



ORIGINAL ARTICLE

Prevalence of SARS-CoV-2 antibodies among nurses: A systematic review and meta-analysis

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Abstract

Aims and Objectives: This systematic review and meta-analysis reports the seroprevalence of SARS-CoV-2 antibodies among nurses.

Background: With a growing body of literature reporting the positive serology for SARS-CoV-2 antibodies among healthcare workers, it remains unclear whether staff at the point of direct patient care are more prone to developing and transmitting the virus. Given nurses make up the majority of the global health workforce, outbreaks among these workers could severely undermine a health system's capability to manage the pandemic. We aimed to summarise and report the seroprevalence of SARS-CoV-2 antibodies among nurses globally.

Design: Systematic review and meta-analyses.

Methods: This systematic review was developed, undertaken and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. We searched the electronic medical literature databases: MEDLINE; CINAHL; and EMBASE for studies reporting the seroprevalence of SARS-CoV-2 antibodies among nursing staff. Studies that reported nursing specific data were included in this review. Study quality was evaluated using the Joanna Briggs Institute checklist for studies reporting prevalence data. Studies were stratified according to the World Health Organisation region classifications, and results were presented using forest plots and summary prevalence and variance was estimated using a random effects model.

Results: Our electronic search identified 1687 potential studies, of which 1148 were screened for eligibility after duplicates were removed, and 51 of the studies were included in our meta-analysis. The overall seroprevalence of SARS-CoV-2 antibodies among nurses was estimated to be 8.1% (95% CI 6.9%–9.4%) among the 60,571

participants included in the studies. Seropositivity was highest in the African region (48.2%, 95% CI 39.2%–57.3%), followed by the European region (10.3%, 95% CI 8.0%–12.5%), the Region of the Americas (8.4%, 95% CI 6.0%–10.7%), the South-East Asia region (3.0%, 95% CI 0.00%–6.5%) and the Western Pacific region (0.5%, 95% CI 0.0%–1.0%). Pooled estimates were unable to be calculated in the Eastern Mediterranean region due to insufficient studies.

Conclusion: The seroprevalence of SARS-CoV-2 antibodies among nurses is comparable to other healthcare workers, and possibly similar to the general population. Early adoption and adherence to personal protective equipment and social distancing measures could explain these similarities, meaning the majority of staff contracted the virus through community transmission and not in a healthcare setting.

Relevance to clinical practice: Fear and uncertainty have been features of this pandemic, including among nurses. This meta-analysis should provide some comfort to nurses that risks are similar to community exposure when adequate PPE is available and there is an adherence to infection control measures.

KEYWORDS

COVID-19, nurses, SARS-CoV-2, seroprevalence

1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) is a respiratory illness caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that was first encountered in December 2019 and continues to challenge governments and healthcare systems across the globe. As of 19 April 2021, the World Health Organization [WHO] (2021) has reported over 141 million cases and over three million attributable deaths since the beginning of the pandemic, with hundreds of thousands of cases detected each day. Serological surveys have also been conducted to help determine the underlying prevalence of SARS-Cov-2 and provide some insight on transmission between asymptomatic individuals. A 2021 systematic review found a seroprevalence rate of 8.0% among the global population (Chen et al., 2021).

Infection rates among healthcare workers are of particular concern, given they seem to be at high risk of both developing and transmitting the illness (Nguyen et al., 2020; Pan et al., 2020; Quigley et al., 2021; Schneider et al., 2020; Wu & McGoogan, 2020). It remains unclear whether staff at the point of direct patient care are more prone to developing and transmitting the virus, due to limited available data around community transmission (Hunter, Price, et al., 2020; Misra-Hebert et al., 2020). A recent systematic review, however, reported nurses accounted for half of all SARS-CoV-2 positive serology among healthcare workers, suggesting prolonged exposure to direct patient care may be a contributing factor (Gómez-Ochoa et al., 2020). Given nurses make up the majority of the global health workforce, outbreaks among these workers could severely undermine a health system's capabilities to manage the pandemic, particularly in low resource settings (WHO, 2020). Specific rates among

What does this paper contribute to the wider global community?

