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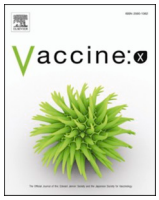

Global COVID-19 vaccine hesitancy among elderly: A systematic review

M.C. Law [a,*], P.K.F. Chiu [b]

[a] Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong
[b] Department of Surgery, The Chinese University of Hong Kong, Hong Kong

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ABSTRACT

Background & Objectives: Elderly infected with COVID-19 has high mortality risk, and the protection from COVID-19 vaccine is limited by vaccine hesitancy. The information of vaccine hesitancy in elderly is incomplete and fragmented. In this study, we attempt to examine the level of vaccine hesitancy in elderly and the related factors in global perspectives.

Methods: A systematic review was conducted to include observational studies of COVID-19 vaccine hesitancy in elderly from January 2020 to September 2021. Search strategies covering COVID-19 vaccine, vaccine hesitancy and elderly in four databases of PUBMED, MEDLINE, EMBASE and COCHRANE LIBRARY were adopted. Studies reporting COVID-19 vaccine hesitancy prevalence in elderly were included. A meta-analysis of the vaccine hesitancy prevalence was performed. The primary outcome is the vaccine hesitancy prevalence in elderly population globally. The secondary outcomes are the factors of COVID-19 vaccine hesitancy among elderly.

Results: Initial 479 articles were included for screening, with 54 studies included for meta-analysis of COVID-19 vaccine hesitancy in elderly and 6 studies included for qualitative analysis of factors for vaccine hesitancy. The overall prevalence of vaccine hesitancy was 27.7 % (95 % C.I: 23.8–31.6 %). The prevalence was significantly higher in Asia than in Europe (35.3 % VS 17.9 %, $p < 0.05$). The vaccine hesitancy was significantly higher before the launch of the vaccine than after (30.3 % VS 18.7 %, $p < 0.05$). Important factors of vaccine hesitancy in elderly identified were low income, low education, perception of COVID-19 being more contagious, more vaccine side effects and lower vaccine efficacy.

Conclusions: COVID-19 vaccine hesitancy is an important problem in elderly, with geographical variation. Tailored policy and strategies targeting the hesitancy factors were required to promote COVID-19 vaccine to elderly.

1. Introduction and literature review

COVID-19 pandemic caused 528 million infections and 6.29 million deaths [1] since its emergence in December 2019. Meta-analysis on epidemiological data showed that the infection fatality ratio (IFR) increased exponentially with increasing age, with a significant change at 65 years old [2]. IFR was less than 0.75 % for patients younger than 65 years old, but it increased to more than 2.5 % for those above 65 years old. COVID-19 vaccine was effective in decreasing severe infection and mortality [3,4]. However, the vaccine hesitancy was high among elderly in Hong Kong [5].

Vaccine hesitancy is defined as delay in acceptance or refusal of vaccination despite availability of vaccination services [6]. General factors of vaccine hesitancy are categorized into individual or group influences, contextual influences and vaccination specific issues. Scoping review and rapid systematic review [7,8] have found factors for high COVID-19 vaccine hesitancy in general population in most of the countries being younger age, females, minor ethnicity and lower income or education level.

While many previous studies have assessed the COVID-19 vaccine hesitancy determinants, most of them were studying the general population with limited data focusing on elderly population. Furthermore, most previous studies were carried out before the launch of COVID-19 vaccine. The association of timing of vaccine availability with the outbreak status and vaccine hesitancy prevalence is still unknown. After finalization of the protocol of this systematic review, first systematic review in elderly COVID-19 vaccine hesitancy was published in October 2021. With inclusion of limited studies, it reported the prevalence of unwillingness and uncertainty to vaccinate being 27.03 % and 19.33 % respectively [9].

* Corresponding author.
E-mail address: denathanlaw@gmail.com (M.C. Law).

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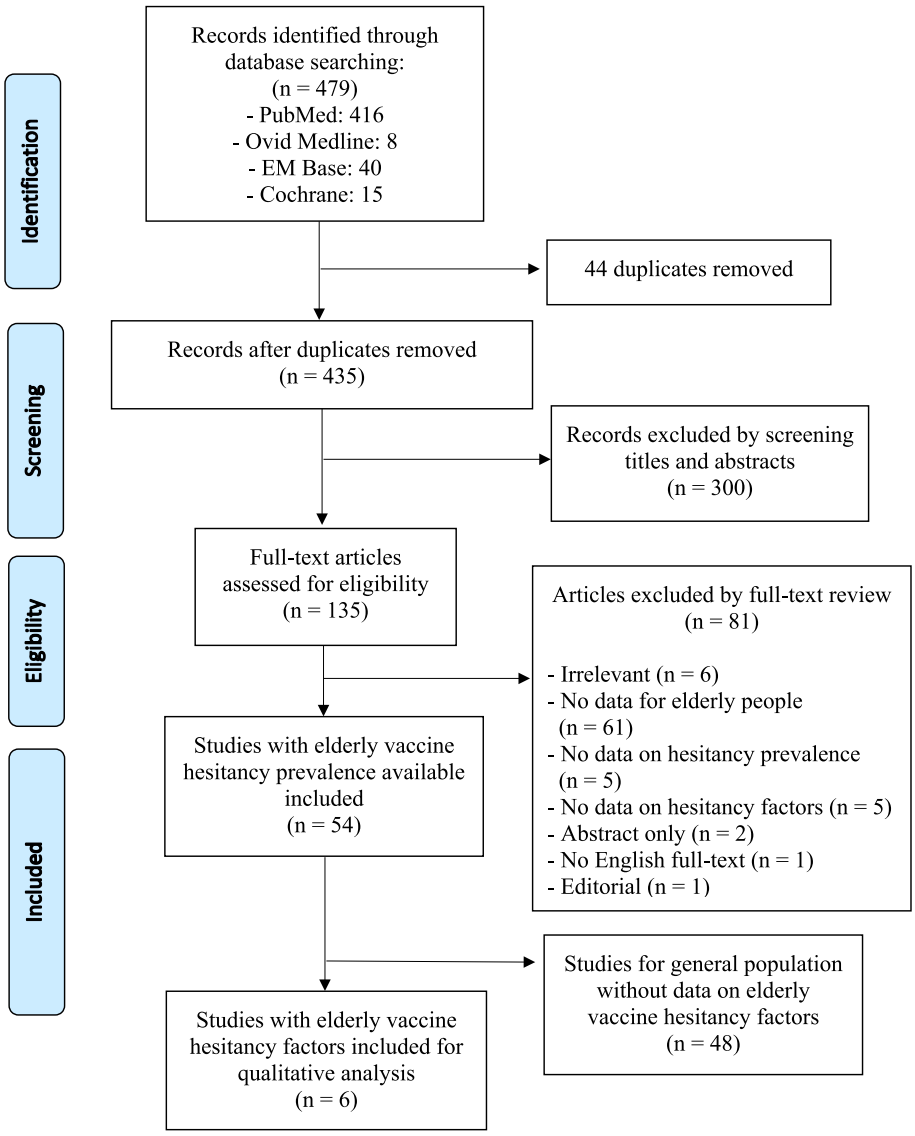


