A systematic review on the relationship between international migration and antimicrobial resistance

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Abstract

Introduction: Antimicrobial drug resistance (AMR) is considered a serious threat to public health worldwide. The relation between AMR and human mobility, particularly international migration, has drawn attention from the scientific community in recent years. However, several aspects about this relation remain unclear. Therefore, we aimed at expanding and updating previous systematic review studies, with a novel focus on the AMR prevalence in migrants compared to the local population of the host country, to examine external validity of previous findings.

Methods: We searched in Ovid MEDLINE all types of observational studies, without language or year of publication restrictions. We aimed at exploring differences in countries´ bacterial drug resistance rates based on immigration rates. All types of AMR were included, except for those related to HIV/AIDS and Tuberculosis. The comparator group of interest was the local population of the host country. The study protocol is registered with PROSPERO, number CRD42018114436.

Results: After screening of 322 articles, 15 papers were selected for data extraction, including 1930 migrants. Compared to the local population, higher rates of methicillin-resistant *Staphylococcus aureus,* Panton-Valentine leucocidin positive strains, multidrug-resistant Gram-negative bacteria, vancomycin-resistant *Enterococcus,* and having at least one multidrug-resistant organism were found in migrants in 12 of the 15 papers. Rates of AMR did not differ significantly in two studies and only one of them reported a lower burden of AMR in migrants.

Conclusions: Higher prevalence of AMR in migrants were presented in the majority of the included articles, addressing the emerge of the circulation of resistant strains within this group. More detailed descriptions, including time span and route taken by migrants to arrive to country of destination and length of stay by the time of inclusion are essential to gain a deeper understanding of the relation in between AMR and migration. Countries with high migration rates outside Europe should be encouraged to implement strategies for screening of both local population and migrants in countries.

Background

Antimicrobial resistance (AMR) is an adaptive phenomenon of microorganisms to survive in the presence of antimicrobials, which has been documented ever since the discovery of antibiotics [1–3]. The inappropriate use of antimicrobials facilitates the emergence and spread of multidrug-resistant microorganisms (MDROs). The process has dramatically accelerated in recent decades, and nowadays it is not uncommon to encounter infections against which there are virtually no effective antimicrobial regimens [4, 5]. According to the World Health Organization (WHO), AMR is considered one of the most serious threats to public health worldwide [6, 7]. AMR is a global phenomenon, caused by several factors, including the massive use of antimicrobials in human and veterinary medicine, lack of prevention and control measures for healthcare-associated infections, and inadequate WASH infrastructure (water, sanitation, and poor hygiene). AMR not only results in increased mortality, morbidity, and health expenditures, but also affects the economic development [6].

According to the AMR report from the US Centers for Disease Control and Prevention (CDC), carbapenem-resistant *Acinetobacter* and carbapenem-resistant *Enterobacteriaceae* are considered urgent threat bacteria

with over 8,500 and 13,100 infections in the USA in 2019, respectively [8]. Methicillin-resistant *Staphylococcus aureus* (MRSA), ranked as serious threat bacteria, causes a wide range of organ-specific infections including skin and subcutaneous tissue, bone and joint infections and pneumonia [9]. Physicians classify the virulence of MRSA strains based on a Panton-Valentine Leucocidin (PVL) factor which is associated to community-level acquired MRSA [10]. Vancomycin-resistant *Enterococci* (VRE), also classified as a serious threat bacteria, caused 54,500 cases and 5,400 deaths in the USA in 2019. VRE have raised concern due to its fast spread and clinical complications usually associated with gut diseases [11]. The genital bacteria *Ureaplasma urealyticum* and *Mycoplasma hominis* are not listed as bacterial threats, but are included in the watch list due to their high colonization capabilities and increasing resistance. They can cause severe complications like pleural effusion, pneumopathy, adenopathy, abscess, or systemic sepsis [12].

A dimension of increasing interest is the relationship between AMR and human mobility of all kinds, particularly international migration. International migration, the crossing of the political border to a country other than that of origin with the intention of settlement [13], is a complex and evolving phenomenon with several public health implications. As a global social process, international migration is directly influenced by international labour stratification, country inequalities, conflicts, poverty, climate change and natural disasters [14]. In all these scenarios, AMR arises as a public health problem of urgent attention, including in migratory contexts.

