

Hand hygiene and facemask use to prevent droplet transmitted viral diseases during air travel: a systematic literature review

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Abstract

Background: Transmission of airborne viral diseases (e.g. influenza A H1N1) takes mainly place in confined spaces including public travel by aircrafts. Adoption of hygiene measures may help to prevent the disease spread in air travel. This review summarizes the evidence on hand hygiene and use of facemask as viral disease prevention measures in aircrafts.

Methods: A literature search was performed in PubMed, Scopus, and Web of Science databases up to 10 June 2020, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses criteria. A PICOS (participants, intervention, comparator, outcome, and study design) approach was used to define the review question.

Results: We included four studies, published between 2007 and 2020, all targeting the influenza virus disease, in the qualitative synthesis. Three studies used mathematical models, and two of them single flight models. The fourth was a case-control designed study to tracing an influenza outbreak in two flights during the 2009 influenza A H1N1 pandemic. Unlike the others, this study provided substantial evidence about the risk of not wearing a facemask in the airplane cabin during a flight from New York City to Hong Kong. Interestingly, none of 9 infected passengers compared to 15 (47%) of 32 healthy control passengers wore a mask (odds ratio, 0.0; 95% confidence interval, 0–0.7). In contrast, both case and control passengers appeared to be equally compliant in hand hygiene. Finally, we discussed the practicability of hygiene measures to control and prevent the SARS-CoV-2 transmission in confined air travel-related spaces.

Conclusions: Facemask use combined with other hygiene measures may minimize the chance of droplet-transmitted virus (including SARS-CoV-2) spread by air travelers. However, more evidence is necessary before hygiene measures become an integral part of standard procedures in aircrafts.

Introduction

Viral respiratory tract infections in humans, causing worldwide outbreaks, are largely spread via respiratory droplets, aerosols, and direct as well as indirect contact transmission. Droplet/aerosol transmission can occur when an infected person ejects large droplets by sneezing, talking, or coughing, which may convert to aerosol particles [Gralton et al., 2011]. Because of a small aerodynamic diameter, these particles are, in close contact to a healthy person, capable of inoculating entry gateways, such as the eye, nose, or mouth. Additionally, particles can deposit on fomites in the direct environment of an infected person leading to indirect contact transmission, whereas direct contact transmission can take place when the virus passes directly from an infected to a healthy person [Boone & Gerba, 2007; Brankston et al., 2007].

Preventive measures of transmission in healthcare settings are addressed in detail in several national and international guidelines, such as the Healthcare Infection Control Practices Advisory Committee (HICPAC) or World Health Organization (WHO) guidelines. In particular, measures include hand hygiene and facemask use for protecting patients as well as additional personal protective equipment, such as medical gloves, gowns, and eye or facial protection devices, for caring personnel in close contact with patients [Siegel et al., 2007; WHO, 2019].

Instead, guidelines mainly created in response to an outbreak, i.e. due to influenza A H1N1 in 2009 [Gallaher et al., 2009] or severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)—the etiological agent of coronavirus disease 2019 (COVID-19) [Coronaviridae Study Group, 2020], recommend specific prevention measures for individuals and communities in public spaces, in terms of non-pharmaceutical interventions, also called community mitigation measures [Barrios et al., 2012; Qualls et al., 2017; ECDC, 2020; WHO, 2019]. Individual precautions include personal protective measures, e.g. hand, respiratory and environmental hygiene, with the aim to reduce individual infection risk. Measures on community level, such as social distancing, travel restrictions, and screening (temperature control and

passenger observation for respiratory symptoms), necessitate the involvement of local, regional, or national authorities [ECDC, 2020; WHO, 2019], with the aim to control or decelerate international virus transmission; however, these measures can have significant economical, legal, and ethical implications.

Viral respiratory transmissions take mainly place in confined spaces; beside spread of viruses in healthcare settings (e.g. influenza A H1N1) [Elder et al., 1996], public transport, not only including busses and ships [Miller et al., 2000; Helfand et al., 1998] but specifically aircrafts [Moser et al., 1979; Olsen et al., 2003; Mangili et al., 2005], pose a major risk of possible infection. Moser et al. [1979] described already in 1979 a major influenza outbreak in a 56-seat aircraft, which was blocked for several hours on the ground without fresh air circulation, resulting in the infection of 39 (72%) of 54 passengers. Olsen et al. [2003] reported results of three flights with passengers infected by the severe acute respiratory syndrome (SARS) virus; in one (3-hour) flight, infections involved 22 (18.3%) of 120 passengers whereas, in the other two (90-minute) flights, involved 0 (0.0%) of 315 and 1 (0.4%) of 246 passengers, respectively. Thus, the authors recommended preventive measures in consideration that travel length and seating distance are relevant factors for possible viral infection [Olsen et al., 2003].

