (73.1%) among physicians compared to nurses (22.2%).[51] In general, MS have the highest level of knowledge, trust, and confidence in vaccine efficacy and safety against COVID-19 among health science students, similar to physicians.[14,21,39,81–84] Disagreement with beliefs stemming from conspiracy theories regarding COVID-19 was reported to be related to COVID-19 vaccination acceptance among MS.[81] Belief in conspiracy theories was associated with high anxiety about COVID-19, leading to a low willingness to be vaccinated against COVID-19.[85] Using a conceptual model constructed by a Canadian research group, belief in conspiracy theories was found to share similarity with denialism typically advocated by anti-vaccination activists in the domain of communication and media.[11]

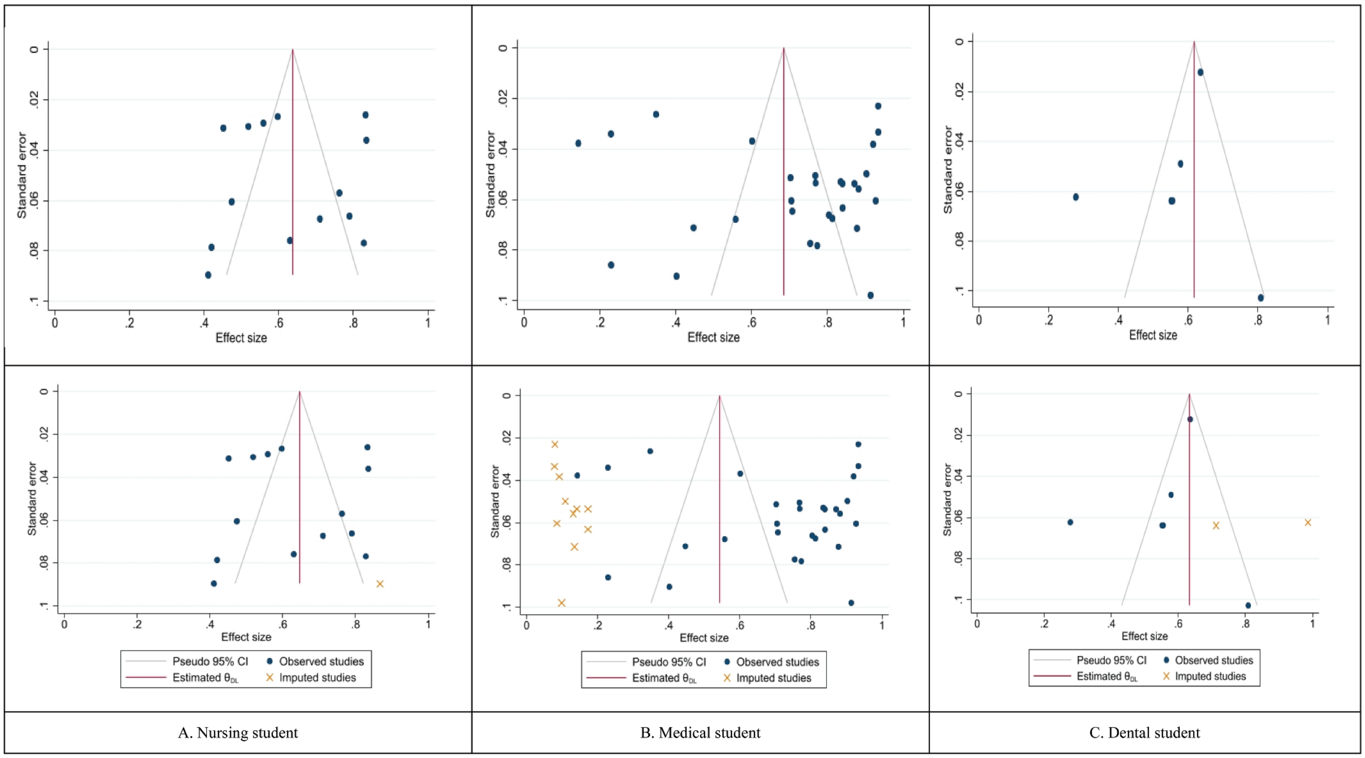

Figure 5. Funnel plot for prevalence of vaccination intention. The upper three display funnel plots by nursing, medical, dental students. The lower three show the non-parametric trim and fill analysis of publication bias. The gray lines are pseudo 95% confidence limits. The x-axis represents the prevalence of vaccination intention, while the y-axis points the standard error of prevalence.