Two systematic reviews have examined the relation between international migration and AMR, one largely dedicated to drug-resistant tuberculosis and the other focused in European countries. Smalen et al. [15] aimed to identify the burden of AMR acquisition and transmission among refugees and asylum seekers, including *Mycobacterium tuberculosis*, *Escherichia coli*, *Klebsiella pneumonia*, *Klebsiella oxytoca*, *Shigella spp.*, *Staphylococcus aureus*, *Enterococcus faecium*, and *Acinetobacter baumannii*. The review found a high percentage of resistant strains have been circulating among refugees and asylum seekers. Focusing in Europe, Nellums et al. [16] analysed 23 observational studies that reported on migration and AMR in 2319 migrants, including methicillin-resistant *Staphylococcus aureus* and antibiotic-resistant Gram-negative bacteria. The results showed a combined prevalence of any infection by resistant bacteria in migrants of 25.4% (I^2 = 98%), with refugees and asylum seekers having a significantly higher risk than other groups of migrants and the general population (33% vs. 6%, I^2 = 92% and 98%, respectively), with no evidence of AMR transmission from migrants to host populations. The review suggests migrants, and refugees and asylum seekers in particular, were exposed to conditions, such as inadequate sanitation, overcrowding, and restricted access to health services, that favoured the emergence of AMR during transit and upon arrival to host countries. Overall, findings highlight the need to improve living conditions, access to healthcare, and adequate treatment for AMR infections among these vulnerable populations.

Previous research has intended to clarify the relation in between migration and drug-resistance, however several important gaps remain in the literature. First, since AMR infection is due to several causes related to the systems and processes of care provision, economic limitations on systems and countries and human behaviour, difficulties has been encountered to identify where the acquisition of AMR specifically takes place and which conditions and factors play a role in the increase of incidence [17]. Second, most studies have been carried out in high-income countries where evidence-based measures for the prevention and control of infection are established. However, the highest percentage of refugees worldwide are hosted by developing

countries, which do not have the resources like surveillance systems providing reliable data to respond and describe the burden that AMR causes, resulting in an information gap [18]. With this systematic review we aimed at expanding and updating previous systematic review studies dedicated to analyse the relationship between international migration and AMR.

Methods

Study design

We conducted a systematic review following international guidelines [19]. The review protocol was made available at the Prospero Web Page before the study was conducted (CRD42018114436) [20]. This manuscript details the review developed for the following research question: According to current international evidence, is there a relationship between AMR and international migration rates and immigrants´ profile (country of origin, legal status, length of stay) at country level? Our systematic review summarises primary studies that include a wide range of international migrants and AMR phenotypes. We followed general principles for conducting systematic reviews, in terms of search strategy, screening of studies, and appraisal of the methodological quality of included primary studies [21].

Types of studies

The review included original research articles written in English, Spanish, Portuguese, French, Dutch, and German. When available, systematic reviews were included as background information, but not in the actual review. We included all types of observational studies (cross-sectional; case-control; prospective, retrospective or mixed cohort designs) and then objectively assessed by the quality of evidence provided, using the quality assessment – Risk of Bias (Strobe v.4 & MMAT v.2011).

Types of participants

For this review, the concept of international migrant was defined as a person who crosses a national border to reside in another country for a significant period of time (i.e. at least one year) [22, 23]. In addition, asylum seekers and refugees were included as specific migrant groups. Studies conducted with ethnic minorities that did not clearly state to be international migrants were set aside and not included in this analysis.

Inclusion criteria: The review was ample, including studies focusing both at general population and specific groups like children or adults of any age group. No sex, ethnic or geographic limitations were made. We were aware that some articles might have used different subpopulations; therefore, we recorded these variations included in each study, in order to describe possible differences in results.

Exclusion criteria: We excluded articles dealing with non-human samples such as animals and environmental specimens. This review was limited to studies on human subjects only.

Types of AMR

We aimed at exploring differences in countries´ bacterial AMR rates based on immigration patterns. We considered the definition of “multidrug resistance” as any organism exhibiting resistance to at least one representative of three or more families of antimicrobials [6]. In this review, we included all types of bacterial

AMR, except for those related to tuberculosis, as they show a distinctive pattern of AMR that require a separate in-depth analysis.

Comparator

The comparator group of interest in this review was the local population at every country were the study was conducted. Studies comparing the prevalence of AMR in migrants with the local population using national prevalence numbers were excluded.

