Web Annex A

Report of the systematic review on the effect of household crowding on health

Harry Shannon, Claire Allen, Mike Clarke, Daniella Dávila, Lizzie Fletcher-Wood, Saurabh Gupta, Katharina Keck, Shona Lang, Ramona Ludolph and Doreen Allen Kahangire

In:

WHO Housing and health guidelines

World Health Organization

Web Annex A

Report of the systematic review on the effect of household crowding on health

Harry Shannon, Claire Allen, Mike Clarke, Daniella Dávila, Lizzie Fletcher-Wood, Saurabh Gupta, Katharina Keck, Shona Lang, Ramona Ludolph and Doreen Allen Kahangire

In:

WHO Housing and health guidelines

WHO/CED/PHE/18.02

Suggested citation. Shannon H, Allen C, Clarke M, Dávila D, Fletcher-Wood L, Gupta S. et al. Web Annex A. Report of the systematic review on the effect of household crowding on health. In: WHO Housing and health guidelines. Geneva: World Health Organization; 2018 (WHO/CED/PHE/18.02). Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Sales, rights and licensing. To purchase WHO publications, see http://apps.who.int/bookorders. To submit requests for commercial use and queries on rights and licensing, see http://www.who.int/about/licensing.

This publication forms part of the WHO guideline entitled *WHO Housing and health guidelines.* It is being made publicly available as supplied by those responsible for its development for transparency purposes and information, as required by WHO (see the *WHO handbook for guideline development*, 2nd edition (2014))**.**

Contents

Introduction

This report assesses the relationship of household crowding to various health effects. A systematic review of this topic was conducted to support the development of the World Health Organization's (WHO) Housing and health guidelines. The aim of this systematic review is to provide the best available evidence from existing research to contribute to the deliberations of the Guideline Development Group (GDG).

After a short background section, this report provides information on the population, exposure, comparator and outcomes (PECOs) and the eligibility criteria for the systematic review, which were agreed upon and approved by the WHO. This is followed by information on the search strategy and methods that were used to identify and summarize potentially relevant studies; and a discussion of the findings of the reviews. The report contains appendices detailing the search strategies for various data sources, the GRADE evidence profiles and summary of findings tables, and the list of excluded studies and the corresponding reasons.

Because of the inherent nature of this topic, experimental evidence from interventions from randomized controlled trials (RCTs) was limited and thus the majority of the evidence from the relevant studies informing this review was observational in nature. Nevertheless, one RCT (Larson et al. 2010 reporting on outcome 1b, non-TB infectious diseases) was identified. However, the study intervention was not associated specifically to crowding and hence crowding was an incidental exposure. Nonetheless, the study was included as it presented the relevant data in line with the research question.

Background

The 1948, Universal Declaration of Human Rights states that "adequate housing" is a basic human right. A fact sheet from the Office of the United Nations High Commissioner for Human Rights and UN Habitat describes the right, and defines what is meant by "adequate" housing. Among the criteria is *habitability*, and housing is considered inadequate if it does not guarantee, inter alia, protection against "other threats to health". (Office of the United Nations High Commissioner for Human Rights and UN Habitat, 2009: 3-4) This implies that any characteristic of housing that leads to adverse health outcomes indicates inadequate housing.

In 2004, Shaw reviewed the evidence linking housing and public health. She noted a number of relationships between overcrowding and various health measures (Shaw, 2004). A report from the Office of the Deputy Prime Minister in the United Kingdom in the same year reviewed the evidence specifically on the effect of overcrowding on health (and education) (Office of the Deputy Prime Minister, 2004). Some decades earlier, Assar (1971: 36) had produced guidelines for sanitation after natural disasters. Among the points made was that in buildings used for shelter, people sleeping on beds or mats should have at least 3.5 m^2 of floor area or 10 m^3 of air space. As well, there should be at least 0.75 m separating beds or mats. Kennedy and Parrack (2012) noted that Assar did not provide any evidence to justify the guideline, but that it appeared in a guide to sanitation and focused on a public health perspective. Indeed, the 3.5 m^2 criterion has been adopted as the standard in disaster settings (Sphere Project, 2011: 258) showing that concerns about overcrowding apply even in emergencies.

In 2011, the International Journal of Public Health published a special issue that examined the relationships between housing and health. An editorial listed “nine main dimensions of residential environments that ought to be considered” (Lawrence, 2011). One of them was “household occupancy conditions”. Another editorial from the WHO perspective identified “crowding” as one of a number of challenges for housing and health (Braubach, 2011).

In summary, there are various concerns about the impact of housing on health, and some evidence suggests that household overcrowding is adversely related to health. This review responds to these concerns.

Eligibility criteria and PECOs

A brief informal protocol was prepared by the review team, prior to initiating the systematic review. The final research question to be answered was:

In the general population exposed to household crowding, what is the exposure-response[1] *relationship between exposure to household crowding and the proportion of persons with poorer health compared to the population not exposed to household crowding?*

The eligibility criteria for the studies in this systematic review were based on this research question. Sections of the original PECO are presented in Table 1.

Table 1 PECO from the WHO for this systematic review

Domain	Criteria
Context	Household crowding is a measure of the relationship between the number of occupants and the dwelling space available, whether measured as rooms or floor area. Crowding occurs where the number of people living in a household exceeds the capacity of the house to provide adequate shelter, space and privacy. It has been defined as the hazards associated with lack of space within the dwelling for living, sleeping and normal family/household life. It is also a marker of poverty and social deprivation and therefore an important environmental determinant of health and well-being. The association between crowding and poor health outcomes is evident in both the developed and developing world and in all cultures.
Further considerations needed for the review work	Household crowding is distinct from the concept of population density, which refers to the number of people per geographical area unit, but does not necessarily relate to crowding, and does not necessarily lead to any detrimental health effects. Crowding as an independent variable can be conflated with outcomes (e.g. informal settlements). The systematic review will use the range of crowding indicators used in the studies although there is a need for international agreement about a measure of household crowding. Crowding recommendations could highlight the issues around difficulties in having universal housing standards applying to both the developed and developing world, where slums are by definition outside of jurisdictional control. All populations need to be examined, but specific attention will need to be given to vulnerable subgroups. The review also needs to identify whether this intervention reduces or increases inequalities.

[1] The original PECO from WHO used the term ‘dose-response’

Domain	Criteria		
Outcomes to be rated by GDG	Close-contact infectious diseases (particularly tuberculosis (TB), rheumatic fever, meningococcal and respiratory infection (URTI/ LRTI disease)		
	Gastroenteritis and diarrhoeal diseases		
	Prevalence of Helicobacter pylori		
	Respiratory symptoms (incl. asthma)		
	Psychological stress		
	Sleep disturbance		
	Mental health		
	Wellbeing outcomes		
	Children's educational performance		
Potential indicators for exposure	Persons per room, persons per dwelling, households per dwelling unit, persons per building, or in-house living area per person (UN Centre for Human Settlements). Percentage of people living in dwellings with more than two persons per room as a percentage of all households in the both rural and urban areas (World Bank indicator). The number of usual household residents divided by the number of rooms (excluding bathrooms, porches, balconies, foyers, hall-ways of half-rooms) (American Crowding Index, continuous or categorical measure). More than one person per room (Official Eurostat definition). Persons per bedroom, accounting for age, sex and relationship. (Canadian Household Crowding Index, similar to European Union measure, continuous or categorical measure.) Crowding recommendations based on regression analysis of data on mortality and morbidity for persons of all age, as applied to dwellings that are below the bedroom standard and adjusted for socioeconomic status (SES), region and population density (operates on guidance system and relies on assessor's experience) (English Health and Rating System adopted by the US Department for Housing and Urban Development as the Healthy Housing Rating System). Every living room should contain at least 120 square feet (11.2 m2) and every bedroom should contain a minimum of 70 square feet (6.5 m2) (USA International Property Maintenance Code). Every dwelling unit should have one room not less than 120 square feet (11.2 m2) of net floor area; other habitable rooms should have net floor area of not less than 70 square feet (6.5 m2) (USA International Building Code).		

Domain	Criteria
Vulnerable subpopulation	Infants under 12 months. Children under 10 years Families with young children People and households on low income Older people Indigenous people Migrant groups Ethnic minorities SES People with disabilities
Confounders	Age Gender Ethnicity Tenure Exposure to second-hand smoke SES Single-storey, multi-storey, multi-family

As the project progressed, a number of changes were made to the PECO. The changes were a result of the time and resource constraints, and requests from the WHO. The following modifications were made:

- Firstly, the review was limited to papers published in or after 2004, and referred to studies conducted no earlier than five years before publication (WHO request).
- Secondly, the WHO conducted an internal survey and identified the five outcomes (or groups of outcomes) with the highest priority. This was done after the Screen 1 (described below) had been conducted. In rank order, the priority outcomes were:
  - Close-contact infectious diseases (particularly tuberculosis (TB), rheumatic fever, meningococcal and respiratory infection incl. URTI/ LRTI disease).
  - Gastroenteritis and diarrhoeal diseases.
  - Psychological stress.
  - Sleep disturbance.
  - Mental health.

Note: The review focuses on these priority outcomes. It was challenging to distinguish the outcomes “psychological stress” and “mental health” and therefore, an informed decision to examine them together for the purposes of this report was made.

The review team identified specific criteria for eligibility based on the original PECO and some further input from the WHO. The criteria were:

- The article must report primary research (new secondary analyses of data were considered primary research).
- There are no language restrictions for the initial screen (though we later restricted papers to those in English as noted below).
- All geographical areas are eligible.

- The measure of crowding must be based on quantitative data, although it could be categorized as a binary variable or an ordinal variable. We also decided that papers referring to “people per household” would not be included as they did not necessarily indicate crowding.
- There must be a quantitative measure of the association between crowding and the outcome, and based on the PECO we would be particularly interested in exposure-response relationships.
- The WHO confirmed that the definition of “residential housing” excluded the following: old age or nursing homes, homeless shelters, residential schools/colleges, orphanages or residential children's homes, hotels, and prisons.

Search strategies, checking of articles and obtaining information[2]

A search strategy was developed by an experienced information specialist in MEDLINE (OvidSP) to identify studies reporting on household crowding. Terms relating to housing were combined using the Boolean operator “AND” with search terms for “crowding”. A range of text words, synonyms and subject headings were identified by scanning key papers identified at the beginning of the project, through discussion with the review team, and the use of database thesauri. The WHO requested that the searches were limited to studies published from 2004 onwards. No language restrictions or study design filters were initially applied to the search strategy. However, due to time and resource constraints, only articles published in English were included. This was based on the likelihood that any research that would have materially changed the results and conclusions would have been published in some form, in English.

Electronic databases covering the fields of health, social science and education were searched during January 2015: MEDLINE, MEDLINE In-Process, EMBASE, ERIC, PsycINFO, Science Citation Index, Social Policy and Practice and the Social Science Citation Index (see Appendices 1-7 for the search strategies). The MEDLINE search strategy was translated for all of the databases searched. Studies on this topic are known to be located within the grey literature. Although a limited amount of grey literature is available on the databases searched, much of it lies elsewhere. However, given the limited resources available for the review, a decision was taken not to carry out further searches for grey literature. However, the review team was later asked by the WHO to search the database “SCIELO” based on the search strategy in Appendix 8.

Records were managed within an EndNote library (EndNote version X7). The retrieved records from the various searches were exported in to EndNote and de-duplication was undertaken. After de-duplication, 2114 records were identified and an additional four records were found in SCIELO, for an overall total of 2118 studies.

The time and resource constraints meant that the review team could not explore all potential sources of information that might be drawn upon in a more comprehensive systematic review. This would entail searching for unpublished studies and for studies in the grey literature or published in journals that are not indexed in the major bibliographic databases.

[2] The description of the search strategy was written by Melissa Harden, Information Specialist at York University

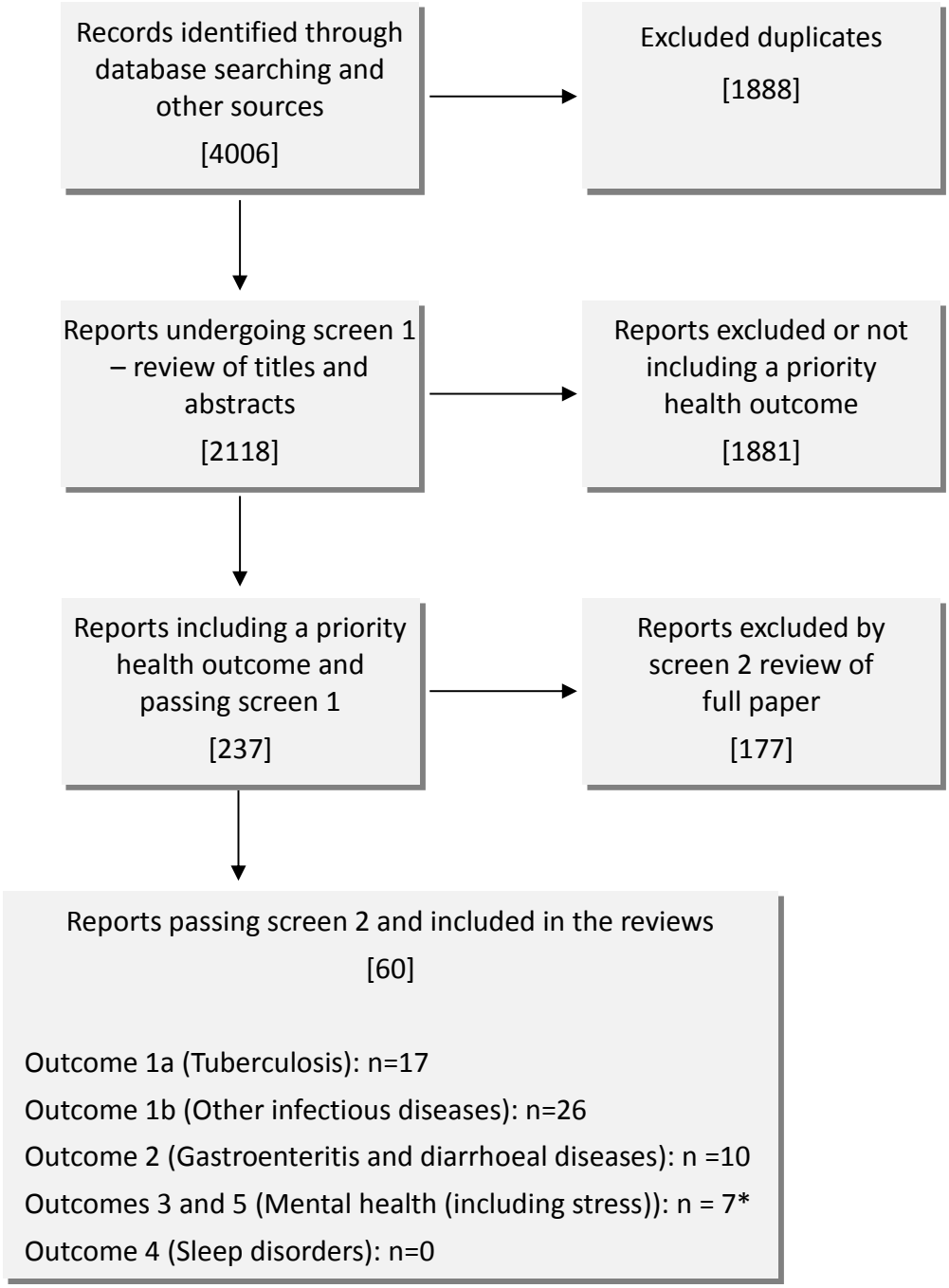
However, our intent was to avoid missing any pivotal study which would transform the overall findings of the systematic review or the conclusions to be drawn from these findings.

For 45 papers, it appeared that the authors might be able to answer some questions or provide additional data or analysis towards our review. The review team attempted to contact the corresponding authors of the reports, and reminders were sent if we had not heard from the author. However, contact information for two authors could not be traced and no replies from 18 authors were ever received. Three authors reported that they never had the information requested, while six no longer had access to their dataset. One author was too busy to provide the analysis we requested, while five replied but at the time of writing had not provided the information requested for in the subsequent correspondence. One author sent a relevant paper from her colleagues that was not identified found in our searches but requested for more time to conduct and complete the analyses requested for (and at the time of writing the report, the review team had not received the data). Two authors conducted extra analyses, and a further seven sent extra information on their studies.

The screening of articles was undertaken in two stages. In the first stage, the titles and, where available, the abstracts for records retrieved from the bibliographic databases were checked independently by two reviewers for eligibility. When there was any doubt, the record was considered provisionally eligible. The two reviewers for each record resolved any disagreements by discussion until a consensus was reached or by the involvement of a third reviewer.

After the initial searches were undertaken, the WHO provided the review team with the prioritized health outcomes. Of the 444 records identified as potentially eligible at that stage, 237 included at least one priority health measure. The full texts of these potentially relevant articles were then retrieved and further assessed for eligibility. Similarly, two reviewers conducted this independently, and resolved any disagreements by discussion until a consensus was reached or by the involvement of a third reviewer. Several papers could not be found. Appendix 9 contains the 177 articles that were excluded, along with the reasons for their exclusion. The total number of the final included studies in 2015 was 60. The flow diagram for the identification of studies is presented in Figure 1.

Figure 1 Flow diagram for identification of studies in both screens in 2015

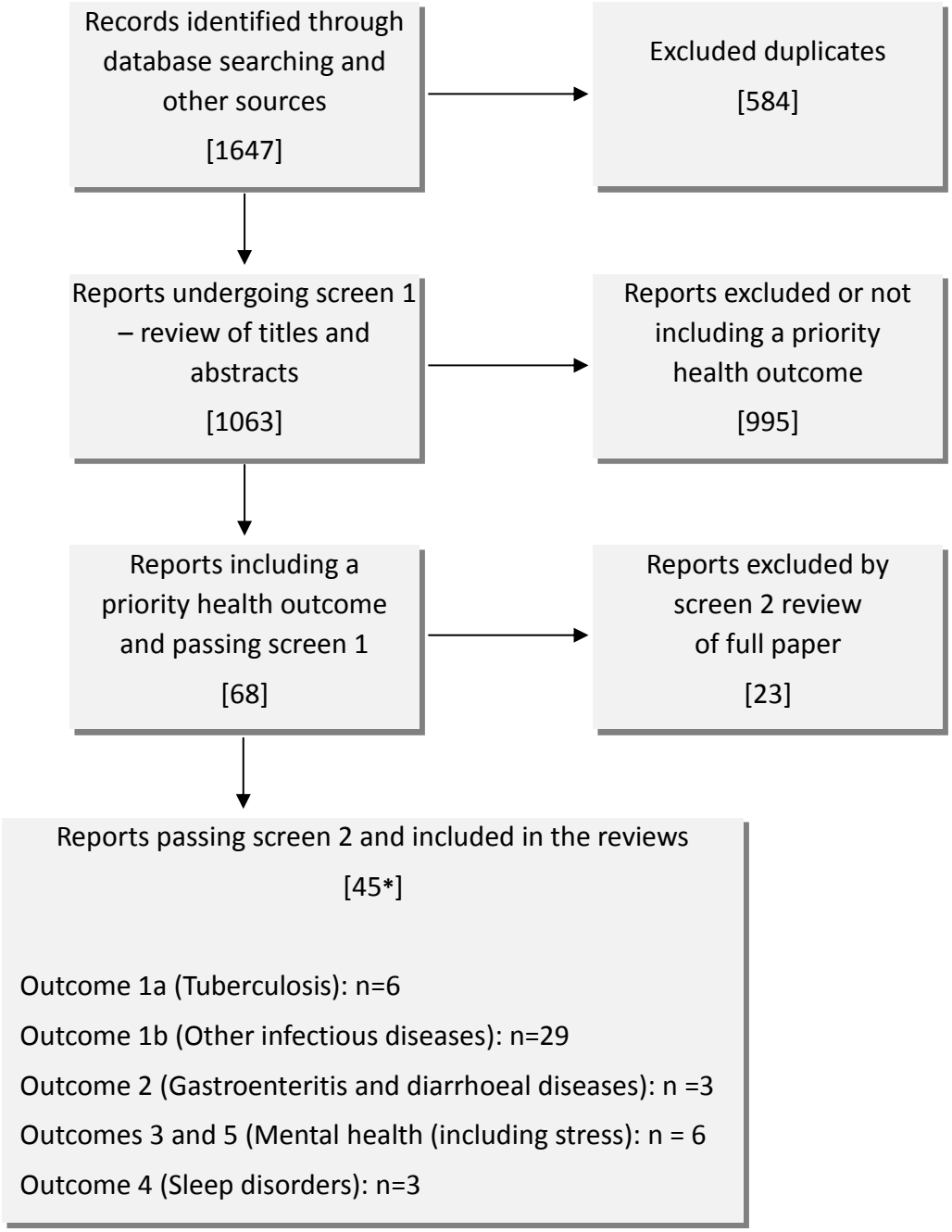


* Only two of the seven studies met the time criterion (published no more than five years after the study was done). To avoid losing such a high proportion of information, we have included these studies.

In order to bring the systematic review up-to-date, new searches for eligible studies were carried out in March 2018 to identify articles published on or after 1 January 2015. The original search strategies for the following databases were utilized: Embase, ERIC, Medline, PsycINFO, Science Citation Index, Social Science Citation Index and SciELO (Appendices 10-16). However, due to access limitations, it was not possible to re-run the search in the Social Policy and Practice database. The retrieved records were checked by two authors and the full text was sought for all studies judged to be potentially eligible.

Once obtained, the full text of each of these articles was checked by two authors for eligibility. Figure 2 shows the flow of articles through this updating process.

Figure 2 Flow diagram for identification of studies during update process in 2018



* For three eligible studies, there was only an abstract available. These were not included in the narrative review of studies and did not contribute to the GRADE evidence profiles. Further, one paper contributed to two different outcome categories (Kohen et al. 2015) and one paper contributed two different outcomes to the same category (Firdaus et al. 2013).

Table 2 shows the electronic databases searched in January 2015 (original search) and March 2018 (update search). A total of 5653 records were retrieved, and after de-duplication, 3181 articles were left. In total, 105 separate studies were included in the

review, of which 102 provided enough information to be considered in the narrative synthesis and GRADE evidence profile.

Table 2 Number of records retrieved and checked from each source

Database	Original search: unduplicated	Original search: after de-duplication	Update search: unduplicated	Update search: after de-duplication
MEDLINE & MEDLINE in process	833	827	351	143
EMBASE	1035	312	435	421
PsycINFO	299	189	115	114
Science Citation Index	770	214	377	199
Social Science Citation Index	620	242	358	175
Social Policy & Practice	352	289	Not accessible	Not accessible
ERIC	74	41	5	5
SCIELO	23	4	6	6
Total	4006	2118	1647	1063

Extraction of information, preparation of narrative summaries, and evidence profiles

For both the original and the updated search, data extraction was carried out by one reviewer and was independently checked by another reviewer for consistency. Any disagreements were resolved through discussion until a consensus was reached or through the involvement of a third reviewer**.** Among the parameters of interest were the following:

- Location and date of study
- Study design, including the methods used for any comparison
- Type and number of participants
- Details of the exposure and any comparator
- Results for all outcomes reported
- Confounders adjusted by any statistical analyses.

