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REVIEW

Attitudes of COVID-19 vaccination among college students: A systematic review and meta-analysis of willingness, associated determinants, and reasons for hesitancy

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ABSTRACT

The significance of COVID-19 vaccine has been declared and this study synthesizes the attitudes and determinants in vaccination hesitancy of college students. We searched in PubMed, Web of Science, Cochrane Library and CNKI to enroll the related studies. The modified NOS was used for quality evaluation. Proportion and OR with 95% CI were pooled to estimate the acceptance rates and determinants of COVID-19 vaccination. Data of 34 studies involving 42 countries were pooled. The pooled acceptance rate of COVID-19 vaccination among all the college students was 69% and varies between countries, while medical students have a slightly higher acceptancy rate. Knowledge, trust conception, social behavior, and information sources were important for their decision. Most of the college students intended to COVID-19 vaccination, but the proportion varied among countries. Governments should strengthen credibility, convey trusted information with media influences and improve vaccination services in urging students to be vaccinated.

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COVID-19; college students; vaccination hesitancy; determinants; meta-analysis

Introduction

All countries were facing an unprecedented public health challenge for the global pandemic of coronavirus disease 2019 (COVID-19).[1] Vaccination is the most effective method for the blocking of prevalence of infectious diseases; by vaccine administration, many infectious diseases, such as smallpox measles and poliomyelitis were controlled or even eradicated during the past century.[2–4] Researchers have proven the safety and scientific validity of COVID-19 vaccines based on large field trials, presenting a promising effective way to control the transmission of SARS-CoV-2.[5] Currently, there are four main types of COVID-19 vaccines available globally, according to the different designing methods: inactivated vaccines, virus vector vaccines, subunit vaccines and nucleic acid vaccines.[6–8] As of 9 October 2021, more than six billions vaccine doses against COVID-19 have been administered on a global scale.[9] From the view of epidemiologists, gaining "herd immunity" by vaccination more than 67% of citizens in each country, theoretically, will block sustained transmission for COVID-19.[10,11] High vaccine coverage is especially critical for growing antimicrobial resistance and booming international travel.[12] Additionally, though being considerable debate for preventing transmission, vaccine uptake was proved to reduce more than 50% (from 59% to 100%) risk for severe illness of COVID-19.[13–15] However, vaccine hesitancy is a barrier for getting immunity to fight against the COVID-19, which grabbed the attention of scientists and government officers.[16] The Strategic Advisory Group of Experts (SAGE) Working Group on Vaccine Hesitancy defined vaccine hesitancy as a delay in acceptance or refusal of vaccination despite availability of vaccination services.[17] Vaccine hesitancy has led a surge of outbreaks in vaccine-preventable diseases, for example, measle outbreak in the United States in 2011, because the vaccine coverage in communities was below the levels needed to maintain herd immunity.[18]

Previous studies have revealed that vaccine hesitancy is a complex phenotype, with different reasons, including different populations, environmental, agent, and host factors, varying across countries.[19–22] The proportion intending to vaccinate against COVID-19 reported in the meta-analysis by Robinson et al. was .729[21] and another study estimated the global COVID-19 vaccination willingness at 66.01%.[23] However, the intention varies substantially between different populations, for example, the prevalence of unwillingness to vaccinate against COVID-19 in older people was 27.03%,[24] while the willingness was 51% for healthcare workers.[22] Sociodemographic and socioeconomic status, experiences with COVID-19, perceived risk, attitudes, beliefs, and perceptions about COVID-19, and COVID-19 vaccine were frequently studied in vaccine acceptance or refusal. In whole population studies, middle-aged and elderly people, males, higher education level, the white race, higher income was significantly associated with increased likelihood of vaccination.[21,23] But in studies of healthcare workers, who was male, aged over 30 years or having a history of influenza vaccination was intending to vaccination.[22] Shakeel et al. deduced that low levels of education and awareness, inefficient government efforts, and initiatives, as well as conspiracy theories and misinformation about the COVID-19 vaccine on social media may explain the different vaccine hesitancy across

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countries and continents.[25] These facts highlighted the necessity of a comprehensive review of different populations and effective interventional educational strategy to enhance the vaccination rate, finally putting an end to this pandemic.

Although older people are at greater infection-fatality risks for COVID-19,[26,27] young adults are vulnerable to coronavirus infection and more likely to transmit the virus. First, young people often work in areas at high risk for exposure to the coronavirus, such as restaurants, schools, manufactories, and retail shops. Additionally, since young people were less likely to get severe infection of COVID-19, they may have a false sense of confidence regarding their safety, with ignoring community pandemic guidelines and not wearing masks. Consistent with a report from Bruine de Bruin, adults aged under 30 years old have the higher risk than elders in getting COVID-19 infection.[28] In addition, college students can be particularly affected by campus outbreaks and spread the coronavirus when they return home or go out for social activities. Therefore, college students could be an ideal population to investigate their view for COVID-19 since they are well-educated and open-minded, and supposed to be the active spreader of the pandemic.[29] However, variations in vaccine acceptance in college students in different reports ranged from .64 to .86.[30–33] A systematic review analyzing the worldwide COVID-19 vaccine-hesitancy in college students could provide scientific evidence for governments and non-governmental organizations to formulate strategies for the future immunization plan. Hence, the principal objective of this meta-analysis was to comprehensively investigate the intention to vaccine uptake against COVID-19 and its influencing factors among college students to promote vaccination-based interventions. Moreover, college students majoring in the health science (e.g., clinical medicine, dentistry, nursing and preventive medicine) will represent the population of healthcare workers in the future, so they would be analyzed as the subgroups.