Identification of studies

Given its relevance to biomedical science, we conducted our search in Ovid MEDLINE (1946 onwards). The search strategy was the following: ("Transients and Migrants"[Mesh] OR "Emigrants and immigrants"[Mesh] OR "Refugee"[All Fields] OR "Migration background"[All Fields] OR "Immigrant background"[All Fields] OR "Migrant"[All Fields] OR "Migrants"[All Fields] OR "Immigrant"[All Fields] OR "Immigrants"[All Fields] OR "Ethnic minority"[All Fields]) AND ("Drug Resistance, Microbial"[Mesh] OR "Drug Resistance, Bacterial"[Mesh] OR “antimicrobial resistance” OR “antibiotic resistance” OR “multidrug resistance”)

Selection of studies

Two authors independently screened titles and abstracts as per inclusion criteria. We obtained full-text manuscripts for all titles selected during the screening process, contacting study authors if necessary. Full-text articles were then reviewed by two authors independently; disagreements were solved through discussion, with a third review author to arbitrate if necessary. The selection of reviews was based on the inclusion and exclusion criteria relating to types of studies, participants, and interventions. We included primary studies regardless of reported outcomes, date and language of publication, and study quality. In addition, references of included studies were extracted to create a matrix to report the unique primary studies identified in this systematic review. This allowed us to assess overlap in the primary studies reported by various reviews.

Dealing with lack of information: When selected papers could not be obtained in their full text format or when the study did not provide enough information to ascertain suitability for inclusion (i.e. classified as “unclear”), we contacted the authors of the study by email at least three times within 30 days asking for the complete article or additional information. In case of failure to communicate with the primary investigators, the study was excluded. We did not need to deal with data duplication, as we only searched the Ovid MEDLINE electronic database.

Data extraction and management

We created a data extraction sheet in Microsoft Excel to collect data from included primary studies, and we piloted the data extraction sheet by entering data from the first ten included studies, adjusting as necessary. Data entry was performed independently by two trained investigators; a third researcher conducted a random check (n = 3) during data extraction, finding no relevant variation during this internal review.

We recorded the following information: full publication reference, first author, year of publication, journal´s impact factor (if available), journal´s country, study objective, study design, level of analysis (individual, aggregated), study representativeness (nation-wide, local), type of sampling strategy (random, purposive, convenience), recipient country, recipient continent, country of origin of migrants, continent of origin of

migrants, type of migrants (no information, mixed/general, refugees/asylum seekers, labour migrants, other), generation of migrants (first or second generation), length of stay of migrants in host country in years, migration status (regular, irregular, no information), comparison group (yes/no), description of comparison group (if available), final sample size of migrants for analysis, final sample size of comparator (locals) for analysis, final age range of study populations (if available), data collection (in months), main study outcome, type of indicator of main outcome (proportion, odds ratio, incidence rate ratio, hazard ratio, prevalence, incidence, other), secondary outcome, type of indicator of secondary outcome (proportion, odds ratio, incidence rate ratio, hazard ratio, prevalence, incidence, other), tertiary outcome, type of indicator of tertiary outcome (proportion, odds ratio, incidence rate ratio, hazard ratio, prevalence, incidence, other), data source (surveillance screening in hospital, screening of high risk population, laboratory records, screening of patients with symptoms), type of data (self-reported, parent-reported, healthcare register, other), confounding variables, main result, and study main conclusion (migrants higher resistance, migrants lower resistance, no difference with locals, nor reported, unclear) and type of resistance test.

Assessment of methodological quality of included reviews

A detailed quality assessment of each selected study was performed and a separate Microsoft Excel spreadsheet was used to record the evaluation. We based our assessment on the items identified in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) initiative and the Mixed Methods Appraisal Tool Version 2011 (MMAT-Version 2011). The following quality assessment information was recorded (yes = 1/no = 0 answers; 20 items): Is the research question well-justified / sound? Are objectives explicit? Is there a clear hypothesis? Is the study design declared? Is the study setting clear? Are study participants described? Are all relevant study variables described? Is source of data clear? Are data sources adequate to respond the hypothesis? Is analysis adjusted by potential confounders? Is sample size clear? Is the sample representative of the population of interest? Has the sample size enough power for analysis? Is data analysis clearly described? Is data analysis adequate to respond to the hypothesis? Are there sound descriptive stats? Are there clear results for the main outcome? Are there clear results for any secondary outcome? Is there a discussion of study limitations? Are figures/stats well presented? Are results generalizable? Is there a clear source of funding of this study? Is there a clear disclosure of the authors?