In the multivariate meta-regression, surprisingly, the level of VI for COVID-19 of NS was higher than that of DS; however, that of MS was not different from that of DS, even though the level of VI for COVID-19 of NS, MS, and DS did not differ in the univariate meta-regression. These results were obtained after controlling for presumed confounding or influencing factors such as the year of data collection, region, country income, daily new COVID-19 cases, and concurrent surveys of intention and acceptance. This suggests that the influencing factors should be considered concurrently when assessing the level of VI among health science students.[14] It was not anticipated that DS would have a low level of VI for COVID-19, although dental practitioners were reported to have a high level (81.1%) of VI for COVID-19 in the meta-analysis.[15] This result was similar to that of a study on influenza, which showed that NS had a 4.75 times higher intention than DS.[86] DS had a reduced risk perception of COVID-19[46] and presented a lack of trust in health authorities and the safety of the vaccine[52,73] This result was also similar to those of previous studies for papillomavirus,[87,88] reporting the lowest knowledge related to lower vaccine uptake among DS. Since the dental procedures can generate considerable amounts of aerosols leading to a high risk of exposure to pathogens,[15] the educational programs should be developed to improve the knowledge and the positive perception toward health authorities and vaccine safety against COVID-19 in DS during their clinical training courses.[86] It was also unexpected that the pooled proportion of VI for COVID-19 of MS did not significantly differ from that of DS. This finding may be attributed to several factors, including the high heterogeneity (99.42%), the issue of publication bias and widely ranging levels of VI (13.33–93.35%) for COVID-19 among MS.

In the multivariate meta-regression, factors such as region, country income, and concurrent surveys of acceptance and intention were found to impact VI for COVID-19 among MS, NS, and DS. For MS in particular, high-income countries, South-East Asia and Western Pacific area, and concurrent surveys on acceptance and intention were identified as related factors, presenting that those located in high-income countries and those located in South-East Asia and Western Pacific exhibited better VI. These findings align with the highest vaccine acceptance rate in the South-East Asia (94.3% for HCW and 93.3% for the general population), in a previous meta-analysis.[89] In high-income countries, people seemed less concerned about vaccine effectiveness and safety, displaying high confidence in the COVID-19 vaccine.[90] Similarly, the high VI observed in South-East Asia could be attributed to the region being among the first hit by the COVID-19 pandemic,[89] leading to strong confidence in vaccine safety and effectiveness.[91]

Regarding MS, regional disproportions may have contributed to the fact that country income and concurrent surveys of acceptance and intention affected VI. Nearly 17 out of 29 (60%) studies for MS were conducted in high income countries, and 25 (86%) studies surveyed intention only, showing an estimated pooled prevalence with an extremely narrow 95% confidence interval of pooled prevalence in the subgroup analysis (Figure 3). While Egger's test did not demonstrate a publication bias for MS, the funnel plot was empty on the left side of the vertical line, indicating a scarcity of studies focusing on the low level of VI for COVID-19 (Figure 5). These results imply that studies on MS are predominantly conducted in areas of high COVID-19 VI, and studies on healthcare students primarily centered around MS and indicated a high interest in high-income countries.

In our study, VI was low in the case of concurrent survey acceptance and intention compared to surveys focused solely on intention. These findings support the two global meta-analyses targeting the general population, revealing decreased VI over time and following the approval of the COVID-19 vaccine.[92,93] A study[94] conducted in the USA has shown that VI has decreased rapidly between April 2020 (71%) and October 2020 (53.6%), with the public concerns over the safety of vaccine potentially contributing to the decline in VI. Therefore, addressing public acceptability, trust, and concerns regarding vaccine safety and benefits becomes crucial.[93]

The unprecedented rapid pace of the COVID-19 vaccine development and distribution during the ongoing pandemic[95] had led to socioeconomic and geographical inequities in securing sufficient doses of the vaccine.[96] The first emergency use of the Pfizer COVID-19 vaccine took place on December 31, 2020, followed by the Astra-Zeneca vaccine on February 16, 2021, Johnson & Johnson on March 12, 2021, and Moderna on April 30, 2021.[97,98] To overcome socioeconomic and geographical inequities, COVAX, coordinated by the WHO, Gavi: The Vaccine Alliance, and the Coalition for Epidemic Preparedness Innovations, aims to support the development of the COVID-19 vaccine and negotiate pricing to benefit low- and middle-income countries.[99] These findings highlight the importance of global health authorities working toward emergency preparedness for potential future pandemics while implementing strategies to mitigate geographical and socioeconomic inequities in vaccine distribution.[6]

Despite its strengths, this study also has certain limitations. First, we investigated studies that focused on VI rather than acceptance rate. Consequently, we did not analyze studies on vaccine acceptance or its influencing factors. Our research aimed to reveal the VI of healthcare students as a predictor and mediator of vaccination behavior when a novel vaccine was introduced during the future pandemic. Second, a high overall heterogeneity was observed, and despite conducting subgroup analyses and meta-regression, the origin of heterogeneity remains unidentified. Future research should explore more variables that affect VI to mitigate heterogeneity. Third, we did not consider various pandemic situations such as outbreak waves and the timing of vaccine introduction. Instead, we considered daily new COVID-19 cases in our analysis as a confounding factor. Future research should incorporate these factors, as well as other influencing, controlling, and confounding variables to assess VI, more comprehensively.