Quality assessment was carried out independently by the same reviewers who carried out the data extraction for the original and update searches, respectively. Any disagreements were resolved by discussion until a consensus was reached or by involving a third reviewer. The Risk of Bias (RoB) checklists were chosen based on the study designs of the studies. For this systematic review, a modified version of the CASP criteria (CASP, 2013), to assess cohort, case control and cross-sectional studies. Additionally, GRADE evidence profile tables were created, which showed the RoB based on the following criteria:

- Consistency of reporting of outcomes across studies.
- Evidence reported by the studies directly addresses the PECO, precision of the results across the studies.
- Any confounding factors affecting the results and corresponding interpretation.
- Overall quality of evidence in the included studies.

Findings

This section details the findings of the review for each outcome. Results are reported narratively and tabulated where appropriate. A summary of the characteristics of the included studies is presented in Appendix 17.

For this review, five outcomes were considered relevant and these included the following:

- Outcome 1:
  - 1a: Tuberculosis (TB)
  - 1b: Other infectious diseases
- Outcome 2: Gastroenteritis and diarrhoeal diseases
- Outcomes 3 and 5: Mental health, including stress
- Outcome 4: Sleep disorders.

The section will detail the quality assessment of the included studies based on their respective design. Interpretation of these findings is also presented. Given the volume of evidence, a decision to report the findings using the GRADE evidence profile tables within the main body of the report was made. The GRADE evidence profile tables provide a detailed assessment of the review outcomes in terms of risk of bias, inconsistency, indirectness, overall quality as well as the importance of the study results and interpretation to the WHO guideline development team.

A summary of the risk of bias for the studies is presented in Tables 3–7; GRADE evidence profile tables for each outcome are presented in Appendix 18.

Results for the risk of bias based on study design of the included studies

To assess the RoB, each included study was considered against several domains. The nature of these domains included whether the study had a clear focus, how accurately the exposure and outcome were measured, identification of confounders, the statistical analysis, and if the results were reliable and could be generalizable to the local population. The results of this assessment are reported below for each outcome.

Outcome 1a (tuberculosis)

Overall, of the 23 included studies on this outcome, at least half were of acceptable quality. Each study addressed a clearly focused issue and took important confounding factors into account in the analysis with five exceptions (Gyawali 2012, Irfan 2017, Larcombe 2011, Pelissari 2017 and Tornee 2005). The analysis of confounders was also not clearly explained in Soburg 2011, Kapoor 2016 and Sacchi 2018 but for the two latter ones, there was only an abstract available. In a majority of the studies, the sample was recruited in an acceptable way and both the exposure and outcome were accurately measured to minimize bias. For a minority of studies, these domains were not clearly reported, for example, in the Larcombe 2011 and Soburg 2011 studies. Furthermore, almost one fifth of the studies gave a clear explanation of how the sample size was determined; the remainder either gave a partial description or did not report this. In at least 80% of the included studies, it was unclear whether the follow-up of subjects was either complete or long enough.

Overall, most studies gave an adequate description of the statistical analysis and the study participants and were considered to have reliable results, which could be applied to the local population. Across all of the domains, the following studies were considered to be of a very high quality with relatively low risk of bias: Corbett 2009, Harling and Castro 2013, Hill 2006, Lienhardt 2005, Khan 2016 and Tesema 2015. A summary of quality assessment of studies reporting on outcome 1a (TB) is presented in Table 3.

Table 3 Risk of bias assessment results for studies reporting on outcome 1a (TB)

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Case control studies													
Garcia-Sancho et al. 2009	+	+	+	+	+	+	Unclear	Unclear	+	NA	NA	NA	NA
Hill et al. 2006	+	NA	+	+	+	+	+	+	+	NA	NA	NA	NA
Irfan et al. 2017	+	+	+	+	-	+	N/A	N/A	Unclear	Unclear	+	-	Unclear
Kapoor et al. 2016*	+	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	-	Unclear
Khan et al. 2016	+	+	+	+	+	+	+	+	+	NA	NA	NA	NA
Lienhardt et al. 2005	+	+	+	+	+	+	Unclear	Unclear	+	NA	NA	NA	NA
Tesema et al. 2015	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
Tipayamongkholgul et al. 2005	+	NA	+	Unclear	Unclear	+	Unclear	Maybe	+	NA	NA	NA	NA
Wayenki et al. 2006	+	NA	+	+	+	+	+	+	Unclear	NA	NA	NA	NA
Jayanthi et al. 2012	+	NA	+	Unclear	+		Unclear	Partial	+	NA	NA	NA	NA
Cross-sectional/cohort studies/ecological studies													
Corbett et al. 2009	+	+	Unclear	+	+	+	NA	NA	+	+	+	+	+
Cluver et al. 2013	+	+	Unclear	Unclear	+	+	NA	NA	Unclear	+	-	+	+

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Goldhaber-Fiebert et al. 2011	+	+	+	+	+	+	NA	NA	+	Unclear	NA	+	+
Harling and Castro, 2013	+	+	+	+	+	+	NA	NA	Unclear	+	+	+	-
Gyawali et al. 2012	+	+	+	+	+	-	NA	NA	-	Unclear	-	-	-
Baker et al. 2008	+	NA	Unclear	+	+	+	Unclear	Unclear	+	+	Partial	Partial	+
Jayanthi et al.	+	+	+	+	+	+	Unclear	Unclear	+	+	Partial	Partial	+
Larcombe et al. 2011	+	+	Unclear	-	-	-	NA	NA	-	+	-	+	Unclear
Tornee et al. 2004	+	+	+	+	+	+	NA	NA	+	+	-	+	+
Tornee et al. 2005	+	+	Unclear	+	-	+	NA	NA	Unclear	+	-	Unclear	-
Sacchi et al. 2018*	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	-	-
Soborg et al. 2011	+	-	Unclear	-	+	Unclear	NA	NA	Unclear	Unclear	Unclear	Unclear	Unclear
Pelissari et al. 2017	+	+	+	+	-	+	NA	NA	+	Unclear	+	+	+

NA indicates not applicable; + study has presented the relevant information;–study did not report the relevant information

* Only abstract available.

Outcome 1b (non-TB infectious diseases)

Overall, 54 separate studies were included for this outcome. The quality assessment results indicate that the majority of the studies were of very good quality based on the RoB domains. Most of the studies addressed a clearly focused issue and were considered to have reliable results that could be applied to the local population. In addition, in all but nine of the studies the cohort was recruited in an acceptable way. Similarly, all the studies, except for 12, clearly stated that the exposure and outcome were accurately measured to minimize bias and only ten studies were unclear about whether confounders were taken into account in the analysis or did not do so. Additionally, 25 of the studies gave a description of how the sample size was determined with the remainder giving only a partial explanation or unclear information about this. Thirty-four studies gave an adequate description of the statistical analysis. Thirty-six studies gave an adequate description of the study participants but overall information about whether the follow-up of subjects had been complete or long enough was often not clear.

Overall, the studies, which were deemed to be of the lowest quality in terms of their risk of bias were: Auguet et al. 2016, Chattopadhyay et al. 2016, Mirabel et al. 2015, Sekhar et al. 2009, Phillips et al. 2014, and MacLennan et al. 2006. For some studies, only abstract data were available and so there was limited information on which to assess the study quality. In general, all of the other studies performed well across most of the domains but of particular note were Alvarado et al. 2016, Baillie et al. 2005, Brander et al. 2017, Doshi et al. 2015, Gares et al. 2017, Grant et al. 2012, Mitra et al. 2018, Olea et al. 2017, Sinha et al. 2015, Tin et al. 2016 and Vincenti Gonzalez et al. 2017. A summary of the quality assessment of studies reporting on outcome 1b (non-TB infectious diseases) is presented in Table 4.

Table 4 Risk of bias assessment results for studies reporting on outcome 1b (non-TB infectious diseases)

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Case control studies													
Alvarado-Esquivel et al. 2016	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
da Fonseca Lima et al. 2016	+	+	+	+	-	+	NA	NA	+	Unclear	+	+	+
Doshi et al. 2015	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
Hosoglu et al 2006	+	+	Unclear	+	Unclear	+	Unclear	Unclear	+	NA	NA	NA	NA
Howie et al. 2016	+	+	+	+	-	+	NA	+	+	Unclear	+	+	+
Mirabel et al. 2015	+	+	+	-	-	+	-	-	Unclear	Unclear	+	-	+
Olea et al. 2017	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
Verani et al. 2016	+	+	+	+	-	+	NA	NA	+	Unclear	+	+	+
Vieira et al. 2016	+	+	Unclear	+	-	Unclear	NA	NA	+	Unclear	-	-	+
Riaz et al 2013	+	+	+	+	+	Unclear	Unclear	Unclear	+	NA	NA	NA	NA
Grant et al 2012	+	+	Unclear	+	+	+	Unclear	+	Unclear	NA	NA	NA	NA
Okello et al 2012	+	Unclear	+	+	Unclear	Unclear	Unclear	Unclear	Unclear	NA	NA	NA	NA
Deutch et al 2004	+	+	+	+	+	+	+	+	+	NA	NA	NA	NA

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Cardoso et al 2004	+	+	+	Unclear	+	+	+	+	+	NA	NA	NA	NA
Cross-sectional/cohort studies/ecological													
Alemayehu et al. 2017	+	Unclear	+	+	+	+	NA	NA	+	Unclear	+	-	+
Brander et al. 2017	+	+	+	+	Unclear	+	NA	NA	+	Unclear	+	+	+
Chattopadhyay et al. 2016	+	Unclear	+	-	Unclear	Unclear	NA	NA	-	Unclear	+	+	-
Diaz et al. 2015	+	Unclear	+	+	-	+	NA	NA	+	Unclear	-	+	+
Forshey et al. 2010	-	+	Unclear	Partial	+	+	+	Partial	+	+	-	+	+
Hegab et al. 2015	+	+	+	Unclear	NA	NA	NA	NA	Unclear	Unclear	+	+	+
Hughes et al. 2017	+	+	+	+	-	+	NA	NA	Unclear	Unclear	-	+	+
Kohen et al. 2015	+	+	+	+	+	+	NA	NA	+	Unclear	NA	+	+
Krueger et al. 2015	+	+	+	+	+	+	NA	NA	+	Unclear	-	+	-
Kumar et al. 2015	+	+	Unclear	+	-	+	NA	NA	+	Unclear	+	+	-
Romani et al. 2017*	+	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	-	+
Sinha et al. 2015	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
Tin et al. 2016	+	+	+	+	+	+	+	+	+	Unclear	+	+	+
Tse et al. 2016	+	+	+	Unclear	+	+	NA	NA	Unclear	Unclear	+	+	+

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Vincenti-Gonzalez et al. 2017	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+
Weber et al. 2017	+	+	+	+	+	+	NA	NA	+	Unclear	-	Unclear	+
Yousey-Hindes et al. 2011	-	+	Partial	Partial	-	-	NA	NA	+	+	-	+	+
Tam et al. 2014	-	+	+	+	-	+	NA	NA	Unclear	+	-	+	-
Baillie et al. 2005	+	+	+	+	+	+	-	NA	+	+	-	+	+
MacLennan et al. 2006	+	+	+	_	Unclear	+	NA	NA	+	Unclear	-	+	-
Mitra et al. 2018	+	+	+	+	+	+	+	+	+	Unclear	+	+	+
Norheim et al. 2014	+	+	+	+	+	+	+	Unclear	+	+	+	Partial	+
Prietsch et al. 2008	+	+	+	+	Unclear	+	NA	NA	+	+	Unclear	Unclear	+
Reisman et al. 2013	+	Unclear	+	+	Unclear	+	NA	NA	+	+	-	Unclear	+
Sekhar et al. 2009	+	-	+	+	Unclear	Unclear	Unclear	Unclear	Unclear	+	+	-	Unclear
Murray et al. 2012	+	+	+	+	Unclear	+	+	Unclear	Unclear	+	-	+	Unclear
Islam et al. 2013	+	+	+	+	+	+	+	+	+	+	+	Partial	+
Larson et al. 2010	+	+	+	+	+	+	+	+	+	+	+	+	+
Al Jarousha et al. 2014	+	+	+	+	+	+	Unclear	Unclear	+	+	+	Partial	+
Rao et al.	+	+	+	+	+	+	+	Unclear	+	+	Unclear	-	+

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
2010													
De Wals et al. 2005	+	+	+	+	+	+	Unclear	Unclear	+	+	-	-	+
Gares et al. 2017	+	+	+	+	+	+	+	Unclear	+	Unclear	+	+	+
Mathew et al. 2014	+	+	+	+	+	+	+	Unclear	+	+	Partial	-	+
Phillips et al. 2014	+	Unclear	Unclear	Unclear	-	-	NA	NA	+	+	NA	+	NA
Firdaus et al. 2013	+	+	Unclear	-	+	Unclear	Unclear	NA	Unclear	Unclear	-	+	-
Kristensen et al. 2006	+	+	+	+	+	+	Unclear	Unclear	+	Unclear	Partial	+	-
Jaine et al. 2011	+	+	+	+	-	+	NA	NA	+	+	-	+	-
Auguet et al. 2016	+	Unclear	Unclear	+	-	Unclear	NA	NA	Unclear	Unclear	-	+	-
Bruden et al.2015	+	+	+	+	Unclear	+	NA	NA	+	Unclear	-	-	+
Chandrasekhar et al. 2017	+	+	+	+	-	+	NA	NA	+	Unclear	+	+	+
Sloan et al. 2015	+	+	+	+	-	+	NA	NA	+	Unclear	-	+	-

NA indicates not applicable; + study has presented the relevant information;–study did not report the relevant information

*Only abstract available.

Outcome 2 (gastroenteritis and diarrhoeal diseases)

All of the eleven cohort and case-control studies had at least one domain at high risk of bias (the number of domains at high risk per study ranged from 1 to 5), although only one study had only one domain at high risk (Abu Mourad 2004). Most studies had predominantly low risk of bias for all domains (number per study ranged from 3 to 10). The domains which were most often at high risk of bias were the identification and consideration of confounders in the analysis, reporting a calculation for study sample size and description of the characteristics of the study participants. The domains which were most often at an unclear risk of bias were whether or not follow-up was adequate or long enough.

The two case-control studies did not have any domains at high risk of bias. Unclear risk of bias was identified for measurement of exposure, reliability of the results and whether the results can be applied to the local population. A summary of the risk of bias for cohort/cross-sectional studies and case-control studies is summarized in Tables 5 and 6, respectively.

Table 5 Risk of bias assessment results for the cohort and cross-sectional studies reporting on outcome 2 (Gastroenteritis and diarrhoeal diseases)

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Harper 2015	+	+	Unclear	Unclear	Unclear	+	NA	NA	Unclear	Unclear	+	+	+
Monasta 2008	+	+	+	Unclear	Unclear	+	+	NA	Unclear	+	-	+	-
Abu Mourad 2004	+	+	+	+	+	-	+	NA	Unclear	+	+	+	+
Etiler 2004	+	+	+	+	-	-	+	+	-	+	+	-	Unclear
Okour 2012	+	+	+	-	-	-	NA	NA	Unclear	Unclear	-	+	+
El-Gilany 2005	+	+	+	+	-	-	NA	NA	+	+	+	+	-
Pezzani 2012	+	Unclear	+	+	-	-	+	NA	-	Unclear	-	+	-
Kyle 2011	+	+	+	+	-	-	NA	NA	Unclear	+	NA	+	-
Mohan 2017	+	Unclear	Unclear	+	+	+	Unclear	+	Unclear	Unclear	-	+	-
Perry 2005	+	+	+	+	Unclear	Unclear	+	NA	+	-	-	-	-
Ramani 2017	+	-	Unclear	Unclear	-	+	NA	NA	Unclear	Unclear	+	-	+

NA indicates not applicable; + study has presented the relevant information;–study did not report the relevant information.

Table 6 Risk of bias assessment results for the case-control studies reporting on outcome 2 (Gastroenteritis and diarrhoeal diseases)

Author	Did the study address a clearly focused issue?	Did the authors use an appropriate method to answer their question?	Were the cases recruited in an acceptable way?	Were the controls selected in an appropriate way?	Was the exposure accurately measured to minimize bias?	Were confounders taken into account in the analysis?	Are the results reliable?	Can the results be applied to the local population?	Do the results of the study fit with other evidence?
Ferrer 2008	+	+	+	+	Unclear	+	Unclear	Unclear	+
Quigley 2006	+	+	+	+	+	+	+	Unclear	+

+ Study has presented the relevant information;–study did not report the relevant information.

Outcomes 3 and 5 (mental health including stress)

Overall, most of the 13 studies were of acceptable quality. In particular, in all but two studies, the exposure was deemed to be measured accurately. All studies except Al-Hemiary 2015 and Cabieses 2012 described their statistical analyses and all studies besides Al-Hemiary 2015 accounted for confounders. Only three studies provided a justification for the sample size used, and in seven of the 13 studies, the outcome was not measured in a way that ensured accuracy. However, several of these studies were population-based surveys with sample sizes likely to be sufficiently large. Information was generally lacking on what percentage of individuals refused participation in the study and whether their characteristics differed from those of responders. Overall, the outcome measurements tended to be fairly weak.

In addition, five of the studies were published more than five years after the data collection had been completed. However, all of these studies conducted a secondary analysis of previously collected data, a sound justification for the very delayed publication after completion of the original study. Because this applied to so many studies, the review team chose to include them in the report, so readers can be aware of how the overall conclusions may have been affected. A summary of the risk of bias for studies reporting on outcomes 3 and 5 is presented in Table 7.

Table 7 Risk of bias assessment results for the cross-sectional/cohort studies reporting on outcomes 3 and 5 (Mental health including stress)

Author	Did the study address a clearly focused issue?	Was the cohort recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Al-Hemiary 2015	+	+	+	Unclear	Unclear	Unclear	NA	NA	-	Unclear	-	-	-
Faisal-Cury 2009	+	+	+	+	+	+	+	NA	+	Unclear	-	+	+
Firdaus 2017	+	Unclear	Unclear	+	+	+	NA	NA	Unclear	Unclear	+	+	+
Gray 2016	+	+	+	+	Unclear	+	NA	NA	Unclear	Unclear	+	+	+
Kohen 2015	+	+	+	+	+	+	NA	NA	+	Unclear	NA	+	+
Pierse 2016	+	+	+	Unclear	Unclear	+	NA	Unclear	Unclear	Unclear	-	+	+
Waters 2017	+	+	+	+	+	NA	-	+	+	Unclear	+	+	+
Riva 2014a	+	+	+	-	+	+	+	NA	Unclear	+	-	+	+
Barnes 2011	+	+	+	+	+	+	Unclear	+	Unclear	+	-	+	-
Cabieses 2012	+	+	+	-	+	+	Unclear	NA	Unclear	+	-	-	+
Kimhy 2006	+	+	+	-	+	+	Unclear	+	Unclear	+	-	+	-
Regoeczi 2008	+	+	+	-	+	+	Unclear	Unclear	+	+	-	+	+
Riva 2014b	+	+	+	Unclear	+	+	Unclear	NA	+	+	-	+	+

NA indicates not applicable; + study has presented the relevant information;–study did not report the relevant information.

Outcome 4 (sleep disorders)

The updated search identified three studies reporting on the association between household crowding and sleep disorders. All three studies were of acceptable quality: Van der Spuy 2017 was of very low risk of bias, while Johnson 2015 did not identify all relevant confounding factors and remained unclear regarding the applicability of results to a local context. The study by Chambers 2016 had the highest risk of bias as it failed to measure the outcome in an accurate manner to minimize bias, did not describe how the sample size was arrived at and was unclear about the reliability of results and their application to the local population. Table 8 presents the risk of bias assessment for the three studies reporting on overcrowding and sleep disorders.

Table 8 Risk of bias assessment results for the cross-sectional/ecological studies reporting on outcome 4 (Sleep disorders)

Author	Did the study address a clearly focused issue?	Was the sample recruited in an acceptable way?	Was the exposure accurately measured to minimize bias?	Was the outcome accurately measured to minimize bias?	Have the authors identified all important confounding factors?	Were confounders taken into account in the analysis?	Was the follow up of subjects complete enough?	Was the follow up of subjects long enough?	Are the results reliable?	Can the results be applied to the local population?	Was there a description of how study size was arrived at?	Was there an adequate description of the statistical analysis?	Is there an adequate description of the study participants?
Chambers 2016	+	+	+	-	+	+	NA	NA	Unclear	Unclear	-	+	+
Johnson 2015	+	+	+	+	-	+	NA	NA	+	Unclear	+	+	+
van der Spuy 2017	+	+	+	+	+	+	NA	NA	+	Unclear	+	+	+

Summary of the review results for each outcome based on the GRADE evidence profile tables

Outcome 1a (tuberculosis)

Twenty-one studies with full text available (10 case-control, eight cross-sectional, two ecological and one retrospective cohort studies) which examined the link between crowding and TB were identified. These studies were consistent in showing that crowding is associated with increased risks of TB, even though the positive association was not statistically significant in a small number of the studies.

Four studies investigated the effect of different levels of crowding on the incidence of TB (Corbett 2009, Lienhardt 2005, Soborg 2011, Tipayamongkholgul 2005). In these studies, increasing numbers of persons per room were analysed in relation to the incidence of TB. One of these found a significant increase for 2–4 persons/room in comparison with one person/room but not at >4 persons/room (Corbett 2009), while the other three studies did not show a statistically significant relationship between increased crowding and the incidence of TB (>1.5, >2, 1–3, 3–5 persons per room) (Lienhardt 2005, Soborg 2011, Tipayamongkholgul 2005). In the two studies that examined an exposure-response relationship for crowding and TB, one found a consistent relationship (Baker 2008), but the other did not (Tipayamongkholgul 2005). The 15 other studies used a threshold for crowding, comparing crowded with non-crowded households. Although crowding was not found to have a statistically significant association in four studies (Garcia Sancho 2009, Goldhaber-Fiebert 2011, Jayanthi 2012, Lakshmi 2012), crowding was significantly associated with TB in each of the other 11 studies (Baker 2008, Cluver 2013, Gyawali 2012, Hill 2006, Irfan 2017, Khan 2016, Pelissari 2017, Tesema 2015, Tornee 2004, Tornee 2005, Wanyeki 2006).

Outcome 1b (non-TB infectious diseases)

Fifty-four separate studies (with full text available) reported on non-TB infectious diseases in relation to crowding. More specifically, 30 papers reported on respiratory infectious diseases other than TB and 25 studies investigated the relationship between crowding and other infectious diseases.