Method

Search strategy

Medline/PubMed, the Cochrane Library, Web of Science, and the China National Knowledge Infrastructure (CNKI) were searched for articles that published up to 31 December 2021. The following Medical Subject Heading (MeSH) terms and related derivative were searched according to the corresponding search formula in the above databases: ((“COVID-19”[All Fields] OR “SARS-CoV-2”[All Fields] OR “2019-nCoV”[All Fields]) AND (“vaccination”[All Fields] OR “vaccine”[All Fields] OR “immunization”[All Fields]) AND “college students” [All Fields] OR “university students” [All Fields] OR “undergraduate students” [All Fields])). We also googled the reference lists, minutes of the meeting, and unpublished data for additional reports.

Inclusion criteria

Studies included featured the following: (1) it was a cross-sectional study; (2) it had an effective sample size >30; (3) it investigated full-time undergraduate and postgraduate students aged 18 years and above; (4) it provided odds ratios (ORs) with 95% confidence intervals (95% CIs) or enough information to calculate them. For reports investigated the same population, only the most recent study or the report with the larger number of participants was included. We defined the proportion of vaccination acceptance as the percentage of respondents who were willing to get available COVID-19 vaccines, have vaccinated or were planning to in the future.

Quality assessment

This meta-analysis followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. We reviewed and assessed the validity of included studies according to the modified Newcastle-Ottawa Scale (NOS) for cross-sectional studies.[34] The total score of NOS is 10 points. Articles scored ≥6 were classified as high quality, 5 and 4 as moderate quality, ≤ 3 as low quality. Low-quality articles were excluded in further analyses.

Data extraction

The following data were extracted from the original reports: first authors, publication year, studied region, investigation time, sampling method, sample size, response rate, age, sex, vaccination intention, as well as associated adjusted variables and risk estimates (ORs with 95% CIs). When both unadjusted and adjusted estimates were available, adjusted estimates were preferred over the unadjusted ones. We have also collected the 7-day average number of new cases and cumulative confirmed cases of all research works during investigation time, provided by Johns Hopkins CSSE (if the investigation time of included studies was reported with month, we assumed it as the last day of this month).[35] All data extraction, integration, and bias assessments were accomplished independently by two reviewers (Geng and Cao). Then, any discrepancies were resolved by consensus with a third reviewer (Liu). Since this meta-analysis was based on previously published studies, ethical approval, or patient consent was not required.

Statistical analysis

Because the included studies differed in sampling method, time and region of survey, and medical services, high potential heterogeneity was assumed. A random-effects model analysis was used to calculate the pooled results. The associated determinants of COVID-19 vaccination were pooled when these were not less than three studies and all studied populations had the same reference groups. The I^2 statistic was used to assess heterogeneity (defined as I^2 >75% as high heterogeneity). For studies with high heterogeneity, besides random-effects model, heterogeneous analysis was also conducted by hierarchical analysis, the leave-one-out method, and meta regression as well as discussion of the sensitivity. Egger’s test was used to assess publication bias. All the data were analyzed with Stata 16.0 (StataCorp, Texas, US). $P < .05$ (2-sided) was considered statistically significant in all analyses.

Results

Included studies and general information

A total of 34 studies were found in four databases and other sources. These articles were screened as the process presented in Figure 1, and finally 34 studies were included in the Meta-analysis. Among these studies, nine were performed in the United States,[33,36–43] five in China[44–48] and three in Italy,[30,49,50] respectively, while three were carried out in multiple countries.[31,51,52] And 15 of the studies recruited students majored in medical science (included clinical medicine, dental and nursing, etc.)[31–33,37,42,47,48,51–58] and 18 studies recruited the non-medical students;[30,36,38–41,43–46,49,50,59–62] one study included the both[63](Table 1). Quality scores of these studies ranged from 4 to 8 (mean ± SD: 6.1 ± 1.21), indicating generally good quality (Table 1, Table S1).

Acceptance of vaccination

For vaccination uptake, the result suggested that the pooled acceptance proportion of all college students (4,2543 subjects) was .69 (95% Cl: .64–.75, heterogeneity $I^2 = 99.5\%$, $P < .001$) (Figure 2). In subgroup analysis of regions, the pooled proportion of studies in the US was .66 (95% CI: .54–.77; heterogeneity $I^2 = 96.3\%$, $P < .001$), which was lower than that of China (.77, 95% CI .72–.82; heterogeneity $I^2 = 96.9\%$, $P < .001$). And the acceptance proportion in Italy was .85 (95% CI: .80–.90; heterogeneity $I^2 = 87.7\%$, $P < .001$) (Table 2, Figure S1). Since the willingness may change with pandemic of COVID-19, time of survey was also analyzed: 15 studies conducted in 2020 with a pooled willingness proportion of .72 (95% CI: .64–.80; heterogeneity $I^2 = 98.2\%$, $P < .001$); and 16 studies in 2021 that the pooled proportion was .70 (95% CI: .66–.74; heterogeneity $I^2 = 97.7\%$, $P < .001$) (Table 2, Figure S2). The pooled acceptance proportion of non-medical students was similar to medical students (.72, 95% CI: .66–.78 *vs* .66, 95%CI: .57–.75, $P > .05$) (Table 2, Figure S3). In medical students, the pooled willingness of nursing students and dental students were .60 (95% CI: .35–.85, heterogeneity $I^2 = 99.0\%$, $P < .001$) and .60 (95% CI: .54–.67, heterogeneity $I^2 = 45.7\%$, $P = .159$), respectively, which was lower than that of entire medical students with a proportion of .74 (95% CI: .67–.81, heterogeneity $I^2 = 97.1\%$, $P < .001$) (Table 2). In general, the acceptance rate of COVID-19 vaccination differed among countries, but neither pandemical year nor major of college students showed difference in vaccination wiliness.