Conclusion

The level of VI for COVID-19 among NS, MS, and DS varied widely in various studies, but the pooled level of VI was highest in MS, followed by NS and DS. The pooled level of VI for NS was significantly higher than that of DS, but that of MS was not. MS in high-income countries displayed a higher VI compared to those in low- and middle-income countries. Moreover, MS from South-East and Western Pacific exhibit higher VI when compared to their African counterparts. Our findings provide confirmative information for healthcare professionals and vaccine policy-makers. We suggest that an increased effort is needed to improve the level of VI of DS globally, and of MS outside of high-income countries. As the VI was affected by a number of factors, multifaceted and multivariate analysis is recommended to investigate the relevant factors. Finally, we suggest conducting further research that compare the levels of VI and uptake rate among healthcare students, and explore the factors which influence the level of VI and uptake rate.

Acknowledgments

We thank all researchers who were involved in studies on COVID-19 vaccination intention and hesitancy.

Author contributions

Choi and Ryu contributed to the conception and design of this study and collected data; Ryu performed the statistical analysis and interpretation. All authors drafted the manuscript and critically revised it. Ryu supervised this study. All the authors have read and approved the final version of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was supported by the Bisa Research Grant from Keimyung University in 2021 [Grant No. 20210653].

ORCID

Jongrim Choi http://orcid.org/0000-0003-4326-2273
Jae Geum Ryu http://orcid.org/0000-0002-5729-7680

References

1. World Health Organization. Statement on the fifteenth meeting of the international health regulations (2005) emergency committee regarding the coronavirus disease (COVID-19) pandemic; [accessed 2023 May 5]. https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic.
2. Park J, Min J, Song J-H, Park MY, Yoo H, Kwon O, Yang M, Kim S, Lee J, Myong JP. The COVID-19 pandemic response and its impact on post-corona health emergency and disaster risk management in Republic of Korea. Sustainability. 2023;15 (4):3175. doi:10.3390/su15043175.
3. Clemens SAC, Clemens R. The need and challenges for development of vaccines against emerging infectious diseases. J Pediatr (Rio J). 2023;99(Suppl 1):S37–S45. doi:10.1016/j.jped.2022.11.002.
4. Karan A. Lack of preparedness for the next pandemic is an emergency. BMJ. 2023;380:489. doi:10.1136/bmj.p489.
5. Rathnayake D, Clarke M, Jayasinghe VI. Health system performance and health system preparedness for the post-pandemic impact of COVID-19: a review. Int J Healthc Manag. 2021;14 (1):250–4. doi:10.1080/20479700.2020.1836732.