From these questions, we created a quality-assessment score of a 0–20 range, which was categorised into four categories as follows: low (1–5 score), medium-low (6–10 score), medium high (11–15 score), and high quality (16–20 score).

Data analysis

We found great heterogeneity in types of migrants, local populations for comparison, and types of AMR in selected studies. Therefore, we report results as a narrative synthesis of the characteristics of included primary studies. We synthesised large epidemiological patterns of AMR between different types of international migrants and the local population in each country.

Ethical considerations

The present study follows the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments. We followed international guidelines on the conduction of

systematic reviews [21].

Results

The search was conducted on September 24th, 2018. Two independent reviewers screened titles and abstracts of 322 records; 166 were included for full-text screening (Figure 1, Study selection).

The most common reasons for exclusion were: ***i)*** study not conducted in humans, ***ii)*** non-primary studies (e.g. editorials, commentaries, debates), and ***iii)*** absence of a direct comparison with the local population. All excluded studies with their respective reason for exclusion are listed in Table S1 (Supplementary material 1, Data hits selection). Among 166 selected papers, we were unable to obtain the full-text format of 12. After fully analysing the remaining 154 manuscripts, 139 were excluded for failure to fulfil the inclusion criteria. 15 studies were selected for data extraction [Reference list, Selected Papers]. All data were extracted and studies were assessed on their quality as described in the review protocol [18]. A detailed description of the data extraction and the quality assessment of the 15 selected papers are provided in Table S2 (Supplementary material 2, Data extraction of selected papers) and Table S3 (Supplementary material 3, Quality assessment of select papers). All studies were published in English, except for one article that was written in Spanish.

Description of included studies

We included 15 articles, all of which analysed the burden of AMR in migrants as compared to the local population of the host country. A summary of the findings is provided in Table 1.

Table 1 Summary of findings

Topic	Nr
Studies with a direct comparison group	**15**
Study main conclusion	
migrants > resistance	12
migrants < resistance	1
no difference	2
Migration status	
regular	2
no information	13
Type of migrants	
no information	8
mixed	1
refugees	5
labour	-
other	1
Data source / sample recollection	
Surveillance screening in hospital/health care centrum	7
Screening of high risk population	4
Laboratory records / Screening for positive strains or high resistance profiles	3
Screening of patients with symptoms	1
Type of study	
Retrospective	4
Prospective	10
Mixed	1

In 13 of the 15 articles, there was no specific data on the migration status of participants; the remaining 2 reported regular migrants. In terms of type of migrants, general migrant population was reported in one manuscript and 5 reported refugees. No details were specified in 9/15 studies and none of the reports focused specifically in labour migrants. Most studies came from developed countries located in the northern hemisphere, particularly Europe and the US. In terms of sample collection, 7 studies included patients using surveillance screening in hospitals or health care centres, 3 accessed laboratory records for MDR strains, 4 screened high-risk population and one study included patients with symptoms compatible with infections. The

study design was retrospective and prospective in 4 and 10 studies, respectively; one of them mixed results from retrospective and prospective data.

Study participants

Sample sizes ranged from 4 to 973 migrants and from 4 to 12989 natives. International migrants came from a range of countries and continents of origin. Five of them reported migrants coming from all continents and the rest included migrant population originating mostly from Asia, Africa and Latin America. Countries of origin were multiple in all studies.

Comparators

The description of the local population as a comparator was often brief but ranged from general hospital population to particular subsets of hospital registries from local natives. In general, there was little description of the comparison groups profile and characteristics, as well as poor justification regarding its selection for each study.

Quality assessment

The quality of the most papers ranged between medium-high to high with an average quality assessment (QA) score of 17,3. Dimensions particularly underreported were adjustment for potential confounders (only 8/15 considered confounding in the analyses) and detailed description of the population (6/15 did not appropriately describe the population). The best reported dimensions were whether the setting and the analysis were clearly described (15/15), followed by whether the research questions were well justified (14/15) and data source adequate to research question (14/15). Table 2 describes a QA summary of selected papers. [INSERTION TABLE 2] Finally, most studies were conducted in developed, high-income countries in North America and Europe, which speaks to the lack of research on AMR and international migration in the developing world. The top-10 countries receiving the largest numbers of migrants and those with highest drug resistance index (DRI) are presented in table 3 to underline this problem [21,22].