Determinants of COVID-19 vaccination acceptance in college students

After reviewing the associated determinants of COVID-19 vaccination, four types of factors were frequently analyzed: demographic characteristics (age, gender, grade, and major), experience for COVID-19 (personal or others of infection), personal views (e.g., support or concerns about COVID-19 and vaccination) and vaccination behavior (vaccination in the past 5 years) (Table 3). As shown in Table 3, age, gender, and grade presented no influence on vaccination wiliness, while medical students were associated with higher odds of intending to vaccinate than non-medical students (OR = 2.75, 95% CI: 2.00–3.50). For experience with the disease, students who had been infected with COVID-19 did not intend to vaccinate (OR = .49, 95% CI: .19–.78) but the experience of relatives or friends' infection did not impact the intend for vaccination (OR = 1.06, 95%

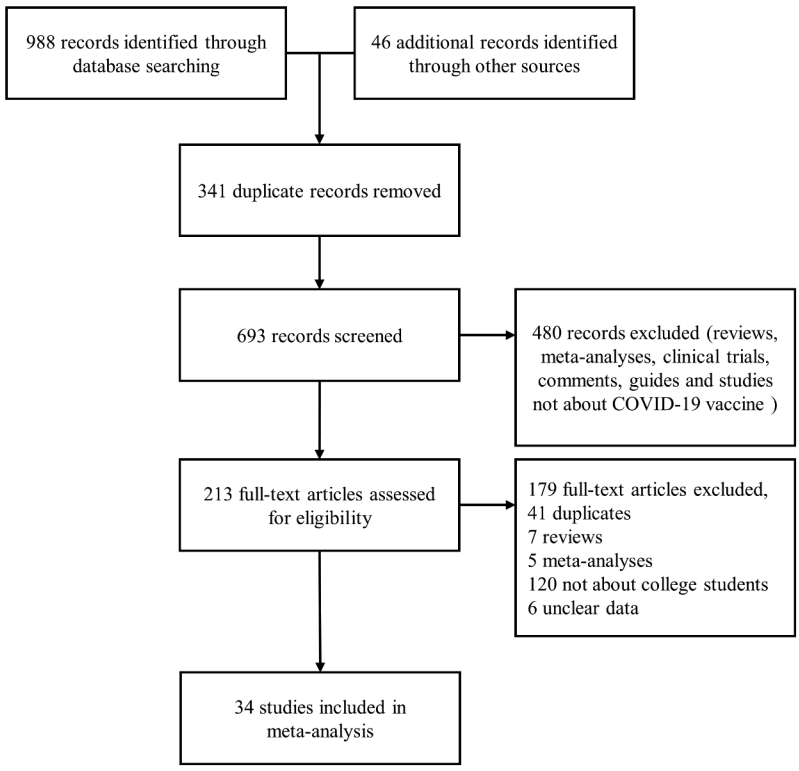

Figure 1. Selection flow chart of reports for inclusion in the meta-analysis.

Table 1. Characteristics of studies on willingness to COVID-19 vaccination among college students.

Author	Published year	Country	Survey time	Sampling method	Sample size, n	Effective response rate, %	Age, mean±SD, range or percentage	Sex, male/female	Vaccination acceptance rate, %	Type	Quality scores
Harapan	2020	Indonesia	March 2020 to April 2020	Simplified-snowball sampling	511	96.93	NR	NR	94.9	Non-medical students	7
Wong	2020	Malaysia	April 2020	NR	99	NR	NR	NR	95.0	Non-medical students	7
Sun	2020	China	March 2020 to April 2020	NR	1912	NR	20.38 ± 2.10	602/1390	64.0	Non-medical students	7
Qiao	2020	US	September 2020 to October 2020	Convenience sampling	1062	NR	23.83 ± 6.66	211/848	60.6	Non-medical students	6
Barello	2020	Italy	NR	NR	735	81.00	23.60 ± 4.90	602/1390	86.1	Non-medical students	5
Lucia	2020	US	NR	NR	168	34	NR	72/96	53.0	Medical students	4
Sallam	2021	Jordan	January 2020	Chain-referral sampling	1106	NR	≤21 years, 63.8%; >21 years, 36.2%	304/802	34.9	Non-medical students	8
Pastorino	2021	Italy	June 2020 to July 2020	NR	436	78	23.09 (range: 21.32–24.74）	129/307	88.5	Non-medical students	7
Alali	2021	Kuwait	June 2020 to July 2020	NR	592	25.06	Range: 19-45	47/545	75.8	Medical students	4
Rosental	2021	Israel	August 2020 to September 2020	Opportunity sampling	628	NR	28.06 ± 3.33 (MS); 26.04 ± 3.74 (NS)	210/418	88.1	Medical and nursing students	7
Cuschieri	2021	Malta	September 2020 to October 2020	NR	679	32.63	18–24 (78.50%)	219/460	56.4	Medical students	4
Kelekar	2021	US	September 2020, November 2020 to December 2020	NR	415	34 (Medical), 18 (Dental)	NR	NR	77.3	Medical students	4
Silva	2021	US	November 2020	NR	237	44.38	18–29 (97%)	82/155	92.0	Non-medical students	4
Graupensperger	2021	US	November 2020	NR	647	46.21	19.77 ± 1.35	228/419	91.6	Non-medical students	6
Yu	2021	China	January 2021	Random sampling and snowball sampling	2608	NR	NR	1509/1099	81.4	Non-medical students	7
Szmyd	2021	Poland	December 2020	NR	1971	NR	Medical: 20 (range: 20–24); Non-medical: 20 (range: 19–22)	970/1001	92.0	Medical students and Non-medical students	7
Bai	2021	China	December 2020 to January 2021	Snowball sampling	2881	99.60	19.83 ± 2.02	961/1920	76.3	Non-medical students	7
Patelarou	2021	Greece, Albania, Cyprus, Spain, Italy, Czech Republic and Kosovo	December 2020 to January 2021	NR	2249	NR	21.60 ± 5.60	344/1902	43.8	Nursing students	6
Tavolacci	2021	France	January 2021	Convenience sampling	3089	10.00	20.30 ± 1.90	883/2206	58.0	Non-medical students	5
Saied	2021	Egypt	January 2021	Convenience sampling	2133	NR	20.24 ± 1.78	742/1391	84.1	Medical students	6
Wu	2021	China	January 2021	Snowball sampling	116	99.46	NR	NR	81.9	Medical students	7

(*Continued*)

Table 1. (Continued).