Fig. 1. PRISMA flow-chart.

2. Aims and objectives

Our review question is "Is COVID-19 vaccine hesitancy a common phenomenon in elderly?" The primary objective of this review is to assess the pooled hesitancy prevalence among elderly in the global perspectives. Secondary objective is to determine the factors of COVID-19 vaccine hesitancy in elderly.

With the high vaccine hesitancy rate and low vaccine uptake rate among elderly in Hong Kong, understanding the determinants of vaccine hesitancy in this subgroup of population is important for healthcare workers and public health policy makers to identify measures to promote vaccine uptake, and hence protect this vulnerable group from COVID-19 infection.

3. Methods

3.1. Protocol and registration

The protocol of this systematic review followed the PRISMA-P statement [10] and was registered at PROSPERO registry (CRD42022313483) in February 2022.

3.2. Study design and eligibility criteria

This is a systematic review designed for qualitative data synthesis on COVID-19 vaccine hesitancy in elderly based on available literature. It followed the PRISMA guidelines [11]. Inclusion criteria for this systematic review were observational studies from January 2020 to September 2021, which reported COVID-19 vaccine hesitancy with focus in elderly population or in the general population with elderly being a sub-group. These included cross-sectional, cohort and case-controlled studies. Only published and peer-reviewed articles retrievable in English language were included. Commentaries, editorials, letters, conference proceedings, position statements of organizations and expert opinions were excluded. Secondary studies including reviews and meta-analyses were also excluded. Primary studies without an abstract will be excluded as the screening for titles and abstracts is impossible.

3.3. Data sources and searches

Published observational studies from January 2020 to September 2021 were searched in the PUBMED, MEDLINE, EMBASE and COCHRANE LIBRARY. The search strategy was composed of three main themes, including COVID-19 vaccine, vaccine hesitancy and elderly.

Table 1
Characteristics of the included studies and the vaccine hesitancy.

A. Asia

Author	Year	Country/ City	End of data collection	Vaccine launched	Data collection method	Elderly sample size	Minimum age	Hesitancy (%)
Qin [15]	2021	China	13/3/2020	No	online survey	30	55	31.25
Luk [16]	2021	HK	23/4/2020	No	telephone	495	60	38.3
Li [17]	2021	China	14/6/2020	No	face-to-face	236	58	16.1
Wong [18]	2021	HK	27/8/2020	No	telephone	823	55	31.9
Alqudeimat [19]	2021	Kuwait	1/9/2020	No	online survey	344	55	57.85
Kishore [20]	2021	India	10/11/2020	No	online survey	33	60	27.27
Mohamed [21]	2021	Malaysia	15/12/2020	No	online survey	175	60	58.29
Syed Alwi [22]	2021	Malaysia	29/12/2020	No	online survey	82	60	36.6
Abedin [23]	2021	Bangladesh	71/1/2021	No	face-to-face	267	60	38.6
Machida [24]	2021	Japan	18/1/2021	No	online sent to e-mail	779	65	25.5
Ali [25]	2021	Bangladesh	31/1/2021	No	face-to-face	31	61	38.7
Ahmed [26]	2021	Pakistan	Apr-21	Yes	online survey	47	60	17
Boon-Itt [27]	2021	Thailand	Apr-21	No	online survey	49	65	59.2
Zhao [28]	2021	China	26/4/2021	Yes	online survey	601	60	35.4
Khankeh [29]	2021	Iran	May-21	Yes	face-to-face	220	60	11.4
Thanapluetiwong^ [30]	2021	Thailand	25/7/2021	Yes	telephone	282	60	44.3

^ Study included for qualitative analysis.

This strategy was adapted from previous systematic reviews evaluating vaccine hesitancy for other vaccines [12]. The following search terms for the three main themes were used: (COVID OR coronavirus OR SARS-COV-2) AND (vaccine hesitancy OR vaccine refusal OR vaccine acceptance) AND (elderly OR aged population OR advanced age). The same search strategy was used for the four databases.

3.4. Study selection

Study selection was performed in three stages from identifying studies, screening titles and abstracts to full-text review by two independent reviewers. Inconsistent results were resolved by consensus. The search results were pooled in the EndNote X9 to identify and remove duplicate search results. Titles and abstracts were screened first and finally full text of the articles was screened using the inclusion and exclusion criteria.

3.5. Data collection and items

Data was extracted from selected studies, which included first author, the country, year of publication, COVID-19 vaccine hesitancy prevalence in elderly, data collection method and end date. Data on potential factors of vaccine hesitancy including gender, race, socio-economic class, education level, outbreak status during the availability of vaccine, vaccine safety and adverse events were extracted. Data items were input into Microsoft Excel with pre-defined format. Data extraction was done by two independent reviewers. Inconsistent data was reviewed for accuracy.