- A comparison of seroprevalence estimates between nurses, healthcare workers and the general population.
- A comparison of nursing seroprevalence estimates among WHO geographical regions.

nursing staff have not been summarised and reported, and further research is needed to determine whether nurses are at higher risk of infection than other members of the healthcare team. Therefore, this systematic review and meta-analysis were planned to summarise and report the seroprevalence of SARS-CoV-2 antibodies among nurses globally.

2 | METHODS

2.1 | Data sources and search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guideline (File S1) was used to plan, undertake and report this systematic review and meta-analysis (Page et al., 2021). A senior health librarian (LH) planned and developed our search strategy. Electronic medical databases included MEDLINE; CINAHL; and EMBASE, which were searched on the 15th of February 2021 using the following keywords: COVID-19, COVID, coronavirus, Wuhan, 2019, SARS, SARS-CoV-2, coronavirus 2, 2019-ncov, SARS-2, health

personnel, health worker, health workforce, health professional, nurse, sero-epidemiologic studies, seroprevalence, antibodies, serologic tests, immunoglobulin, IgG, IgA and IgM. Preprint studies and results prior to 2019 were excluded. We also searched Google Scholar for primary citations and checked any subsequent citation of papers included in our review. A hand search of the references lists of all included papers was also undertaken to ensure no further papers could be included in our systematic review and meta-analysis.

2.2 | Inclusion and exclusion criteria

All observational studies were considered, and longitudinal studies were only included if a point prevalence was reported (baseline figures were extracted). Studies must have assessed the prevalence of SARS-CoV-2 using a serological test that detected the presence of SARS-CoV-2 antibodies (IgG, IgM, IgA or a combination of the three) among a sample of healthcare workers. Studies that did not report any raw nursing data were excluded.

We merged all the retrieved studies from individual databases into Endnote version X9.3.3 and all duplicate references were filtered and removed. Authors SH and HM independently reviewed selected titles and abstracts for potential inclusion. If any discrepancies were observed between the review authors and could not be resolved, review authors SF and EA would be consulted to arbitrate (this was not required). We also scanned the reference lists and citations of included studies for further references to additional studies. Study authors were contacted for additional information when nursing and/or serological specific data was not made clear due to grouping with other measures of outcomes.

2.3 | Data extraction and quality assessment

Extraction of data was conducted by one investigator (SH) and was validated by another (SF). Information acquired included: first author; year of publication; study design; dates of data collection; region/country of study; sample size; therapeutic areas assessed; number of sites where the study was conducted; antibodies assessed; and type of immunoassay. With regard to studies that utilised multiple immunoassays, the final immunoassay used to determine seropositivity was recorded.

Quality assessment of the studies was undertaken by the two authors (SH and HM) using the Joanna Briggs Institute (JBI) critical appraisal checklist for studies reporting prevalence data (Munn et al., 2015). Despite there being a lack of consensus around how to appraise prevalence studies, the JBI checklist has been found to be the most comprehensive and widely used amongst researchers (Borges Migliavaca et al., 2020). A scaling measurement was created to differentiate studies according to a level of quality. One point was assigned to each 'Yes' response to the nine checklist items (Low = 0–4 checklist items; Moderate = 5–7 checklist items; High = 8–9 checklist items). No studies were excluded on the basis of quality.

2.4 | Data analysis

The seroprevalence rates of SARS-CoV-2 antibodies among nurses were expressed as proportions with 95% confidence intervals and presented as Forest plots (Barendregt et al., 2013). We considered the degree of heterogeneity of results by calculating the I^2 statistic. In order to minimise heterogeneity between seroprevalence estimates, the studies were stratified and data pooled according to WHO region classifications: African region, Eastern Mediterranean region, European region, Region of the Americas, South-East Asia region and Western Pacific Region. A random effects (RE) model was used to present pooled seroprevalence estimates due to high heterogeneity post-stratification. Publication bias was assessed upon visual inspection of forest plot and test of plot asymmetry (Egger et al., 1997). All analysis was undertaken using the meta-package as part of the R statistical program (R Core Team, 2017).

3 | RESULTS

3.1 | Electronic search results

Our initial search generated 1687 results, from which 539 duplicates were removed. The remaining 1148 studies had their titles and abstracts screened for compliance with our eligibility criteria (see Figure 1 PRISMA search flowchart). Fifty-one studies were included in the final review (see Table 1 for study characteristics), with the majority of the studies conducted in the Region of the Americas region ($n = 19$), followed by the European region ($n = 18$), Western Pacific region ($n = 8$), South-East Asia region ($n = 3$), African region ($n = 2$) and Eastern Mediterranean ($n = 1$).