Screening of air travelers at entry points from designated/recognized areas of a severe respiratory syndrome by observation, questionnaires, and body temperature assessment in combination with personal protective measures are the most recommended mitigation measures [ECDC, 2020; Aerospace Medical Association Task Force, 2004]. However, most recommendations have unknown efficacy because of scarce or lacking scientific evidence, and rely on studies developed in settings other than aircrafts; specifically, the use of facemasks is controversial.

The present systematic review of the literature summarizes the evidence of hand hygiene and use of facemask to prevent droplet transmitted viral diseases specifically during travels with aircrafts. Furthermore, recommendations and guidelines regarding the applicability of viral disease prevention measures were reviewed to provide an overview.

Methods

In this systematic review of the literature, we followed the statements of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [Liberati et al., 2009]. A PICOS (participants, intervention, comparator, outcome, and study design) approach was adopted to define the review question. In particular, we considered eligible the studies that involved general public travelling aboard aircraft and that evaluated the impact of hand hygiene and/or facemask use in preventing droplet transmitted viral diseases in air travelers. No language restriction was applied and all study design types were considered eligible. We excluded reviews, commentaries, editorials, and letters. We searched PubMed, Scopus, and Web of Science databases up to 10 June 2020 (the detailed search strategy is reported in Supplementary Material, Annex 1). Additional articles were identified by hand searching the reference lists of included studies and of reviews dealing with the topic. Grey literature was searched in Opengrey, US ClinicalTrials.gov, WHO International clinical trials registry platform search portal, Metaregister of controlled trials, using the following search terms: "infection", "communicable disease", "aircraft", "airplane", and "travel". A Google advanced search was also conducted to identify websites publishing documents on the relevant subject area. The first twenty pages (representing 200 results) were reviewed for potentially relevant titles. Relevant websites (e.g. WHO) were also hand-searched for potentially relevant documents.

After retrieving all studies and removing duplicates, two authors (GDA, FML) independently examined titles and abstracts and, in a second step, full-text articles of studies not meeting the inclusion criteria were discarded (Figure 1). From each included study, the following data were independently extracted by the two authors, and then checked for agreement: first author's name and year of publication, type of study, type of viral infection, flight details (i.e. number of passengers and duration of flight), hand hygiene strategy, type of facemask, presence of preventive measures other

than hand hygiene and facemask wearing, outcome of the study, and main results. In case of disagreement between the two authors, a senior author was consulted (BP).

We evaluated the quality of evidence for aircraft-related virus transmission using a bias assessment tool proposed by Leitmeyer et al. [2016]. The tool includes the following criteria: definitions of index (the first case of infection identified at the beginning of an outbreak) or secondary (susceptible individuals who develop infection after exposure to the index case) cases; strategy, timeliness, and follow-up of contact tracing; and alternative exposure means for infection to flight. Based on a score assignment, each study was categorized as having a low (0–3 points), medium (4–6 points), or high (7–9 points) level of evidence.

Results

The search strategy retrieved 1205 records from scientific databases (164 from PubMed, 756 from Scopus, and 285 from Web of Science) and 247 from grey literature sources. An additional of 35 articles were manually retrieved from the references of included studies and of relevant reviews. A number of 1126 titles and abstracts were evaluated after deduplication, and 1104 of them were discarded because they were not relevant for the review question. Of 22 full-text articles remaining, 4 were finally included in the qualitative analysis (Figure 1).

3.1. Characteristics of included studies

Table 1 describes in detail the four included studies [Caley et al., 2007; Gupta et al., 2012; Nicolaidis et al., 2020; Zhang et al., 2013], which targeted the influenza virus infection. All studies were published between 2007 and 2020 and were from four different continents. Three studies used mathematical models [Caley et al., 2007; Gupta et al., 2012; Nicolaidis et al., 2020], with two of them using single flight models [Caley et al., 2007; Gupta et al., 2012].