3.6. Data analysis and result synthesis

A PRISMA flowchart diagram was used to show the numbers and reasons of the exclusion of studies at each stage of the review. The characteristics of the included studies was summarized with descriptive statistics, including year of study, continent and country of study, number of study participants and methodology of data collection. Meta-analysis of the elderly COVID-19 vaccine hesitancy prevalence was performed using OpenMeta[Analyst]. Random effect model [13] was used for computational model for analysis as studies were included globally. I^2 metric test was used to assess heterogeneity across the studies. $I^2 > 50$ % will be considered as significant heterogeneity. Publication bias was assessed by visual inspection of funnel plots [14].

All studies having secondary outcome results were used to present a narrative summary of COVID-19 vaccine hesitancy factors. According to the Strategic Advisory Group of Experts (SAGE) on immunization [6], the factors were grouped into three main categories of contextual influences, individual or group influences and vaccination specific issues for assessment.

Table 1b
Europe.

Author	Year	Country/City	End of data collection	Vaccine launched	Data collection method	Elderly sample size	Minimum age	Hesitancy (%)
Kourlaba [31]	2021	Greece	3/5/2020	No	computer assisted tel or web	374	55	32.6
Ward [32]	2020	France	4/5/2020	No	online survey	1234	64	10.7
Fadda^ [33]	2021	Switzerland south	15/5/2020	No	telephone	19	64	36.8
La Vecchia [34]	2020	Italy	28/9/2020	No	interview (computer assisted)	444	55	41.8
Sethi [35]	2021	UK	9/10/2020	No	online survey	1466	60	11.12
Kessels [36]	2021	Belgium	16/10/2020	No	survey	748	55	16.65
Robertson [37]	2021	UK	1/12/2020	No	telephone or online	4352	55	9.4
Malesza^ [38]	2021	Germany	17/1/2021	Yes	face-to-face	1037	76	21.8
Valerio [39]	2021	Italy	16/2/2021	Yes	online survey	1538	61	3.6
Raciborski [40]	2021	Poland	18/4/2021	Yes	telephone + online + personal (computer assisted)	357	60	23.35
Galle^ [41]	2021	Italy	Aug-21	Yes	online sent to phone	1041	65	6.95

^ Study included for qualitative analysis.

Table 1c
North America.

Author	Year	Country/ City	End of data collection	Vaccine launched	Data collection method	Elderly sample size	Minimum age	Hesitancy (%)
Shih [42]	2021	USA	2020/3/22	No	online survey	242	56	37
Kelly [43]	2021	USA	Apr-2020	No	survey online to address	511	65	15.1
Szilagyi [44]	2021	USA	1st: 14/4/2020 2nd: 16/3/2021	Yes	online survey	No data	65	1st: 33.8 2nd: 17.55
Fisher [45]	2020	USA	20/4/2020	No	online survey	298	60	23.5
Reiter [46]	2020	USA	May-2020	No	online survey	504	65	24
Ruiz [47]	2021	USA	16/6/2020	No	online survey	255	55	30.75
Wagner [48]	2021	USA	20/7/2020	No	telephone + online	189	65	40.45
Nguyen [49]	2021	USA	1st: 1/10/2020 2nd: 20/12/2020	Yes	online survey	No data	65	1st: 29.8 2nd: 18.7
Holaday [50]	2021	USA	Nov-2020	No	online survey	6715	65	38.5
Unroe [51]	2021	USA – Indiana	2020/11/17	No	survey online to phone	938	60	35.9
Nikolovski^ [52]	2021	USA	20/11/2020	No	mobile apps	7402	65	8.7
Salmon [53]	2021	USA	7/12/2020	No	online survey	865	60	39
Siegler [54]	2021	USA	1st: 8/12/2020 2nd: 21/4/2021	Yes	online survey	400	55	1st: 26 2nd: 7
Ogilvie [55]	2021	Canada	10/12/2020	No	online survey	1370	60	15.8
Daly [56]	2021	USA	1st: 5/1/2021 2nd: 29/3/2021	Yes	online survey	No data	60	1st: 36.2 2nd: 21
Szilagyi [57]	2021	USA	19/1/2021	No	online survey	1536	65	28.2
Garcia [58]	2021	USA	11/2/2021	No	online survey	715	65	15.5
El-Mohandes [59]	2021	USA – NYC, LA, Dallas, Chicago	Apr-21	Yes	Not mentioned	Nat:596 NY: 284 LA: 263 Da: 217 Chi: 275	60	7.95
Fernandez-Penny [60]	2021	USA – Philadelphia	11/5/2021	Yes	face-to-face	307	56	10.25

^ Study included for qualitative analysis.

Table 1d
South America, Oceania, Africa and multiple continents.

Author	Year	Country/ City	End of data collection	Vaccine launched	Data collection method	Elderly sample size	Minimum age	Hesitancy (%)
South America								
Oliveira [61]	2021	Brazil	30/10/2020	No	online survey	No data	60	22.8
Macinko^ [62]	2021	Brazil	Nov-2020	No	telephone	6681	50	29.1
Oceania								
Seale [63]	2021	Australia	24/3/2020	No	online survey	198	70	9.1
Thaker [64]	2021	New Zealand	13/7/2020	No	online survey	354	56	21.5
Africa								
Echoru [65]	2021	Uganda	9/2020	No	online survey	50	60	42
Multiple Continents								
Trent [66]	2021	United States, United Kingdom, Australia	Sep-2020	No	online survey	727	65	11
Kaadan [67]	2021	22 Arab countries	14/1/2021	No	online survey	39	65	41
Qunaibi [68]	2021	23 Arab + 122 other	29/1/2021	No	online survey	664	60	77.6

^ Study included for qualitative analysis.