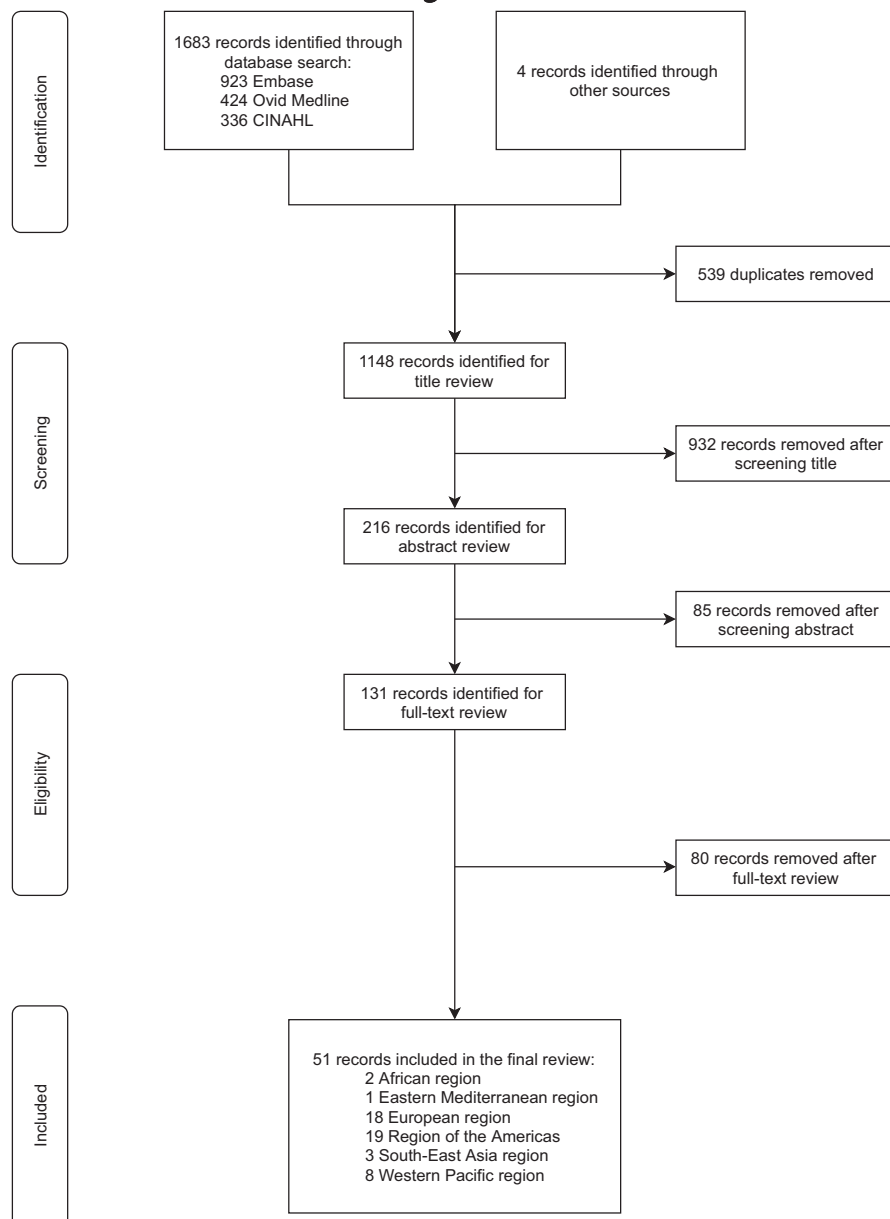
3.2 | Quality assessment

Utilising the JBI critical appraisal checklist, we determined 16 studies to be of high quality, 33 studies to be of moderate quality and two studies were considered low quality. The majority of investigations recruited participants appropriately, either by inviting the entire target population or randomly selecting their sample ($n = 38$, 75%). Twenty-two studies did not report a response rate, and forty-four studies did not provide evidence of sufficient coverage of the identified sample.