Table 3 Top-10 countries hosting migrants versus countries with the highest DRI (2020)

Host country	Number of inmigrants (millions)	Country	Drug Resistance Index
USA	50.7	India	71 (65-78)
Germany	13.1	Thailand	60 (55-66)
Saudi Arabia	13.1	Ecuador	60 (43-77)
Russia Federation	11.6	Vietnam	59 (36-82)
United Kingdom	9.6	Romania	57 (41-74)
United Arab Emirates	8.6	Serbia	56 (42-70)
France	8.3	Turkey	55 (50-60)
Canada	8	Taiwan	55 (41-69)
Australia	7.5	South Africa	54 (50-59)
Italy	6.3	Venezuela	53 (27-78)

Main outcomes of the studies

Among the 15 papers included, results of 12 suggested that migrants presented higher AMR frequency than the local population. Rates of AMR did not differ significantly in two studies and only one of them reported a lower burden of AMR in migrants. Table 4 presents the data extraction of the 15 articles by AMR strains, showing the prevalence rates of the migrant groups and the local population. [INSERTION TABLE 4]

Types of MDROs included in the studies

Methicillin-resistant *Staphylococcus aureus*

Eight studies analysed MRSA as part of their outcomes (Table 4A), with 6 of them reporting a higher MRSA prevalence in migrants as compared to the local population (differences ranged from 4.4% to 65.7%). In contrast, Piper et al. (2016) studied rates of community-acquired MRSA carriage in nares and wound infections and reported lower prevalence in the migrant population as compared to locals (differences ranged from 5.4% in nasal infections and 9.5% in wound infections respectively). The article by Frick et al. (2010) did not find significant prevalence differences.

Finally, 3 out of 4 articles specifically searching for Panton-Valentine leucocidin-producing MRSA strains, found higher rates of such isolates in migrants as compared to the local population (Table 4B).

Multidrug-resistant Gram-negative bacteria(MDRGN)

All five articles reporting on MDRGN bacteria found a higher prevalence among migrants, with differences ranging from 16.3% up to 66.7% compared to the local population (Table 4C). Of note, all such studies performed screening of high-risk population, including asylum seekers and refugee patients in the hospital setting. Sánchez-Montalvá et al. (2015) studied subjects with signs of infection and reported a higher prevalence of imported drug-resistant *Salmonella typhi* or *Salmonella paratyphi* among immigrants arriving to

Spain within 4 weeks of symptom onset (75% vs. 8.3%, p=.001). Similarly, Banatvala et al. (1994) prospectively studied patients attending for routine diagnostic upper gastrointestinal endoscopy and found higher rates of metronidazole-resistant *Helicobacter pylori* in migrants as compared to subjects born in the UK (43% vs. 17%, p=.001).

Vancomycin-resistant *Enterococci*

Oelmeier et al. (2017) studied anorectal colonization with VRE in pregnant refugees and pregnant residents upon admission at the clinic and found a higher rate among the refugees women (1.8% vs. 0%, respectively) (table 4D).

At least one MDRO

Costa et al. (2017) reported on the rates of intestinal colonization with at least one MDRO on hospital admission and found significantly higher rates of colonization among non-Italian vs. Italian children (Table 4E). A difference of 37.1% was found for MDRO carriage including MRSA, extended spectrum beta-lactamase (ESBL)-producing and carbapenem-resistant *Enterobacteriaceae*, and VRE. Perniciaro et al. (2018) compared cases of invasive pneumococcal disease, defined as *Streptococcus pneumoniae* isolated from a normally sterile site, in refugee children with Germany-born children. A higher percentage of MDR pneumococcal isolates was found in the refugee children group (38% vs. 2%, respectively).

Ureaplasma urealyticum & *Mycoplasma hominis*

Leli et al. (2012) reported on differences in prevalence and antimicrobial susceptibility of *U. urealyticum* and *M. hominis* in a population of Italian and immigrant outpatients reporting symptoms of urethritis (Table 4F). Immigrants showed to have a 6.3% higher prevalence of *U. urealyticum* and 1.6% higher prevalence of *M. hominis*. Susceptibility for both bacteria was tested to eight different antibiotics, but these results were not shown in between groups.

Discussion

Summary of main findings

This systematic review shows that the majority of the included studies analysing the burden of AMR on migrants as compared to the local population of the host country, present a higher prevalence in the migrant population. These results confirm the emerge of the circulation of resistant strains among migrant groups being highlighted in previous research and reports of international health organisations like the WHO [15, 16, 22–24].