6. Sharfstein JM, Lurie N. Public health emergency preparedness after COVID-19. Milbank Q. 2023;101(S1):653–73. doi:10.1111/1468-0009.12615.
7. Giurgea LT, Morens DM, Yount J. Great expectations of COVID-19 herd immunity. mBio. 2022;13(1):e0349521. doi:10.1128/mbio.03495-21.
8. Ye L, Fang T, Cui J, Zhu G, Ma R, Sun Y, Li P, Li H, Dong H, Xu G. The intentions to get vaccinated against influenza and actual vaccine uptake among diabetic patients in Ningbo. Hum Vaccin Immunother. 2021;17(1):106–18. doi:10.1080/21645515.2020.1761201.
9. Preis H, Mahaffey B, Lobel M. Factors related to COVID-19 vaccination intention and uptake among childbearing women. Vaccine hesitancy: an overview. Health Psycho. 2022;42(8):567–76. doi:10.1037/hea0001221.
10. Lawal L, Bello MA, Murwira T, Avoka C, Ma'aruf SY, Harrison Omonhinmin I, Maluleke P, Tsagkaris C, Onyeaka H. Low coverage of COVID-19 vaccines in Africa: current evidence and the way forward. Hum Vaccin Immunother. 2022;18(1):2034457. doi:10.1080/21645515.2022.2034457.
11. Dubé E, Laberge C, Guay M, Bramadat P, Roy R, Bettinger J. Vaccine hesitancy: an overview. Hum Vaccin Immunother. 2013;9(8):1763–73. doi:10.4161/hv.24657.
12. Saied SM, Saied EM, Kabbash IA, Abdo SAE. Vaccine hesitancy: beliefs and barriers associated with COVID-19 vaccination among Egyptian medical students. J Med Virol. 2021;93(7):4280–91. doi:10.1002/jmv.26910.
13. Hosek MG, Chidester AB, Gelfond J, Taylor BS. Low prevalence of COVID-19 vaccine hesitancy in students across health science disciplines in Texas. Vaccine. 2022;10:100154. doi:10.1016/j.jvacx.2022.100154.
14. Geng H, Cao K, Zhang J, Wu K, Wang G, Liu C. Attitudes of COVID-19 vaccination among college students: a systematic review and meta-analysis of willingness, associated determinants, and reasons for hesitancy. Hum Vaccin Immunother. 2022;18(5):2054260. doi:10.1080/21645515.2022.2054260.
15. Lin GSS, Lee HY, Leong JZ, Sulaiman MM, Loo WF, Tan WW, Kielbassa AM. COVID-19 vaccination acceptance among dental students and dental practitioners: a systematic review and meta-analysis. PLoS One. 2022;17(4):e0267354. doi:10.1371/journal.pone.0267354.
16. Gautier S, Luyt D, Davido B, Herr M, Cardot T, Rousseau A, Annane D, Delarocque-Astagneau E, Josseran L. Cross-sectional study on COVID-19 vaccine hesitancy and determinants in healthcare students: interdisciplinary trainings on vaccination are needed. BMC Med Educ. 2022;22(1):299. doi:10.1186/s12909-022-03343-5.
17. Le CN, Nguyen UTT, Do DTH. Predictors of COVID-19 vaccine acceptability among health professions students in Vietnam. BMC Public Health. 2022;22(1):854. doi:10.1186/s12889-022-13236-3.
18. Ashok N, Krishnamurthy K, Singh K, Rahman S, Majumder MAA, Majumder MA. High COVID-19 vaccine hesitancy among healthcare workers: should such a trend require closer attention by policymakers? Cureus. 2021;13(9). doi:10.7759/cureus.17990.
19. Fan C-W, Chen I-H, Ko N-Y, Yen CF, Lin CY, Griffiths MD, Pakpour AH. Extended theory of planned behavior in explaining the intention to COVID-19 vaccination uptake among mainland Chinese university students: an online survey study. Hum Vaccin Immunother. 2021;17(10):3413–20. doi:10.1080/21645515.2021.1933687.
20. Al-Amer R, Maneze D, Everett B, Montayre J, Villarosa AR, Dwekat E, Salamonson Y. COVID-19 vaccination intention in the first year of the pandemic: a systematic review. J Clin Nurs. 2022;31(1–2):62–86. doi:10.1111/jocn.15951.
21. Galanis P, Vraka I, Fragkou D, Bilali A, Kaitelidou D. Intention of healthcare workers to accept COVID-19 vaccination and related factors: a systematic review and meta-analysis. Asian Pac J Trop Med. 2021;14(12):543–54. doi:10.4103/1995-7645.332808.