3.3 | Seroprevalence of SARS-CoV-2 antibodies among nurses

The overall seroprevalence of SARS-CoV-2 antibodies among nurses was estimated (using random effects modelling) to be 8.1% (95% CI 6.9%–9.4%) among the 60,571 participants included in all the studies (see Figure 2 for forest plot). Pooled seroprevalence estimates varied across WHO regions, with the highest rates observed in the African region (48.2%, 95% CI 39.2%–57.3%), followed by the European region (10.3%, 95% CI 8.0%–12.5%), the Region of the

FIGURE 1 PRISMA search flowchart



Americas (8.4%, 95% CI 6.0%–10.7%), the South-East Asia region (3.0%, 95% CI 0.00%–6.5%) and the lowest rates in the Western Pacific region (0.5%, 95% CI 0.0%–1.0%). Overall statistical heterogeneity was obvious from the forest plots and supported by the high I^2 statistic (99%). Pooled estimates were unable to be calculated in the Eastern Mediterranean region due to insufficient studies ($n = 1$). Only two regions (European region and the Region of the Americas) met the minimum number of studies ($n > 10$) required for testing of funnel plot asymmetry. Funnel plots and associated p values from Egger's test are presented in the Appendices 1 and 2.

4 | DISCUSSION

Our study found that the pooled seroprevalence of SARS-CoV-2 antibodies among nurses was 8.1%, ranging from 0% to 51% between

studies. Within the growing body of literature investigating the prevalence of SARS-CoV-2 among healthcare workers, it is important to determine whether certain occupations experience higher rates of infection. A recent systematic review reported that nurses accounted for almost half of their positive cases, suggesting it could be attributed to their prolonged exposure to patients when delivering care (Gómez-Ochoa et al., 2020).

Our results are congruent with rates reported in healthcare workers as a whole, with 7% and 8.7% in reviews conducted by Gómez-Ochoa et al. (2020) and Galanis et al. (2021), respectively. These findings seem to suggest that despite differences in roles, the likelihood of infection for nurses is similar to other healthcare workers. Given nurses make up around 50% of the health workforce, the high proportion of SARS-CoV-2 positive nurses seen in previous studies may simply be due to overrepresentation (Bandyopadhyay et al., 2020; Gómez-Ochoa et al., 2020). Any similarities in seroprevalence