Author	Published year	Country	Survey time	Sampling method	Sample size, n	Effective response rate, %	Age, mean±SD, range or percentage	Sex, male/female	Vaccination acceptance rate, %	Type	Quality scores
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	NR	6639	NR	22.06 ± 2.79	1836/4682	63.6	Dental students	5
Sharma	2021	US	February 2021 to March 2021	Quantitative cross-sectional and survey-based research methodology	282	67.79	25.00 ± 7.90	95/177	47.5	Non-medical students	8
Jain	2021	India	February 2021 to March 2021	NR	1068	NR	NR	549/519	89.4	Medical students	6
Kecojevic	2021	US	February 2021 to March 2021	Simple random sampling	457	19.5	24.70 ± 6.38	109/342	63.7	Non-medical students	7
Velikonja	2021	Slovenia, Poland and Serbia	February 2021 to March 2021	Snow-ball sampling	872	45.04	23.50 ± 6.50	97/775	35.0	Nursing students	6
Gallè	2021	Italy	February 2021 to April 2021	NR	3226	NR	23.30 ± 3.90	1421/1805	81.3	Non-medical students	6
Jiang	2021	China	March 2021	NR	1488	98.41	<18, .34%; 18-, 10.95%; 19-, 21.91%; 20-, 19.69%; 21-, 23.99%; 22-, 16.20%; 23-, 6.96%	234/1254	84.4	Nursing students	5
Kanyike	2021	Uganda	March 2021	NR	600	NR	0–24, 61.2%; ≥24, 38.8%	377/223	37.3	Medical students	7
Sovicova	2021	Slovakia	March 2021	NR	1228	22.85	22 (range: 18–33)	361/867	71.7	Medical students	6
Mascarenhas	2021	US	2020	NR	248	NR	26.30 ± 3.80	104/144	56.0	Dental students	6
Synnott	2021	US	NR	Systematic sampling	592	36.2	NR	206/378	50.5	Non-medical students	5
Alzubaidi	2021	UAE	March 2021	Heterogeneous sampling	669	76.6	20.98 ± 3.87	126/543	68.2	Non-medical students	8
Hossain	2021	Bangladesh	March 2021 to April 2021	Convenient sampling	900	NR	23.95 ± 3.38	502/398	72.7	Non-medical students	7

NR, not reported.

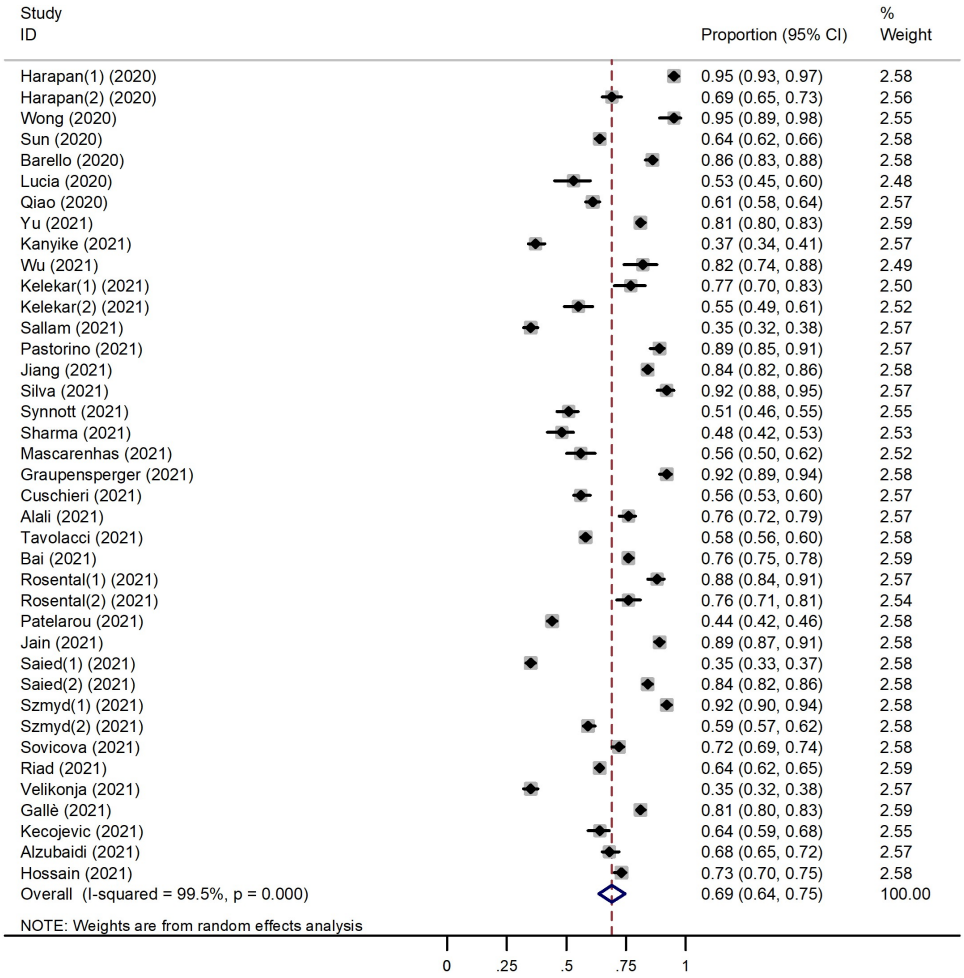

Figure 2. Forest plots of COVID-19 vaccine acceptance among college students.

Table 2. COVID-19 vaccine acceptance rate among college student after subgroup analysis.