4. Results

4.1. Search results

The PRISMA flow-chart was shown in Fig. 1. Initially 479 articles were identified, in which 44 were duplicate results. After screening out 300 articles by the titles and abstracts, 135 full-text articles were reviewed. 54 studies [15–68] with elderly vaccine hesitancy prevalence reported were included, giving total sample size of 49,699 elderly. For factors of vaccine hesitancy, most studies were for general population without subgroup analysis for elderly. Target study population was elderly only in 6 of the studies [30,33,38,41,52,62]. They were included for qualitative analysis for elderly vaccine hesitancy factors.

4.2. Study characteristics

The main descriptive findings of the 54 included studies, including author, city or country of study, publication year, data collection method and end date, elderly sample size and minimum age, were charted in Table 1 and grouped by continents. Most of the studies were

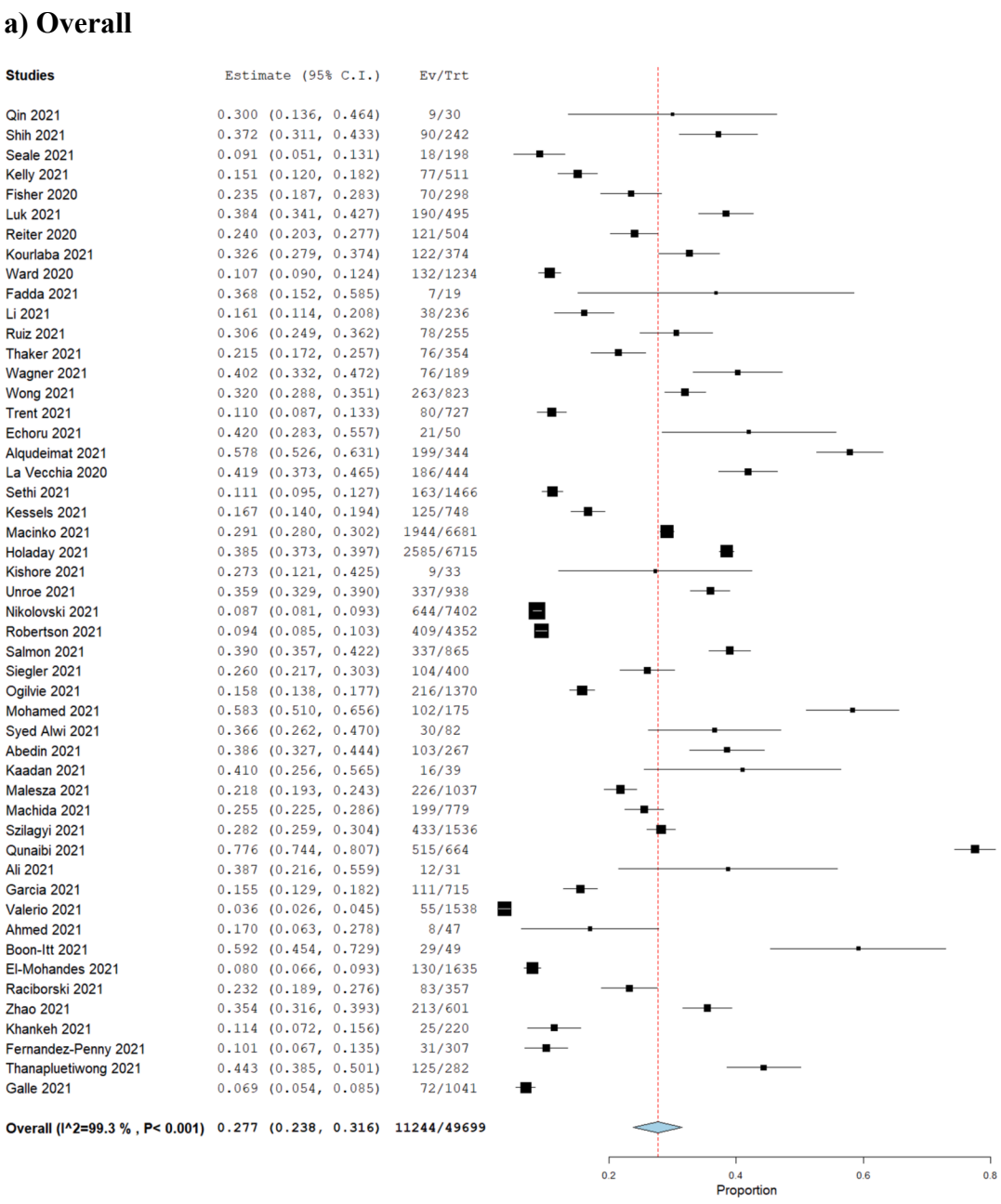


Fig. 2. Forest plots of the prevalence of COVID-19 vaccine hesitancy.

from North America (n = 19), followed by Asia (n = 16), Europe (n = 11), South America (n = 2), Oceania (n = 2) and Africa (n = 1). The remaining 3 studies were multi-national studies covering more than 1 continent. 34 studies collected data in 2020 and 20 studies finished data collection in 2021, in which only 14 studies collected data after the vaccine was launched. 4 studies were longitudinal studies [44,49,54,56].

4.3. COVID-19 vaccine hesitancy prevalence in elderly

The prevalence of the COVID-19 vaccine hesitancy in elderly from individual studies was listed in Table 1. Four studies reported the elderly vaccine hesitancy prevalence but not the number of elderly population studied, and therefore not included in the meta-analyses. The overall vaccine hesitancy prevalence across the included studies was 27.7 % (95 % C.I: 23.8–31.6 %), with high heterogeneity ($I^2 = 99.3$ %) (Fig. 2a). The prevalence was significantly higher in Asia than in Europe (35.3 % VS 17.9 %, $p < 0.05$) (Fig. 2b & c). The prevalence in North America was 24.7 % (95 % C.I: 17.8–31.6 %) (Fig. 2d), which was similar to the overall prevalence.