TABLE 1 Characteristics of included studies

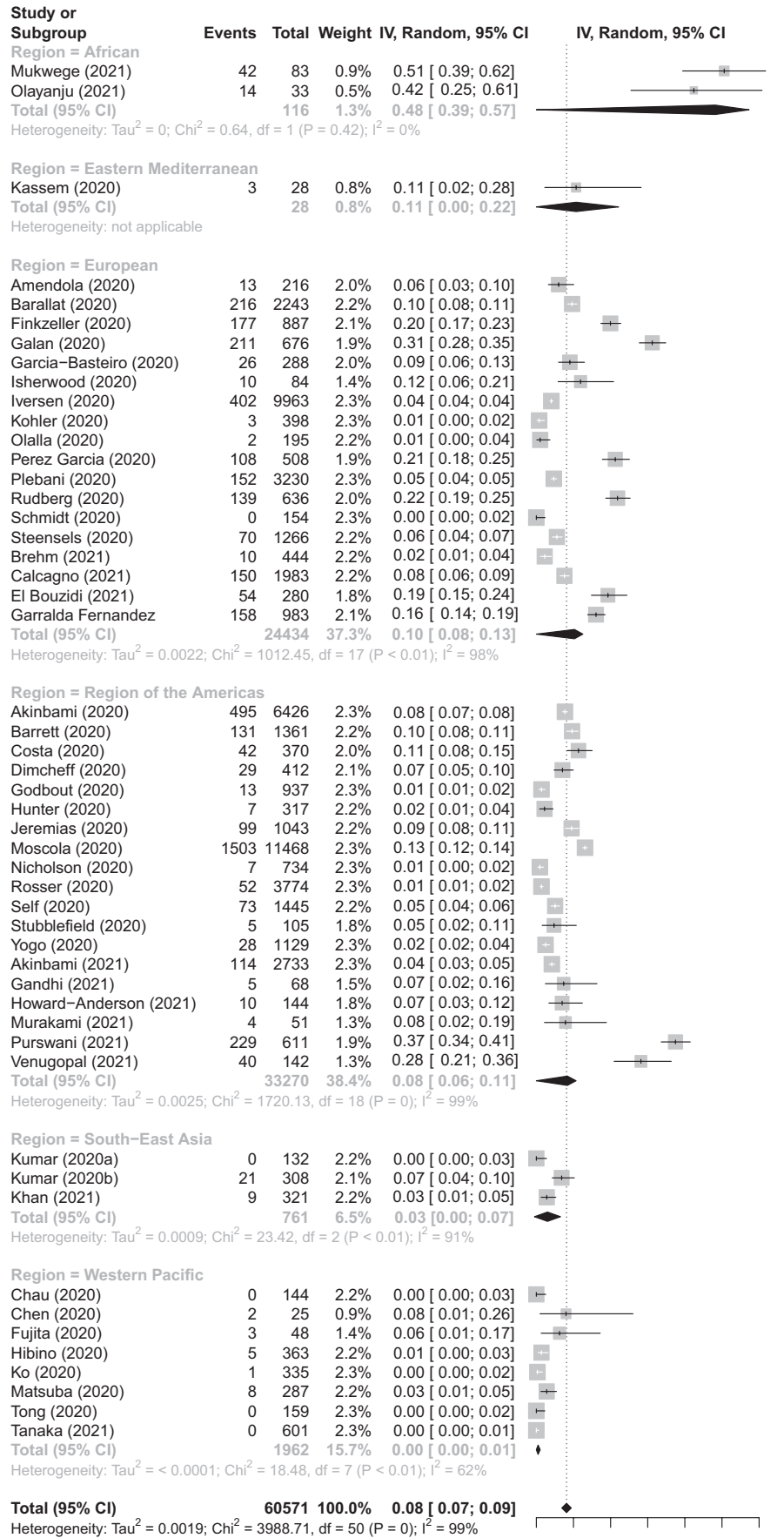
First author (year)	City/region, country	Type	Setting	Number of participants	Antibodies assessed	Quality assessment
Akinbami et al. (2020)	Detroit, USA	Cross-sectional	First responders, multi-centre	6426	IgG	Moderate
Akinbami et al. (2021)	Rhode Island, USA	Cross-sectional	Hospital, multi-centre	2733	IgG	Moderate
Amendola et al. (2020)	Lombardy, Italy	Cross-sectional	Hospital, paediatrics, single-centre	216	IgG	High
Barallat et al. (2020)	Barcelona, Spain	Cross-sectional	Region-wide screen	2243	IgG	High
Barrett et al. (2020)	New Jersey, USA	Cross-sectional	Hospital, all services, single-centre	1361	IgG	High
Brehm et al. (2021)	Hamburg, Germany	Longitudinal	Hospital, all services, single-centre	444	IgG	Moderate
Calcagno et al. (2021)	Piedmont, Italy	Cross-sectional	Hospital, all services, multi-centre	1983	IgG	Moderate
Chau et al. (2021)	Ho Chi Minh, Vietnam	Cross-sectional	Hospital, infectious diseases, single-centre	144	IgG	Moderate
Chen et al. (2020)	Jiangsu Province, China	Cross-sectional	Hospital, direct contacts of COVID-19 patients, single-centre	25	IgG, IgM	High
Costa et al. (2020)	Sao Paulo, Brazil	Cross-sectional	Hospital, all services, single-centre	370	IgG, IgM	High
Dimcheff et al. (2021)	Ohio and Michigan	Cross-sectional	Hospital, veteran affairs, Multi-centre	412	IgG	Moderate
El Bouzidi et al. (2021)	Lambeth, England	Cross-sectional	Hospital, critical care services, single-centre	280	IgG, IgM	Moderate
Finkenzeller et al. (2020)	Weiden in der Oberpfalz and Tirschenreuth, Germany	Cross-sectional	Hospital, all services, multi-centre,	887	IgG, IgM	High
Fujita et al. (2020)	Kyoto, Japan	Cross-sectional	Hospital, infectious disease, respiratory medicine, otolaryngology, emergency medicine, Single-centre	48	IgG	Moderate
Galán et al. (2020)	Madrid, Spain	Cross-sectional	Hospital, all services, single-centre	676	IgG	High
Gandhi et al. (2021)	New Jersey, USA	Cross-sectional	Hospital, direct contacts of COVID-19 patients, single-centre	68	IgG	Low
García-Basteiro et al. (2020)	Barcelona, Spain	Cross-sectional	Hospital, all services, single-centre	288	IgG, IgM, IgA	High
Garraida Fernandez et al. (2021)	Madrid, Spain	Cross-sectional	Hospital, all services, single-centre	983	IgG, IgM	High
Godbout et al. (2020)	Virginia, USA	Cross-sectional	Hospital, all services, single-centre	937	IgG	Moderate
Hibino et al. (2021)	Kanagawa, Japan	Cross-sectional	Hospital, all services, single-centre	363	IgG	Moderate
Howard-Anderson et al. (2021)	Fulton County, USA	Cross-sectional	Hospital, all services, multi-centre	144	IgG	Moderate
Hunter, Dbeibo, et al. (2020)	Indiana, USA	Cross-sectional	Hospital, all services multi-centre	317	IgG	Moderate
Isherwood et al. (2020)	Leicester, England	Cross-sectional	Hospital, all services, single-centre	84	IgG	Low
Iversen et al. (2020)	Capital Region of Denmark, Denmark	Cross-sectional	Region-wide screen	9963	IgG or IgM	High
Jeremias et al. (2020)	New York, USA	Cross-sectional	Hospital, all services, single-centre	1043	IgG	Moderate
Kassem et al. (2020)	Cairo, Egypt	Cross-sectional	Hospital, gastroenterology, single-centre	28	IgG or IgM	Moderate