Quality of the evidence

All papers included in this systematic review were categorized as medium-high to high quality according to the QA 20-items scale, with an average QA score of 17,3. However, we acknowledge that the evidence has some key limitations. In 5 of the 15 articles screening was performed on refugee patients in hospital settings or asylum seekers. Since these specific groups are known for being high-risk population, the results might give

an overestimation of resistance prevalence [25, 26]. None of the 15 articles described the time span and the route taken by the migrants to arrive to the country of destination, neither about the length of stay from the moment of arrival to the date of inclusion. While knowing that long complicated routes and staying in high-risk areas such as detention centres can have a major impact on the health of migrants, this additional information could be of big value in understanding the relation between migrants and antimicrobial resistance [26–29]. A more diverse migrant group, including detailed description would give a better representation of the migrant population and therefore result in generalizable evidence.

A second dimension that affects the quality of evidence is the strategy chosen for the inclusion of articles. For this review, the decision was to only include articles making a direct comparison between migrants and the local population. Studies comparing the prevalence of AMR in migrants with the local population using national prevalence numbers were excluded, hence, resulting in a smaller total inclusion. Furthermore, we observed that the current state of the literature greatly underrepresents some geographical regions, particularly developing countries, which play a major role in migration worldwide and are largely affected by AMR. Therefore, future studies providing information from these regions are urgently needed to draw appropriate conclusions in this matter. In addition, it is important to highlight that other variables play an important role in determining the risk of MDRO acquisition and spread in the population, including overcrowding, antibiotic usage, and proper healthcare access, all of which are potentially relevant in the migrant population.

Conclusions

This systematic review provides an update of the evidence available to understand the relationship between AMR and international migration. This study shows the importance of considering international migration as a relevant dimension in clinical practice for AMR, as it might be associated with higher chances of AMR in some subgroups of international migrants like refugees. Higher AMR does not imply that migrants import them from countries of origin but could also reflect upon risks they experience during transit and arrival. In countries that are averse to international migration, this must be carefully considered to prevent stigma and discrimination towards migrant populations. Human rights protection of international migrants during transit and arrival should become a global priority, not only for AMR prevention in the case of migrants in adverse social and political environments, but also for the development of inclusive, respectful societies.

Future research could improve our systematic review by updating it and including additional electronic databases for articles search. Based on our findings, primary studies in future should significantly improve the description and justification of selected migrant populations and local populations used for comparison. A more detailed report of the study would allow adequate pooled estimations of risk or prevalence of AMR in different populations. Research in other continents besides North America and Europe is urgently required. Given the complex dynamics of AMR and its geographically patterned features, a global comprehension of its true importance for prevention and control needs more evidence from other regions like Latin America and the Caribbean and Asia.

Abbreviations

AMR – Antimicrobial drug resistance

CDC – Centers for Disease Control and Prevention

MDRGN – Multidrug-resistant Gram-negative bacteria

MDRO – Multidrug-resistant microorganism

MRSA – Methicillin-resistant *Staphylococcus aureus*

PVL – Panton-Valentine Leucocidin

QA – Quality assessment

STROBE - Strengthening the Reporting of Observational Studies in Epidemiology

VRE – Vancomycin-resistant *Enterococci*

WHO – World Health Organization

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article [and its supplementary information files].

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

AP, BC, and JM were responsible for the design of the research. EU did the database search. AP and BC did the screening, quality assessment, data extraction, analysis, and contributed to the writing of the manuscript, in collaboration with OR, MA, SA, RA and JM. All authors read and approved the final manuscript.

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Tables

Table 2 Quality Assessment summary (n=15)

			QUALITY ASSESSMENT - RISK OF BIAS (Strobe v.4 & MMAT v.2011)																		QA	QA
No.	First author	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	score	category
1	Oelmeier de Murcia	2017																					16	high
2	Ravensbergen	2017																					15	medium-high
3	Reinheimer	2017																					17	medium-high
4	Jenks	2016																					20	high
5	Reinheimer	2016																					20	high
6	Sánchez-Montalva	2015																					16	high
7	Casado-Verrier	2012																					16	high
8	Frick	2010																					17	high
9	Bocher	2008																					19	hgh
10	Manzur	2008																					13	medium-high
11	Cercenado	2008																					12	medium-high
12	Banatvala	1994																					20	high
13	Perniciaro	2018																					20	high
14	Costa	2017																					20	high
15	Leli	2012																					19	high

Legend of QA items:

1	Question well justified?
2	Clear objectives?
3	Clear hypothesis?
4	Clear study design?
5	Clear setting?
6	Participants well described?
7	Variables well described?
8	Data source well described?
9	Adjustment by confounders?
10	Adequate sample size?
11	Analysis well described?
12	Clear descriptive stats?
13	Main outcome clearly described?
14	Limitations discussed?
15	Results well interpreted?
16	Results generalizable?
17	Financial disclosure?
18	Conflict of interest?
19	Data source adequate to research question?
20	Sample representative of population of interest?