			Heterogeneity	
Subgroup	No. of studies	Pooled rate (95% CI)	*I2* (%)	*P* value
Region				
United States	9	0.66 (.54–.77)	96.3	<.001
China	5	0.77 (.72–.82)	96.9	<.001
Italy	3	0.85 (.80–.90)	87.7	<.001
Time of survey				
2020	15	0.72 (.64–.80)	98.2	<.001
2021	16	0.70 (.66–.74)	97.7	<.001
Population				
Non-medical student	19	0.72 (.66–.78)	99.3	<.001
Medical student	16	0.66 (.57–.75)	99.6	<.001
Medical student				
Medical student	11	0.74 (.67–.81)	97.1	<.001
Nursing student	4	0.60 (.35–.85)	99.0	<.001
Dental student	3	0.60 (.54–.67)	45.7	0.159

CI: .65–1.46). In personal view, students who were concerning about infection with COVID-19 (OR = 1.41, 95% CI: 1.05–1.78), perceived sufficient knowledge about COVID-19 (OR = 1.22, 95% CI: 1.02–1.42), the students who realized the importance of COVID-19 (OR = 1.24, 95% CI: 1.14–1.33) or supported the compulsory vaccination for public (OR = 2.33, 95% CI: 1.13–3.53) were more likely to get vaccinated. While the participants who were worries about the adverse effect (OR = .57, 95% CI: .40–.73), getting a compulsory vaccination of COVID-19 (OR = .32, 95% CI: .06–.69) made them refuse COVID-19 vaccine. Interestingly, infection risk and previous vaccine behavior showed no association with acceptance for COVID-19 vaccination.

Other related factors excluded in meta-analysis

Since some studies have investigated some factors associated with COVID-19 vaccination but these data were insufficient for pooling, we sorted out the positive results presented in Table 4 for further discussion.

Social environmental factors were important for vaccination wiliness. Fear of the increasing deaths, suffering from distance to friends during pandemic containment or concerns for passing the virus to relatives made them more likely to accept COVID-19 vaccine.[49,63] And COVID-19 vaccine uptake of respondents' relatives or friends also have a beneficial impact on their attitudes and behaviors (e.g., advising relatives and friends to vaccinate).[41,46] Surprisingly, the information sources of the COVID-19 affected the respondents' attitude toward vaccination. If scientists disseminated vaccine knowledge, it would be conducive to the students' vaccination. The information from mass media, health agencies, and pharmaceutical companies was trusted by college students and improved their willingness to vaccination, implying the importance of

Table 3. Determinants of COVID-19 vaccination willingness among college students.

Survey item	No. of studies	Pooled OR (95%CI)	Heterogeneity	
			I^2 (%)	*P* value
Demographic characteristics				
Age	12	1.10 (0.97-1.22)	89.9	<0.001
Female	12	0.85 (0.69-1.02)	78.6	<0.001
Grade (senior vs junior)	5	1.41 (0.95-1.87)	82.0	<0.001
Major (medical vs non-medical)	5	**2.75 (2.00-3.50)**	87.9	<0.001
Experience with COVID-19				
Self-experience of COVID-19 infection themselves	6	**0.49 (0.19-0.78)**	38.2	0.167
People on whose social network getting COVID-19 infection	6	1.06 (0.65-1.46)	90.3	<0.001
People on whose social network died of COVID-19 infection	3	0.89 (0.55-1.23)	0.0	0.604
Personal views about COVID-19 and vaccination				
Knowledge about COVID-19 vaccines	3	**1.22 (1.02-1.42)**	71.7	0.007
With higher exposure risk of COVID-19	7	1.16 (0.99-1.33)	97.8	<0.001
Concerns about getting infection with COVID-19	4	**1.41 (1.05-1.78)**	90.1	<0.001
Importance of COVID-19 vaccination for individuals	4	**1.24 (1.14-1.33)**	0.0	0.870
Vaccination is better than none	3	0.88 (0.07-1.68)	95.8	<0.001
Trust in vaccine information from medical experts	4	2.29 (0.75-3.83)	35.9	0.197
Concerns about the adverse effects of COVID-19 vaccines	6	**0.57 (0.40-0.73)**	90.7	<0.001
Support the compulsory COVID-19 vaccination of public	3	**2.33 (1.13-3.53)**	42.2	0.177
Getting vaccinated if it is compulsory	3	**0.32 (-0.06-0.69)**	88.8	<0.001
Vaccination Behavior				
Have other vaccination in the past five years	9	1.08 (0.82-1.34)	46.7	0.037

media in information transmission for college students.[36] Pharmaceutical companies' information as sources of COVID-19 vaccine did not promote vaccine reception. Information of COVID-19 vaccine from social media and students who had hesitancy of other vaccines were more reluctant to accept COVID-19 vaccine as well[36,57] (Table 4). And suffering high levels of stigmatization hindered the COVID-19 vaccination.[44] Vaccine or vaccination service factors also influence the vaccination acceptance rate for COVID-19. Signing informed consent documents before vaccination could reduce the wiliness for vaccination but perceiving easy access to a vaccination center increase the acceptance rate.[44]

Table 4. Determinants not included in the meta-analysis.