(Continues)

TABLE 1 (Continued)

First author (year)	City/region, country	Type	Setting	Number of participants	Antibodies assessed	Quality assessment
Khan et al. (2021)	Kashmir, India	Cross-sectional	Region-wide screen	321	IgG	Moderate
Ko et al. (2020)	Multiple sites, South Korea	Cross-sectional	Hospital, all services, multi-centre,	335	IgG	Moderate
Kohler et al. (2020)	St. Gallen, Switzerland	Cross-sectional	Hospital, paediatrics, multi-centre,	398	IgG	Moderate
Kumar, Sathyapalan, et al. (2020)	Kerala, India	Cross-sectional	Hospital, all services, single-centre	132	IgG	Moderate
Kumar, Bhartiya, et al. (2020)	Mumbai, India	Cross-sectional	Hospital, all services, multi-centre	308	IgG, IgM	Moderate
Matsuba et al. (2020)	Kanagawa, Japan	Cross-sectional	Hospital, all services, multi-centre	287	IgG	Moderate
Moscioia et al. (2020)	New York City, New York	Cross-sectional	Hospital, all services, multi-centre	11,468	IgG	Moderate
Mukwege et al. (2021)	Bukavu, Congo	Cross-sectional	Hospital, all services, single-centre	83	IgG, IgM	High
Murakami et al. (2021)	Washington DC, USA	Cross-sectional	Hospital, emergency, single-centre	51	IgG	High
Nicholson et al. (2020)	San Diego County, USA	Cross-sectional	Hospital, all services, multi-centre	734	IgG	Moderate
Olalla et al. (2020)	Malaga, Spain	Cross-sectional	Hospital, direct contacts of COVID-19 patients, single-centre	195	IgM, IgG	Moderate
Olayanju et al. (2021)	Ibadan, Nigeria	Cross-sectional	Hospital, all services, single-centre	33	IgG	Moderate
Perez-Garcia et al. (2020)	Madrid, Spain	Cross-sectional	Hospital, all services, single-centre	508	IgG, IgM	High
Plebani et al. (2020)	Veneto Region, Italy	Cross-sectional	Hospital, all services, multi-centre	3230	IgG, IgM	Moderate
Purswani et al. (2021)	Bronx, USA	Cross-sectional	Hospital, all services, multi-centre	611	IgG	Moderate
Rosser et al. (2020)	San Francisco, USA	Cross-sectional	Hospital, all services, multi-centre	3774	IgG	Moderate
Rudberg et al. (2020)	Danderyd, Sweden	Cross-sectional	Hospital, all services, single-centre	636	IgG	Moderate
Schmidt et al. (2020)	Hamel-Pyrmont, Germany	Cross-sectional	Hospital, all services, single-centre	154	IgG	Moderate
Self et al. (2020)	Multiple sites, USA	Cross-sectional	Hospital, all services, multi-centre	1445	IgG, IgM, IgA	Moderate
Steensels et al. (2020)	Limburg, Belgium	Cross-sectional	Hospital, all services, single-centre	1266	IgG, IgM	High
Stubblefield et al. (2020)	Davidson, USA	Cross-sectional	Hospital, direct contacts of COVID-19 patients, single-centre	105	IgG	Moderate
Tanaka et al. (2021)	Tokyo, Japan	Cross-sectional	Hospital, all services, single-centre	601	IgG	High
Tong et al. (2020)	Jiangsu Province, China	Cross-sectional	Hospital, direct contacts of COVID-19 patients, single-centre	159	IgG, IgM	High
Venugopal et al. (2021)	Bronx, USA	Cross-sectional	Hospital, trauma, single-centre	142	IgG	Moderate
Yogo et al. (2020)	San Diego County, USA	Cross-sectional	Hospital, all services, multi-centre	1129	IgG	Moderate