Four studies [44,49,54,56] were longitudinal studies comparing the vaccine hesitancy before and after the launch of the vaccine of the same studied population. All studies were conducted in USA. The hesitancy prevalence ranged from 26 % to 38.3 % before the availability of the vaccine. All of the studies reported a lower hesitancy prevalence after the launch of the vaccine (7–21 %). Meta-analyses of the vaccine hesitancy of all included studies were performed with stratification to the availability of vaccine. The hesitancy prevalence was 30.3 % (95 % C.I: 25.7–35.0 %) before the launch of the vaccine from 39 included studies (Fig. 2e). The prevalence after the vaccine launched from 11 included

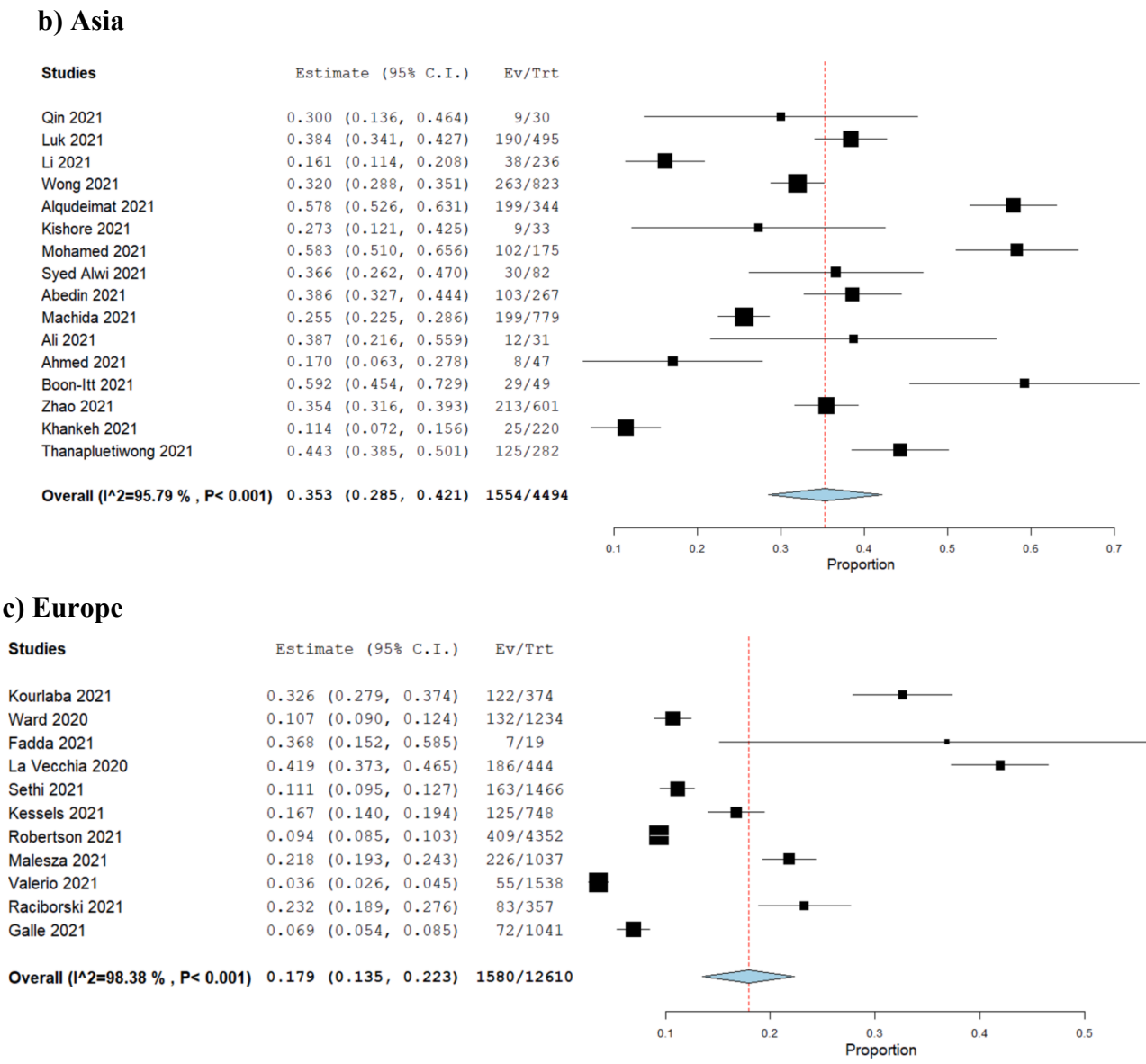


Fig. 2. (*continued*).

studies was 18.7 % (95 % C.I: 13.0–24.3 %), which was statistically significant lower (Fig. 2f).

4.4. *Factors of COVID-19 vaccine hesitancy prevalence in elderly*

The 6 studies targeting elderly population were carried out in Switzerland, Brazil, USA, Germany, Thailand and Italy. The Swiss study [33] was a qualitative study with 19 participants for the attitude towards the COVID-19 vaccine. The data on factors of vaccine hesitancy was from an open-ended question and the factors were simply concluded. The main individual, contextual and vaccine-specific factors of vaccine hesitancy were personal perception of health and past experiences, decreased number of COVID-19 cases and efficacy and safety of vaccine respectively.

The remaining 5 articles studied the relative risks or odds ratios of different factors of vaccine hesitancy. Due to the great heterogeneity of the questionnaire design of individual studies, quantitative analysis for combined effects of the vaccine hesitancy factors was not appropriate. Instead, a narrative summary categorized into individual influence, contextual influence and vaccine-specific factors was shown in Table 2.

For individual influence, if only statistically significant results from included studies were considered, lower income [52] and lower education [41,52] were factors of vaccine hesitancy. However, contradictory results were found for gender [41,52] and elder age group within the elderly population [41,62] as factors of vaccine hesitancy.