In one study, Caley et al. [2007] simulated a unique 12-h flight per day to travel from an epidemic region to a still infection-free region and to carry 10 to 400 passengers. In the second study, Gupta et al. [2012] simulated a unique 4-h flight in which a fully occupied twin-aisle cabin carried the index passenger occupying the center seat of the cabin. The twenty passengers around the index passenger (six on the same row, and seven on the front and on the back rows) represented the study population. In the third study, Nicolaidis et al. [2020] simulated multiple flights to move through a large network of 120 international airports in order to mimic a global spread of viral disease.

Unlike other three studies, the study by Zhang et al. [2013] described the contact tracing of a real influenza outbreak that involved two flights during the 2009 influenza A H1N1 pandemic. One flight carried 274 passengers from New York City (United States) to Hong Kong (China), with stopover in Vancouver. Sixty-three passengers, including the index patient, continued to travel on a connection flight from Hong Kong to Fuzhou (China), which carried 144 passengers in total. Contact tracing identified eight secondary influenza A H1N1 cases, 7 in Fuzhou and 1 in Hong Kong, and all the infected passengers shared the flight from New York to Hong Kong, where transmission could have taken place. The basic reproductive number (R_0) was provided in two studies only, and was of 1.5–3.5 in one study [Caley et al., 2007] and 3.0 in the other study [Gupta et al., 2012].

3.1.1. Studies evaluating use of facemask as a preventive measure

Regarding the use of facemask during air travel, Gupta et al. [2012] analyzed specifically N95 respirator, whereas no details on the type of facemask were provided in other two studies [Caley et al., 2007; Zhang et al., 2013].

Caley et al. [2007] explored several variables that might affect the time delaying the epidemic onset in an infection-free region following importation through air travel. The authors found that maximal compliance to facemask use and other

non-pharmaceutical control measures (i.e. border screening, flight-based quarantining, or immediate presentation at the onset of symptoms) affected this time much less than the number of travelers per day, with a modest impact of R_0 values. For example, during a 12-h travel of 400 passengers per day, facemask use increased the median time delay from 57 to 79 days at an R_0 value of 1.5 and from 17 to 20 days at an R_0 value of 3.5. Conversely, adopting facemask use together with another non-pharmaceutical control measure and reducing passenger numbers from 400 to 10 per day both delayed the time to 125 days at an R_0 value of 1.5 and to 26 days at an R_0 value of 3.5.

In the study by Gupta et al. [2012], a computational fluid-dynamic simulation allowed to estimate the quantity and distribution of influenza virus particles of a single-cough exhalation (measured as “quanta” per hour). The effect of N95 respirator on the risk of infection was evaluated as a function of the inhaled influenza virus particles. The infection probability wearing N95 mask was reduced from 15% (3/20) to 0% (0/20) at 103 exhaled quanta per hour or from 100% (20/20) to 55% (11/20) at 5226 exhaled quanta per hour.

In the study by Zhang et al. [2013], a case-control analysis allowed to identify wearing a facemask during the flight as a significant protective factor from influenza A H1N1 infection on the flight from New York City to Hong Kong. Thus, none of the 9 infected passengers compared to 15 (47%) of 32 healthy control passengers wore a mask (odds ratio, 0.0; 95% confidence interval, 0–0.7).

3.1.2. Studies evaluating hand hygiene as a preventive measure

Two studies evaluated hand hygiene as a mitigation strategy [Nicolaidis et al., 2020; Zhang et al., 2013]. In the study by Nicolaidis et al. [2020] using Monte Carlo simulation, four hand-hygiene scenarios were hypothesized. In one scenario, increasing the percentage of people that in all airports cleaned hands at any time from 20% (i.e. one over five people) to 30%, 40%, 50%, or 60% allowed to reduce the infection prevalence of 18.2%, 33.0%, 45.2%, and 55.4%, respectively. Similarly, the total square displacement of infected people—i.e. the measure of airports’ power to spread a disease across the globe—was reduced of 23.7%, 43.4%, 58.6%, and 69.1%, respectively. The three other scenarios explored the effect of a less expensive and more contained strategy, i.e. hand-hygiene implementation only in a subset of more busy airports, on aforementioned outcomes, thus leading to similar results.