Legend of QA categories:

1	low (1-5)
2	medium-low (6-10)
3	medium high (11-15)
4	high (16-20)

Table 4A. Differences in the prevalence of methicillin-resistant *Staphylococcus aureus* in between migrants and local population

udy	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
ocher et al (2008)	Denmark	9	112	MRSA	88.9%	23.2%	↑65.7%
ısado-Verrier et al 012)	Spain	16	23	CA-MRSA	50%	21.7%	↑28.3%
einheimer et al (2017)	Germany	117	495	MRSA	10.3%	1.4%	↑8.9%
ıvensbergen et al (2017)	Netherlands	973	12989	MRSA	10.3%	2.1%	↑7.9%
elmeier et al (2017)	Germany	50	50	MRSA	6.0%	0	↑6%
einheimer et al (2016)	Germany	143	1489	MRSA	5.6%,	1.2%	↑4.4%
ick et al (2010)	Spain	6	6	MRSA	100%	100%	0%
per et al (2016)	US	40	77	*wound infections* CA-MRSA	37.5%	42.9%	↓5.4%
				Nasal infections CA-MRSA	10%	19.5%	↓9.5%

Table 4B. Differences in the prevalence of PVL (+) strains in between migrants and local population

udy	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
anzur et al (2008)	Spain	15	4	PLV(+) strains	78.9%	21.1%	↑57.8%
ıvensbergen et al (2017)	Netherlands	973	12989	PVL(+) strains	42%	17.8%	↑24.2%
ercenado et al (2008)	Spain	7	6	PLV(+) strains	53.8%	46.2%	↑7.6%
ick et al (2010)	Spain	6	6	PVL(+) strains	100%	100%	0%

Table 4C Differences in the prevalence of multidrug-resistant Gram-negative bacteria in between migrants and local population

udy	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
nchez-Montalvá al (2015)	Spain	4	12	Salmonella Typhi/Salmonella Paratyphi	75%	8.3%	↑66.7%
inheimer et al 017)	Germany	117	495	MDRGN	52.1%	7.9%	↑44.2%
inheimer et al 016)	Germany	143	1489	MDRGN	60.8%	16.7%	↑44.1%
natvala al (1994)	England	54	46	H. pylori metronidazole resistant strains	43%	17%	↑26%
vensbergen et al 017)	Netherlands	973	12989	ESBL MDRE	20.3% 21.4%	3.2% 5.1%	↑17.1% ↑16.3%

Study	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
Oelmeier et al (2017)	Germany	50	50	VRE	1(1.8%)	0	↑1.8%

Table 4D Differences in the prevalence of vancomycin-resistant *Enterococcus* in between migrants and local population

Table 4E Differences in the prevalence of at least one multidrug-resistant organism in between migrants and local population

udy	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
sta et al 017)	Italy	354	141	At least one MDRO at admission (MRSA; ESBL; CPE; VRE)	61.9%	24.8%	↑37.1%
rniciaro et (2018)	Germany	21	405	invasive pneumococcal disease isolates resistant to >3 classes of antimicrobial drugs	38%	2%	↑36%

Table 4F Differences in the prevalence of colonization by *Ureaplasma urealyticum* and *Mycoplasma hominis*

udy	Country	N° Migrants	N° Population	Type resistance	Prevalence Migrants	Prevalence Population	Difference
li et al (2012)	Italy	121	312	Ureaplasma urealyticum Mycoplasma hominis	39.6% 2.5%	33.3% 0.9%	↑6.3% ↑1.6%

Table 4 Prevalence of antibiotic resistance in migrants and host population by organism

MDRO=multidrug-resistant organisms. (CA)-MRSA=(community acquired) methicillin-resistant *Staphylococcus aureus*. PVL=Panton-Valentine leucocidin. ESBL=expended-spectrum beta-lactamase. MDRGN=multidrug-resistant Gram-negative bacteria; defined as Enterobacteriaceae with extended spectrum beta-lactamase (ESBL)–phenotype as well as Enterobacteriaceae, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* resistant against piperacillin, any