Among the non-TB respiratory disease studies, there were 14 cross-sectional, six case-control, five cohort (including a randomized trial in which the intervention was not related to housing) and five ecological studies. Seven trials investigated flu-related hospitalizations and illnesses (Chandrasekhar 2017, Doshi, 2015, Forshey 2010, Sekhar 2009, Sloan 2015, Tam 2014, Yousey-Hindes 2011); six studies looked into pneumonia (Fonseca Lima 2016, Grant 2012, Howie 2016, Mathew 2014, Reisman 2014, Verani 2016), 16 articles reported on acute respiratory illness (Cardoso 2004, Chattopadhyay 2017, Diaz 2015, Firdaus 2013, Hughes 2017, Islam 2013, Kohen 2015, Kristensen 2006, Kumar 2015, Larson 2010, Murray 2012, Prietsch 2018, Sinha 2015, Tin Tin 2016, Tse 2016, Weber 2017); and one on respiratory syncytial virus (Bruden 2015).

Twenty-five studies investigated an association between crowding and other infectious diseases such as rheumatic fever and heart disease: five studies (Jaine 2011, Mirabel 2015, Okello 2012, Philips 2014, Riaz 2013); typhoid fever: one study (Hosoglu 2006); meningococcal disease: seven studies (Alemayehu 2017, De Wals 2005, Deutch 2004, Jarousha 2014, MacLennan 2006, Norheim 2014, Olea 2017); throat eye and skin infections:

three studies (Bailie 2005, Firdaus 2013, Hegab 2015); dengue fever: one study (Vincenti-Gonzalez 2017); Helicobacter pylori: one study (Krueger 2015); methicillin-resistant staphylococcus aureus: two studies (Auguet 2016, Vieira 2016); parasite Toxoplasma gondii: one study (Alvarado-Esquivel 2016); Epstein Barr virus: one study (Gares 2017); neonatal infections: one study (Mitra 2018); multi-drug non-susceptible enteric infections: one study (Brander 2017); and risk factors for WASH: one study (Rao 2013). Study designs included ten cross-sectional, nine case control, one ecological and five cohort studies. In general, the risk of acquiring the studied infectious diseases was associated with crowding.

The definitions of crowding in these studies were variable and based on persons/room, rooms/house, square meterage of living space or living in single or multiple rooms. Across the majority of outcomes, the risk of non-TB infectious diseases was associated with crowding. Given the breadth of outcomes identified, it is challenging to draw definitive conclusions on each outcome due to the low number of studies reporting on each outcome. The GRADE evidence profiles for outcomes 1a and 1b are presented in the tables in Appendix 18.

Outcome 2 (gastroenteritis and diarrhoeal diseases)

Thirteen studies (two case-control, seven cross-sectional and four cohort studies) were identified that related crowding to diarrhoea or gastrointestinal diseases or parasites, showing that crowding appears to be associated with gastroenteritis and diarrhoeal diseases. Among the included studies, four looked at the effects of different levels of crowding (Abu Mourad 2004, Etiler 2004, Okour 2012, Ramani 2017). In two of the studies, the higher levels of crowding (greater than three or four people per room) were associated with significantly more cases of diarrhoea compared with the lower levels (less than two or four people per room) (Etiler 2004 and Okour 2012). In two studies, the level of crowding did not significantly affect the number of cases of diarrhoea, but in one of these studies all levels of crowding were associated with the surrogate outcome of increased intestinal parasite infection (Abu Mourad 2004).

Overall, the evidence suggests that crowding may be associated with gastroenteritis and diarrhoeal diseases, but the data are not completely consistent. The GRADE evidence profile for outcome 2 is presented in Appendix 18.

Outcomes 3 and 5 (mental health including stress)

Of the 13 separate studies in this category (one of which assessed two different mental health outcomes), eight studies reported at least one significant association between household crowding and the mental health outcome. A prospective cohort study (Regoeczi 2011), a retrospective cohort study (Barnes 2011) and five cross-sectional studies (Al-Hemiary 2015, Faisal-Cury 2009, Firdaus 2017, Riva 2014a, Riva 2014b) all reported that participants living in a crowded household were more likely to report a mental health problem than those not living in crowded conditions. These mental health concerns included: psychological distress, alcohol abuse, feeling depressed and feeling unhappy about one's health. Notably, Cabieses (2012) found that crowding was associated with a *lower* prevalence of psychiatric disability among Chileans, although this was a cross-sectional study. Four cross-sectional studies could not detect any relationship between crowding and mental health outcomes such as inattention-hyperactivity and emotional symptoms (Kohen 2015), psychological distress (Pierse 2016), suicidal ideation and self-esteem

(Gray 2016), or drug abuse (Al-Hemiary 2015). Further, one retrospective cohort study carried out in Israel reported no association between crowding during infancy and development of schizophrenia in later life (Kimhy 2006) and one cohort study conducted in the United States of America found no link between overcrowding and autonomic nervous system reactivity or externalizing behaviour problems (Waters 2016).

This evidence suggests that crowding may be linked to milder forms of mental health problems such as feelings of stress and unhappiness. This also leads to the question of whether alleviating crowding in the household can lead to improvements in mental health. We found no eligible studies that tested the effect of interventions or naturally occurring alleviations of crowding on mental health. In a study by Wells and Harris (2007), low-income women who relocated to newly constructed homes reported significant improvements in psychological distress as a result of decreased crowding. Because the authors did not use a purely quantitative measure of crowding, the study was excluded from the present review. However, further research, which considers the effect of improvements in crowding on mental health outcomes, would be valuable.

Two types of exposure-response relationship may be of interest. Firstly, one may suppose that living in crowded conditions for a longer period of time would lead to worse mental health outcomes than living in crowded conditions for shorter periods. Only one study (Barnes 2011) investigated this hypothesis. This study found that children living in a crowded household for between three and five years had significantly greater odds of feeling unhappy about their health. However, there was no difference in the outcome for those who had never lived in a crowded household and those who had lived in a crowded household for one or two years in the previous five years. This suggests that worse mental health outcomes may only arise when spending longer periods of time in crowded living conditions. However, further evidence that looks at more clearly defined mental health outcomes is needed before conclusions can be drawn.

Secondly, mental health is most likely to deteriorate in the most crowded conditions. Few studies have explicitly investigated this exposure-response relationship. Those studies which considered this question have not established a clear exposure-response relationship. Faisal-Cury (2009) found that participants in very crowded households were more likely to show symptoms of common mental disorders than those living in the least crowded households. However, participants living in households with between 0.76 and one person per room also had increased odds of reporting symptoms of common mental disorders, while those in slightly more crowded households did not. In their prospective cohort study, Regoeczi et al. (2008) explored non-linear relationships between crowding and mental health outcomes. They found that both living in a very uncrowded household and living in a very crowded household were associated with increased odds of depression. Furthermore, when splitting the analysis by gender, in very crowded households women had increased odds of depression while men had decreased odds of depression. On the other hand, men had higher odds of reporting symptoms of withdrawal in highly crowded households.

Overall, the evidence suggests that crowding may be associated with mental health outcomes. Based on the current evidence, further studies should seek to clarify the relationship between crowding and depression as well as crowding and stress. In particular, more studies should investigate whether men and women respond differently to living in a crowded household. The GRADE results for outcomes 3 and 5 are shown in Appendix 18.

Outcome 4 (sleep disorders)

Two recent cross-sectional (Chambers 2016, van der Spuy 2017) and one ecological study (Johnson 2015) investigated the associations between crowding and sleep disorders. One cross-sectional study found excessive daytime sleepiness with >1 person per room (van der Spuy 2017). Another study concluded that living in a crowded household (≥1 person per room) is not significantly associated with outcomes relevant to sleep disturbance but did find a significant relationship between crowding and duration of sleep in some analyses (Chambers 2016). The ecological study found a significant positive relationship between percentage of neighbourhood-level crowding (>1 person per room) and the apnoea–hypopnoea index (Johnson 2015).

Discussion (including limitations of the review)

There are several limitations to consider when drawing conclusions from this review. The majority of the included studies were observational studies and no controlled trials of reducing crowding were found. In the only RCT included (Larson et al. 2010 reporting on outcome 1b, non-TB infectious diseases), the experimental interventions were not related to crowding, which was simply an incidental variable. Thus, the standard cautions about using non-experimental evidence to assess causation apply.

Additionally, the included studies did not allow for quantitative pooling of results (meta-analysis) due to the variability in the crowding definitions, outcomes as well as subgroups of interest. While many included studies used “people per room” as the measure of crowding, the cut-points used to identify “over-crowded” housing varied between studies. Different sets of confounders were used, and sometimes no adjustment for confounding was made. Few studies examined exposure-response relationships between crowding and the health outcomes. When they did, the relationship was not always monotonic, that is it did not increase steadily with increased crowding.

As noted earlier, the full rigour of standard systematic reviews could not be applied because of time and resource constraints. For example, the review team did not check the reference lists of papers to identify additional studies that may have met the eligibility criteria. Nevertheless, every attempt to contact authors and request for more details or further data on their studies was made, but with little success.

In a number of papers, crowding was included as a confounder, and the text merely reported that it was adjusted for in the analysis (along with other confounders), but did not show the magnitude of crowding’s association with the health outcome. On other occasions, papers reported only those associations that were statistically significant. Since studies not reporting a quantitative association were excluded from this review, this biases the current review results towards finding an association between crowding and health outcomes. Additionally, few of the studies identified in this review could be labelled “high quality” and therefore, study results should be interpreted in the light of these limitations.

Furthermore, studies published before 2004 were not considered eligible for inclusion in this review. Still, coincidentally, a systematic review of essentially the same topic was published in 2004 (Office of the Deputy Prime Minister, 2004). While the criteria used were not the same as in this review, we refer interested readers to that document for a review of earlier literature.

Given the limitations inherent in studying this topic, we tentatively conclude that overcrowding may increase risks to health. Consistent exposure-response relationships would have added to the confidence with which associations could be considered causal, if they had been reported in a standard manner across studies. Yet, in several instances, these relationships were not consistent. Finally, we hope that future research will use standard measures and definitions of crowding to allow for pooled quantitative analyses to be carried out, while not precluding use of other measures if desired by investigators.

Contributors

Original review authorship: Harry Shannon (McMaster University, Hamilton, Canada), Claire Allen (Evidence Aid, United Kingdom), Daniella Dávila (Oxford, United Kingdom), Lizzie Fletcher-Wood (Evidence Aid, United Kingdom), Saurabh Gupta (Ambition Health Pvt Ltd, Gurgaon, India), Katharina Keck (Oxford, United Kingdom), Shona Lang (Evidence Aid, United Kingdom) and Doreen Allen Kahangire (PHSR Consulting Services LTD, Middlesex, United Kingdom).

Updated review prepared by Ramona Ludolph (Department of Public Health, Environmental and Social Determinants of Health, World Health Organization, Switzerland) and Mike Clarke (Evidence Aid, United Kingdom and Queen's University of Belfast, Northern Ireland) and commented on by Claire Allen, Shona Lang and Doreen Allen Kahangire.

Melissa Harden (Centre for Reviews and Dissemination, University of York, the United Kingdom) designed and conducted the search strategies for this review.

References

General references

Assar M. Guide to Sanitation in Natural Disasters. Geneva: WHO; 1971 (http://apps.who.int/iris/bitstream/10665/41031/1/10678_eng.pdf, accessed on 27 April 2015).

Braubach M. Key challenges of housing and health from WHO perspective. International Journal of Public Health. 2011;56:579–580.

Critical Appraisal Skills Programme (CASP) Checklists. CASP; 2013 (http://www.casp-uk.net/#!casp-tools-checklists/c18f8, accessed 1 May 2015).

Kennedy J, Parrack C. The History of Three Point Five Square Metres. In: Shelter Projects 2011–2012. Global Shelter Cluster; 2012 (http://www.sheltercasestudies.org/shelterprojects2011–2012/B01-3point5.pdf , accessed on 27 April 2015).

Lawrence RJ. Housing for health promotion. International Journal of Public Health. 2011; 56:577–578.

The Impact of Overcrowding on Health and Education: A review of the Evidence and Literature. London: Office of the Deputy Prime Minister; 2004 (http://dera.ioe.ac.uk/5073/1/138631.pdf, accessed on 27 April 2015).

Office of the United Nations High Commissioner for Human Rights and UN Habitat The Right to Adequate Housing. Fact Sheet No. 21/Rev.1. Geneva: Office of the United Nations High Commissioner for Human Rights; 2009 (http://www.ohchr.org/Documents/Publications/FS21_rev_1_Housing_en.pdf, accessed on 27 April 2015).

Shaw M. Housing and Public Health. Annual Reviews of Public Health. 2004;25:397–418.

References for papers included in the review of outcome 1a (tuberculosis)

Baker M, Das D, Venugopal K, Howden-Chapman P. Tuberculosis associated with household crowding in a developed country. Journal of Epidemiology & Community Health. 2008;62(8):715−21.

Cluver L, Orkin M, Moshabela M, Kuo C, Boyes M. The hidden harm of home-based care: pulmonary tuberculosis symptoms among children providing home medical care to HIV/AIDS-affected adults in South Africa. AIDS Care. 2013;25(6):748−55.

Corbett EL, Bandason T, Cheung YB, Makamure B, Dauya E, Munyati SS, et al. Prevalent infectious tuberculosis in Harare, Zimbabwe: burden, risk factors and implications for control. International Journal of Tuberculosis & Lung Disease. 2009;13(10):1231.

García-Sancho MC, García-García L, Báez-Saldaña R, Ponce-de-León A, Sifuentes-Osornio J, Bobadilla-del-Valle M, et al. Indoor pollution as an occupational risk factor for tuberculosis among women: a population-based, gender oriented, case-control study in Southern Mexico. Revista de Investigacion Clinica. 2009;61(5):392−8.

Goldhaber-Fiebert JD, Jeon CY, Cohen T, Murray MB. Diabetes mellitus and tuberculosis in countries with high tuberculosis burdens: individual risks and social determinants. International Journal of Epidemiology. 2011;40(2)417−28.

Gyawali N, Gurung R, Poudyal N, Amatya R, Niraula S, Jha P, et al. Prevalence of tuberculosis in household contacts of sputum smears positive cases and associated demographic risk factors. Nepal Medical College Journal. 2012;14(4):303−7.

Harling G, Castro MC. A spatial analysis of social and economic determinants of tuberculosis in Brazil. Health & Place. 2014;25:56−67.

Hill PC, Jackson-Sillah D, Donkor SA, Otu J, Adegbola RA, Lienhardt C. Risk factors for pulmonary tuberculosis: a clinic-based case control study in The Gambia. BMC Public Health. 2006;6(1):1.

Irfan SD, Faruque MO, Islam MU, Sanjoy SS, Afrin D, Hossain A. Socio-demographic determinants of adult tuberculosis: a matched case-control study in Bangladesh. American Journal of Infectious Diseases. 2017;13(3):32−7.

Jayanthi M, Shanthi G, et al. Socio economic status responsible for high prevalence of tuberculosis in Cuddalore District, Tamil Nadu, South India. Asian Journal of Microbiology, Biotechnology & Environmental Sciences. 2012;14(2):267−74.

Kapoor AK, Deepani V, Dhall M, Kapoor S. Pattern of socio-economic and health aspects among TB patients and controls. Ind J Tubercul 2016; 63(4): 230–5.

Khan FA, Fox GJ, Lee RS, Riva M, Benedetti A, Proulx JF, et al. Housing and tuberculosis in an Inuit village in northern Quebec: a case-control study. CMAJ Open. 2016;4(3):E496−506.

Lakshmi P, Virdi NK, Thakur J, Smith KR, Bates MN, Kumar R. Biomass fuel and risk of tuberculosis: a case-control study from Northern India. Journal of Epidemiology & Community Health. 2012;66(5):457−61.

Lienhardt C, Fielding K, Sillah J, Bah B, Gustafson P, Warndorff D, et al. Investigation of the risk factors for tuberculosis: a case-control study in three countries in West Africa. International Journal of Epidemiology. 2005;34(4):914−23.

Larcombe L, Nickerson P, Singer M, Robson R, Dantouze J, McKay L, et al. Housing conditions in 2 Canadian First Nations communities. International Journal of Circumpolar Health. 2012;70(2):141−53.

Pelissari DM, Diaz-Quijano FA. Household crowding as a potential mediator of socioeconomic determinants of tuberculosis incidence in Brazil. PLOS ONE. 2017;12(4):e0176116-e.

Sacchi FPC, Tatara MB, de Lima CC, et al. Genetic clustering of tuberculosis in an indigenous community of Brazil. Amer J Trop Med Hygiene 2018; 98(2): 372–5

Søborg B, Andersen AB, Melbye M, Wohlfahrt J, Andersson M, Biggar RJ, et al. Risk factors for Mycobacterium tuberculosis infection among children in Greenland. Bulletin of the World Health Organization. 2011;89(10):741−8.

Tesema C, Tadesse T, Gebrehiwot M, Tsegaw A, Weldegebreal F. Environmental and host-related determinants of tuberculosis in Metema district, north-west Ethiopia. Drug Healthcare & Patient Safety. 2015;7:87−95.

Tipayamongkholgul M, Podhipak A, Chearskul S, Sunakorn P. Factors associated with the development of tuberculosis in BCG immunized children. Southeast Asian Journal of Tropical Medicine & Public Health. 2005;36(1):145−50.

Tornee S, Kaewkungwal J, Fungladda W, Silachamroon U, Akarasewi P, Sunakorn P. Risk factors for tuberculosis infection among household contacts in Bangkok, Thailand. Southeast Asian Journal of Tropical Medicine & Public Health. 2004;35:375−83.

Tornee S, Kaewkungwal J, Fungladda W, Silachamroon U, Akarasewi P, Sunakorn P. The association between environmental factors and tuberculosis infection among household contacts. Southeast Asian Journal of Tropical Medicine & Public Health. 2005;36:221.

Wanyeki I, Olson S, Brassard P, Menzies D, Ross N, Behr M, et al. Dwellings, crowding, and tuberculosis in Montreal. Social Science & Medicine. 2006;63(2):501−11.

References for papers included in the review of outcome 1b (non-TB infectious diseases)

Alemayehu T, Mekasha A, Abebe T. Nasal carriage rate and antibiotic susceptibility pattern of Neisseria meningitidis in healthy Ethiopian children and adolescents: a cross-sectional study. PLOS ONE. 2017;12(10):e0187207-e.

Alvarado-Esquivel C, Pacheco-Vega SJ, Hernandez-Tinoco J, Berumen-Segovia LO, Sanchez-Anguiano LF, Estrada-Martinez S, et al. High prevalence of Toxoplasma gondii infection in miners: a case-control study in rural Durango, Mexico. Journal of Clinical Medicine Research. 2016;8(12):870−7.

Bailie RS, Stevens MR, McDonald E, Halpin S, Brewster D, Robinson G, et al. Skin infection, housing and social circumstances in children living in remote indigenous communities: testing conceptual and methodological approaches. BMC Public Health. 2005;5:128.

Brander RL, Walson JL, John-Stewart GC, Naulikha JM, Ndonye J, Kipkemoi N, et al. Correlates of multi-drug non-susceptibility in enteric bacteria isolated from Kenyan children with acute diarrhea. PLOS Neglected Tropical Diseases. 2017;11(10):e0005974-e.

Bruden DJT, Singleton R, Hawk CS, et al. Eighteen years of respiratory syncytial virus surveillance changes in seasonality and hospitalization rates in Southwestern Alaska native children. Pediatr Infect Dis J 2015; 34: 945–50.

Cardoso M, Cousens S, de Góes Siqueira L, Alves F, D'Angelo L. Crowding: risk factor or protective factor for lower respiratory disease in young children? BMC Public Health. 2004;4(1):19.

Chandrasekhar R, Sloan C, Mitchel E, Ndi D, Alden N, Thomas A, et al. Social determinants of influenza hospitalization in the United States. Influenza & Other Respiratory Viruses. 2017;11(6):479−88.

Chattopadhyay K. Prevalence and predictors of respiratory diseases among coal-based sponge iron plant workers: a cross-sectional study in Barjora, India. Annals of Global Health. 2017.

De Wals P, Deceuninck G, De Serres G, Boivin JF, Duval B, Remis R, et al. Effectiveness of serogroup C meningococcal polysaccharide vaccine: results from a case-control study in Quebec. Clinical Infectious Diseases. 2005;40(8):1116−22.

Deutch S, Labouriau R, Schonheyeder HC, Ostergaard L, Norgard B, Sorensen HT. Crowding as a risk factor of meningococcal disease in Danish preschool children: a nationwide population-based case-control study. Scandinavian Journal of Infectious Diseases. 2004;36(1):20−3.

Diaz J, Morales-Romero J, Pérez-Gil G, Bedolla-Barajas M, Delgado-Figueroa N, García-Román R, et al. Viral coinfection in acute respiratory infection in Mexican children treated by the emergency service: a cross-sectional study. Italian Journal of Pediatrics. 2015;41:33.

Doshi S, Silk BJ, Dutt D, Ahmed M, Cohen AL, Taylor TH, et al. Household-level risk factors for influenza among young children in Dhaka, Bangladesh: a case-control study. Tropical Medicine & International Health. 2015;20(6):719−29.

Firdaus G, Ahmad A. Relationship between housing and health: a cross-sectional study of an urban centre of India. Indoor & Built Environment. 2013;22(3):498−507.

Fonseca Lima EJ da, Mello MJG, Albuquerque M de FPM de, et al. Risk factors for community-acquired pneumonia in children under five years of age in the post-pneumococcal conjugate vaccine era in Brazil: a case control study. BMC Pediatrics. 2016;16(1):157.

Forshey BM, Laguna-Torres VA, Vilcarromero V, et al. Epidemiology of influenza-like illness in the Amazon Basin of Peru, 2008–2009. Influenza & Other Respiratory Viruses. 2010;4(4):235−43.

Gares V, Panico L, Castagne R, Delpierre C, Kelly-Irving M. The role of the early social environment on Epstein Barr virus infection: a prospective observational design using the Millennium Cohort Study. Epidemiology & Infection. 2017;145(16):3405−12.

Grant CC, Emery D, Milne T, et al. Risk factors for community-acquired pneumonia in pre-school-aged children. Journal of Paediatrics & Child Health. 2012;48(5):402−12.

Hegab DS, Kato AM, Kabbash IA, Dabish GM. Scabies among primary schoolchildren in Egypt: sociomedical environmental study in Kafr El-Sheikh administrative area. Clinical, Cosmetic & Investigational Dermatology. 2015;8:105−11.

Hosoglu S, Celen M, Geyik M, Akalin S, Ayaz C, Acemoglu H, et al. Risk factors for typhoid fever among adult patients in Diyarbakir, Turkey. Epidemiology & Infection. 2006;134(03):612−6.