For contextual influence, more COVID-19 fatality was associated with lower vaccine hesitancy, which was studied only by the Brazilian study [62]. Perception of COVID-19 being more contagious was also associated with lower vaccine hesitancy as shown in the study by USA [52] and Germany [38]. Lack of trusted source of COVID-19 information was one of the factors of vaccine hesitancy as shown in the Thai [30] and Italian [41] study, but the German study [38] found contradictory result.

For vaccine specific issues, vaccine side effects were analyzed by the studies from USA [52], Germany [38] and Italy [41]. All showed perception of more vaccine side effects being a significant factor of vaccine hesitancy. Perception of lower vaccine efficacy was another significant factor of vaccine hesitancy as shown in the studies from USA [52] and Germany [38].

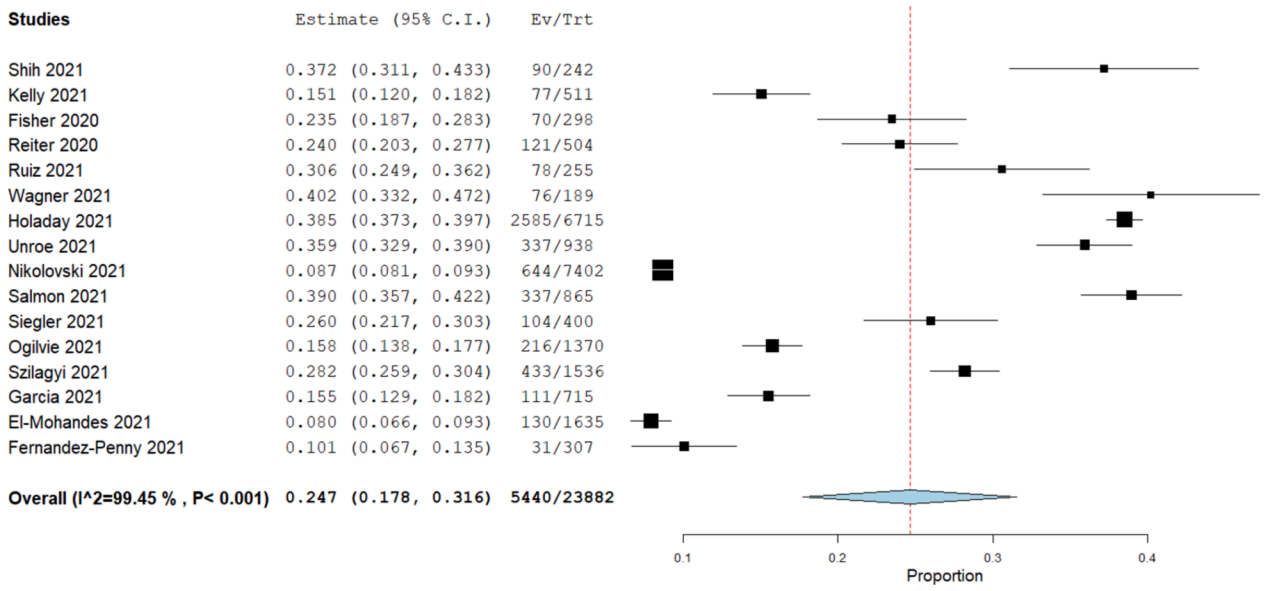


Fig. 2. (*continued*).

5. Discussion

Upon finalization of the protocol of this systematic review, there was no published systematic review or registered protocol on the topic of COVID-19 vaccine hesitancy in elderly. One systematic review and meta-analysis on this topic [9] was published in October 2021, which searched for studies until 18th June 2021. Fifteen studies with 9753 elderly were included. To the best of our knowledge, our systematic review was the only one with comprehensive inclusion of studies covering worldwide data as in April 2024. Total 54 studies were included from literature search between January 2020 and September 2021. Sample size of more than 49,600 elderly people recruited globally showed the overall prevalence of COVID-19 vaccine hesitancy being around 27.7 %. Our result was similar to the previous meta-analysis [9]. However, the prevalence of vaccine hesitancy by the previous meta-analysis was separated into 2 parts of unwillingness to vaccinate and uncertainty to vaccinate. The prevalence of uncertainty to vaccinate was higher in American countries (25.57 %) than in European countries (11.62 %), but the study failed to demonstrate the geographical difference of prevalence of unwillingness to vaccinate. Our result provided additional information on the prevalence of COVID-19 vaccine hesitancy in elderly in Asia (35.3 %), which was significantly higher than in western countries. Our systematic review also reported vaccine hesitancy from Oceania and Africa, which were not included in the previous meta-analysis.