3rd/4thgeneration cephalosporin, and fluoroquinolones. CPE=carbapenemase-producing *Enterobacteriaceae*. MDRE=multidrug-resistant *Enterobacteriaceae*. VRE=vancomycin-resistant *Enterococci*

Figures

Figure 1 Study selection

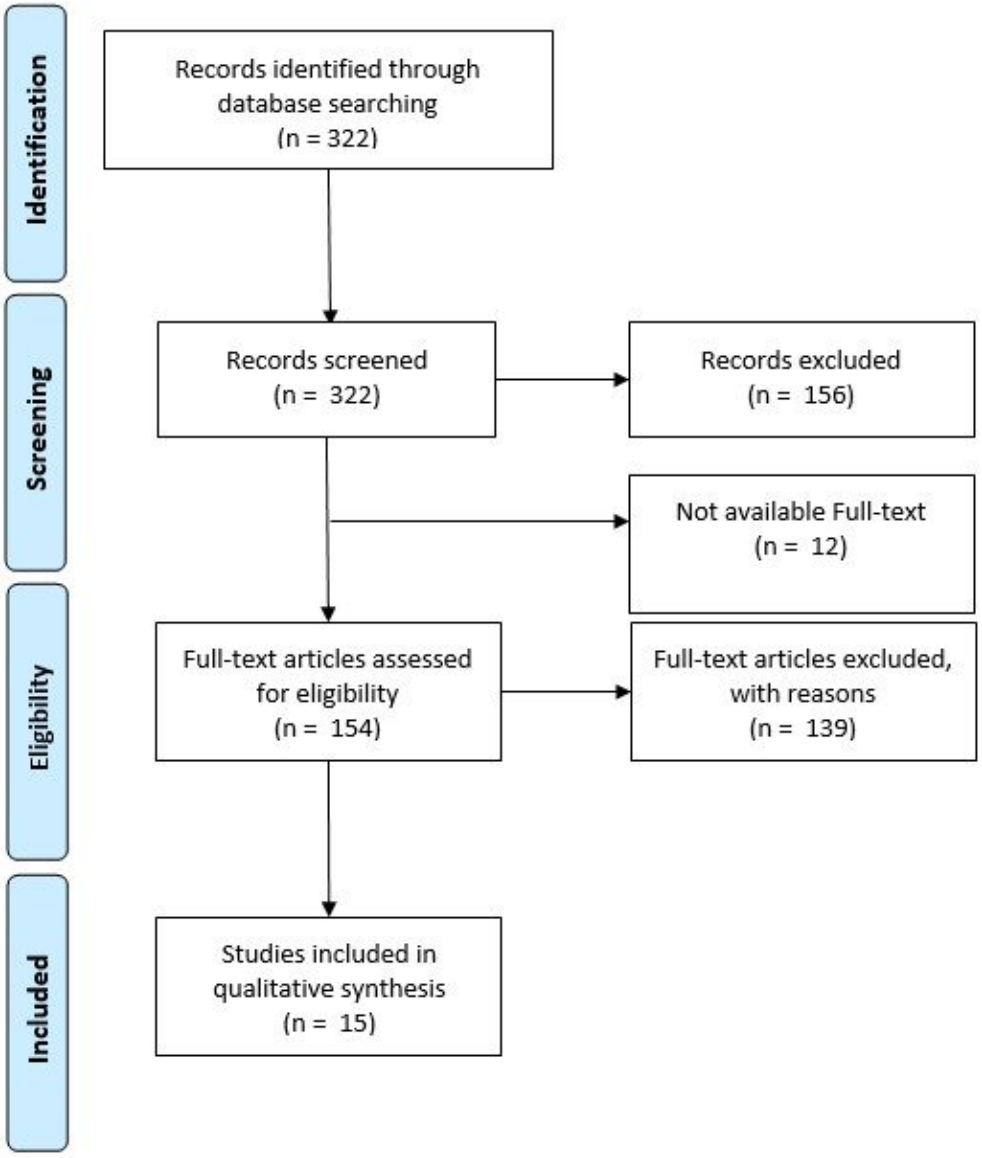

Figure 1

Study selection

Supplementary Files

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- Supplementaryfile1Datahitsselection.xlsx