Authors (year)	Item
Sun et al. (2020)	[a] Lower socioeconomic status (OR=1.49, 95%CI: 1.21-1.83);
	[a] COVID-19 prosocial behaviors (OR=1.19, 95%CI: 1.07-1.33);
	[a] Perceived COVID-19 societal stigma (OR=0.86, 95%CI: 0.78-0.95);
	[a] Concerns over time necessary for participating in a medical study (OR=0.60, 95%CI: 0.43-0.83);
	[c] Informed consent signature (OR=0.55, 95%CI: 0.40-0.75).
Qiao et al. (2020)	[b] Getting information from: scientists (OR=1.23, *P*=0. 240), pharmaceutical companies (OR=0.79, *P*=0.042).
	[b] Trusted information sources: social media (OR=0.86, *P*=0.037), mass media (OR=1.28, *P*<0.001), health agencies (OR=1.22, *P*=0.004), scientists (OR=1.19, *P*=0.033), pharmaceutical companies (OR=1.16, *P*=0.002).
Sallam et al. (2021)	[a] Public university (OR=2.10, 95%CI: 1.40-3.30);
Pastorino et al. (2021)	[b] Fear about the increase in deaths (OR=1.58, 95%CI: 1.18-2.10);
	[b] Suffering from distance to friends during pandemic containment (OR=1.30, 95%CI: 1.10-1.67).
Kelekar et al. (2021)	[a] I would like to be involved in a COVID-19 vaccine trial (OR=2.30, 95%CI: 1.53-3.47);
	[a] I am concerned that a COVID-19 vaccine may not be effective (OR=2.78, 95%CI: 1.80-4.36);
	[a] As an adult, I have ever decided not to get a vaccine for reasons other than illness or allergy (OR=0.41, 95%CI: 0.23-0.73);
	[b] The COVID-19 vaccination should be mandatory for all health care providers (OR=5.18, 95%CI: 3.15-8.76).
Szmyd et al. (2021)	[a] Depression (OR=0.930, 95%CI: 0.867-0.997);
	[b] The fear of passing on the disease to relatives (OR=1.255, 95%CI: 1.113-1.413).
Bai et al. (2021)	[a] Urban residents (OR=1.409, 95%CI: 1.152-1.724);
	[a] Heard about COVID-19 vaccine previously (OR=1.659, 95%CI: 1.268-2.710);
	[a] Feel vaccine could keep you free of COVID-19: yes VS no (OR=1.957, 95%CI: 1.286-2.979), not sure VS no (OR=2.009, 95%CI: 1.331-3.034);
	[a] Suggest your family to inject vaccine: yes VS no (OR=17.745, 95%CI: 12.271-25.660), not sure VS no (OR=2.580, 95%CI: 1.760-3.782).
Patelarou et al. (2021)	[a] Working in healthcare facilities during the COVID-19 pandemic (OR=0.63, 95%CI: 0.48-0.82);
	[a] Trust in government (OR=1.85, 95%CI: 1.49-2.29);
Saied et al. (2021)	[a] Self-perception of own health status: bad VS very bad (OR=1.196, 95%CI: 0.436-3.279), average VS very bad (OR=0.506, 95%CI: 0.282-0.909), good VS very bad (OR=0.675, 95%CI: 0.499-0.913), very good VS very bad (OR=0.733, 95%CI: 0.566-0.950).
Kecojevic et al. (2021)	[a] Positive Attitude regarding COVID-19 vaccine (OR=1.16, 95%CI: 1.04-1.29);
	[b] Family member or friend received COVID-19 vaccine (OR=5.03, 95%CI: 2.00-2.60).
Kanyike et al. (2021)	[a] Marital status: single VS married (OR=2.1, 95%CI: 1.1-3.9).
	[a] I have ever been reluctant or hesitate to get a vaccination before (OR=0.60, 95%CI: 0.40-0.90).
Alzubaidi et al. (2021)	[a] Positive beliefs and attitudes toward the COVID19 vaccination (OR=1.336, 95%CI: 1.122-1.590);
	[a] Believing that social distancing would not need to be followed if vaccinated (OR=0.890, 95%CI: 0.812-0.976);
	[c] Perceiving easy access to a vaccination center (OR=1.220, 95%CI: 1.100-1.353).

[a]Individual factors, [b]Social environmental factors, [c]Vaccine or vaccination service factors.

Sensitivity analysis and publication bias

Because of heterogeneity of the pooled results, we conducted a sensitivity analysis of all the studies (Figure 3). We found slightly significant publication bias in 34 studies ($P = .041$). Four studies (Sallam et al., Patelarou et al., Velikonja et al. and Kanyike et al.) significantly affected the heterogeneity of merged results.[51,52,57,61] Among them, two (Patelarou et al. and Velikonja et al.) were joint surveys of multiple countries[51, 52]and the other two performed in Jordan and Uganda where had no new case reported during the surveys.[57, 64] Though the investigating time, regions, new cases, and cumulative cases were included for meta-regression analysis, no significant factors were observed (Table S2). After excluding four studies above, no significant graphic or statistical bias was identified by linear regression analysis (Egger's test) ($P = .188$) (Figure 4).

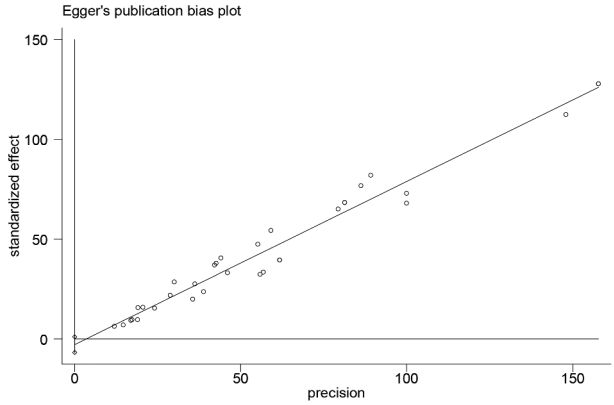

Figure 4. Egger's plots of publication bias for the studies in this meta-analysis.

Discussion

Global public health system is facing unprecedented challenges because of the pandemic of COVID-19. High vaccination coverage for "herd immunity" globally was critical to end the pandemic,[65,66] and commercialized vaccines demonstrating high protection rate were authorized to prevent the infection. However, young people, though at greater risk for exposure and virus transmission, was less likely to uptake COVID-19 vaccine.[67] As the most active youth group, college students were prone to suffering from outbreaks of COVID-19. Investigation on the willingness and associated factors of college students' vaccination hesitancy would be favorable evidence for the government to formulation policies to promote vaccination. In our study, we systematic reviewed the acceptance proportion of COVID-19 among college students and determinants of willingness for vaccine uptake based on existing studies, suggesting the necessity of knowledge education and belief promotion for young adults, as well as the importance of credibility of government.