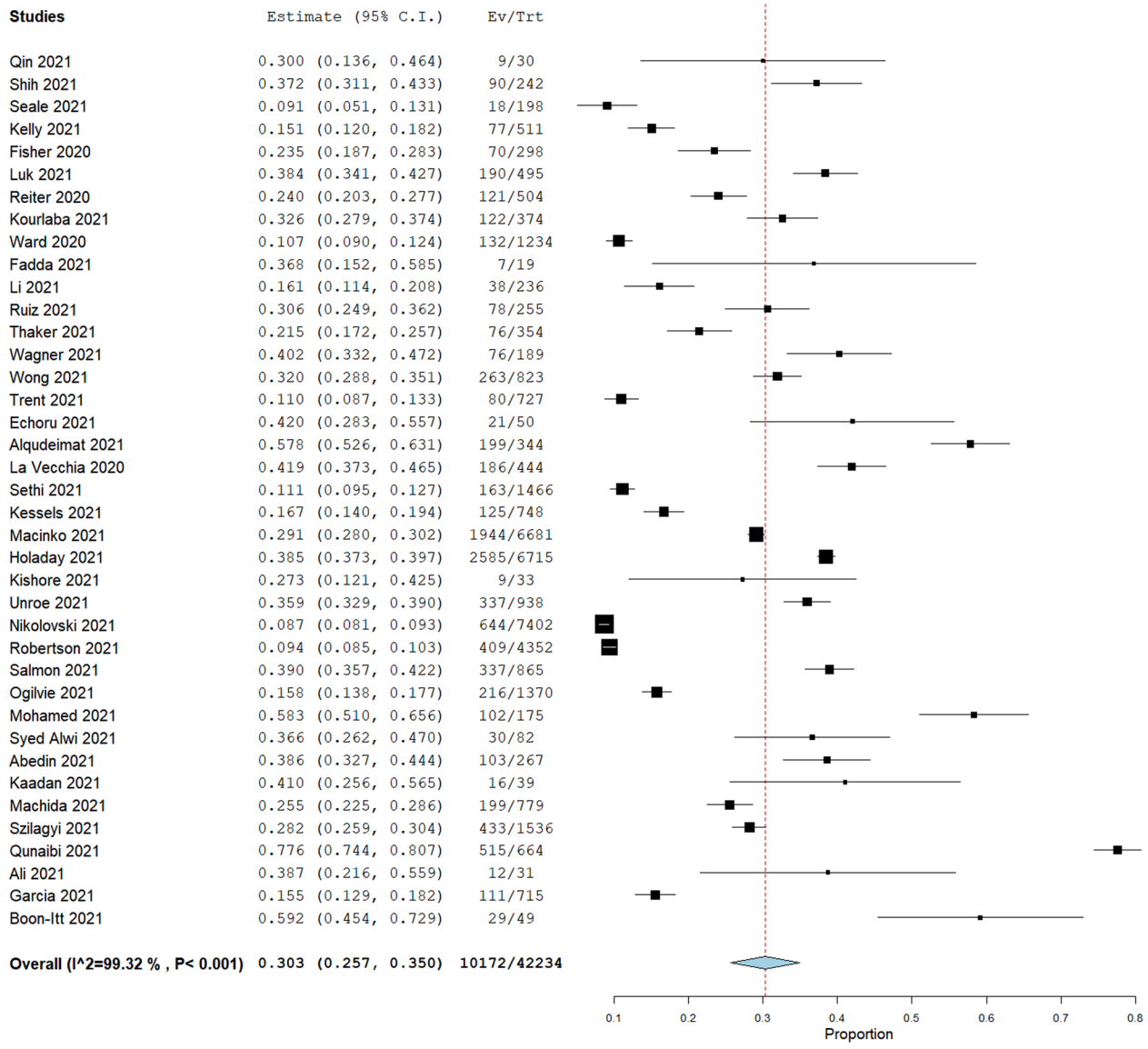
Our result showed that COVID-19 vaccine hesitancy is significant in elderly, especially in Asian countries or cities. The COVID-19 vaccine uptake rate in elderly is lower than younger age groups in Hong Kong and many countries. In countries with vaccine readily available, vaccine hesitancy is the main reason for low vaccine uptake rate. We should understand the significance of vaccine hesitancy and the factors to improve vaccine hesitancy and hence the uptake rate to protect elderly, community and healthcare system.

There was wide geographical variation in vaccine hesitancy across different continents. Only 1 study in Africa was included. It showed the vaccine hesitancy was 42 %, but it was not representative due to single study. The second highest vaccine hesitancy was in Asia. There were many contributing factors. Generally, the socioeconomic status is lower in Asian countries than western countries, especially those in South Asia. Lower digital health literacy in elderly in some Asian countries was another factor [69]. These contributed to misinformation and less confidence in COVID-19 vaccine. Cultural and religious beliefs in some Asian regions would impact the vaccine hesitancy. One reason was the possible conflict of vaccine ingredients with religious practices. Government trust is another important contributing factor. Many South Asian countries were governed by more dictated governments. In Southeast Asia, past government performance, low transparency and limited communication channels jeopardized public trust towards government and hence vaccine acceptance [70].

Our result also showed the vaccine hesitancy decreased following the availability of the vaccine. It may be explained by the contextual influence and vaccine specific issues as factors of vaccine hesitancy. Serial nationwide cross-sectional studies and longitudinal studies found that not only vaccine hesitancy, but also related factors were in dynamic evolution. With COVID-19 virus evolution, different waves of COVID-19 outbreak, increasing availability of COVID-19 vaccines, widespread reports of vaccine adverse effects and changing government policy on vaccine, the contextual factors and individual perception changed a lot. Vaccine was launched after few waves of COVID-19 outbreaks in most of the countries. People may have stronger perception of the highly contagious COVID-19. The longer time the vaccine was launched, safety and efficacy of the vaccine was reported more. These may contribute to the overall decreased hesitancy towards the novel vaccine.

Concerning factors of vaccine hesitancy, individual influence is not amenable but should be understood to identify the at-risk group for vaccine refusal. Lower income and lower education were persistently shown as important factors in our result, many previous studies and the previous meta-analysis [9]. One of the proposed theory to explain the reasons of these group of people having vaccine hesitancy is the knowledge, attitude and practice (KAP) model. The lower income and education groups were believed to have less knowledge and hence less access to correct information of COVID-19 and vaccine [71]. This contributed the hesitancy towards vaccine. Factors of contextual influence and vaccine-specific issues can be amenable. By understanding that contagiousness of COVID-19, vaccine efficacy and safety are important factors, education on these issues should be delivered to elderly by their trusted bodies, such as healthcare professionals and health authority of the government [62].