Howie SRC, Schellenberg J, Chimah O, Ideh RC, Ebruke BE, Oluwalana C, et al. Childhood pneumonia and crowding, bed-sharing and nutrition: a case-control study from The Gambia. International Journal of Tuberculosis & Lung Disease. 2016;20(10):1405−15.

Hughes H, Matsui EC, et al. Pediatric asthma health disparities: race, hardship, housing, and asthma in a national survey. Academic Pediatrics. 2017;17(2):127−34.

Islam F, Sarma R, Debroy A, Kar S, Pal R. Profiling acute respiratory tract infections in children from Assam, India. Journal of Global Infectious Diseases. 2013;5(1):8−14.

Jaine R, Baker M, Venugopal K. Acute rheumatic fever associated with household crowding in a developed country. Pediatric Infectious Disease Journal. 2011;30(4):315−9.

Jarousha AM, Afifi AA. Epidemiology and risk factors associated with developing bacterial meningitis among children in Gaza Strip. Iranian Journal of Public Health. 2014;43(9):1176−83.

Kohen DE, Bougie E, Guèvremont A. Housing and health among Inuit children. Health Reports. 2015;26(11):21−7.

Kristensen I, Olsen J. Determinants of acute respiratory infections in Soweto − a population-based birth cohort. South African Medical Journal. 2006;96(7):633−40.

Krueger WS, Hilborn ED, Converse RR, Wade TJ. Environmental risk factors associated with Helicobacter pylori seroprevalence in the United States: a cross-sectional analysis of NHANES data. Epidemiology & Infection. 2015;143(12):2520−31.

Kumar SG, Majumdar A, Kumar V, Naik BN, Selvaraj K, Balajee K. Prevalence of acute respiratory infection among under-five children in urban and rural areas of Puducherry, India. Journal of Natural Science, Biology & Medicine. 2015;6(1):3−6.Larson E, Ferng Y-H, Wong-McLoughlin J, et al. Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. Public Health Reports. 2010;125(2):178−91.

Larson E, Ferng Y-H, Wong-McLoughlin J, et al. Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. Public Health Reports. 2010;125(2):178−91.

MacLennan J, Kafatos G, Neal K, Andrews N, Cameron JC, Roberts R, et al. Social behavior and meningococcal carriage in British teenagers. Emerging Infectious Diseases. 2006;12(6):950−7.

Mathew J, Singhi S, Ray P, Nilsson A. Predictors of bacterial community acquired pneumonia in children: preliminary results from CAPES (Community Acquired Pneumonia Etiology Study). International Journal of Infectious Diseases. 2014;21(S1):239.

Mirabel M, Fauchier T, Bacquelin R, Tafflet M, Germain A, Robillard C, et al. Echocardiography screening to detect rheumatic heart disease: a cohort study of schoolchildren in French Pacific Islands. International Journal of Cardiology. 2015;188:89−95.

Mitra DK, Mullany LC, Harrison M, Mannan I, Shah R, Begum N, et al. Incidence and risk factors of neonatal infections in a rural Bangladeshi population: a community-based prospective study. Journal of Health, Population & Nutrition. 2018;37(1):6.

Murray CJ, Vos T, Lozano R, Naghavi M, Flaxman AD, Michaud C, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990−2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2197−223.

Norheim G, Sadarangani M, Omar O, et al. Association between population prevalence of smoking and incidence of meningococcal disease in Norway, Sweden, Denmark and the Netherlands between 1975 and 2009: a population-based time series analysis. BMJ Open. 2014;4(2):e003312.

Okello E KB, Sebatta E, Kayima J, Kuteesa M, et al. Socioeconomic and environmental risk factors among rheumatic heart disease patients in Uganda. PLOS ONE. 2012;7(8):3−8.

Olea A, Matute I, González C, Delgado I, Poffald L, Pedroni E, et al. Case-control study of risk factors for meningococcal disease in Chile. Emerging Infectious Diseases. 2017;23(7):1070−8.

Phillips DI, Osmond C. Is susceptibility to chronic rheumatic heart disease determined in early infancy? An analysis of mortality in Britain during the 20th century. Global Cardiology Science & Practice. 2014;2014(4):464−72.

Prietsch SOM, Fischer GB, César JA, Lempek BS, Barbosa Jr. LV, Zogbi L, et al. Acute lower respiratory illness in under-five children in Rio Grande, Rio Grande do Sul State, Brazil: prevalence and risk factors. Cadernos de Saúde Pública. 2018;24:1429−38.

Rao GG, Blackstock AJ, Derado G, López B, Cuéllar V, Juliao P, et al. Water, sanitation and hygiene risk factors for soil-transmitted helminth infection in Nueva Santa Rosa, Guatemala 2010. Conference paper presented at the 62nd Annual Meeting of the American Society of Tropical Medicine & Hygiene, Washington (DC), 2013 (abstract 277).

Reisman J, Rudolph K, Bruden D, Hurlburt D, MG B, Hennessy T. Risk factors for pneumococcal colonization of the nasopharynx in Alaska Native adults and children. Journal of the Pediatric Infectious Diseases Society. 2014;3(2):104−11.

Riaz BK, Selim S, Karim MN, Chowdhury KN, Chowdhury SH, Rahman MR. Risk factors of rheumatic heart disease in Bangladesh: a case-control study. Journal of Health, Popululation & Nutrition. 2013;31(1):70−7.

Romani L, Whitfeld MJ, Koroivueta J, et al. The epidemiology of scabies and impetigo in relation to demographic and residential characteristics: baseline findings from the Skin Health Intervention Fiji Trial. Amer J Trop Med Hygiene 2017; 97: 845–50

Sekhar S, Chakraborti A, Kumar R. Haemophilus influenzae colonization and its risk factors in children aged <2 years in Northern India. Epidemiology & Infection. 2009;137(2):156−60.

Sinha B, Vibha, Singla R, Chowdhury R. Allergic rhinitis: a neglected disease – a community based assessment among adults in Delhi. Journal of Postgraduate Medicine. 2015; 61(3):169−75.

Sloan C, Chandrasekhar R, Mitchel E, Schaffner W, Lindegren ML. Socioeconomic disparities and influenza hospitalizations, Tennessee, USA. Emerging Infectious Diseases. 2015; 21(9):1602−10.

Tam K, Yousey-Hindes K, Hadler JL. Influenza-related hospitalization of adults associated with low census tract socioeconomic status and female sex in New Haven County, Connecticut, 2007−2011. Influenza & Other Respiratory Viruses. 2014;8(3):274−81.

Tin Tin S, Woodward A, Saraf R, Berry S, Atatoa Carr P, Morton SMB, Grant CC. Internal living environment and respiratory disease in children: findings from the Growing Up in New Zealand longitudinal child cohort study. Environmental Health. 2016;15(1):120.

Tosas Auguet O, Betley JR, Stabler RA, Patel A, Ioannou A, Marbach H, et al. Evidence for community transmission of community-associated but not health-care-associated methicillin-resistant Staphylococcus aureus strains linked to social and material deprivation: spatial analysis of cross-sectional data. PLOS Medicine. 2016;13(1):e1001944-e.

Tse SM, Weiler H, Kovesi T. Food insecurity, vitamin D insufficiency and respiratory infections among Inuit children. International Journal of Circumpolar Health. 2016;75.

Verani JR, Groome MJ, Zar HJ, Zell ER, Kapongo CN, Nzenze SA, et al. Risk factors for presumed bacterial pneumonia among HIV-uninfected children hospitalized in Soweto, South Africa. Pediatric Infectious Disease Journal. 2016;35(11):1169−74.

Vieira MT, Marlow MA, Aguiar-Alves F, et al. Living conditions as a driving factor in persistent methicillin-resistant Staphylococcus aureus colonization among HIV-infected youth. Pediatric Infectious Disease Journal. 2016;35(10):1126−31.

Vincenti-Gonzalez MF, Grillet M-E, Velasco-Salas ZI, Lizarazo EF, Amarista MA, Sierra GM, et al. Spatial analysis of dengue seroprevalence and modeling of transmission risk factors in a dengue hyperendemic city of Venezuela. PLOS Neglected Tropical Diseases. 2017;11(1):e0005317-e.

Weber A, Fuchs N, Kutzora S, Hendrowarsito L, Nennstiel-Ratzel U, von Mutius E, et al. Exploring the associations between parent-reported biological indoor environment and airway-related symptoms and allergic diseases in children. International Journal of Hygiene & Environmental Health. 2017;220(8):1333−9.

Yousey-Hindes KM, Hadler JL. Neighborhood socioeconomic status and influenza hospitalizations among children: New Haven County, Connecticut, 2003–2010. American Journal of Public Health. 2011;101(9):1785−9.

References for papers included in the review of outcome 2 (gastroenteritis and diarrhoeal diseases)

Abu Mourad T. Palestinian refugee conditions associated with intestinal parasites and diarrhoea: Nuseirat refugee camp as a case study. Public Health. 2004;118(2):131−42.

El-Gilany AH, Hammad S. Epidemiology of diarrhoeal diseases among children under age 5 years in Dakahlia, Egypt. Eastern Mediterranean Health Journal. 2005;11(4):762−75.

Etiler N, Velipasaoglu S, Aktekin M. Risk factors for overall and persistent diarrhoea in infancy in Antalya, Turkey: a cohort study. Public Health. 2004;118(1):62−9.

Ferrer SR, Strina A, Jesus SR, Ribeiro HC, Cairncross S, Rodrigues LC, et al. A hierarchical model for studying risk factors for childhood diarrhoea: a case-control study in a middle-income country. International Journal of Epidemiology. 2008;37(4):805−15.

Harper SL, Edge VL, Ford J, Thomas MK, Pearl DL, Shirley J, et al. Acute gastrointestinal illness in two Inuit communities: burden of illness in Rigolet and Iqaluit, Canada. Epidemiology & Infection. 2015;143(14):3048−63.

Kyle RG, Kukanova M, Campbell M, Wolfe I, Powell P, Callery P. Childhood disadvantage and emergency admission rates for common presentations in London: an exploratory analysis. Archives of Disease in Childhood. 2011;96(3):1093−6.

Mohan VR, Karthikeyan R, Babji S, McGrath M, Shrestha S, Shrestha J, et al. Rotavirus infection and disease in a multisite birth cohort: results from the MAL-ED Study. Journal of Infectious Diseases. 2017;216(3):305−16.

Monasta L, Andersson N, Ledogar RJ, Cockcroft A. Minority health and small numbers epidemiology: a case study of living conditions and the health of children in 5 foreign Romá camps in Italy. American Journal of Public Health. 2008;98(11):2035−41.

Okour A, Al-Ghazawi Z, Gharaibeh M. Diarrhea among children and the household conditions in a low-income rural community in the Jordan Valley. Jordan Medical Journal. 2012;46(2).

Perry S, de la Luz Sanchez M, Hurst PK, Parsonnet J. Household Transmission of Gastroenteritis. Emerging Infectious Diseases. 2005; 11:1093–1096.

Pezzani B, Ciarmela ML, Apezteguía MC, Molina N, Orden A, Rosa D, Minvielle MC. Intestinal parasitoses in suburban and rural schoolchildren in Argentina. Revista Patol Trop. 2012;41:63–73.

Quigley MA, Cumberland P, Cowden JM, Rodrigues LC. How protective is breast feeding against diarrhoeal disease in infants in 1990s England? A case-control study. Archives of Disease in Childhood. 2006;91(3):245−50.

Ramani SV, Fruhauf T, Dutta A. On diarrhoea in adolescents and school toilets: insights from an Indian village school study. Journal of Development Studies. 2017;53(11):1899−914.

References for papers included in the review of outcomes 3 and 5 – mental health including stress

Al-Hemiary NJ, Hashim MT, Al-Diwan JK, Razzaq EA. Alcohol and drug abuse in post-conflict Iraq. Journal of the Faculty of Medicine, Baghdad University. 2015;57(4):290−4.

Barnes M, Butt S, Tomaszewski W. The duration of bad housing and children's well-being in Britain. Housing Studies. 2011;26(1):155−76.

Cabieses B, Pickett KE, Tunstall H. Comparing sociodemographic factors associated with disability between immigrants and the Chilean-born: are there different stories to tell? International Journal of Environmental Research & Public Health. 2012;9(12):4403−32.

Faisal-Cury A, Menezes P, Araya R, Zugaib M. Common mental disorders during pregnancy: prevalence and associated factors among low-income women in São Paulo, Brazil. Archives of Women's Mental Health. 2009;12(5):335−43.

Firdaus G. Increasing rate of psychological distress in urban households: how does income matter? Community Mental Health Journal. 2017.

Gray AP, Richer F, Harper S. Individual- and community-level determinants of Inuit youth mental wellness. Canadian Journal of Public Health. 2016;107(3):e251−e7.

Kimhy D, Harlap S, Fennig S, Deutsch L, Draiman BG, Corcoran C, et al. Maternal household crowding during pregnancy and the offspring's risk of schizophrenia. Schizophrenia Research. 2006;86(1):23−9.

Kohen DE, Bougie E, Guèvremont A. Housing and health among Inuit children. Health Reports. 2015;26(11):21−7.

Pierse N, Carter K, Bierre S, Law D, Howden-Chapman P. Examining the role of tenure, household crowding and housing affordability on psychological distress, using longitudinal data. Journal of Epidemiology & Community Health. 2016;70(10):961−6.

Regoeczi WC. Crowding in context: an examination of the differential responses of men and women to high-density living environments. Journal of Health & Social Behavior. 2008;49(3):254−68.

Riva M, Larsen CVL, Bjerregaard P. Household crowding and psychosocial health among Inuit in Greenland. International Journal of Public Health. 2014a;59(5):739−48.

Riva M, Plusquellec P, Juster R-P, Laouan-Sidi EA, Abdous B, Lucas M, et al. Household crowding is associated with higher allostatic load among the Inuit. Journal of Epidemiology & Community Health. 2014b:jech-2013-203270.

Waters SF, Boyce WT, Eskenazi B, Alkon A. The impact of maternal depression and overcrowded housing on associations between autonomic nervous system reactivity and externalizing behavior problems in vulnerable Latino children. Psychophysiol. 2016; 53(1): 97–104.

Additional reference

Wells NM Harris JD. Housing quality, psychological distress, and the mediating role of social withdrawal: A longitudinal study of low-income women. Journal of Environmental Psychology, 2007;27(1):69-78

References for papers included in the review of outcome 4 – sleep disorders

Chambers EC, Pichardo MS, Rosenbaum E. Sleep and the housing and neighborhood environment of urban Latino adults living in low-income housing: the AHOME Study. Behavioral Sleep Medicine. 2016;14(2):169−84.

Johnson DA, Drake C, Joseph CLM, Krajenta R, Hudgel DW, Cassidy-Bushrow AE. Influence of neighbourhood-level crowding on sleep-disordered breathing severity: mediation by body size. Journal of Sleep Research. 2015;24(5):559−65.

van der Spuy I, Karunanayake CP, Dosman JA, McMullin K, Zhao G, Abonyi S, et al. Determinants of excessive daytime sleepiness in two First Nation communities. BMC Pulmonary Medicine. 2017;17(1):192.

Appendices

Appendix 1 Search strategy for Embase – Original search conducted in January 2015

EMBASE via OvidSP

http://ovidsp.ovid.com/

1974 to Jan 16th 2015 (week 4)

Searched on: 19 January 2015

Records retrieved: 1035

1 (house or houses or housing).ti, ab. (87464)

2 (home or homes or household or households).ti, ab. (263967)

3 (dwelling* or residence* or accommodation or slum*).ti, ab. (77173)

4 (living adj2 (condition* or standard*)).ti, ab. (8731)

5 housing/ or home for the aged/ (27074)

6 or/1-5 (426234)

7 "crowding (area)"/ (516)

8 (crowd* or overcrowd*).ti, ab. (15523)

9 7 or 8 (15635)

10 6 and 9 (2011)

11 Animal/ or animal experiment/ or nonhuman/ (6342628)

12 expr human/ or human experiment/ (15383504)

13 11 not (11 and 12) (5024501)

14 10 not 13 (1911)

15 limit 14 to yr="2004 -current" (1035)

Key:

/ = indexing term (EMTREE heading)
expr = exploded indexing term (EMTREE heading)
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)

Appendix 2 Search strategy for ERIC – Original search conducted in January 2015

ERIC (Education Resource Information Center database) via EBSCO

https://www.ebsco.com/

1965 – 2014

Searched on: 20th January 2015

Records retrieved: 74

#	Query	Results
S12	S7 AND S10 Limiters – date published: 20040101	74
S11	S7 AND S10	246
S10	S8 OR S9	1 624
S9	TI ((crowd* or overcrowd*)) OR AB ((crowd* or overcrowd*))	1 559
S8	DE "Crowding"	151
S7	S1 OR S2 OR S3 OR S4 OR S5 OR S6	76 459
S6	DE "Living Standards"	745
S5	DE "Housing" OR DE "Emergency Shelters" OR DE "Group Homes"	3 442
S4	TI ((living N2 (condition* or standard*))) OR AB ((living N2 (condition* or standard*)))	1 376
S3	TI ((dwelling* or residence* or accommodation or slum*)) OR AB ((dwelling* or residence* or accommodation or slum*))	10 023
S2	TI ((home or homes or household or households)) OR AB ((home or homes or household or households))	50 527
S1	TI ((house or houses or housing)) OR AB ((house or houses or housing))	17 798

Key:

DE = indexing term
* = truncation
TI = words in the title
AB = words in the abstract
N2 = terms within two words of each other (any order)

Appendix 3 Search strategy for MEDLINE – original search conducted in January 2015

MEDLINE In-Process and Other Non-Indexed Citations and MEDLINE via OvidSP
http://ovidsp.ovid.com/

1946 to 15 January 2015

Searched on: 19 January 2015

Records retrieved: 833

1 (house or houses or housing).ti,ab. (65495)

2 (home or homes or household or households).ti,ab. (207955)

3 (dwelling* or residence* or accommodation or slum*).ti,ab. (63915)

4 (living adj2 (condition* or standard*)).ti,ab. (7696)

5 housing/ or housing for the elderly/ or public housing/ (15808)

6 or/1–5 (332082)

7 crowding/ (2295)

8 (crowd* or overcrowd*).ti,ab. (13770)

9 7 or 8 (14830)

10 6 and 9 (1921)

11 exp animals/ not humans/ (3969827)

12 10 not 11 (1787)

13 limit 12 to yr="2004 -Current" (833)

Key:

/ = indexing term (MeSH heading)
exp = exploded indexing term (MeSH heading)
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)

Appendix 4 Search strategy for PsycINFO – original search conducted in January 2015

PsycINFO via OvidSP

http://ovidsp.ovid.com/

1806 to week 2 January 2015

Searched on: 19 January 2015

Records retrieved: 299

1 (house or houses or housing).ti,ab. (23324)

2 (home or homes or household or households).ti,ab. (110658)

3 (dwelling* or residence* or accommodation or slum*).ti,ab. (24121)

4 (living adj2 (condition* or standard*)).ti,ab. (3102)

5 exp housing/ (7038)

6 1 or 2 or 3 or 4 or 5 (154146)

7 crowding/ (896)

8 (crowd* or overcrowd*).ti,ab. (5046)

9 7 or 8 (5147)

10 6 and 9 (781)

11 (animal or animals or rat or rats or mouse or mice or hamster or hamsters or dog or dogs or cat or cats or bovine or sheep or ovine or pig or pigs).ti,id,de. (221075)

12 10 not 11 (736)

13 limit 12 to yr="2004 -Current" (299)

Key:

/ = indexing term
exp = exploded indexing term
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)
id = key concepts field
de = descriptors field

Appendix 5 Search strategy for Science Citation Index – original search conducted in January 2015

Science Citation Index via Web of Science

http://thomsonreuters.com/

1900 – 19 January 2015

Searched on: 19 January 2015

Records retrieved: 770

# 10	770	#7 NOT #8 *Indexes=SCI-EXPANDED Timespan=2004–2015*
# 9	1 244	#7 NOT #8 *Indexes=SCI-EXPANDED Timespan=all years*
# 8	1 957 026	TI=(rat or rats or mouse or mice or hamster or hamsters or animal or animals or dog or dogs or cat or cats or bovine or sheep) *Indexes=SCI-EXPANDED Timespan=all years*
# 7	1 304	#6 AND #5 *Indexes=SCI-EXPANDED Timespan=all years*
# 6	20 203	TS=(crowd* or overcrowd*) *Indexes=SCI-EXPANDED Timespan=all years*
# 5	399 337	#4 OR #3 OR #2 OR #1 *Indexes=SCI-EXPANDED Timespan=all years*
# 4	7 890	TS=(living NEAR/2 (condition* or standard*)) *Indexes=SCI-EXPANDED Timespan=all years*
# 3	97 513	TS=(dwelling* or residence* or accommodation or slum*) *Indexes=SCI-EXPANDED Timespan=all years*
# 2	205 942	TS=(home or homes or household or households) *Indexes=SCI-EXPANDED Timespan=all years*
# 1	107 262	TS=(house or houses or housing) *Indexes=SCI-EXPANDED Timespan=all years*

Key:

TS = topic tag; searches terms in title, abstract, author keywords and keywords plus fields
* = truncation
NEAR/2 = terms within 2 words of each other
TI = terms in the title field

Appendix 6 Search strategy for Social Policy and Practice – original search conducted in January 2015

Social Policy and Practice via OvidSP

http://ovidsp.ovid.com/

Inception – November 2014

Searched on: 19 January 2015

Records retrieved: 352

1 (house or houses or housing).ti,ab,de,hw. (54026)

2 (home or homes or household or households).ti,ab,de,hw. (52778)

3 (dwelling* or residence* or accommodation or slum*).ti,ab,de,hw. (13548)

4 (living adj2 (condition* or standard*)).ti,ab,de,hw. (1396)

5 or/1-4 (96153)

6 (crowd* or overcrowd*).ti,ab,de,hw. (769)

7 5 and 6 (566)

8 limit 7 to yr="2004 -Current" (352)

Key:

* = truncation
.ti,ab.de,hw = terms in either title or abstract or descriptor or heading word fields
adj2 = terms within two words of each other (any order)

Appendix 7 Search strategy for Social Science Citation Index – original search conducted in January 2015

Social Science Citation Index via Web of Science

http://thomsonreuters.com/

1956 – 19 January 2015

Searched on: 19 January 2015

Records retrieved: 620

# 10	620	#7 NOT #8 *Indexes=SSCI Timespan=2004–2015*
# 9	955	#7 NOT #8 *Indexes=SSCI Timespan=all years*
# 8	55 922	TI=(rat or rats or mouse or mice or hamster or hamsters or animal or animals or dog or dogs or cat or cats or bovine or sheep) *Indexes=SSCI Timespan=all years*
# 7	966	#6 AND #5 *Indexes=SSCI Timespan=all years*
# 6	7 129	TS=(crowd* or overcrowd*) *Indexes=SSCI Timespan=all years*
# 5	225 368	#4 OR #3 OR #2 OR #1 *Indexes=SSCI Timespan=all years*
# 4	6 907	TS=(living NEAR/2 (condition* or standard*)) *Indexes=SSCI Timespan=all years*
# 3	33 835	TS=(dwelling* or residence* or accommodation or slum*) *Indexes=SSCI Timespan=all years*
# 2	148 675	TS=(home or homes or household or households) *Indexes=SSCI Timespan=all years*
# 1	54 480	TS=(house or houses or housing) *Indexes=SSCI Timespan=all years*

Key:

TS = topic tag; searches terms in title, abstract, author keywords and keywords plus fields
* = truncation
NEAR/2 = terms within two words of each other
TI = terms in the title field

Appendix 8 Search strategy for SciELO – original search conducted in March 2015

SciELO

http://www.scielo.br/

Searched on: 13 March 2015

Records retrieved: 37

Due to the limited search features available on this database a simple search was performed using the Articles search with the following strategy:

Crowd or crowded or crowding or overcrowd or overcrowded or overcrowding

AND

House or houses or housing or home or homes or household or household or dwelling or dwellings or residence or residences or accommodation or slum or slums

37 records retrieved before deduplication

18 after deduplication (19 duplicates)

14/18 = pre-2004

Total = 4 new records for screening

Appendix 9 List of studies excluded after full-text screening phase during original search with reasons for exclusion

Articles were deemed to be "excludes" if the following were noted. The reasons for exclusions across the studies included the following:

- Not a priority outcome
- Language (not English)
- More than five years between study and publication
- No definition of crowding provided (including crowding was part of an index and cannot be split out)
- Definition of crowding was people per household
- Paper was review not primary research
- No quantitative measure of association between crowding and health outcome

Note that for many papers, we attempted to contact (or contacted) the corresponding author for more information (e.g. definition of crowding or value of odds ratio). As stated in the main text, their requests for additional information had mixed success.