FIGURE 2 Seroprevalence of SARS-COV-2 antibodies among nurses stratified into WHO regions



between professions could also be a result of mandated personal protective equipment (PPE) use and compliance with social distancing measures, both of which have been shown to reduce the risk of COVID-19 infection in healthcare workers (Feng et al., 2020; Lewnard & Lo, 2020; Nguyen et al., 2020). Instead, any variance in this population may be due to the clinical specialty the workers operate in, that may influence the level of occupational exposure to COVID-19 patients. Our study lacked the data to compare seroprevalence among different specialty areas. However, a recent systematic review by Chen et al. (2021) found that high-risk healthcare workers experienced significantly higher seroprevalence than low-risk healthcare workers. It is important to note there are potential confounding variables influencing these results, as the authors categorised high-risk healthcare workers as personnel in contact with COVID-19 patients and those with inadequate access to PPE.

We found seropositivity varied among countries, with those in the Western Pacific Region registering the lowest estimates. None of the studies included in the review could guarantee whether infections were a result of nosocomial or community transmission. Our results bared resemblance to seroprevalence estimates among the general population by Chen et al. (2021): Overall (8.1% compared to 8%); Western Pacific region (0.5% compared to 1.6%); and the Region of the Americas (8.4% compared to 6.8%), although the European estimates differed greatly (10.3% compared to 4.7%). Indeed, working in high-risk areas of the hospital would compound the risk of infection, but it would seem community transmission still has an important influence in determining seroprevalence among nurses.

Though there were only two studies from the African region, the pooled seroprevalence of 48.2% among nursing staff was still considerably higher than other WHO regions. It has previously been reported that rates of hospital-acquired infections (HAIs) are higher in developing countries compared to those observed in Europe and the United States of America (Allegranzi et al., 2011; Harrison et al., 2015). Potential contributing factors could include poor health infrastructure, inadequate access to resources and limited application of infection control measures (Allegranzi et al., 2011; Ogunisola & Mehtar, 2020). Be that as it may, a recent publication suggested the preparedness of African countries to manage COVID-19 was underestimated, when one considers recent work undertaken with the Ebola outbreak of the mid-2010s (Kapata et al., 2020). Kapata et al. (2020) also highlighted that early recognition of the risk of COVID-19, and assistance from WHO had may somewhat mitigate African nations to widespread and potentially uncontrollable disease. It is difficult to assess whether such preparations have had an effect on seroprevalence among African countries, given the lack of studies and reported data within this region.

4.1 | Strengths and limitations

To the authors' knowledge, this is the first systematic review that specifically investigates the seroprevalence of SARS-CoV-2 among

nurses. A potential limitation to this meta-analysis, as with any systematic review of literature, is that studies reporting results in contrast to the included studies may have been missed. To mitigate this potential problem, we have undertaken an extensive electronic search. A further limitation may be selection bias due to the majority of studies failing to provide the characteristics of non-responders to compare against. Some studies were able to limit the impact of bias by having a high response rate. It is also worth noting that the majority of studies were conducted in the Americas or Europe, settings where there was adequate access to PPE. Secondly, there was high heterogeneity among the studies. This was mitigated to the best of our ability by utilising a random effects model and sub-group analysis when reporting results. However, even within WHO region, infection rates of COVID-19 can differ by country, state or city. It was not feasible to stratify by regions other than WHO regions or continent, as there would have been a lack of studies to compare against certain areas. The region-specific seroprevalence estimates should be interpreted with caution, as they may not be representative of all countries or states involved. There was also a lack of data in certain WHO regions, namely the Eastern Mediterranean Region, South-East Asia region and the African region where resources are lower. More prevalence studies need to be conducted in these areas in order to properly estimate the overall seroprevalence of SARS-CoV-2 antibodies in the population. Lastly, we were limited in our ability to analyse potential factors influencing seroprevalence variability. Given the majority of studies looked at healthcare workers as a whole, we were unable to isolate certain demographic identifiers within the nursing sample. There were also various immunoassays used. Though the majority of tests proclaimed sensitivity and specificity >90%, variance may still have affected rates of infection. Moreover, there was not specific information available concerning local infection control practices.