22. Al-Metwali BZ, Al-Jumaili AA, Al-Alag ZA, Sorofman B. Exploring the acceptance of COVID-19 vaccine among healthcare workers and general population using health belief model. J Eval Clin Pract. 2021;27(5):1112–22. doi:10.1111/jep.13581.
23. Khalafalla HE, Tumambeng MZ, Halawi MHA, Masmali EM, Tashari TB, Arishi FH, Shadad RH, Alfaraj SZ, Fathi SM, Mahfouz MS. COVID-19 vaccine hesitancy prevalence and predictors among the students of Jazan University, Saudi Arabia using the health belief model: a cross-sectional study. Vaccines. 2022;10(2):289. doi:10.3390/vaccines10020289.
24. Yenew C, Dessie AM, Gebeyehu AA, Genet A. Intention to receive COVID-19 vaccine and its health belief model (HBM)-based predictors: a systematic review and meta-analysis. Hum Vaccin Immunother. 2023;19(1):2207442. doi:10.1080/21645515.2023.2207442.
25. Wismans A, Thurik R, Baptista R, Dejardin M, Janssen F, Franken I, Delcea C. Psychological characteristics and the mediating role of the 5C model in explaining students' COVID-19 vaccination intention. PLoS One. 2021;16(8):e0255382. doi:10.1371/journal.pone.0255382.
26. Ngaybe MB, Schmitt HJ, Mallaha S, Sena R, Werts S, Rooney B, Margrath P, Madhivanan P. Qualitative assessment of COVID-19 vaccination acceptance among healthcare workers in Pima County. Hum Vaccin Immunother. 2023;19(1):2211464. doi:10.1080/21645515.2023.2211464.
27. Moola SMZ, Tufanaru C, Aromataris E, Sears K, Sfetcu R, Currie M, Qureshi R, Mattis P, Lisy K, Mu P-F. JBI manual for evidence synthesis. https://synthesismanual.jbi.global.
28. World Health Organization. WHO coronavirus (COVID-19) dashboard. World Health Organization (WHO); 2023 Feb 22 [accessed 2023 Feb 28]. https://covid19.who.int/.
29. The World Bank. The world by income and region. The World Bank; [accessed 2023 Mar 6]. https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html.
30. World Health Organization. WHO coronavirus (COVID-19) dashboard; situation by region, country, territory & area; 2023 Mar 1 [accessed 2023 Mar 6]. https://covid19.who.int/table.
31. Graeber D, Schmidt-Petri C, Schroder C, Capraro V. Attitudes on voluntary and mandatory vaccination against COVID-19: evidence from Germany. PLoS One. 2021;16(5):e0248372. doi:10.1371/journal.pone.0248372.
32. Willems LD, Dyzel V, Sterkenburg PS. COVID-19 vaccination intentions amongst healthcare workers: a scoping review. Int J Environ Res Public Health. 2022;19(16):10192. doi:10.3390/ijerph191610192.
33. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med. 2002;21(11):1539–58. doi:10.1002/sim.1186.
34. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60. doi:10.1136/bmj.327.7414.557.
35. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA, ed. Cochrane handbook for systematic reviews of interventions version 6.3. Cochrane; 2022 [Accessed 2022 Dec 31].
36. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Syst Rev. 2021;10(1):89. doi:10.1186/s13643-021-01626-4.
37. Mose A, Haile K, Timerga A. COVID-19 vaccine hesitancy among medical and health science students attending Wolkite University in Ethiopia. PLoS One. 2022;17(1):e0263081. doi:10.1371/journal.pone.0263081.
38. Raja SM, Osman ME, Musa AO, Hussien AA, Yusuf K, Patel SKS. COVID-19 vaccine acceptance, hesitancy, and associated factors among medical students in Sudan. PLoS One. 2022;17(4):e0266670. doi:10.1371/journal.pone.0266670.
39. Al Janabi T, Chinsky R, Pino MA. Perceptions of COVID-19 vaccines among osteopathic medical students (OMS). Int J Osteopath Med. 2021;42:23–28. doi:10.1016/j.ijosm.2021.10.008.