Study	Reason for exclusion
Outcome 1a: TB	
Ahmad, S. R. and Velhal G. D. (2013). Study of treatment outcome of new sputum smear positive TB cases under dots–strategy. International Journal of Pharma and Bio Sciences, 4(3), B1215–B1222.	Cases only
Aleksic, E, Merker M, et al. (2013). First molecular epidemiology study of Mycobacterium tuberculosis in Kiribati. PLoS ONE Electronic Resource, 8(1), e55423.	Cases only
Djomo P, Mangtani P, Rodrigues L, Ronning K, Cappelen I, Heldal E, Abubakar I (2013). Effectiveness of BCG against tuberculosis in adults: Ean historical cohort study. European Journal of Epidemiology, 28: S15–S16	No definition of crowding
Bexson, T. (2004). Too close encounters spearhead revival of tuberculosis. Environmental Health News, 19(28), 6–7.	No quantitative data reported
Pelly, T. F, C. F. Santillan, et al. (2005). Tuberculosis skin testing, anergy and protein malnutrition in Peru. International Journal of Tuberculosis & Lung Disease, 9(9), 977–984.	No association measure
Bhatt, G, Vyas S, et al. (2012). An epidemiological study of multi drug resistant tuberculosis cases registered under Revised National Tuberculosis Control Programme of Ahmedabad City. Indian Journal of Tuberculosis, 59(1), 18–27.	Cases only
Bloss, E, Macintyre K, et al. (2010). Gender differences among tb patients in hardto-reach pastoralist regions in northern Kenya. American Journal of Epidemiology, 171: S42.	No association measure
Canadian Tuberculosis Committee. (2007). Housing conditions that serve as risk factors for tuberculosis infection and disease. An Advisory Committee Statement (ACS). Canada Communicable Disease Report = Releve des Maladies Transmissibles au Canada, 33(ACS-9), 1–13.	Not primary data
Che, D, Cailhol J, et al. (2004). Epidemiology of tuberculosis in Ile-de-France in 2001. Revue des Maladies Respiratoires, 21(2 Pt 1), 272–278.	No person per household data reported
Couceiro, L, Santana P, et al. (2011). Pulmonary tuberculosis and risk factors in Portugal: a spatial analysis. International Journal of Tuberculosis & Lung Disease, 15(11), 1445–1454.	No definition of crowding

Study	Reason for exclusion
Gupta, S, Bandyopadhyay D, et al. (2012). A sociodemographic study of multidrug resistant tuberculosis cases from DOTS clinics of Kolkata. Journal of the Indian Medical Association, 110(10), 723–725.	cases only
Gustafson, P, Gomes V. F, et al. (2004). Tuberculosis in Bissau: incidence and risk factors in an urban community in sub-Saharan Africa. International Journal of Epidemiology, 33(1), 163–172.	> 5 years since study
Hasan, K, Jolly P, et al. (2006). Viral etiology of pneumonia in a cohort of newborns till 24 months of age in Rural Mirzapur, Bangladesh. Scandinavian Journal of Infectious Diseases, 38(8), 690–695.	No person per room data reported
Keshavjee, S, Gelmanova I. Y, et al. (2008). Treating multidrug-resistant tuberculosis in Tomsk, Russia: Developing programs that address the linkage between poverty and disease. Reducing the Impact of Poverty on Health and Human Development: Scientific Approaches, Blackwell Publishing Inc.: 1–11.	No quantitative data
Khurram, M, Khaar H. T, et al. (2012). Multidrug-resistant tuberculosis in Rawalpindi, Pakistan. Journal of Infection in Developing Countries, 6(1), 29–32.	Cases only
London Housing (2004). Overcrowded housing and the effects on London's communities.Publisher's website (PDF) (as at 17/11/04)– http://www.londonhousing.gov.uk/upload/public/attachments/338/briefing_overcrowdingcommAMENDED2004.pdf	No association measure
Lonnroth, K. and Raviglione M. (2008). Global epidemiology of tuberculosis: prospects for control. Seminars in Respiratory & Critical Care Medicine, 29(5), 481–491.	review
Machado Leyva, P. H, Valdes Diaz S, et al. (2007). Risk of the adults living with sputum-positive carriers for contracting tuberculosis. Revista Cubana de Medicina Tropical, 59(1), 30–34.	Language
Mateus-Solarte, J. C. and Carvajal-Barona R. (2008). Factors predictive of adherence to tuberculosis treatment, Valle del Cauca, Colombia. International Journal of Tuberculosis & Lung Disease, 12(5), 520–526.	Cases only
McDonald, M. I, Towers R. J, et al. (2006). Low rates of streptococcal pharyngitis and high rates of pyoderma in Australian aboriginal communities where acute rheumatic fever is hyperendemic. Clinical Infectious Diseases, 43(6), 683–689	No association measure
Nelliyanil, M, Sharada M. P, et al. (2012). A study of the socio-demographic profile and treatment outcome of paediatric tuberculosis patients in Bangalore Mahanagar Palike area. Indian Journal of Tuberculosis, 59(4), 207–213.	No definition of crowding
Reitmanova, S. and Gustafson D. (2012). Rethinking immigrant tuberculosis control in Canada: from medical surveillance to tackling social determinants of health. Journal of Immigrant & Minority Health, 14(1), 6–13.	Not primary data
San Pedro, A. and Oliveira R. M. (2013). Tuberculosis and socioeconomic indicators: systematic review of the literature. Pan American Journal of Public Health, 33(4), 294–301.	Language
Scotto, G, Saracino A, et al. (2004). Epidemiology of tuberculosis in immigrant patients hospitalized in Infectious Diseases Units in Italy: multicentric study. Infezioni in Medicina, 12(4), 245–251.	Language
Singleton, R. J, Valery P. C, et al. (2014). Indigenous children from three countries with non-cystic fibrosis chronic suppurative lung disease/bronchiectasis. Pediatric Pulmonology, 49(2), 189–200.	No association measure
Shafee, M, Abbas F, et al. (2014). Hematological profile and risk factors associated with pulmonary tuberculosis patients in Quetta, Pakistan. Pakistan Journal of Medical Sciences, 30(1), 36–40.	No person per household data reported
Tanrikulu, A. C, Abakay A, et al. (2007). Factors affecting incidence of tuberculosis in Diyarbakir. Tuberkuloz ve Toraks, 55(1), 18–23.	Language

Study	Reason for exclusion
Thompson, L. (2004). Victorian values. Public Health News 23 Feb.Http://www.publichealthnews.com/	No association measure
Top, R, Boshuizen H, et al. (2013). Similar seasonal peak in clustered and unique extra-pulmonary tuberculosis notifications: winter crowding hypothesis ruled out? International Journal of Tuberculosis & Lung Disease, 17(11), 1466–1471.	Only cases
Wingfield, T, Schumacher S. G, et al. (2014). The seasonality of tuberculosis, sunlight, vitamin D, and household crowding. Journal of Infectious Diseases, 210(5), 774–783.	No association measure
Yasar, K. K, Pehlivanoglu F, et al. (2011). Tuberculous meningoencephalitis with severe neurological sequel in an immigrant child. Journal of Neurosciences in Rural Practice, 2(1), 77–79.	Cases only
Zaman, F. A, Sheikh S, et al. (2014). An epidemiological study of newly diagnosed sputum positive tuberculosis patients in Dhubri district, Assam, India and the factors influencing their compliance to treatment. Journal of Natural Science Biology & Medicine, 5(2), 415–420.	Cases only
Zammarchi, L, Bartalesi F, et al. (2014). Tuberculosis in tropical areas and immigrants. Mediterranean Journal of Hematology & Infectious Diseases, 6(1), e2014043.	Review
Suddin Siddiqui, E, Ejaz K, et al. (2010). Investment in paediatric tuberculosis prevention in Pakistan: loss or gain? JPMA–Journal of the Pakistan Medical Association, 60(11), 897–901.	Cases only
Outcome 1b: Other infectious diseases	
Adamia, N, Chkhaidze I, et al. (2012). Prevalence of bronchitis and revealing of the risk factors in the children's population. World Allergy Organization Journal, 5: S185.	No definition of crowding
Mitra, D. K. Risk factors and care seeking for neonatal infections: A community based prosepective study in rural Bangladesh. Dissertation Abstracts International: Section B: The Sciences and Engineering 2013; 74(3–B (E)).	No quantitative data
Akintola, O. and Hangulu L. (2014). Infection control in home-based care for people living with HIV/AIDS/TB in South Africa: an exploratory study. Global Public Health, 9(4), 382–393.	No quantitative data
Banerji, A, Greenberg D, et al. (2009). Risk factors and viruses associated with hospitalization due to lower respiratory tract infections in Canadian Inuit children: a case-control study. Pediatric Infectious Disease Journal, 28(8), 697–701.	No person per household data reported
Basta, N, Sow S, et al. (2012). Age-specific prevalence estimates and risk factors for asymptomatic Neisseria meningitidis carriage in Bamako, Mali. International Journal of Infectious Diseases, 16: e211.	No disease outcome
Bourrous, M, Drais G, et al. (2010). Seroprevalence of the viral hepatitis a in febrile icteric children living in the area of Marrakech, Morroco. FrenchSeroprevalence de l'hepatite virale A dans les icteres febriles chez les enfants de la region de Marrakech, Maroc. Journal de Pediatrie et de Puericulture, 23(2), 76–81.	Language
Del Castillo-Sanchez, D. L, E. Sabag-Ruiz, et al. (2006). Community-acquired pneumonia: risk focus and family functionality. Revista Medica del Instituto Mexicano del Seguro Social, 44(1), 35–38.	Language
Brandon, S. (2008). An ill wind. Inside Housing 5th December.	No primary data
Braubach, M, Jacobs D. E, et al. (2011). Environmental burden of disease associated with inadequate housing: methods for quantifying health impacts of selected housing risks in the WHO European region. Denmark, WHO Regional Office for Europe.	Review

Study	Reason for exclusion
Charania, N. A. and Tsuji L. J. (2011). The 2009 H1N1 pandemic response in remote First Nation communities of Subarctic Ontario: barriers and improvements from a health care services perspective. International Journal of Circumpolar Health, 70(5), 564–575.	No quantitative data
Charania, N. A. and Tsuji L. J. (2013). Assessing the effectiveness and feasibility of implementing mitigation measures for an influenza pandemic in remote and isolated First Nations communities: a qualitative community-based participatory research approach. Rural & Remote Health, 13(4), 2566.	No quantitative data
Chisti, M. J, Duke T, et al. (2011). Co-morbidity: exploring the clinical overlap between pneumonia and diarrhoea in a hospital in Dhaka, Bangladesh. Annals of Tropical Paediatrics, 31(4), 311–319.	Cases only
Coen, P. G, Tully J, et al. (2006). Is it exposure to cigarette smoke or to smokers which increases the risk of meningococcal disease in teenagers? International Journal of Epidemiology, 35(2), 330–336.	No crowding definition; no quant. Data presented
Colombo, C, Galli A, et al. (2011). Sociodemographic and health conditions of the Roma population in Milan. Epidemiologia e Prevenzione, 35(5–6), 282–291.	Language
Colosia, A. D, Masaquel A, et al. (2012). Residential crowding and severe respiratory syncytial virus disease among infants and young children: a systematic literature review. BMC Infectious Diseases, 12: 95.	Review
Cooper, P. J, Chico M. E, et al. (2004). Risk factors for atopy among school children in a rural area of Latin America. Clinical & Experimental Allergy, 34(6), 845–852.	Atopy
Curiel-Reyes, R, Barcenas-Lopez R. M, et al. (2013). Respiratory tract infections in indigenous migrant Mexican day-laboring families' children. Revista de Salud Publica, 15(2), 271–280.	Language
Dalecha, D. (2012). Meningitis outbreak investigation-Kembata zone, Southern Ethiopia, February, 2011. International Journal of Infectious Diseases, 16: e252.	Not priority outcome
Dayan, G. H, Panero M. S, et al. (2004). Varicella seroprevalence and molecular epidemiology of varicella-zoster virus in Argentina, 2002. Journal of Clinical Microbiology, 42(12), 5698–5704.	Not priority outcome
Dobson, J, Steer A. C, et al. (2012). Environmental factors and rheumatic heart disease in Fiji. Pediatric Cardiology, 33(2), 332–336.	No definition of crowding
Ercis, S, Koseoglu O, et al. (2005). The prevalence of nasopharyngeal Neisseria meningitidis carriage, serogroup distribution, and antibiotic resistance among healthy children in Cankaya municipality schools of Ankara province. Mikrobiyoloji Bulteni, 39(4), 411–420.	Language
Flores, P, Rebelo-de-Andrade H, et al. (2004). Bronchiolitis caused by respiratory syncytial virus in an area of portugal: epidemiology, clinical features, and risk factors. European Journal of Clinical Microbiology & Infectious Diseases, 23(1), 39–45.	No person per household data reported
Giray, H. and Keskinoglu P. (2006). The prevalence of Enterobius vermicularis in schoolchildren and affecting factors. Turkiye Parazitoloji Dergisi, 30(2), 99–102.	Language
Goel, S, Kaur H, et al. (2014). Socio-epidemiological determinants of 2002 plague outbreak in Himachal Pradesh, India: a qualitative study. BMC Public Health, 14, 325.	No quantitative data
Greenaway, C, Boivin, J.F, Cnossen, S, Rossi, C, Tapiero, B, Schwartzman, K, Olson, S. (2014). Risk factors for susceptibility to varicella in newly arrived adult migrants in Canada. Epidemiology and Infection 142: 1695–1707	People per house
Gupta, S, Jamwal D. S, et al. (2011). Morbidity among under five children in a rural area of Jammu. JK Science, 14(2), 85–88.	No definition of crowding

Study	Reason for exclusion
Gurley, E. S, Salje H, et al. (2011). Indoor exposures to respirable particulate matter and age at first pneumonia episode in a low-income, urban community in Bangladesh. American Journal of Tropical Medicine and Hygiene 1): 15.	Full paper not available
Harimoto, T, Paes B. A, et al. (2013). RSV hospitalization in infants with neuromuscular disease in the Canadian registry of synagis (CARESS) following prophylaxis (2005–2012). Value in Health, 16 (3), A243.	No person per household data reported
Herrera Sarmiento, C. A, Higuera Rapa M, et al. (2004). Hansen disease in patients attended at the Auguste Malave Villalba outpatient clinic in the San Carlos Municipality of Cojedes State. Years 1997–2002. SpanishPacientes con enfermedad de Hansen atendidos en el Ambulatorio Augusto Malave Villalba, San Carlos, Estado Cojedes, anos 1997–2002. Salus, 8(2), 17–21.	Language
Hjuler, T, Wohlfahrt J, et al. (2007). Perinatal and crowding-related risk factors for invasive pneumococcal disease in infants and young children: a population–based case–control study. Clinical Infectious Diseases, 44(8), 1051–1056.	Cases only
Jackson, S, Mathews K. H, et al. (2013). Risk factors for severe acute lower respiratory infections in children: a systematic review and meta-analysis. Croatian Medical Journal, 54(2), 110–121.	Review
Jacoby, P, Carville K. S, et al. (2011). Crowding and other strong predictors of upper respiratory tract carriage of otitis media-related bacteria in Australian Aboriginal and non-Aboriginal children. Pediatric Infectious Disease Journal, 30(6), 480–485.	People per house
Jacups, S. P. (2011). The continuing role of Haemophilus influenzae type b carriage surveillance as a mechanism for early detection of invasive disease activity. Human Vaccines, 7(12), 1254–1260.	Not primary data
Johnson, A. W, Osinusi K, et al. (2008). Etiologic agents and outcome determinants of community-acquired pneumonia in urban children: a hospital-based study. Journal of the National Medical Association, 100(4), 370–385.	Cases only
Jonaidi Jafari, N, Radfar M. H, et al. (2007). Incidence of infectious diseases one month after the bam eartquake (2004). Journal of Medical Sciences, 7(4), 597–602.	Cases only
Kaul, R. U. R, Masoodi M. A, et al. (2005). Prevalence of rheumatic heart disease in school children (5–15 years) in a rural block of Srinagar. JK Practitioner, 12(3), 160–162.	No association measure
Kaya, A. D, Ozturk C. E, et al. (2008). Changing patterns of hepatitis A and E sero-prevalences in children after the 1999 earthquakes in Duzce, Turkey. Journal of Paediatrics & Child Health, 44(4), 205–207.	People per house
Kearns, T, Clucas D, et al. (2013). Clinic attendances during the first 12 months of life for Aboriginal children in five remote communities of northern Australia. PLoS ONE Electronic Resource, 8(3), e58231.	No association measure
Kimbally-Kaky, G, Gombet T, et al. (2008). Rheumatic heart disease in schoolchildren in Brazzaville. Medecine Tropicale, 68(6), 603–605.	Language
Kovesi, T. (2012). Respiratory disease in Canadian First Nations and Inuit children. Paediatrics & Child Health, 17(7), 376–380.	Review
Kovesi, T, Gilbert N. L, et al. (2007). Indoor air quality and the risk of lower respiratory tract infections in young Canadian Inuit children. CMAJ Canadian Medical Association Journal, 177(2), 155–160.	No person per household data reported
Kruszon-Moran, D. and McQuillan G. M. (2005). Seroprevalence of six infectious diseases among adults in the United States by race/ethnicity: data from the third national health and nutrition examination survey, 1988–94. Advance Data, (352), 1–9.	> 5 years since study

Study	Reason for exclusion
Letaief, A, Kaabia N, et al. (2005). Age-specific seroprevalence of hepatitis among school children in central Tunisia. American Journal of Tropical Medicine & Hygiene, 73(1), 40–43.	No person per household reported
Lezcano, A, Balbaryski J, et al. (2008). Seroprevalence of Mycoplasma pneumoniae in children aged under 12 years. Archivos Argentinos de Pediatria, 106(1), 6–10.	Language
Li, Y, S. Duan, et al. (2005). Multi-zone modeling of probable SARS virus transmission by airflow between flats in Block E, Amoy Gardens. Indoor Air, 15(2), 96–111.	Cases only
Macedo, S. E, Menezes A. M, et al. (2007). Risk factors for acute respiratory disease hospitalization in children under one year of age. Revista de Saude Publica, 41(3), 351–358.	Language
Marin, M, Nguyen H. Q, et al. (2006). Measles transmission and vaccine effectiveness during a large outbreak on a densely populated island: implications for vaccination policy. Clinical Infectious Diseases, 42(3), 315–319.	No association measure
McDonald, E, Bailie R, et al. (2009). A case study of physical and social barriers to hygiene and child growth in remote Australian Aboriginal communities. BMC Public Health, 9:346.	No association measure
McDonald, E, Bailie R, et al. (2010). An ecological approach to health promotion in remote Australian Aboriginal communities. Health Promotion International, 25(1), 42–53.	No association measure
Moller, V, Erstad I, et al. (2010). Drinking, smoking, and morality: Do 'drinkers and smokers' constitute a stigmatized stereotype or a real TB risk factor in the time of HIV/AIDS? Social Indicators Research, 98(2), 217–238.	No definition of crowding
Murray, E. L. (2009). Environmental risk factors for respiratory infections in urban Bangladeshi children. Dissertation Abstracts International: Section B: The Sciences and Engineering, 70(3–B), 1572.	No quantitative data
Nyabade, G. (2010). Acute respiratory infections in rural communities in Kenya. Respirology, 15: 85.	No definition of crowding
Onal, A. E, Gurses C, et al. (2006). Subacute sclerosing panencephalitis surveillance study in Istanbul. Brain & Development, 28(3), 183–189.	No person per household reported
Paes, B. A, Li A, et al. (2013). Respiratory syncytial virus hospitalization in infants with congenital airway anomalies in the Canadian registry of synagis (CARESS) following prophylaxis (2005–2012). Value in Health, 16 (7), A366–A367.	No person per room reported
Panczak, R, Galobardes B, et al. (2013). High life in the sky? Mortality by floor of residence in Switzerland. European Journal of Epidemiology, 28(6), 453–462.	Not priority outcome (mortality)
Papenburg, J, Hamelin M. E, et al. (2012). Comparison of risk factors for human metapneumovirus and respiratory syncytial virus disease severity in young children. Journal of Infectious Diseases, 206(2), 178–189.	Cases only
Pollock, S. L, Sagan M, et al. (2012). Investigation of a pandemic H1N1 influenza outbreak in a remote First Nations community in northern Manitoba, 2009. Canadian Journal of Public Health. Revue Canadienne de Sante Publique, 103(2), 90–93.	Cases only
Prietsch, S. O, Fischer G. B, et al. (2008). Acute lower respiratory illness in under-five children in Rio Grande, Rio Grande do Sul State, Brazil: prevalence and risk factors. Cadernos de Saude Publica, 24(6), 1429–1438.	> 5 yr since study
Roussy, J. F, Carbonneau J, et al. (2014). Human metapneumovirus viral load is an important risk factor for disease severity in young children. Journal of Clinical Virology, 60(2), 133–140.	No reply crowding Children per house