e) Before launch of vaccine



f) After launch of vaccine

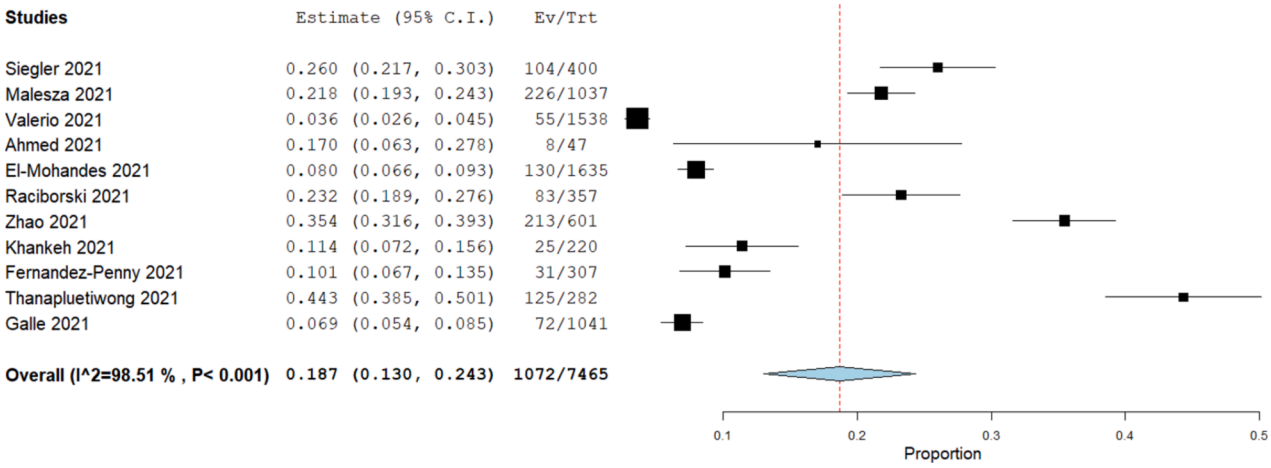


Fig. 2. (*continued*).

Table 2
Factors of COVID-19 vaccine hesitancy.

Factors	RR/OR for vaccine hesitancy				
	Brazil Macinko [62]	**USA** Nikolovski [52]	**Germany** Malesza [38]	**Thailand** Thanapluetiwong [30]	**Italy** Galle [41]
Individual influence					
Elder age group	2.46*	0.78	0.89	1.78	0.15*
Gender (Female)	1.3	2.04*	0.10	1.32	0.59*
Higher education	1.25	0.45*	0.17	0.39	0.54*
Higher income	No data	0.38*	0.12	Not significant	No data
Chronic disease	1.13	No data	1.87	No data	No data
Contextual influence					
More COVID-19 cases	0.99	No data	No data	0.15	No data
More COVID-19 fatality	0.89*	No data	No data	No data	No data
Perceive COVID-19 more contagious	No data	0.22*	0.86*	No data	No data
Lack of trusted source of COVID-19 information	1.71	No data	0.98*	2.55*	2.42*
Vaccine specific issues					
Perceived more vaccine side effects	No data	5.26*	1.15*	No data	5.78*
Perceived higher protection from vaccine	No data	0.03*	0.625*	No data	No data

RR: relative risks.
OR: Odds ratios.
* Statistically significant, $p < 0.05$.

Understanding the problems of vaccine hesitancy in elderly and contributing factors, we propose that government should organize educational campaigns to elderly, especially those less educated and in the lower socio-economic class. Outreach teams to elderly nursing homes should be established for the educational campaigns. The focus of the education material should be on the high contagion of COVID-19, low side effect profile of and high protection from the vaccine.

Our study is the most comprehensive systematic review including global studies after launching of the vaccine. PRISMA guideline [11] was adhered. However, there are few limitations of our systematic review. First, most of the studies included were collecting data by online survey and self-administered questionnaires. There would be sample selection bias towards more knowledgeable and healthier elderly. There would be limitation to generalize the results to the whole elderly population. Those more fragile elderly with multiple co-morbidities and limited mobility were less likely to participate in the individual studies. Indeed, they are the most vulnerable population from COVID-19 infection, who need to be protected most by vaccination. This group of elderly was the one with less access to online information about the vaccine and COVID-19. This was associated with vaccine scepticism. Therefore, our study probably underestimated the prevalence of COVID-19 vaccine hesitancy in elderly.

Second, the definitions of elderly population were heterogenous in the included studies. Different studies use different minimum age, which was detailed in Table 1. Overall 24 % of included studies used age cut-off of 55 to 59, 44 % used age cut-off of 60 to 64 and 26 % used age cut-off of 65. Meta-analyses of the vaccine hesitancy were conducted with stratification to these three groups of age cut-off. The hesitancy rates were 28.5 %, 30.3 % and 25.3 % respectively, which were similar to the overall hesitancy prevalence of 27.7 %.

Third, there was publication bias in our meta-analysis. Reviewing the countries in individual studies, many Asian countries and some European countries were not included. Under-reporting from these countries is possible.

Fourth, there was great heterogeneity of the data. We have performed different subgroup analyses including continents of the studying country, timing with launch of vaccine and the minimum age cut-off of elderly. Great heterogeneity persisted in the subgroup analyses suggesting diverse sources of heterogeneity. The questionnaire designs from different studies varied greatly. The measurement tools of vaccine hesitancy from individual studies also differ, including 5-point or 7-point Likert scale and simply yes or no scale. These affected the accuracy of our combined results.

6. Conclusions

This systematic review reported the prevalence of COVID-19 vaccine hesitancy in elderly in different countries and continents. Geographical variation exists, but the problem of vaccine hesitancy is overall significant, especially in Asia. Vaccine hesitancy in elderly depends on many factors. Tailored policy and specific strategies targeting on these factors should be implemented by public health policy makers to promote vaccine uptake in elderly.

7. Contributor

SS Lee, Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong.

Serve as scientific advisor and project supervisor.

CRediT authorship contribution statement

M.C. Law: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **P.K.F. Chiu:** Formal analysis, Data curation.

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Declaration of competing interest

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

Data availability

Data will be made available on request.

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