5 | CONCLUSION

To conclude, the overall seroprevalence of SARS-CoV-2 antibodies in nurses is comparable to other healthcare workers, and possibly the general population depending on the setting. Early adoption and adherence to PPE and social distancing measures could explain these similarities, meaning the majority of staff could be contracting the virus through community transmission and not in a healthcare setting. More research is needed to investigate whether this observation is valid, given the mixed evidence currently available.

6 | RELEVANCE TO CLINICAL PRACTICE

The COVID-19 pandemic has identified a range of vulnerabilities across society and also in healthcare settings. The availability and access to PPE and training in infection control practices have been major factors in protecting healthcare workers (Jackson et al., 2020). Workforce shortages and limited PPE have demonstrated the

vulnerability of the aged care sector and reflected in high mortality (Davidson & Szanton, 2020). Fear and uncertainty have also been features of the pandemic including among nurses (Davidson et al., 2020). This meta-analysis should provide some comfort to nurses that risks are similar to community exposure when adequate PPE is available and there is adherence to infection control measures.

The global pandemic has challenged traditional models of occupational health and safety as well as challenging standards of reporting and monitoring. Standardising methods of monitoring occupational exposure are important in ensuring protection for health workers (Jackson et al., 2020). Given the evolution of SARS-CoV-2 virus and vaccination strategies, ongoing monitoring and assessment of seroprevalence are necessary.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHOR CONTRIBUTION

Data curation, formal analysis, investigation, methodology, project administration, software, writing—original draft and writing—review and editing: Steven He; Conceptualisation and writing—review and editing: Anthony Hecimovic and Vesna Matijasevic; Formal analysis, investigation, project administration, and writing—review and editing: Ha Thi Mai; Investigation, methodology, resources, software, and writing—review and editing: Linda Heslop; Methodology and writing—review and editing: Jann Foster; Writing—review and editing: Kate Alexander, Naru Pal, and Patricia M. Davidson; Supervision and writing—review and editing: Evan Alexandrou; Conceptualisation, formal analysis, methodology, software, supervision, validation, visualisation, writing—original draft and writing—review and editing: Steven A. Frost.

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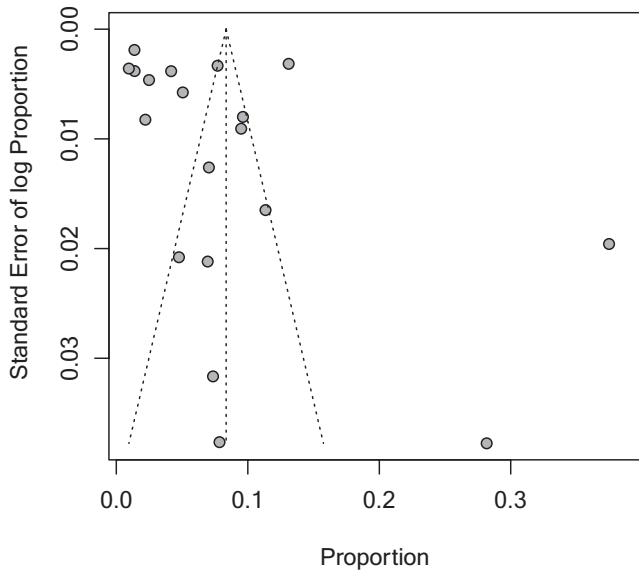
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APPENDIX 1

Funnel plot inspecting publication bias of seroprevalence estimates from studies in the Region of the Americas



APPENDIX 2

Funnel plot inspecting publication bias of seroprevalence estimates from studies in the European region