40. Chaves IES, Brito PRP, Rodrigues J, Costa MS, Candido EL, Moreira MRC. Hesitation regarding the COVID-19 vaccine among medical students in Brazil. Rev Assoc Med Bras. 2021;67(10):1397–402. doi:10.1590/1806-9282.20210379.
41. Fontenot HB, Mattheus DB, Lim E, Michel A, Ryan N, Knopf A, Abuelezam NN, Stamp K, Hekel B, Branson S, et al. Undergraduate nursing students' COVID-19 vaccine intentions: a national survey. PLoS One. 2021;16(12):e0261669. doi:10.1371/journal.pone.0261669.
42. Gala D, Parrill A, Patel K, Rafi I, Nader G, Zhao R, Shoaib A, Swaminath G, Jahoda J, Hassan R, et al. Factors impacting COVID-19 vaccination intention among medical students. Hum Vaccin Immunother. 2022;18(1):2025733. doi:10.1080/21645515.2022.2025733.
43. Kelekar AK, Lucia VC, Afonso NM, Mascarenhas AK. COVID-19 vaccine acceptance and hesitancy among dental and medical students. J Am Dent Assoc. 2021;152(8):596–603. doi:10.1016/j.adaj.2021.03.006.
44. Lucia VC, Kelekar A, Afonso NM. COVID-19 vaccine hesitancy among medical students. J Public Health (Oxf). 2021;43(3):445–9. doi:10.1093/pubmed/fdaa230.
45. Manning ML, Gerolamo AM, Marino MA, Hanson-Zalot ME, Pogorzelska-Maziarz M. COVID-19 vaccination readiness among nurse faculty and student nurses. Nurs Outlook. 2021;69(4):565–73. doi:10.1016/j.outlook.2021.01.019.
46. Mascarenhas AK, Lucia VC, Kelekar A, Afonso NM. Dental students' attitudes and hesitancy toward COVID-19 vaccine. J Dent Educ. 2021;85(9):1504–10. doi:10.1002/jdd.12632.
47. Mayan D, Nguyen K, Keisler B, Rowley JA. National attitudes of medical students towards mandating the COVID-19 vaccine and its association with knowledge of the vaccine. PLoS One. 2021;16(12):e0260898. doi:10.1371/journal.pone.0260898.
48. Alshehry AS, Cruz JP, Alquwez N, Alsharari AF, Tork HMM, Almazan JU, Alshammara F, Alabdulaziz H, Alsolami F, Tumala R, et al. Predictors of nursing students' intention to receive COVID-19 vaccination: a multi-university study in Saudi Arabia. J Adv Nurs. 2022;78(2):446–57. doi:10.1111/jan.15002.
49. Bolatov AK, Seisembekov TZ, Askarova AZ, Pavalkis D. Barriers to COVID-19 vaccination among medical students in Kazakhstan: development, validation, and use of a new COVID-19 vaccine hesitancy scale. Human Vaccin Immunother. 2021;17(12):4982–92. doi:10.1080/21645515.2021.1982280.
50. Gotlib J, Sobierajski T, Jaworski M, Wawrzuta D, Borowiak E, Dobrowolska B, Dyk D, Gaworska-Krzemińska A, Grochans E, Kózka M, et al. "Vaccinate, do not hesitate!". Vaccination readiness against COVID-19 among Polish nursing undergraduate students: a national cross-sectional survey. Vaccines. 2021;9(9):1029. doi:10.3390/vaccines9091029.
51. Grochowska M, Ratajczak A, Zdunek G, Adamiec A, Waszkiewicz P, Feleszko W. A comparison of the level of acceptance and hesitancy towards the influenza vaccine and the forthcoming COVID-19 vaccine in the medical community. Vaccines (Basel). 2021;9(5):475. doi:10.3390/vaccines9050475.
52. Kateeb E, Danadneh M, Pokorna A, Klugarová J, Abdulqader H, Klugar M, Riad A. Predictors of willingness to receive COVID-19 vaccine: cross-sectional study of Palestinian dental students. Vaccines (Basel). 2021;9(9):954. doi:10.3390/vaccines9090954.
53. Katz M, Azrad M, Glikman D, Peretz A. COVID-19 vaccination compliance and associated factors among medical students during an early phase of vaccination rollout—a survey from Israel. Vaccines (Basel). 2021;10(1):27. doi:10.3390/vaccines10010027.
54. Kaya MO, Yakar B, Pamukçu E, Önalan E, Akkoç RF, Pirinçci E, Gürsu MF. Acceptability of a COVID-19 vaccine and role of knowledge, attitudes and beliefs on vaccination willingness among medical students. Eur Res J. 2021;7(4):417–24. doi:10.18621/eurj.907213.