Overall, the acceptance proportion of COVID-19 vaccine in college students was about .70 on a global scale. There were great differences in college students' attitudes toward COVID-19 vaccines in different countries.[68] In Europe, the lowest vaccination intention was 13% (also the lowest in all studied countries), revealed by an investigation in Slovenia, Poland, and Serbia by Velikonja et al.[52] And the study by Patelarou et al. including seven European countries reported a second lowest vaccination intention (44%),[51] among which Kosovo (38.5%), Albania (32.6%) and Czech Republic (21.4%) presented the low acceptance proportions. Surprisingly, Italian college students' willingness to vaccinate were comparatively high (.85, 95% CI: .80, .90). This could be explained by the impact of the rapidly increased cases in campus, leading to social isolation, concern for personal health and psychological

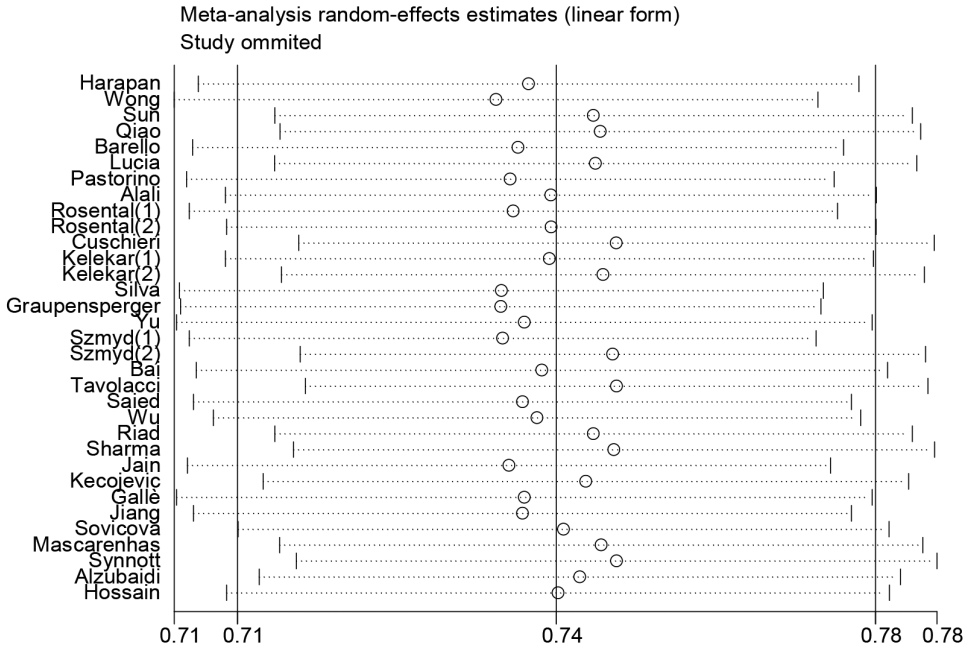

Figure 3. Sensitivity analyses for difference.

distress.[69,70] The rates in some other countries were also significantly lower, such as Jordan (35%), Uganda (37%), and some investigations of multination.[51,52,57,61] This may be due to that no new cases were reported in Jordan and Uganda during the time of the surveys.[57,61] Additionally, major knowledge gaps and inequities in vaccine distribution could also be the reasons for low intentions in Uganda.[71,72] An effective international mutual aid system named COVAX, has been set up to help African countries achieve equal distribution of vaccine, effective preservation, and vaccination due to their difficulties in vaccine access.[71] Comparatively, college students from Asian countries had relatively higher acceptance (Indonesia: 94.9%, Malaysia: 95.0%, Israel: 88.1%, India: 89.4%, the pooled proportion of China: 77.0%). The phenomenon was not limited to college student groups; a meta-analysis of the public by Sallam et al. showed that the entire population acceptance of COVID-19 vaccine were comparatively high in East and Southeast Asia.[64] College students in the US, Europe and Africa were relatively less willing to receive the COVID-19 vaccine. The results were almost consistent with previous studies of the public,[64] which may be the results of the public's concerns about the effectiveness and safety of vaccines in different regions, from a study which reported an emerging inverse relationship between vaccine sentiments and socioeconomic status.[73] Correspondingly, the acceptance proportion of college student in the U.S. were lower. The conspiracy theories, "Gates had himself created the virus" for example, were proved to be barriers to controlling the spread of COVID-19 in the U.S., by a resistance to both preventive behaviors and future vaccination for the virus.[74] Psychologists believed that belief in conspiracy theories was driven by motives for understanding one's environment, being safe and in control of one's environment, and maintaining a positive image of the self and the social group, of which the first two were what people needed during the pandemic of COVID-19.[75] It is not possible to stop people from spreading ill-founded rumors but effective strategies would slowdown the spread of rumors.[76] To improve the vaccine acceptance rate, government institutions should first and foremost implement strategies to eliminate the concerns about COVID-19 vaccines.