Study	Reason for exclusion
Roy, A. L. and Raver C. C. (2014). Are all risks equal? Early experiences of poverty-related risk and children's functioning. Journal of Family Psychology, 28(3), 391–400.	No definition of crowding
Savitha, M. R, Nandeeshwara S. B, et al. (2007). Modifiable risk factors for acute lower respiratory tract infections. Indian Journal of Pediatrics, 74(5), 477–482.	No definition of crowding
Sharma, D, Kuppusamy K, et al. (2013). Prevalence of acute respiratory infections (ari) and their determinants in under five children in urban and rural areas of Kancheepuram district, South India. Annals of Tropical Medicine and Public Health, 6(5), 513–518.	No definition of crowding
Sommer, C, Resch B, et al. (2011). Risk factors for severe respiratory syncytial virus lower respiratory tract infection. The Open Microbiology Journal, 5: 144–154.	Review
Tessera, R. A. (2010). Acute Respiratory Infection, Main Cause For Morbidity For Children 0–5 Years Of Age, In Postearthquake, Haiti, 2010. American Journal of Tropical Medicine and Hygiene 1): 338.	Cases only
Tiewsoh, K, Lodha R, et al. (2009). Factors determining the outcome of children hospitalized with severe pneumonia. BMC Pediatrics, 9, 15.	Cases only
Tomialoic, R, Stefanoff P, et al. (2015). Incidence and factors predicting whooping cough due to parapertussis diagnosis among patients referred to general practitioners, Poland, 2009–2011. European Journal of Clinical Microbiology & Infectious Diseases, 34(1), 101–107.	Cases only
Trenholme, A, Vogel A, et al. (2012). Household characteristics of children under 2 years admitted with lower respiratory tract infection in Counties Manukau, South Auckland. New Zealand Medical Journal, 125(1367), 15–23.	Cases only
Unger, A. (2013). Children's health in slum settings. Archives of Disease in Childhood, 98(10), 799–805.	Review
Vain, N. E, Farina D, et al. (2012). Neonatology in the emerging countries: the strategies and health-economics challenges related to prevention of neonatal and infant infections. Early Human Development, 88 Suppl 2, S53–59.	Not primary data
Velasco-Salas, Z. I, Sierra G. M, et al. (2014). Dengue seroprevalence and risk factors for past and recent viral transmission in Venezuela: a comprehensive community-based study. American Journal of Tropical Medicine & Hygiene, 91(5), 1039–1048.	Not priority outcome
Vieira, R. A, Ceccon M, et al. (2012). Emerging respiratory viruses in hospitalized newborns affected by lower respiratory tract infection in Sao Paulo, Brazil. Journal of Maternal-Fetal and Neonatal Medicine, 25: 107.	Cases only
Weitzman, M, Baten A, et al. (2013). Housing and child health. Current Problems in Pediatric & Adolescent Health Care, 43(8), 187–224.	No quantitative data
Woldeamanuel, Y. W. and Girma B. (2014). A 43-year systematic review and meta-analysis: case-fatality and risk of death among adults with tuberculous meningitis in Africa. Journal of Neurology, 261(5), 851–865.	Review
Wood, R, Morrow C, et al. (2014). Quantification of shared air: a social and environmental determinant of airborne disease transmission. PLoS ONE Electronic Resource, 9(9), e106622. del Castillo-Sanchez, D. L, E. Sabag-Ruiz, et al. (2006). Community-acquired pneumonia: risk focus and family functionality. Revista Medica del Instituto Mexicano del Seguro Social, 44(1), 35–38.	Not priority outcome
Del Castillo-Sanchez, D. L, Sabag-Ruiz E, et al. (2006). Community-acquired pneumonia: risk focus and family functionality. Revista Medica del Instituto Mexicano del Seguro Social, 44(1), 35–38.	Language

Study	Reason for exclusion
Zabihullah, Z, Manaseki-Holland S, et al. (2010). RCT Methodology, population profile and pneumonia rates in socio-economically deprived infants of Kabul: Data from a RCT investigating the effects of vitamin D supplementation on the incidence of infant pneumonia. International Journal of Infectious Diseases, 14: e421–e422.	Overcrowding not used in analyses
Outcome 2: Gastrointestinal and diarrhoeal diseases	
Aksoy, U, Akisu C, et al. (2007). Demographic status and prevalence of intestinal parasitic infections in schoolchildren in Izmir, Turkey.Erratum appears in Turk J Pediatr. 2008 May–Jun; 50(3), 306. Turkish Journal of Pediatrics, 49(3), 278–282.	No definition of crowding
Aksoy, U, Akisu C, et al. (2007). Demographic status and prevalence of intestinal parasitic infections in schoolchildren in Izmir, Turkey.Erratum appears in Turk J Pediatr. 2008 May–Jun; 50(3), 306. Turkish Journal of Pediatrics, 49(3), 278–282.	Language
Dagci, H, Kurt O, et al. (2008). The prevalence of intestinal parasites in the province of Izmir, Turkey. Parasitology Research, 103(4), 839–845.	No definition of crowding
Fabiana, A, Donia D, et al. (2007). Influence of enteric viruses on gastroenteritis in Albania: epidemiological and molecular analysis. Journal of Medical Virology, 79(12), 1844–1849.	Cases only
Gamboa, M. I, Navone G. T, et al. (2011). Socio-environmental conditions, intestinal parasitic infections and nutritional status in children from a suburban neighborhood of La Plata, Argentina. Acta Tropica, 118(3), 184–189.	No association measure
Gamboa, M. I, Kozubsky L. E, et al. (2009). Associations between geohelminths and socioenvironmental conditions among different human populations in Argentina. Pan American Journal of Public Health, 26(1), 1–8.	Language
Garcia, E. A, Garrote N, et al. (2013). Family feeding practices in 0–4 children with preventable pathologies background. Annals of Nutrition and Metabolism, 63: 1035.	Cases only
Gbary, A. R, Dossou J. P, et al. (2011). Epidemiologic and medico-clinical aspects of the cholera outbreak in the Littoral department of Benin in 2008. Medecine Tropicale, 71(2), 157–161.	Language
Karmakar, S, Rathore A. S, et al. (2008). Post-earthquake outbreak of rotavirus gastroenteritis in Kashmir (India), An epidemiological analysis. Public Health, 122(10), 981–989.	No association measure
Khosla, R, Bhanot A, et al. (2005). Sanitation: a call on resources for promoting urban child health. Indian Pediatrics, 42(12), 1199–1206.	No primary data
Masoumeh, R, Farideh T, et al. (2012). Intestinal parasitic infection among school children in Golestan province, Iran. Pakistan Journal of Biological Sciences, 15(23), 1119–1125.	No person per household data reported
Molina, N, Minvielle M, et al. (2011). High prevalences of infection with Giardia intestinalis genotype B among children in urban and rural areas of Argentina. Annals of Tropical Medicine & Parasitology, 105(4), 299–309.	Cases only
Monasta, L, Andersson N, et al. (2008). Minority health and small numbers epidemiology: a case study of living conditions and the health of children in 5 foreign Roma camps in Italy. American Journal of Public Health, 98(11), 2035–2041.	> 5 yr since study
Ostan, I, Kilimcioglu A. A, et al. (2007). Health inequities: lower socio-economic conditions and higher incidences of intestinal parasites. BMC Public Health, 7:A99 342.	No person per household data reported
Sanchez, R, Echeverri J, et al. (2004). The brachial and cephalic perimeters as indicators of poverty and acute diarrhea in children under five years in Bogota. Revista de Salud Publica, 6(2), 167–182.	Language

Study	Reason for exclusion
Sanchez-Uribe, E, Esparza-Aguilar M, et al. (2013). Risk factors associated with rotavirus gastroenteritis during a community outbreak in Chiapas, Mexico during the postvaccination Era. Journal of the Pediatric Infectious Diseases Society, 2(1), 15–20.	No person per household data reported
Semba, R. D, de Pee S, et al. (2009). Purchase of drinking water is associated with increased child morbidity and mortality among urban slum-dwelling families in Indonesia. International Journal of Hygiene & Environmental Health, 212(4), 387–397.	No data available
Wells, N. M. and Harris J. D. (2007). Housing quality, psychological distress, and the mediating role of social withdrawal: A longitudinal study of low-income women. Journal of Environmental Psychology, 27(1), 69–78.	No cut point for crowding
Outcome 4: Sleep disorders	
Bask, M. (2011). Cumulative disadvantage and connections between welfare problems. Social Indicators Research, 103(3), 443–464.	> 5 yr since study
Bright, B. R, Carnethon M. R, et al. (2013). Does neighborhood poverty account for race/ethnic differences in sleep duration? Circulation 127 (12 Meeting Abstracts).	No association measure
Brown, E. D. and Low C. M. (2008). Chaotic living conditions and sleep problems associated with children's responses to academic challenge. Journal of Family Psychology, 22(6), 920–923.	No association measure
Lianqi, L, Chaojuan M, et al. (2004). Sleep Problems and Related Factors of Elementary School Students. Chinese Mental Health Journal, 18(9), 613–616.	language
McGrath, J. and Jarrin D. C. (2013). Children's perception of neighborhood safety buffers the effect of neighborhood disorder on sleep. Psychosomatic Medicine, 75 (3), A–8.	No association measure
Outcome 5: Mental health	
Umlauf, M. G, Bolland J. M, et al. (2011). Sleep disturbance among disadvantaged minority teens. Sleep, 34: A299.	No definition of crowding
Ahmadzad-Asl, M, Davoudi F, et al. (2013). Correlates of mental health service utilization in married women in Tehran 2011. European Psychiatry, 28.	Not priority outcome
Ahmadzad-Asl, M, Davoudi, et al F. (2013). Correlates of mental health service utilization in married women in tehran 2011. Iranian Journal of Psychiatry & Behavioral Sciences, 7(1), 51–60.	Not priority outcome
Al-Khatib, I. A, Arafat R. N, et al. (2005). Housing environment and women's health in a Palestinian refugee camp. International Journal of Environmental Health Research, 15(3), 181–191.	Data not available
Ambrose, P. (2010). Overcrowding. Roof 35(2), 31–33.	No original data
Bazalgette, l, Barnes M,, et al. (2012). A wider lens (disadvantaged families).http://www.demos.co.uk/files/Wider_Lens_-_web.pdf?1350665726	No association measure
Binbay, T, Elbi H, et al. (2010). High prevalence of psychosis continuum in a highly urbanized area of Turkey: Turksch study. Schizophrenia Research, 117 (2–3), 435.	No definition of crowding
Borders, A. E, Grobman W. A, et al. (2007). Chronic stress and low birth weight neonates in a low-income population of women. Obstetrics & Gynecology, 109(2 Pt 1), 331–338.	Not priority outcome
Chen, N, Deater-Deckard K, et al. (2014). The role of temperament by family environment interactions in child maladjustment. Journal of Abnormal Child Psychology, 42(8), 1251–1262.	No measure of crowding

Study	Reason for exclusion
Coutinho, L. M, Matijasevich A, et al. (2014). Prevalence of common mental disorders and the relationship to the social context: multilevel analysis of the Sao Paulo Ageing & Health Study (SPAH). Cadernos de Saude Publica, 30(9), 1875–1883.	Language
Drury, A. Norheim, K. et al. For Greater London Authority and Hatc (2006). Housing space standards, Greater London Authority.	No original data
Eriksson, A, Romelsjo A, et al. (2011). Early risk factors for criminal offending in schizophrenia: a 35-year longitudinal cohort study. Social Psychiatry & Psychiatric Epidemiology, 46(9), 925–932.	Review
Evans, G. W. and Cassells R. C. (2014). Childhood poverty, cumulative risk exposure, and mental health in emerging adults. Clinical Psychological Science, 2(3), 287–296.	No association measure
Ferguson, K. T, Cassells R. C, et al. (2013). The physical environment and child development: an international review. International Journal of Psychology, 48(4), 437–468.	Review
Fisher, J. R, Tran H, et al. (2007). Relative socioeconomic advantage and mood during advanced pregnancy in women in Vietnam. International Journal of Mental Health Systems, 1(1), 3.	No association measure
Fisher, J. R, de Mello M. C, et al. (2011). The Ha Noi Expert Statement: recognition of maternal mental health in resource-constrained settings is essential for achieving the Millennium Development Goals. International Journal of Mental Health Systems, 5(1), 2.	Not primary research
Gariepy, G, Blair A, et al. (2014). Neighbourhood characteristics and 10-year risk of depression in Canadian adults with and without a chronic illness. Health & Place, 30, 279–286.	No association measure
Grzywacz, J. G, Quandt S. A, et al. (2010). Depressive symptoms among Latino farmworkers across the agricultural season: Structural and situational influences. Cultural Diversity & Ethnic Minority Psychology, 16(3), 335–343.	No quantitative crowding measure
Guite, H. F, Clark C, et al. (2006). The impact of the physical and urban environment on mental well-being. Public Health 120(12), 1117–1126.	No association measure
Handy, C. (2014). Housing, health and social care- an introduction. Journal of Integrated Care, 22(1).	No original data
Helm, D, Laussmann D, et al. (2010). Assessment of environmental and socio-economic stress. Central European Journal of Public Health, 18(1), 3–7.	No association measure
Hunter-Hernandez, M, Costas-Muniz R, et al. (2014). Quality of life and household composition of Latino and black cancer patients. Psycho-Oncology, 23: 403.	No association measure
Kyle, T. and Dunn J. R. (2008). Effects of housing circumstances on health, quality of life and healthcare use for people with severe mental illness: a review. Health & Social Care in the Community, 16(1), 1–15.	Review
Lemery-Chalfant, K, Kao K, et al. (2013). Childhood temperament: passive gene-environment correlation, gene-environment interaction, and the hidden importance of the family environment. Development & Psychopathology, 25(1), 51–63.	Crowding data not separately reported
London Health Commission (2005). Health in London: review of the London Health Strategy high level indicators: 2005 update. Focus on the health of children and young people. London, London Health Commission.	No original data
Mariu, K. R, Merry S. N, et al. (2012). Seeking professional help for mental health problems, among New Zealand secondary school students. Clinical Child Psychology & Psychiatry, 17(2), 284–297.	Not priority outcome

Study	Reason for exclusion
Maziak, W, Ward K. D, et al. (2005). Mapping the health and environmental situation in informal zones in Aleppo, Syria: report from the Aleppo household survey. International Archives of Occupational & Environmental Health, 78(7), 547–558.	No association measure
McNeely, J. M, Waldstein S. R, et al. (2013). The impact of poor quality residential environments on physical and mental health related quality of life in urban dwelling adults. Psychosomatic Medicine, 75 (3), A-148.	No association measure
Murphy, A. L. (2013). A holistic examination of the impact of child maltreatment on child behavioral outcomes: A longitudinal multilevel analysis. Dissertation Abstracts International Section A: Humanities and Social Sciences 74(4-A (E)), No Pagination Specified.	No definition of crowding reported
Ndom, R. J, Igbokwe D. O, et al. (2012). Overcrowding, age and gender differences in the manifestation of state anxiety among undergraduate students in a Nigerian public university. IFE Psychologia: An International Journal, 20(1), 323–337.	Hostel housing
Packard, C. J, Bezlyak V, et al. (2011). Early life socioeconomic adversity is associated in adult life with chronic inflammation, carotid atherosclerosis, poorer lung function and decreased cognitive performance: a cross-sectional, population-based study. BMC Public Health, 11:42.	Not priority outcome
Pevalin, D. J, Taylor M. P, et al. (2008). The dynamics of unhealthy housing in the UK: a panel data analysis. Housing Studies, 23(5), 679–695.	No definition of crowding reported
Rahi, M, Kumavat A. P, et al. (2005). Socio-demographic co-relates of psychiatric disorders. Indian Journal of Pediatrics, 72(5), 395–398.	No definition of crowding reported
Rice, B. (2006). Against the odds: an investigation comparing the lives of children on either side of Britain's housing divide. London, Shelter.	No original data
Rohe, W. M. and Han H. S. (2012). Housing and health: time for renewed collaboration. North Carolina Medical Journal, 73(5), 374–380.	Review
Rollings, K. A. (2014). Environments and health: Assessing influences of the built and natural environment on mental and physical health. Dissertation Abstracts International Section A: Humanities and Social Sciences 74(11-A (E)), No Pagination Specified.	No definition of crowding reported
Sahin, E. M. and Kilicarslan S. (2010). Depressive, anxiety levels and affecting factors of third trimester pregnant women. TurkishSon trimester gebelerin depresyon ve kaygi duzeyleri ile bunlari etkileyen etmenler. Trakya Universitesi Tip Fakultesi Dergisi, 27(1), 51–58.	No original data
Sengupta, N. K, Osborne D, et al. (2012). How much happiness does money buy? Income and subjective well-being in New Zealand. New Zealand Journal of Psychology, 41(2), 21–34.	No association measure
Jones S, et al. (2005). Generation squalor: Shelter's national investigation into the housing crisis, Shelter.	No definition of crowding reported
Shepherd, C. C, Li J, et al. (2012). Socioeconomic disparities in the mental health of Indigenous children in Western Australia. BMC Public Health, 12, 756.	Authors response to our request not received
Khandaker, G. M, Stoch J, et al. (2013). Early epstein barr virus (EBV) exposure, neurodevelopment and childhood psychotic symptoms: Findings from the ALSPAC birth cohort. Schizophrenia Bulletin, 39: S66–S67.	Outcome measure not relevant
Suglia, S. F, Duarte C. S, et al. (2011). Housing quality, housing instability, and maternal mental health. Journal of Urban Health, 88(6), 1105–1116.	Author replied but has not provided required information'

Study	Reason for exclusion
Williams, E. D, Kooner I, et al. (2007). Psychosocial factors related to cardiovascular disease risk in UK South Asian men: a preliminary study.Erratum appears in Br J Health Psychol. 2008 Feb; 13(Pt 1), 188. British Journal of Health Psychology, 12(Pt 4), 559–570.	Author replied but has not provided required information'
Yadava, A, Anita, K et al. (2006). Effect of residential density on mental health. Indian Journal of Community Psychology, 2(1), 147–151.	Authors response to our request not received

*Only one reason given per study

PPH = People per house; CPH = children per house. Both measures were deemed insufficient evidence of crowding (see text).

PPR = People per room.

Appendix 10 Search strategy for Embase – update search conducted in March 2018

EMBASE via OvidSP

http://ovidsp.ovid.com/

1974 to 16 January 2015 (week 4)

Searched on: 29 January 2018

Records retrieved: 435

1 (house or houses or housing).ti, ab. (100888)

2 (home or homes or household or households).ti, ab. (320316)

3 (dwelling* or residence* or accommodation or slum*).ti, ab. (97236)

4 (living adj2 (condition* or standard*)).ti, ab. (9786)

5 housing/ or home for the aged/ (24514)

6 or/1–5 (506826)

7 "crowding (area)"/ (1920)

8 (crowd* or overcrowd*).ti, ab. (19236)

9 7 or 8 (19693)

10 6 and 9 (2373)

11 Animal/ or Animal Experiment/ or Nonhuman/ (5909865)

12 expr Human/ or Human Experiment/ (342638)

13 11 not (11 and 12) (5897794)

14 10 not 13 (2116)

15 limit 14 to yr="2015 -Current" (435)

Key:

/ = indexing term (EMTREE heading)
expr = exploded indexing term (EMTREE heading)
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)

Appendix 11 Search strategy for ERIC – update search conducted in March 2018

ERIC (Education Resource Information Center database) via EBSCO

https://www.ebsco.com/

1965–2018

Searched on: 29 March 2018

Records retrieved: 5

#	Query
S12	S7 AND S10 Limiters – date published: 20150101
S11	S7 AND S10
S10	S8 OR S9
S9	TI ((crowd* or overcrowd*)) OR AB ((crowd* or overcrowd*))
S8	DE "Crowding"
S7	S1 OR S2 OR S3 OR S4 OR S5 OR S6
S6	DE "Living Standards"
S5	DE "Housing" OR DE "Emergency Shelters" OR DE "Group Homes"
S4	TI ((living N2 (condition* or standard*))) OR AB ((living N2 (condition* or standard*)))
S3	TI ((dwelling* or residence* or accommodation or slum*)) OR AB ((dwelling* or residence* or accommodation or slum*))
S2	TI ((home or homes or household or households)) OR AB ((home or homes or household or households))
S1	TI ((house or houses or housing)) OR AB ((house or houses or housing))

Key:

DE = indexing term
* = truncation
TI = words in the title
AB = words in the abstract
N2 = terms within two words of each other (any order)

Appendix 12 Search strategy for MEDLINE – update search conducted in March 2018

MEDLINE In-Process & Other Non-Indexed Citations and MEDLINE via OvidSP
http://ovidsp.ovid.com/

1946 to present

Searched on: 29 March 2018

Records retrieved: 351

1 (house or houses or housing).ti,ab. (80269)

2 (home or homes or household or households).ti,ab. (259837)

3 (dwelling* or residence* or accommodation or slum*).ti,ab. (82388)

4 (living adj2 (condition* or standard*)).ti,ab. (9451)

5 housing/ or housing for the elderly/ or public housing/ (18394)

6 or/1-5 (414327)

7 crowding/ (2847)

8 (crowd* or overcrowd*).ti,ab. (18207)

9 7 or 8 (19452)

10 6 and 9 (2306)

11 exp animals/ not humans/ (4435919)

12 10 not 11 (2455)

13 limit 12 to yr="2004 – Current" (351)

Key:

/ = indexing term (MeSH heading)
exp = exploded indexing term (MeSH heading)
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)

Appendix 13 Search strategy for PsycINFO – update search conducted in March 2018

PsycINFO via OvidSP

http://ovidsp.ovid.com/

1806 to March week 3 2018

Searched on: 29 March 2018

Records retrieved: 115

1 (house or houses or housing).ti,ab. (28424)

2 (home or homes or household or households).ti,ab. (134828)

3 (dwelling* or residence* or accommodation or slum*).ti,ab. (29942)

4 (living adj2 (condition* or standard*)).ti,ab. (3895)

5 exp housing/ (8365)

6 1 or 2 or 3 or 4 or 5 (188015)

7 crowding/ (1038)

8 (crowd* or overcrowd*).ti,ab. (6678)

9 7 or 8 (6787)

10 6 and 9 (925)

11 (animal or animals or rat or rats or mouse or mice or hamster or hamsters or dog or dogs or cat or cats or bovine or sheep or ovine or pig or pigs).ti,id,de. (261846)

12 10 not 11 (875)

13 limit 12 to yr="2004 – Current" (115)

Key:

/ = indexing term
exp = exploded indexing term
* = truncation
.ti,ab. = terms in either title or abstract fields
adj2 = terms within two words of each other (any order)
id = key concepts field
de = descriptors field

Appendix 14 Search strategy for Science Citation Index – update search conducted in March 2018