In contrast, the study by Zhang et al. [2013] did not find significant differences in self-assessed hand-hygiene compliance (either hand-washing after toilet use or hand-cleaning by wet-towel before eating) between case and control passengers. In both passenger groups, high rates of compliance were reported, namely 100% (9/9 and 32/32, respectively) for washing hands after toilet use, and 89% (8/9) and 91% (29/32) for cleaning hands before eating, respectively.

3.2. Quality of included studies

The quality of evidence for aircraft-related transmission was possible only for one study based on real outbreak data [Zhang et al., 2013]. We evaluated positively the following criteria: index case classification (+1 point), secondary case definition (+2), contact tracing strategy (+2), and completeness of follow-up (+1). Zero point was assigned to timeliness of contact tracing and alternative exposure means for infection to flight were considered during investigation. Thus, the study was assigned a medium level of evidence (Table 1).

Discussion

Despite our extensive literature searching on the topic, we were able to summarize the results of only four recently published studies that tried to investigate the potential of practices, such as facemask use or hand hygiene, in limiting the transmission of influenza virus-laden droplets and aerosols in aircrafts. While the results from three studies [Caley et

al., 2007; Gupta et al., 2012; Nicolaidis et al., 2020] were probabilistic concerning the first practice, the case-control study by Zhang et al. [2013] provided substantial evidence about the risk of not wearing a facemask in a confined space such as the airplane cabin during a flight. Less convincing are the results from these studies concerning the hand washing of passengers in airport/aircraft settings [Caley et al., 2007; Gupta et al., 2012; Nicolaidis et al., 2020]. Again in the study by Zhang et al. [2013], passengers in both case and control groups appeared to be equally compliant in hand hygiene, with 100% of passengers stating to have washed hands after using toilet, which may be a receptacle of virus-contaminated fomites [Morawska, 2006]. Although self-inoculation of the nasal mucosa by contaminated hands is a well-documented mode to transmit the influenza virus [Tellier, 2009], aerosols or droplets represent the primary source of direct transmission from influenza (or other respiratory) virus-infected person(s) [Morawska, 2006]. Therefore, while contextualizing the findings from this systematic review to the current growing evidence on COVID-19 transmission/prevention concerns, we will discuss how common practices (i.e. wearing masks) may be effective to control and prevent the SARS-CoV-2 transmission in confined air travel-related spaces.

As seen with influenza virus [Long et al., 2020] to which SARS-CoV-2 has expressly been compared [Petersen et al., 2020], surgical masks and N95 respirators became popular with severe respiratory syndromes due to SARS-CoV, MERS-CoV, and SARS-CoV-2, particularly in healthcare centers [Jayaweera et al., 2020]. Leung et al. [2020] detected viral RNA from three viruses (influenza, rhinovirus, and coronavirus) in respiratory droplets (30%, 26%, and 28%) and aerosols (40%, 35%, and 56%), respectively, which were collected from virus-infected participants while not wearing a surgical mask. In another study, Radonovich et al. [2019] showed that N95 respirators were equally effective to surgical masks for preventing viral respiratory infections among healthcare personnel. Very recently, Jayaweera et al. [2020] hypothesized the trajectories of droplets and aerosols from SARS-CoV-2 infected passengers seated in an aircraft who coughed with a surgical mask, with a N95 respirator, and without facemask. In case an infected passenger coughs, droplets and aerosols diffuse mainly forward—affecting passengers up to five rows ahead—but also backward—affecting passengers one row behind—and side wards—affecting the passenger seated next to the infected person. Consequently, in the absence of social distancing, wearing a surgical mask/N95 respirator allows to filter 20% to 30% of the SARS-CoV-2 load eventually present in the cabin air [Jayaweera et al., 2020].

Consistent with previous observations [Huizer et al., 2015], we suggest a strategy aimed to control/prevent the spread of airborne viral diseases, including the formidable SARS-CoV-2, through air travel. This strategy will necessarily include hygiene measures (i.e. wearing facemask or promoting personal hygiene), even though other measures may be adopted before and during boarding to prevent virus transmission. All these measures are underscored in International guidelines from the Aerospace Medical Association Task Force in 2004 and, more recently, from the European Centre for Disease Prevention and Control (ECDC) or the *World Health Organization* (WHO) agencies. A summary of key prevention measures was provided by us as follows.