Our finding also indicated the importance of the trust in government is, as well as trustworthy sources of information and reliable guidance, especially in an uncertain and rapidly changing situation like COVID-19 pandemic, in that personal views about COVID-19 and vaccine were substantial determinants on college students' vaccine hesitation; studies have suggested that vaccination trust was not only dependent on vaccine knowledge but also comes from trust in authorities, health professionals, government, or public health institutions.[36,77] A global survey of the potential acceptance of a COVID-19 vaccine revealed that participants reporting higher levels of trust in information from government were more likely to be vaccinated, with the fact that acceptance in countries with strong trust in central governments (China, South Korea and Singapore) tend to exceed 80%.[20] An example of how government ruined the government credibility is Philippines, whose Food and Drug Authority (FDA) overturned the stipulations that the emergency use of authorization of China vaccine Sinovac was not granted for health frontliners and the elderly and those with comorbidities in February 2021, inducing distrust in governments and experts, as well as misinformation or rumors, widespread.[78] Additionally, response to vaccination in media of public figures, like football players, actors, and leaders, may urge students to get vaccinated. According to the results of Qiao et al., students obtained information on the COVID-19 vaccine from mass media, health agencies, and scientists would increase the likelihood of vaccination.[36] Dissemination of scientific information by mainstream media or influencer would be beneficial for increase in the public (college students included) vaccination acceptance rate for COVID-19; since the willingness of college students was consistently associated with that of entire population in different countries, indicating the influence of overall social circumstances and policies of the country.[21] However, any negative news or attitude related to COVID-19 vaccine may weaken public confidence in vaccination, with the fact that 22% of Brazilians, raising for 9% in 4 months, refuse to be vaccinated since their president expressed his refusal for vaccines against COVID-19 in local media.[79] Therefore, more efforts are needed to strengthen the credibility of government and the utility of media influences, providing honest information about the benefits and risks of immunization, which would also mitigate their negative impact of rumors.

Intriguingly, vaccine hesitation is not directly related to vaccination behavior, in the fact that people still felt hesitant even after get vaccinated.[18] The reasons are complex.[80] A review suggested that vaccination hesitancy involved emotional, cultural, social, spiritual, and political factors, as well as cognitive factor.[80] And most of factors were separately or simultaneously investigated in the studies included in our meta-analysis. Among them, experience with COVID-19, personal views about COVID-19 and vaccination, and vaccination behavior were the most frequently asked questions, and some of them were significantly correlated with vaccination hesitancy of college students. Notably, researchers explored some social, political, and cultural elements that may promote the acceptance by college students (Tables 3 and 4). College students are knowledgeable, full of energy and creativity, fast accessing for information and in the stage of concepts and values formation, but emotional and fear of restraint. So, if they knew the outcomes of infection and perceived the importance of vaccine uptake, they would weight and take actions (Table 3).[33,42,44,58,63,81–83] However, mandatory vaccination and consent signature (though have to) would reduce the wiliness for vaccination in college students. Also, they were easily affected by conspiracy ideation (discussed above), religiosity and political position, as well as distance requirement and quarantine rules in pandemic.[71,84] Even though, they have a sense of responsibility toward society, e.g., the fear of passing virus to relatives make them acceptable for vaccination,[63] while they also concern about the increasing deaths due to COVID-19 infection.[49] And they were also encouraged and affected by friends or relatives, because they enjoyed sharing their life (e.g., vaccination experiences) or information of COVID-19 (e.g., vaccination information).[85] Utilizing the media resources mentioned above would greatly promote the vaccination wiliness of college students. In addition, it was interesting that students who had self-experience of COVID-19 infection were not willing to get vaccination. The result could be explained by the misconception of passive immunity[86] and implied that the COVID pandemic should be controlled by active prevention, because the herd immunity from natural infection of

most population may suffer from stronger hesitancy or even vaccination resistance if another virus attacks. Last but not the least, available and convenient vaccine or vaccination service were important drivers for college students to get vaccinated,[33,41,42,58] and it was also the main reason for vaccine hesitation in economically backward areas.[87] For Africa and other areas, the supply of the vaccine should be the priority.

The acceptance of COVID-19 vaccine between non-medical students and medical students were similar. After adjusting for other factors, medical students appeared to have a substantially higher rate of willingness. Among medical students, the willingness of nursing and dental students was significantly lower than that of other medical students. It is noteworthy that dentists and nurses might undergo the higher risk for the SARS-CoV-2 virus exposure due to the intimate contact with patients and the aerosols and droplets containing viruses.[5,88] Mandated vaccination could not maximize the social responsibility of healthcare workers but medical health personnel should be the advocates and educators in against COVID-19.[89] Since recommended by healthcare workers, vaccine confidence and self-efficacy would increase intention for vaccination in public health, education in medical students were significantly meaningful for improving the perceptions against the pandemic in entire population. On the other hand, the influencing factors of vaccine hesitation can be divided into three categories: individual factors, social environmental factors, vaccine or vaccination service factors.[17] For individual factors, gender, age, and grades did not affect intention of COVID-19 vaccination of college students in our study while previous studies found that gender and age influenced vaccination acceptance in the public and healthcare workers.[21,22] It might be explained by the diversity of values and knowledge in all population with wider age ranges, another possible reason was that college students' active social behavior, and the age and gender difference would be covered.

This systematic review has the limitations. First, considering the inevitable heterogeneity of the pooled results, in addition to the random effect model and hierarchical analysis, we also performed sensitivity analysis and meta regression to identify the source of heterogeneity. In the sensitivity analysis, we found that four studies had a great impact on the pooled results.[51,52,57,64] Based on these results, we considered that the investigation time, region, new cases and cumulative cases might affect the pooled results. However, meta regression showed no significant results. Moreover, more determined factors and reasonable indicators should be considered in the future research. In addition, due to the process of review and publication, this study cannot provide the latest meta results. And small sample sizes and sources of different countries which might inevitably cause some bias. Thus, more research on vaccination wiliness in college students is still needed in the future. Finally, the included studies only considered college students rather than the entire population, which might make our study within limits.

Conclusion

In conclusion, most of the college students intend to accept vaccination of COVID-19 and the proportion varied among countries. The lower acceptance proportion in some countries needs more attention. Medical students were more likely to accept the COVID-19 vaccine. Knowledge of COVID-19, trust conception and social behavior were important determinants in students' vaccination wiliness. Vaccine information on social media significantly impacts the vaccine acceptance among college students. For governments, strengthening credibility and conveying trusted information with media influences, as well as improving vaccination services, are critical in urging college students to be vaccinated.

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