Science Citation Index via Web of Science

http://thomsonreuters.com/

1945 – 28 March 2018

Searched on: 29 March 2018

Records retrieved: 377

# 10	377	#7 NOT #8 *Indexes=SCI-EXPANDED Timespan=2015-2018*
# 9	1 629	#7 NOT #8 *Indexes=SCI-EXPANDED Timespan=all years*
# 8	2 113 602	TI=(rat or rats or mouse or mice or hamster or hamsters or animal or animals or dog or dogs or cat or cats or bovine or sheep) *Indexes=SCI-EXPANDED Timespan=all years*
# 7	1 703	#6 AND #5 *Indexes=SCI-EXPANDED Timespan=all years*
# 6	28 284	TS=(crowd* or overcrowd*) *Indexes=SCI-EXPANDED Timespan=all years*
# 5	513 722	#4 OR #3 OR #2 OR #1 *Indexes=SCI-EXPANDED Timespan=all years*
# 4	10 364	TS=(living NEAR/2 (condition* or standard*)) *Indexes=SCI-EXPANDED Timespan=all years*
# 3	126 721	TS=(dwelling* or residence* or accommodation or slum*) *Indexes=SCI-EXPANDED Timespan=all years*
# 2	269 721	TS=(home or homes or household or households) *Indexes=SCI-EXPANDED Timespan=all years*
# 1	133 898	TS=(house or houses or housing) *Indexes=SCI-EXPANDED Timespan=all years*

Key:

TS = topic tag; searches terms in title, abstract, author keywords and keywords plus fields
* = truncation
NEAR/2 = terms within two words of each other
TI = terms in the title field

Appendix 15 Search strategy for Social Science Citation Index – update search conducted in March 2018

Social Science Citation Index via Web of Science

http://thomsonreuters.com/

1956 – 28 March 2018

Searched on: 29 March 2018

Records retrieved: 358

# 10	358	#7 NOT #8 *Indexes=SSCI Timespan=2015–2018*
# 9	1 321	#7 NOT #8 *Indexes=SSCI Timespan=all years*
# 8	60 366	TI=(rat or rats or mouse or mice or hamster or hamsters or animal or animals or dog or dogs or cat or cats or bovine or sheep) *Indexes=SSCI Timespan=all years*
# 7	1 336	#6 AND #5 *Indexes=SSCI Timespan=all years*
# 6	10 682	TS=(crowd* or overcrowd*) *Indexes=SSCI Timespan=all years*
# 5	293 227	#4 OR #3 OR #2 OR #1 *Indexes=SSCI Timespan=all years*
# 4	9 104	TS=(living NEAR/2 (condition* or standard*)) *Indexes=SSCI Timespan=all years*
# 3	46 101	TS=(dwelling* or residence* or accommodation or slum*) *Indexes=SSCI Timespan=all years*
# 2	196 621	TS=(home or homes or household or households) *Indexes=SSCI Timespan=all years*
# 1	67 022	TS=(house or houses or housing) *Indexes=SSCI Timespan=all years*

Key:

TS = topic tag; searches terms in title, abstract, author keywords and keywords plus fields
* = truncation
NEAR/2 = terms within two words of each other
TI = terms in the title field

Appendix 16 Search strategy for SciELO – update search conducted in March 2018

SciELO

http://www.scielo.br/

Searched on: 13 March 2015

Records retrieved: 6

Due to the limited search features available on this database a simple search was performed using the Articles search with the following strategy:

crowd or crowded or crowding or overcrowd or overcrowded or overcrowding

AND

house or houses or housing or home or homes or household or household or dwelling or dwellings or residence or residences or accommodation or slum or slums

40 search results

Six published 2015 and later

Appendix 17 Characteristics of the included studies

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Studies reporting on outcome 1a: Tuberculosis						
Baker et al. 2008 New Zealand	20001 census data using the number of TB cases in each CAU for 2000–4 using the number of TB cases in each CAU notified between 1995–9.	% of crowded houses in quintile 5 >6.4	% of crowded houses in quintile 1: <1.6; quintile 2 >1.6 -2.5; quintile 3 >2.5 -3.8; quintile 4 >3.8	TB	Ecological study	1860 CAUs
Garcia-Sancho et al. 2009 Mexico	Cases were selected from among TB patients with *M.tuberclosis* in sputa diagnosed in the study area between March 1995 and April 2003 residing in communities with fewer than 15000 inhabitants	Household crowding (PCROWDNZ<40) years	Proportions of households that are crowded based on bedroom deficit of one or more	Bacteriologically confirmed TB	Population based case control	42 PTB cases and 84 controls
Jayanthi et al. 2012 India	300 samples from patients aged between 15 and 75 years in hospitals in India in that 150 samples were positive and the remaining cases were negative	Household size more than 4 persons	Household size less than 4 persons	TB	Case-control	300 cases (150 cases and 150 controls)
Cluver et al. 2013 South Africa	Random sampling from six urban and rural census enumeration sites	more than 3 persons per room	≤ 3 people per room	Pulmonary TB symptoms	Cross-sectional	6002
Corbett et al. 2009 Zimbabwe	Randomly selected adults Living in 46 study neighbourhoods	more than 4 people per room	Less than 4 people per room	Prevalent smear positive TB	Cross-sectional	1092
Goldhaber-Fiebert et al. 2011 Global (mainly low and middle income; 46 countries)	World Health Survey	Additional person per room	Additional person per room	Symptoms of tuberculosis	Cross-sectional	124 545
Gyawali et al. 2012 Nepal	Household contacts (HC) of index cases (IC) of pulmonary TB in Dharan	Between 2 to 3 persons per room	Less than 2 persons per room	Pulmonary tuberculosis culture confirmed	Cross-sectional	802 HCs of 184 ICs
Harling et al. 2013 Brazil	Notified cases of TB in national passive surveillance system	>2 people per sleeping room	< 2 people per sleeping room	Notified pulmonary and extra-pulmonary TB cases	Retrospective cohort	719 663

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Hill et al. 2006 Gambia	Presenting to a health clinic	At least 4 persons and at least 2 persons per room in a household	Less than 4 persons and less than 2 people sleeping per room on average	Pulmonary tuberculosis sputum culture positive	Case control	100 cases + 200 controls
Lakshmi et al. 2012 India	Women with TB	4 or more persons per room	Less than 4 persons per room	Pulmonary tuberculosis sputum culture positive	Case control	126 cases and 252 controls
Lienhardt et al. 2005 Guinea, Guinea-Bissau, and Gambia	Age >15 years who had presented at major urban health centres with laboratory confirmed TB	Persons per room	2 controls – household and community (age matched within 10 years)	Pulmonary tuberculosis sputum culture positive	Case control	2376 (846 cases, 702 household controls, and 828 community controls).
Larcombe et al. 2011 Canada	All willing households in 2 communities in Canada	1.2 persons per room	0.9 persons per room	Self-reported TB case(s) in household	Cross-sectional	129 households
Tipayamongkholgul et al. 2005 Thailand	Diagnosed and treated at one hospital	Five or more persons per room	One person or less	Tuberculosis – hospital diagnosed – 50% pulmonary, 36% lymph nodes	Case control	130 cases + 130 controls
Tornee et al. 2004 Thailand	Household contacts of sputum-smear-positive pulmonary TB patients aged over 15 years	Three or more persons per room	Two persons or less	Positive Tuberculin skin test	Cross-sectional	500
Tornee et al. 2005* Thailand	household contacts of tuberculosis patients	Three or more persons per room	Two persons or less	Tuberculin skin test positive	Cross-sectional	480 (dwellings) 325 children
Soborg et al. 2011 Greenland	child attending one of the schools in the 5 selected towns	≥ 1.50 Average no. of people per room	1–1.49 Average no. of people per room	Interferon gamma release assay (IGRA) and a tuberculin skin test (TST)	Cross-sectional	1797
Wanyeki et al. 2006 Canada	individuals residing in the City of Montreal	Per 0.1 increase in persons per room	Matched by dwelling unit	Diagnosis of active TB	Case control (case cohort design)	545 cases and 5450 controls
Irfan et al. 2017 Bangladesh	Adults from a TB hospital	≥2 persons per room	Less than 2 persons per room	Tuberculosis	Case-control	178 cases and 179 controls
Kapoor et al. 2016 India Abstract data only	TB patients and controls	3–5 persons per room	Less than 3 persons per room	Tuberculosis	Case-control	893 cases and 333 controls

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Khan et al. 2016 Canada	Newly diagnosed TB patients and controls (Inuit)	>1 person per room	1 person per room	Tuberculosis	Case-control	44 cases and 156 controls
Pelissari et al. 2017 Brazil	Tuberculosis patients.	Proportion of population with >2 persons per bedroom	2 persons or less per bedroom	Tuberculosis	Ecological	63 907 cases in 3839 municipalities
Sacchi et al. 2018 Brazil Abstract data only	Indigenous community	Crowding (not defined)	Not reported	Tuberculosis	Cohort	Not reported
Tesema et al. 2015 Ethiopia	TB patients and community controls	<4m2 per person per room	4m2 or more per person per room	Tuberculosis	Case-control	218 cases and 437 controls
Studies reporting on outcome 1b: Other infectious diseases						
Islam et al. 2013 India	Children under 5 with either a positive or negative ARI at the time of the interview	floor space) and type of house	Not applicable	Prevalence of acute respiratory infections	Population based analytical cross-sectional study	7 slums
Al Jarousha et al. 2014 West Bank and Gaza Strip	Children admitted to hospital for acute bacterial meningitis	>3 persons per room	<3 persons per room	Risk factors for bacterial meningitis	Cross-sectional	1853 children
Rao et al. 2010 Guatemala Abstract data only	Randomly selected households from roofs identified in aerial photos	Prevalence ratio for crowding (no cut-off point reported for the description)	Not applicable	Water, sanitation and hygiene (WASH) risk factors	Cross-sectional survey	701 persons in 184 households
De Wals et al. 2005 (study added as supplementary evidence, published 5yrs after data collection) Canada	Cases with confirmed serogroup C meningococcal disease reported after the beginning of the campaign until 31 March 1998	Household crowding	Not applicable	Effectiveness of Serogroup C Meningococcal Polysaccharide Vaccine	Case-control	74 individuals
Mathew et al. 2014 India Abstract data only	Children (1 month–12 years) fulfilling World Health Organization criteria for pneumonia (cough or difficult breathing, and tachypnea; for <7days)	Over-crowding at home (number of members of opposite gender – who are not older than 10 years of age, is greater than the number of average rooms available for sleeping in)	No over crowding	Microbiologic etiology of childhood CAP (bacterial)	Etiology study, cross-sectional	2333 children

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Yousey-Hindes et al. 2011 USA	Children from birth to age 17 years living in impoverished or crowded neighbourhoods	1.0–2.9 (Proportion of houses in census tract with more than 1 person per room)	Not applicable	Flu-related hospitalization	Other	517 cases
Forshey et al. 2010 Peru	Population across 45 city blocks in Amazon Basin of Peru	People per room>2.0	People per room1–1.9>	Flu and flu-like illness	Prospective cohort	10 341
Hosoglu et al. 2006 Turkey	Cases: Patients admitted to hospital with fever and blood culture showing s.typhi	Greater than mean, above mean number per household of all participants number per household (2.25)	Not applicable	Typhoid fever	Case control	1094 cases and 128 controls
Tam et al. 2014 USA	Anyone admitted to hospital for flu; denominator 64- all adults in New Haven County, Connecticut	Proportion of houses in census tract with more than >5.0 people per room	Proportion of houses in census tract with more than one person per room 0–0.9; 1.0–2.9; 3.0–4.9	Flu-related hospitalization	Other (census survey)	2006 to 2010 population survey of at least 670 000 people
Bailie et al. 2005 Australia	Children <7 years of age who had spent at least six of the previous 12 months living in 3 remote indigenous communities (unspecified)	Crowding, resident per bedroom i.e. >4 persons per bedroom	Crowding, resident per bedroom i.e. <2, >2 <4 persons and <4 persons	Skin infections (scabies, bacterial infection, impetigo or infected skin sores)	Cross-sectional	161
MacLennan et al. 2006 the United Kingdom	Students from 15 to 19 years of age who were attending school or college full- or part-time	Persons sharing bedroom: >3	Persons sharing bedroom: 1, 2	Meningococcal carriage (confirmed colonies of N. meningitidis)	Cross-sectional	14,057 swabs
Norheim et al. 2014 Norway, Sweden, Denmark, Netherlands	Children under 5 years of age	People per room (excluding kitchen and bathroom, for all countries and excluding the living room in Sweden) ≥2	Single person living in one room i.e. categories of ≤ 2 2–≤4 4–8.33	Invasive meningococcal disease	Other	Approximately 35 million people in the four countries including Norway, Sweden, Denmark and the Netherlands

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Riaz et al. 2013 Bangladesh	People with and without Rheumatic Fever in Bangladesh	>3 people sharing a living room	People per room 0–1 >1–1.5 >1.5	Rheumatic heart disease and rheumatic fever	Case control	103 cases and 309 controls
Grant et al. 2012 New Zealand	Children under 5 years of age hospitalized with pneumonia, plus children under 5 years of age with pneumonia discharged from the emergency department	>1 person per room	1 person per room	Pneumonia	Case control	428 cases and 351 controls
Okello et al. 2012 Uganda	Cases were subjects aged 5 to 60 years diagnosed with Rheumatic Heart Disease (RHD)	Household with more than 8 people (average space area per person calculated with standard being that each person should have ≥ 90 square feet of space) >8	Household with less than 8 people	Rheumatic heart disease	Case control	243 cases and 243 controls
Prietsch et al. 2008 Brazil	Children aged 0 to 59 months of age, residing in the urban areas of the municipality of Rio Grande, Rio Grande do Sul State, Brazil	People per room ≥4	People per room ≤2; 3	Acute lower respiratory illness	Cross-sectional	775
Reisman et al. 2013 USA	Alaska Native adults and children in 8 rural Alaskan villages in 3 regions (Yukon-Kuskokwim, Norton Sound and Bristol Bay)	People per room	Not applicable	Pneumococcal colonization	Cross-sectional	12535
Deutch et al. 2004 Denmark	Children younger than 6 years of age, born in Denmark between 1 January 1980 and 31 December 1996, with a discharge diagnosis of meningococcal disease	Meters square per person (Definition from Danish Prevention Registry) ≥50	Meters square per person (Definition from Danish Prevention Registry) <20; 20–29; 30–39; 40–49; ≥50; <20; 20–29; 30–39; 40–49 and	Discharge diagnosis of meningococcal disease	Case control	1222 cases and 24,549 controls

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Sekhar et al. 2009 India	Children aged <2 years living in chosen communities from rural, urban slum and city areas	People per room: >2.0	People per room: <2.0	Carriage of H. Influenzae	Prospective cohort	1000
Murray et al. 2012 Bangladesh	Children aged <5 years who are residents of Kamalapur	People per room: ≥6	People per room: <3; ≥3–<4; ≥4–<5; ≥5–<6 and	Acute respiratory infection	Other	718
Larson et al. 2010 USA	Individuals living in Upper Manhattan neighbourhood with predominantly immigrant Latino population	People per room. Index (number of people in the household divided by the number of rooms)	Not applicable	Upper respiratory infections and infleunza symptoms	RCT	2788 members (509 households)
Phillips et al. 2014 the United Kingdom	Population in geographic district in England or Wales	People per room. Measure was continuous. Rooms per person: mean = 1.2 (range: 0.7–1.6)	Not applicable	Standardized mortality ratio of deaths from chronic rheumatic; heart disease Throat, eye and skin infections	Retrospective Cohort	Not reported
Firdaus et al. 2013 India	Households in three different urban zones of National Capital Territory of Delhi, India	Floor space/room (m²)	Not applicable	Acute respiratory infection; throat eye and skin infections	cross-sectional	1896

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Kristensen et al 2006 South Africa	Children aged 0–1 years of age in Soweto, South Africa	Number of adults in same bedroom as child: 1, 2 and ≥3	Number of adults in same bed as child: 1 and ≥2	Acute respiratory infection	Prospective cohort	571
			Number of siblings in same bedroom as child: 0, 1 and ≥2			
			Number of siblings in same bedroom as child: 0, 1 and >3			
			Number of adults in same bedroom as child: 1, 2 and >3			
			Number of adults in same bedroom as child: 1, 2 and >3			
			Number of siblings in same bed as child: 0 and >1			
			Number of siblings in same bedroom as child: 0, 1 and >2			
			Number of adults in same bed as child: 1 and >2			
			Number of siblings in same bedroom as child: 0, 1 and >2			
			Number of adults in same bedroom as child: 1, 2 and >3			
			Number of siblings in same bed as child: 0 and >1			
Cardoso et al. 2004 Brazil	Children aged 2–59 months in São Paulo	Number of people sleeping in child's bedroom	Not applicable	Acute lower respiratory disease	Case control	396 cases and 336 controls
Jaine et al. 2011 New Zealand	Small populations of approximately 3000–5000 people in New Zealand	Proportion of crowded households in census area unit	Not applicable	Acute rheumatic fever	Retrospective cohort	1249

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Alemayehu et al. 2017 Ethiopia	Healthy children and adolescents	>1 person per room		Nasal carriage and antibiotic susceptibilities of meningococcal isolates	Cross-sectional	240
Alvarado-Esquivel et al. 2016 Mexico	Miners	Semi-crowded: 1.6–3.5 persons per bedroom Overcrowded: ≥3.6 persons per bedroom		Toxoplasma gondii Infection (presence of anti-T. gondii IgG and IgM antibodies using enzyme-linked immunoassays)	Case-control	125 miners and 250 age- and gender-matched non-miners
Auguet et al. 2016 the United Kingdom	All population	Overcrowding variables are based on bedroom occupancy rating data in which the ages of the household members and their relationships to each other are used to derive the number of bedrooms they require. “Occupancy rating of −1” implies 1 fewer bedroom than required		Methicillin-resistant Staphylococcus aureus (MRSA)	Ecological	Hospital-based microbiology diagnostic services serve 867 254 usual residents, with 471 MRSA cases
Brander et al. 2017 Kenya	HIV-negative children (6 months to 15 years) presenting with acute diarrhoea	≥3 persons per room		Multi-drug non-susceptible enteric infections	Cross-sectional, within a hospital-based surveillance study of acute diarrhoea	292
Bruden et al. 2015 USA	Native children (<3 years)	Percentage of households with >1.5 persons per room		Respiratory syncytial virus	Ecological	1903 children positive for respiratory syncytial virus
Chandrasekhar et al. 2017 USA	Population-based surveillance system at 14 sites in the USA	>1 person per room, with tracts with 0–4.9% persons in crowded households compared to tracts with ≥5.0%		Influenza	Ecological	33 515 laboratory-confirmed influenza-associated hospitalizations
Chattopadhyay et al. 2016 India	Coal-based sponge iron plant workers	≥3 persons per room		Respiratory disease	Cross-sectional	258
da Fonseca Lima et al. 2016 Brazil	Children (1–59 months)	≥2 persons sleeping in the same room as the child		Pneumonia	Case-control	407 cases and 407 controls
Diaz et al. 2015 Mexico	Children (<5 years)	≥3 persons per bedroom		Acute respiratory infections with coinfections	Cross-sectional	162

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Doshi et al. 2015 Bangladesh	Children (12–59 months)	≥4 persons (including the child) sleeping in the same room		Influenza	Case–control	145 cases and 341 controls
Gares et al. 2017 the United Kingdom	Children included in the UK Millennium Cohort Study (at 3 years of age)	≤1.5 rooms per person		Epstein Barr virus (EBV) infection	Cohort	12 457
Hegab et al. 2015 Egypt	Primary school children	≥1.5 persons per room		Scabies	Cross-sectional	2014 (92 cases of scabies)
Howie et al. 2016 Gambia	Children (2–59 months)	Crowding index (persons per room)		Pneumonia	Case-control	458 with severe pneumonia, 322 with non-severe pneumonia, and 801 neighbourhood controls
Hughes et al. 2017 USA	Households with children (6–17 years), as a secondary analysis of the 2011 American Housing Survey	>2 persons per bedroom		Asthma	Cross-sectional	33 201 households
Kohen et al. 2015 Canada	Inuit children (2–5 years), as part of 2006 Aboriginal Children's Survey	>1 person per room (also did >1.5 persons per room, with results available on request from the authors)		Acute respiratory illness	Cross-sectional	1233
Krueger et al. 2015 USA	Participants of the National Health and Nutrition Examination Survey (NHANES)	>1 person per room		Helicobacter pylori	Cross-sectional	7398
Kumar et al. 2015 India	Parents of children (<5 years)	Overcrowding "based on the number of persons and living rooms"		Acute respiratory infections	Cross-sectional	509
Mirabel et al. 2015 New Caledonia	Children	≥3 persons per room		Rheumatic heart disease	Case-control	114 cases and 227 controls
Mitra et al. 2018 Bangladesh	Newborns	≤0.5 bedrooms per person		Infections	Cohort (inside a randomized trial)	30 267
Olea et al. 2017 Chile	Cases identified by monitoring system of the Ministry of Health of Chile. Controls lived in the same municipalities as cases.	>2.5 persons per bedroom		Meningococcal disease	Case-control	135 cases and 618 controls (59 cases and 281 controls <5 years of age; and 76 cases and 337 controls >5 years)

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Romani et al. 2017 Fiji Abstract data only	People from 6 island communities	≥4 persons per room compared to 1 person per room		Scabies and impetigo	Cross-sectional (baseline for a trial)	2051
Sinha et al. 2015 India	Adults (≥30 years)	>2 persons per room or <110 sq ft for 2 persons		Allergic rhinitis	Cross-sectional	1203
Sloan et al. 2015 USA	Persons hospitalized with confirmed influenza, in the Tennessee Emerging Infections Program	5.0–9.9, ≥10.0 persons per room (compared to <5.0)		Influenza	Ecological	1743
Tin et al. 2016 New Zealand	Children	<1, 1–2, ≥2 persons per bedroom		Acute respiratory infections	Cohort	6112
Tse et al. 2016 Canada	Inuit children (3–5 years)	Persons per room (continuous)		Severe respiratory infections	Cross-sectional	388
Verani et al. 2016 South Africa	HIV-negative children	>2 persons sleeping in the same room as the child		Presumed bacterial pneumonia	Case-control	889 cases and 2628 controls
Vieira et al. 2016 Brazil	HIV-infected youth (<25 years)	≥5 persons per household		Methicillin-resistant Staphylococcus aureus	Case-control	117
Vincenti-Gonzalez et al. 2017 Venezuela (the Bolivarian Republic of)	Persons (5–30 years) with no intention to move in the next 3 years	Persons per room, divided into quartiles and cut-off point set between the third and fourth quartiles (at ~1.5 persons per room)		Dengue virus	Cross-sectional	1985
Weber et al. 2017 Germany	Children	>1 person per room (including kitchen but not bathroom) or <20m2 living space per person (including kitchen and bathroom)		Respiratory problems	Cross-sectional	4732
Studies reporting on outcome 2: Gastroenteritis and diarrhoeal diseases						
Monasta et al. 2008 Italy	Gender: NR Age: 0–4 years Housing: informal settlement. Ethnicity: Roma Mean people/house: NR Mean rooms/house: NR	>2.5 PPR	<2.5 PPR	Diarrhoea in past 15 days	Cross-sectional	165