Since the aircraft ventilation system is highly efficient, viral transmission may uniquely occur due to person-to-person contact [Aerospace Medical Association Task Force, 2004]. Consequently, before boarding, airplanes should be sanitized and adequate ventilation should be ensured at all times. Social distancing, whenever possible, is also recommended. Importantly, individuals, including the crew, with viral respiratory infection³fever (over 37.5°C) and/or respiratory symptoms (i.e., cough or sneeze)⁴should not take an aircraft until full remission [Aerospace Medical Association Task Force, 2004]. In case of SARS-CoV-2 infection, at least two consecutively negative nasopharyngeal swabs from the index passenger are required to protect other passengers from contracting the disease. During an ongoing pandemic all passengers, including the crew, regardless of their departure country should be screened; instead, during an epidemic it is enough to screen passengers departing from WHO designated viral infection areas [Aerospace Medical Association Task Force, 2004]. Screening includes, besides temperature control³thought to have limited effect as a screening method alone [Huizer et al., 2015]⁴observation of respiratory symptoms [ECDC, 2020]. It is

recommended that passengers use hand disinfection gel and surgical masks, which should be made available during the boarding procedure. Surgical mask should be mandatory during the flight, as possibly infected passengers may be asymptomatic (and then escaping thermal control) or may use antipyretics to suppress fever [WHO, 29 February 2020].

It is recommended that flight attendants observe passengers for respiratory symptoms at all times. On medium- and long-haul flights, temperature control should be repeated [Huizer et al., 2015]. Hand disinfection with gel or swabs should be insured before distributing foods and should be repeated as well. Soap and disinfection should be available on toilets at all times. Passenger contracting fever and/or respiratory symptoms during a flight should be socially distanced from other passenger [Aerospace Medical Association Task Force, 2004], moving other passengers several seats away from the infected passenger [Huizer et al., 2015]. In case of a full flight, N95 respirators should be handed to the infected passenger including those around him/her. Flight attendants carrying for infected person should wear gloves and a N95 respirator [Aerospace Medical Association Task Force, 2004].

To increase correct behavior and compliance, easily understandable health information should be provided on board e.g., video clips about hand hygiene and facemask use and disposal [WHO, 5 June 2020]. Questionnaires at arrival, e.g. health declarations with contact details of passengers, are recommended to permit contact tracing and risk assessment [WHO, 2006] and, importantly, to provide insights on how hand hygiene and facemask use mitigates viral infection risk. It is important to recall that the effect of the facemask is curtailed when not used in the appropriate way and duration [Huizer et al., 2015], as well as it was suggested that facemask use promotion can be achieved by distributing free masks [Lau et al., 2004].

In summary, we conclude that adoption of facemask use combined with other hygiene measures may help to minimize the chance of the SARS-CoV-2 spread by air travelers. However, more efforts are required before hygiene measures become an integral part of standard procedures in airplanes. Efforts include extensive resources and preparation for implementing and/or increasing the passengers' compliance to these measures. Meanwhile, understanding the effectiveness of different measures aimed to control/prevent infectious diseases, like the ongoing COVID-19 pandemic, necessitates rigorous and well-designed studies in the future.

Declarations

Disclosure

All authors have read and approved the article.

Authors contributions

GDA performed the literature search, helped to design the study and was the lead author for the article. FML was an originator and designer of the literature review, and critically contributed to revising of the article. AG helped with performing of the literature search and with designing of the literature review. BP contributed critically to the design of the study and drafted the article. MS was an originator and designer of the study and provided critical review of the draft of the article.

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Tables

Table 1. Characteristics of studies included in the qualitative synthesis

Author, year of publication	Type of study	Type of viral infection	Setting (no. of passengers)	Preventive measures		Outcome(s)	Main result(s)	Quality level (score)*
				Facemask use/Hand hygiene	Other measures			
Caley, 2007	Mathematical model	Influenza	Flight (10-400)	Facemask use	Border screening, immediate presentation following symptom onset, flight-base quarantining	Time (days) delaying the epidemic onset in an infection-free region following importation through air travel	Median time delay (days) increased from 57 to 79 days at an R_0 of 1.5, and from 17 to 20 days at an R_0 of 3.5	Not available
Gupta, 2012	Mathematical model	Influenza	Flight (21)	N95 respirator [†] use	None	Infection probability	Infection probability was reduced from 15% to 0% (at 103 quanta per hour [‡]) or from 100% to 55% (at 5226 quanta per hour)	Not available
Nicolaides, 2020	Mathematical model	Influenza	Flights moving through a network of (unspecified) international airports	Increasing the percentage of hand hygiene for air traveling people at any time from 20% (i.e. one over five people) to 30%, 40%, 50%, or 60%	None	Infection prevalence and total square displacement (TSD)	Infection prevalence and TSD were reduced by 18.2-55.4% and 23.7-69.1%, respectively	Not available
Zhang, 2013	Case-control study	Influenza A (H1N1)	Flight 1 (274) Flight 2 (144)	Facemask use and hand hygiene	None	Risk for infection transmission	Wearing mask during flight reduced the infection transmission risk (OR, 0.0; 95% CI, 0.0-0.7) No difference in hand-hygiene compliance between infected and uninfected passengers	Medium (6)