55. Lindner-Pawlowicz K, Mydlikowska-Smigorska A, Lampika K, Sobieszczanska M. COVID-19 vaccination acceptance among healthcare workers and general population at the very beginning of the national vaccination program in Poland: a cross-sectional, exploratory study. Vaccines (Basel). 2021;10(1):66. doi:10.3390/vaccines10010066.
56. Lo Moro G, Cugudda E, Bert F, Raco I, Siliquini R. Vaccine hesitancy and fear of COVID-19 among Italian medical students: a cross-sectional study. J Community Health. 2022;47(3):475–83. doi:10.1007/s10900-022-01074-8.
57. Mahdi BM. COVID-19 vaccine hesitancy and acceptance among medical students: an online cross-sectional study in Iraq. Open Access Maced J Med Sci. 2021;9(A):955–8. doi:10.3889/oamjms.2021.7399.
58. Malygin V, Malygin YV, Iskandirova A, Pahtusova EE, Merkuryeva YA, Ogarev VV, Hudiakov AV, Asasian MA. Multifactorial model of willingness to get vaccinated in medical students during 3rd wave of COVID-19 pandemic. Neurol Neuropsych Psychosom. 2021;13(6):29–34. doi:10.14412/2074-2711-2021-6-29-34.
59. Mubarak AS, Baabbad AS, Almalki NA, Alrbaiai GT, Alsufyani GA, Kabrah DK. Beliefs, barriers, and acceptance associated with COVID-19 vaccination among Taif University students in Saudi Arabia. J Family Med Prim Care. 2022;11(1):224–32. doi:10.4103/jfmpc.jfmpc_1255_21.
60. Pastorino R, Villani L, Mariani M, Ricciardi W, Graffigna G, Boccia S. Impact of COVID-19 pandemic on flu and COVID-19 vaccination intentions among university students. Vaccines (Basel). 2021;9(2):70. doi:10.3390/vaccines9020070.
61. Rosental H, Shmueli L. Integrating health behavior theories to predict COVID-19 vaccine acceptance: differences between medical students and nursing students. Vaccines. 2021;9(7):783. doi:10.3390/vaccines9070783.
62. Sovicova M, Zibolenova J, Svihrova V, Hudeckova H. Odds ratio estimation of medical students' attitudes towards COVID-19 vaccination. Int J Environ Res Public Health. 2021;18(13):6815. doi:10.3390/ijerph18136815.
63. Szmyd B, Bartoszek A, Karuga FF, Staniecka K, Blaszczyk M, Radek M. Medical students and SARS-CoV-2 vaccination: attitude and behaviors. Vaccines (Basel). 2021;9(2):128. doi:10.3390/vaccines9020128.
64. Han M, Park S, Kim Y. Factors associated with COVID-19 vaccination intention among nursing students: applying the health belief model. J Converg Cult Technol. 2021;7(3):343–51. (In Korean).
65. Jain J, Saurabh S, Kumar P, Verma MK, Goel AD, Gupta MK, Bhardwaj P, Raghav PR. COVID-19 vaccine hesitancy among medical students in India. Epidemiol Infect. 2021;149:e132. doi:10.1017/S0950268821001205.
66. Jiang N, Wei B, Lin H, Wang Y, Chai S, Liu W. Nursing students' attitudes, knowledge and willingness of to receive the coronavirus disease vaccine: a cross-sectional study. Nurse Educ Pract. 2021;55:103148. doi:10.1016/j.nepr.2021.103148.
67. Kausar A, Parveen SS, Afreen U, MaazHussain S. Vaccine perception: acceptance, hesitancy, beliefs and barriers associated with COVID-19 vaccination among medical students. Eur J Mol Clin Med. 2021;8:2021.
68. Le an P, Nguyen HTN, Nguyen DD, Vo LY, Huynh G. The intention to get a COVID-19 vaccine among the students of health science in Vietnam. Hum Vaccin Immunother. 2021;17(12):4823–8. doi:10.1080/21645515.2021.1981726.
69. Li M, Zheng Y, Luo Y, Ren J, Jiang L, Tang J, Yu X, Luo D, Fan D, Chen Y. Hesitancy toward COVID-19 vaccines among medical students in Southwest China: a cross-sectional study. Hum Vaccin Immunother. 2021;17(11):4021–7. doi:10.1080/21645515.2021.1957648.
70. Nguyen VT, Nguyen MQ, Le NT, Nguyen TNH, Huynh G. Predictors of intention to get a COVID-19 vaccine of health science students: a cross-sectional study. Risk Manag Healthc Policy. 2021;14:4023–30. doi:10.2147/RMHP.S328665.
71. Shah AK, Daniel RA, Kusuma YS. Knowledge and willingness to accept vaccine against SARS-CoV-2 among undergraduate medical students in Delhi, India. Curr Health Sci J. 2021;47(4):479–84. doi:10.1007/s10900-022-01072-w.

72. Zhou Y, Wang Y, Li Z. Intention to get vaccinated against COVID-19 among nursing students: a cross-sectional survey. Nurse Educ Today. 2021;107:105152. doi:10.1016/j.nedt.2021.105152.
73. Riad A, Abdulqader H, Morgado M, Domnori S, Koščík M, Mendes JJ, Klugar M, Kateeb E, IADS-SCORE. Global prevalence and drivers of dental students' COVID-19 vaccine hesitancy. Vaccines (Basel). 2021;9(6):566. doi:10.3390/vaccines9060566.
74. Sutton AJ, Duval SJ, Tweedie RL, Abrams KR, Jones DR. Empirical assessment of effect of publication bias on meta-analyses. BMJ. 2000;320(7249):1574–7. doi:10.1136/bmj.320.7249.1574.
75. Dratva J, Wagner A, Zysset A, Volken T. To vaccinate or not to vaccinate—this is the question among Swiss University students. Int J Environ Res Public Health. 2021;18(17):9210. doi:10.3390/ijerph18179210.
76. Schäfer M, Stark B, Werner AM, Mülder LM, Heller S, Reichel JL, Schwab L, Rigotti T, Beutel ME, Simon P, et al. Determinants of university students' COVID-19 vaccination intentions and behavior. Sci Rep. 2022;12(1):18067. doi:10.1038/s41598-022-23044-9.77.
77. Gao L, Su S, Du N, Han Y, Wei J, Cao M, Miao Q, Wang X. Medical and non-medical students' knowledge, attitude and willingness towards the COVID-19 vaccine in China: a cross-sectional online survey. Human Vaccin Immunother. 2022;18(5):2073757. doi:10.1080/21645515.2022.2073757.
78. Karlsson LC, Lewandowsky S, Antfolk J, Salo P, Lindfelt M, Oksanen T, Kivimäki M, Soveri A, Angelillo IF. The association between vaccination confidence, vaccination behavior, and willingness to recommend vaccines among Finnish healthcare workers. PLoS One. 2019;14(10):e0224330. doi:10.1371/journal.pone.0224330.
79. Bavel JJV, Baicker K, Boggio PS, Capraro V, Cichocka A, Cikara M, Crockett MJ, Crum AJ, Douglas KM, Druckman JN, et al. Using social and behavioural science to support COVID-19 pandemic response. Nature Human Behav. 2020;4(5):460–71. doi:10.1038/s41562-020-0884-z.
80. Machida M, Nakamura I, Kojima T, Saito R, Nakaya T, Hanibuchi T, Takamiya T, Odagiri Y, Fukushima N, Kikuchi H, et al. Trends in COVID-19 vaccination intent from pre-to post-COVID-19 vaccine distribution and their associations with the 5C psychological antecedents of vaccination by sex and age in Japan. Human Vaccin Immunother. 2021;17(11):3954–62. doi:10.1080/21645515.2021.1968217.
81. Jamil OBK, Muhib M, Abbal MA, Ahmed AM, Khan HH, Khan NY. Medical students in Karachi and COVID-19: myths and facts. SAGE Open Med. 2022;10:20503121221094208. doi:10.1177/20503121221094208.
82. Galanis P, Vraka I, Katsiroumpa A, Siskou O, Konstantakopoulou O, Katsoulas T, Mariolis-Sapsakos T, Kaitelidou D. COVID-19 vaccine uptake among healthcare workers: a systematic review and meta-analysis. Vaccines. 2022;10(10):1637. doi:10.3390/vaccines10101637.
83. Gabrovec B, Selak Š, Crnkovič N, Šorgo A, Cesar K, Fafangel M, Vrdelja M, Trop Skaza A. Compliance with preventive measures and COVID-19 vaccination intention among medical and other healthcare students. Int J Environ Res Public Health. 2022;19(18):11656. doi:10.3390/ijerph191811656.
84. Razzaghi H, Masalovich S, Srivastav A, Black CL, Nguyen KH, de Perio MA, Laney AS, Singleton JA. COVID-19 vaccination and intent among healthcare personnel, U.S. Am J Prevent Med. 2022;62(5):705–15. doi:10.1016/j.amepre.2021.11.001.
85. Sallam M, Dababseh D, Yaseen A, Al-Haidar A, Ababneh NA, Bakri FG, Mahafzah A. Conspiracy beliefs are associated with lower knowledge and higher anxiety levels regarding COVID-19 among students at the University of Jordan. Int J Environ Res Public Health. 2020;17(14):4915. doi:10.3390/ijerph17144915.
86. Chittano Congedo E, Paladino ME, Riva MA, Belingheri M. Adherence, perception of, and attitude toward influenza and flu vaccination: a cross-sectional study among a population of future healthcare workers. Int J Environ Res Public Health. 2021;18(24):13086. doi:10.3390/ijerph182413086.
87. Rashwan HH1, Nz S, Abd MDN. Knowledge, attitude and practice of Malaysian medical and pharmacy students towards human papillomavirus vaccination. Asian Pacific J Cancer Prev. 2012;13(5):2279–83. doi:10.7314/APJCP.2012.13.5.2279. PMID: 22901207.
88. Swarnapriya K, Kavitha D, Reddy GM. Knowledge, attitude and practices regarding HPV vaccination among medical and para medical students, India: a cross sectional study. Asian Pac J Cancer Prev. 2015;16(18):8473–7. doi:10.7314/APJCP.2015.16.18.8473. PMID: 26745104.
89. Salomoni MG, Di Valerio Z, Gabrielli E, Montalti M, Tedesco D, Guaraldi F, Gori D. Hesitant or not hesitant? A systematic review on global COVID-19 vaccine acceptance in different populations. Vaccines. 2021;9(8):873. doi:10.3390/vaccines9080873.
90. Sallam M. COVID-19 vaccine hesitancy worldwide: a concise systematic review of vaccine acceptance rates. Vaccines. 2021;9(2):160. doi:10.3390/vaccines9020160.
91. Larson HJ, De Figueiredo A, Xiahong Z, Schulz WS, Verger P, Johnston IG, Cook AR, Jones NS. The state of vaccine confidence 2016: global insights through a 67-country survey. EBioMedicine. 2016;12:295–301. doi:10.1016/j.ebiom.2016.08.042.
92. Mahmud S, Mohsin M, Hossain S, Islam MM, Muyeed A. The acceptance of COVID-19 vaccine at early stage of development and approval: a global systematic review and meta-analysis. Heliyon. 2022;8(9):e10728. doi:10.1016/j.heliyon.2022.e10728.
93. Robinson E, Jones A, Lesser I, Daly M. International estimates of intended uptake and refusal of COVID-19 vaccines: a rapid systematic review and meta-analysis of large nationally representative samples. Vaccines. 2021;39(15):2024–34. doi:10.1016/j.vaccine.2021.02.005.
94. Daly M, Robinson E. Willingness to vaccinate against COVID-19 in the US: representative longitudinal evidence from April to October 2020. Am J Prevent Med. 2021;60(6):766–73. doi:10.1016/j.amepre.2021.01.008.
95. Diamond MS, Pierson TC. The challenges of vaccine development against a new virus during a pandemic. Cell Host Microbe. 2020;27(5):699–703. doi:10.1016/j.chom.2020.04.021.
96. Haldane V, Ariyarajah A, Berry I, Loutet M, Salamanca-Buentello F, Upshur RE, Basu S. Global inequity creates local insufficiency: a qualitative study of COVID-19 vaccine implementation challenges in low-and-middle-income countries. PLoS One. 2023;18(2):e0281358. doi:10.1371/journal.pone.0281358.
97. World Health Organization. COVID19 vaccines; [accessed 2023 May 5]. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines.
98. Francis AI, Ghany S, Gilkes T, Umakanthan S. Review of COVID-19 vaccine subtypes, efficacy and geographical distributions. Postgrad Med J. 2022;98(1159):389–94. doi:10.1136/postgradmedj-2021-140654.
99. Herzog LM, Norheim OF, Emanuel EJ, McCoy MS. Covax must go beyond proportional allocation of covid vaccines to ensure fair and equitable access. BMJ. 2021;372:m4853. doi:10.1136/bmj.m4853.