*The quality of evidence for aircraft-related transmission was evaluated using the bias assessment tool proposed by Leitmeyer et al. [19]. Based on a score assignment, each study was categorized as low (0-3 points), medium (4-6

points), or high (7–9 points) level of evidence.

†N95 is a respiratory protective device designed to achieve a very close facial fit and very efficient filtration of airborne particles (i.e., droplets containing an infectious agent).

‡“Quantum” is a unit of measure that defines the amount of infectious material able to infect $1-(1/e)$ (i.e., 63.2%) of the people in an enclosed space [21].

Figures

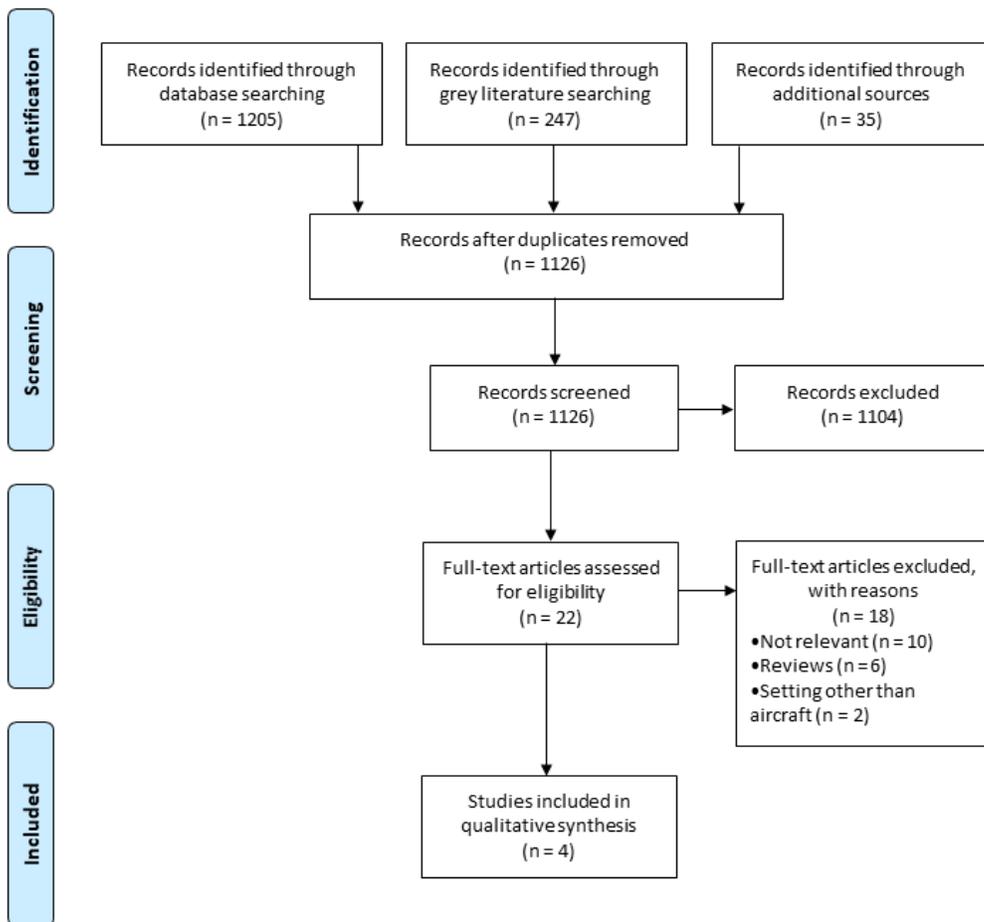


Figure 1

PRISMA based diagram depicting the search strategy and the selection process of studies included in the systematic review

Supplementary Files

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- [AnnexSearchstrategy.docx](#)