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Abu Mourad et al. 2004 West Bank and Gaza Strip	Gender: 72% Female Age: NR Housing: informal settlement. Ethnicity: NR Median people/house: 8 Mean rooms/house: NR	3.46–6.74 PPR 6.75–10.03 PPR	0.17–3.45 PPR	Households that reported diarrhoea; Households that reported intestinal parasites	Cross-sectional	1655
Etiler et al. 2004 Turkey	Gender: 50% Female Age: <12 months Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	1.01–2.00 PPR 3 PPR	<=1 PPR	Overall diarrhoea; Persistent diarrhoea >14 days)	Prospective cohort	204
Okour et al. 2012 Jordan	Gender: 49% Female Age: 0–13 years Housing: residential. Ethnicity: NR Mean people/house: 7 Mean rooms/house: NR	1.3–2.5 PPR 2.6–4.0 PPR >4 PPR	<=1.2 PPR	Diarrhoea	Cross-sectional	197
El-Gilany et al. 2005 Egypt	Gender: 49% Female Age: 0–5 years Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	>3 PPR	<3 PPR	Diarrhoea during the last two weeks (period prevalence); diarrhoea during the last 24 hours (point prevalence)	Cross-sectional	4458
Pezzani et al. 2012 Argentina	Gender: 54% Female Age: 3–17 years Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	>3 PPR	<3 PPR	Parasitic infection	Cross-sectional	716

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Ferrer et al. 2008 Brazil	Gender: NR Age: 0–10 years Housing: residential. Ethnicity: White: cases 7%, controls 8%. Black: cases 30%, controls 30% Others: cases 63%, controls 61% Mean people/house: NR Mean rooms/house: NR	>3 PPR	<3 PPR	Diarrhoea	Case control	1688 (cases) 1676 (controls)
Kyle et al. 2011 the United Kingdom	Gender: NR Age: 0–14 years Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	Overcrowding (IMD definition)	No overcrowding	Emergency admissions due to diarrhoea	Retrospective cohort	24 481
Perry et al. 2005 USA	Gender: 50% Female Age: NR Housing: residential. Ethnicity: Predominantly Hispanic Mean people/house: NR Mean rooms/house: NR	Shares a bed with a primary gastroenteritis patient	Does not share a bed with a primary gastroenteritis patient	Secondary transmission of gastroenteritis	Prospective cohort	5015
Quigley et al. 2006 the United Kingdom	Gender: 42% Female (cases) 48% female (controls) Age: <12 months. Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	>1 PPR	<1 PPR	Diarrhoea	Case control	167 (cases) 137 (controls)
Harper et al. 2015 Canada	Inuit	Overcrowding (not defined)		Acute gastrointestinal illness	Cross-sectional	1517

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Mohan et al. 2017 Bangladesh, Brazil, India, Nepal, Peru, Pakistan, South Africa, United Republic of Tanzania	Children (< 2 years)	>2 persons per room		Rotavirus infection and diarrhoea	Cohort	1737 children, contributing 22 646 surveillance and 7440 diarrhoeal specimens
Ramani et al. 2017 India	Adolescents in the school environment in an Indian coastal	<2, 2 to <4 and ≥4 persons per room		Diarrhoea	Cross-sectional	114
Studies reporting on outcomes 3 and 5: Mental health (including stress)						
Faisal-Cury et al. 2009 Brazil	Gender: 100% female age: <12 months. Housing: residential. Ethnicity: White (377); Black (124); Mixed/Other (330). Mean people/house: NR Mean rooms/house: NR	0.76–1.00 PPR 1.00–1.75 PPR >1.75 PPR	0-0.75 PPR	Common mental disorders	Cross-sectional	831
Riva et al. 2014a Greenland	Gender: 56% female age: 18–95 (mean = 44.3) yrs. Housing: residential. Ethnicity: NR Mean people/house: 2.1 Mean rooms/house: 3.2	Per additional person per room	NR	Feeling anxious or feeling depressed	Cross-sectional	3066
Riva et al. 2014b Canada	Gender: 56% female mean age (SD): 37 (14.1) yrs. Housing: residential. Ethnicity: 100% Inuit Mean people/house: 2.4 Mean rooms/house: 5.6	>1 PPR	<1 PPR	Stress	Cross-sectional	839
Kimhy et al. 2006 Israel	Gender: 49% female age: NR. Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: 4.2	1–1.99 PPR 2–2.99 PPR >3 PPR	<1 PPR	Schizophrenia	Retrospective cohort	11 015 (104 cases)

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Cabieses et al. 2012 Chile	Gender: Chilean born = 51%; non-Chilean born= 55% female Mean age: Chilean born = 33; non-Chilean born= 33 yrs. Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	>1 PPR	<1 PPR	Psychiatric disability (self-report)	Cross-sectional	268 873
Regoeczi et al. 2008 Canada	Gender: 57% female mean age (SD): 37 (10) yrs. Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	PPR	NR	Depression or aggression or withdrawal	Prospective cohort	Wave 1: 1,393; Wave 2: 1206; Final analyses: 1018
Barnes et al. 2011 the United Kingdom	Gender: NR Age: 5–18 years Housing: residential. Ethnicity: NR Mean people/house: NR Mean rooms/house: NR	0 years living in an overcrowded house 3–5 years living in an overcrowded house	1–2 years living in an overcrowded house	Feeling unhappy about one's health	Retrospective cohort	6341
Al-Hemiary et al. 2015 Iraq	Participants randomly selected from youth centres	≥2 persons per room		Alcohol and drug abuse	Cross-sectional	2678
Firdaus et al. 2017 India	Adults (≥18 years)	Overcrowding (not defined)		Psychological distress	Cross-sectional	4326 households
Gray et al. 2016 Canada	Inuit youth (15–30 years) from the 2004 Nunavik Inuit Health Survey	Crowding: number of people divided by number of bedrooms + 2		Mental health	Cross-sectional	452
Kohen et al. 2015 Canada	Inuit children (2–5 years), as part of 2006 Aboriginal Children's Survey	>1 person per room (also did >1.5 persons per room, with results available on request from the authors)		Mental health	Cross-sectional	1233

Study, year Country	Population	Exposure	Comparator	Outcome	Study design	Sample size
Pierse et al. 2016 New Zealand	Adults (18–80 years)	Number of bedrooms available versus number of bedrooms required (≥2 excess bedrooms, 1 excess, no deficit or excess, 1 bedroom deficit, ≥2 bedrooms deficit)		Psychological distress	Cross-sectional	>13,800 responses to each wave in a longitudinal study
Waters et al. 2017 USA	Vulnerable Latino children (<7 years)	>1.5 persons per room		Autonomic nervous system reactivity and externalizing behaviour problems	Cohort	99 families
Studies reporting on outcomes 4: Sleep disorders						
Chambers et al. 2016 USA	Low-income Latino adults	≥1 persons per room		(a) sleep duration, (b) sleep disturbance, (c) prolonged sleep latency (i.e. falling asleep), and (d) self-reported sleep quality	Cross-sectional	371
Johnson et al. 2015 USA	Adults with sleep-disordered breathing	Percentage of households in a census tract with >1 person per room		Sleep disorders	Ecological	1789
van der Spuy et al. 2017 Canada	Two First Nation communities, in the First Nations Lung Health Project	>1 person per room		Excessive daytime sleepiness	Cross-sectional	874

*Study reports on people per room but not clear on cut -off point as per crowding definition; PPR – person per room; NR – not reported; SD-standard deviation

Appendix 18 GRADE evidence profile tables

Tuberculosis (outcome 1a) and other respiratory diseases (outcome 1b, part 1)

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Tuberculosis (TB)										
21 (Baker 2008, Cluver 2013, Corbett 2009, Garcia-Sancho 2009, Goldhaber-Fiebert 2011, Gyawali 2012, Harling 2014, Hill 2006, Irfan 2017, Jayanthi 2012, Khan 2016, Lakshmi 2012, Larcombe 2011, Lienhardt 2005, Pelissari 2017, Soborg 2011, Tesema 2015, Tipayamongkholgul 2005, Tornee 2004, Tornee 2005, Wanyeki 2006)	Cohort: 1 (Harling 2014) Case-control: 10 (Garcia-Sancho 2009, Hill 2006, Irfan 2017, Jayanthi 2012, Khan 2016, Lakshmi 2012, Lienhardt 2005, Tesema 2015, Tipayamongkholgul 2005, Wanyeki 2006) Cross-sectional: 8 (Cluver 2013, Corbett 2009, Goldhaber-Fiebert 2011, Gyawali 2012, Larcombe 2011, Soborg 2011, Tornee 2004, Tornee 2005) Ecological: 2 (Baker 2008, Pelissari 2017)	Moderate	Consistent	Direct	Precise	Studies were in 719,663 people in Brazil (Harling 2014), 126 people with and without TB in Mexico (Garcia-Sancho 2009), 300 people with and without TB in Gambia (Hill 2006), 357 people with and without TB in Bangladesh (Irfan 2017), 300 people with and without TB in India (Jayanthi 2012), 200 people with and without TB in Canada (Khan 2016), 378 people with and without TB in India (Lakshmi 2012), 2376 people with and without TB in Guinea, Guinea-Bissau, and Gambia (Lienhardt 2005), 655 people with and without TB in Ethiopia (Tesema 2015), 260 people with and without TB in Thailand (Tipayamongkholgul 2005), 5995 people with and without TB in Canada (Wanyeki 2006), 6002 people in South Africa (Cluver 2012), 1092 people In Zimbabwe (Corbett	Cohort study: 719 663 Case-control studies: 10 947 Cross-sectional studies: 135 789 people and 129 households Ecological studies: 65 765 cases	Cohort study: TB was more common in households with >2 people per sleeping room (IRR: 1.37, 95% CI: 1.35-1.39) (Harling 2014) Case-control studies: Five studies found that TB was significantly more common in households of at least 4 persons with at least 2 people per room (compared to households of <4 persons and <2 people sleeping per room) (OR 5.12:, 95% CI: 1.82- 14.38) (Hill 2006), with >2 per room (OR: 3.49, 95% CI: 2.08-5.93) (Irfan 2017), with >1 per room if living with a smear positive person (aOR: 1.8, 95% CI: 1.1-2.9) (Khan 2016), with <4m^2 per room per person (aOR: 3.11, 95% CI: 2.09-4.63) (Tesema 2015) and for each 0.1 increase in persons per room (OR: 1.5, 95% CI: 1.1–1.9) (Wanyeki 2006). However, although the other studies found that TB was more common with crowding, the findings were not significant for households with a one bedroom deficit (OR: 1.7, 95% CI: 0.4-7.3) (Garcia-Sancho 2009), with >4 per room (OR 1.55, 95% CI: 0.95-2.51) (Lakshmi 2012), with 1-2 per room (OR: 1.07, 95% CI: 0.64-1.82) or >2 per room (OR: 1.26, 95% CI: 0.73–2.16) (Lienhardt 2005), ≥5 per room (compared to ≤1 per room) (OR: 3.02, 95% Ci: 0.88 -10.32) (Tipayamongkholgul 2005) and with >4 people who were not in a single room (OR: 0.72, 95% CI: 0.36 to 1.42) (Jayanthi 2012).	⊕⊕⊕⊕ High	High

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
						2009), 124,607 in the world health survey of 46 countries (Goldhaber-Fiebert 2011), 184 cases and 802 household contacts in Nepal (Gyawali 2012), 129 households in Canada (Larcombe 2011), 1797 people in Greenland (Soborg 2011), 500 people in Thailand (Tornee 2004), 325 cases and 480 household contacts in Thailand (Tornee 2005), and using census data for 1898 notified TB cases in New Zealand (Baker 2008) and 63,907 new TB cases in Brazil (Pelissari 2017).		Cross-sectional studies: all studies found that TB was more common with crowding. The studies used varying definitions of crowding, and the association was statistically significant in most studies. The studies had the following results based on the definitions of crowding that they used: households with >3 persons per room (OR: 1.35, 95% CI: 1.06-1.72, p<0.017) (Cluver 2013), 2-4 per room (OR: 2.19, 95% CI: 1.12-4.26) or >4 per room (OR: 3.64, 95% CI: 0.81-16.46) (Corbett 2009), an additional person per room in the world health survey (OR: 1.04, 95% CI: 0.98-1.09) (Goldhaber-Fiebert 2011), 2-3 per room (compared to less) (OR: 7.46, 95% CI: 2.36-23.49) (Gyawali 2012), 1.2 per room (compared to 0.9 per room) (OR: 1.21, p=0.001) (Larcombe 2011), ≥1.50 per room (compared to 1-1.49 per room) (OR: 1.15, 95% CI: 0.59-2.26) (Soborg 2011), ≥3 per room (compared to ≤2 per room) (OR: 2.63, 95% CI: 1.18-5.85) (Tornee 2004), and ≥3 per room (compared to ≤2 per room) (OR: 5.19; 95% CI: 2.65-8.69) (Tornee 2005) Ecological studies: TB was more common in households with a bedroom deficit of at least one (IRR: 1.05, 95% CI: 1.02 to 1.08, p=0.001) (Baker 2008) and with >2 per room (IRR: 1.2, 95% CI 1.17-1.23) (Pelissari 2017).		
Flu-related hospitalization										
2 (Tam 2014, Yousey-Hindes 2011)	Ecological: 2 (Tam 2014, Yousey-Hindes 2011)	Low	Consistent	Direct	Precise	Studies were done with census data for more than 670,000 people in the USA (Tam 2014), and 517 children (<18 years) in the USA (Yousey-Hindes 2011).	Ecological studies: population of >670,000 in one study and 517 cases in the other study.	Ecological studies: flu-related hospitalizations were more common if the proportion of houses in the census tract had >5.0 per room: RR: 2.77 (Tam 2014) and OR: 3.56 (Yousey-Hindes 2011).	⨁⨁⨁⊖ Moderate	Moderate

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Pneumonia										
6 (da Fonseca Lima 2016, Grant 2012, Howie 2016, Mathew 2014, Reisman 2013, Verani 2016)	Case-control: 4 (da Fonseca Lima 2016, Grant 2012, Howie 2016, Verani 2016) Cross-sectional: 2 (Mathew 2014, Reisman 2013)	Moderate	Inconsistent	Direct	Imprecise	Studies were in 814 children (1–59 months) with and without pneumonia in Brazil (da Fonseca Lima 2016), 779 children (<5 years) with and without pneumonia in New Zealand (Grant 2012), 1581 children with and without pneumonia in Gambia (Howie 2016), 2333 children (1 month to 12 years) in India (Mathew 2014), 3517 children with and without pneumonia in South Africa (Verani 2016), and 12,535 indigenous people in the USA (Reisman 2013).	Case-control studies: 6691 Cross-sectional studies: 14 868	Case-control studies: two studies found significant increases in pneumonia if ≥2 people were sleeping in a child's room (aOR: 2.15; 95% CI: 1.46-3.18) (da Fonseca Lima 2016) or >2 sleeping in child's room for those without malnutrition (aOR: 2.29, 95% CI: 1.89–2.78) but not for those with malnutrition (aOR: 1.13, 95% Ci: 0.71–1.80) (Verani 2016). One study found pneumonia was non-significantly increased for >1 per room (OR: 1.39, 95% CI: 0.78-2.48) (Grant 2012) and one found no significant association (Howie 2016). Cross-sectional studies: One study found that for each additional person per room the odds of pneumonia increased in each age group (<10 years, OR: 1.14, p<0.001; 10-17 years OR: 1.12, p=0.002; ≥18 years, OR: 1.08, p=0.008) (Reisman 2013) but the other study found a reduction in microbiological etiology of community acquired pneumonia if the number of members of opposite genders (not married or >10 years) is greater than the number of sleeping rooms (OR: 0.54, 95% CI: 0.12 - 0.89) (Mathew 2014).	⊕⊕⊕⊖ Moderate	Low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Flu and flu-like illness										
5 (Chandrasekhar 2017, Doshi 2015, Forshey 2010, Sekhar 2009, Sloan 2015)	Cohort: 2 (Forshey 2010, Sekhar 2009) Case-control: 1 (Doshi 2015) Ecological: 2 (Chandrasekhar 2017, Sloan 2015)	Moderate	Consistent	Direct	Precise	Studies were in 10 341 people in Peru (Forshey 2010), 1000 children (<2 years) in India (Sekhar 2009), in 486 children with and without influenza in Bangladesh (Doshi 2015), 33,515 cases in the USA (Chandrasekhar 2017) and 1743 people hospitalized with influenza in the USA (Sloan 2015).	Cohort studies: 11 341 Case control study: 486 Ecological studies: 35 258	Cohort studies: flu and flu-like illness was more common with >2 per room (OR: 1.56, 95% CI: 1.17-2.08) (Forshey 2010) and Haemophilus influenzae colonization was more common with >2 per room (OR 9.2, 95% CI: 2.3-36.1) (Sekhar 2009). Case control study: influenza was more common with ≥4 per room (OR: 1.88, 95% CI: 1.22–2.92, p=0.005). (Doshi 2015). Ecological studies: influenza was more common among persons in a census tract with more than 5% vs <5% living with >1 per room (aOR: 1.17, 95% CI: 1.11-1.23) (Candrasekhar 2017) and 5.0–9.9 per room (RR: 1.3, 95% CI: 1.1–1.5) and ≥10.0 per room (RR: 1.6, 95% CI: 1.2–2.2) (compared to <5 per room) (Sloan 2015).	⨁⨁⨁⊖ Moderate	Moderate
Acute respiratory illness										
16 (Cardoso 2004, Chattopadhyay 2016, Diaz 2015, Firdaus 2013, Hughes 2017, Islam 2013, Kohen 2015, Kristensen 2006, Kumar 2015 , Larson 2010, Murray 2012,	Cohort: 3 (Kristensen 2006, Larson 2010, Tin 2016) Case-control: 1 (Cardoso 2004) Cross-sectional: 12 (Chattopadhyay 2016, Diaz 2015, Firdaus 2013, Hughes 2017, Islam 2013, Kohen 2015, Kumar 2015, Murray 2012, Prietsch 2008, Sinha 2015, Tse 2016, Weber 2017)	Moderate	Consistent	Direct	Precise	Studies were in 571 infants (<1 year) in South Africa (Kristensen 2006), in 2788 households in the USA (Larson 2010), 6112 children in New Zealand (Tin 2016) 832 children with and without acute lower respiratory disease in Brazil (Cardoso 2004), 258 coal-based sponge iron plant workers in India (Chattopadhyay 2016), 162 children (<5 years) in Mexico (Diaz 2015), 1896 households in India (Firdaus 2013), 33 201	Cohort studies: 9471 Case-control study: 832 Cross-sectional studies: 10 344 people and 35,097 households	Cohort studies: one study found an increase in acute respiratory infection if >3 adults were sleeping in a child's room (RR: 1.75, 95% CI: 1.26-2.44) (Kristensen 2006) and another study found a non-significant increase in adjusted analyses for ≥2 per bedroom (aHR1: 1.11, 95% CI: 0.95-1.29; aHR2: 1.07, 95% CI: 0.91-1.25; aHR3: 1.07, 95% CI: 0.91-1.26) (Tin 2016) and the other study (which was a randomized trial where the intervention was not relevant to crowding) found a decrease in upper respiratory tract infections with crowding (OR: 0.8, 95% CI: 0.72-0.89) (Larson 2010). Case-control study: increase in children with acute lower respiratory disease if >4 persons were sleeping in a child's room	⨁⨁⨁⊖ Moderate	Moderate

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Prietsch 2008, Sinha 2015, Tin 2016, Tse 2016, Weber 2017)						households in the USA (Hughes 2017), 370 children (<5 years) in India (Islam 2013), 1233 children (2-5 years) in Canada (Kohen 2015), 509 parents of children (<5 years) in India (Kumar 2015), 718 children (<5 years) in Bangladesh (Murray 2012), 771 children in Brazil (<10 years) (Prietsch 2008), 1203 adults (≥30 years) in India (Sinha 2015), 388 children (3-5 years) in Canada (Tse 2016), and 4732 children in Germany (Weber 2017).		(OR: 2.5, 95% CI: 1.02-6.09) (Cardoso 2004). Cross-sectional studies: most studies found increases in acute respiratory illness in crowded houses, associated with ≥3 persons per sleeping room (OR: 2.6, 95% CI: 1.1-6.1) (Diaz 2015), decreasing floor space per room (OR: 1.62, 95% CI: 1.42-1.84) (Firdaus 2013), not specified overcrowding (Islam 2013), not defined overcrowding (aOR: 1.492, p<0.001) (Kumar 2015), ≥3 persons per room (OR: 3·31, 95% CI: 2.03-5.38) (Murray 2012), ≥4 per room (PR: 1.54, 95% CI: 1.08-2.19) (Prietsch 2008), for allergic rhinitis with >2 persons per room or <110 sq ft for 2 persons (aOR: 6.376 (95% CI: 3.65-11.13, p<0.0005) (Sinha 2015), and for severe chest infections with overcrowding (OR: 1.51, 95% CI: 1.09-2.09, p=0.01) (Tse 2016). One study found significant increases in asthma diagnosis (OR: 1.23, 95% CI: 1.05–1.44, p<0.05) and emergency department visits related to asthma (OR: 1.56, 95% CI: 1.08-2.26, p<0.05) with >2 persons per bedroom (Hughes 2017). Three other studies found no significant association for ARI (p=0.115) or rhinoconjuctivitis with >3 per room (Chattopadhyay 2016), for chronic respiratory allergies, asthma or bronchitis with >1 per room (aOR 0.76, p=0.223) (Kohen 2015), or for allergic rhinitis (OR: 0.64, 95% CI: 0.36-1.16) and asthma (OR: 1.25, 95% CI: 0.77-2.02) with >1 person per room or <20m2 living space per person (Weber 2017).		

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Respiratory syncytial virus										
1 (Bruden 2015)	Ecological: 1 (Bruden 2015)	Moderate	Not applicable (one study)	Direct	Imprecise	1903 children (<3 years) in the USA (Bruden 2015)	Ecological study: 1903	Ecological study: found that for each 20% increase in the percentage of crowded households: univariate RR: 1.28 (95% CI: 1.23-1.35, p<0.0001); multivariate RR: 1.20 (95% CI: 1.13-1.28, p<0.0001) (Bruden 2015).	⊕⊖⊖⊖ Very low	Very low

Diarrhoea (outcome 2) and other non-respiratory infectious diseases (outcome 1b, part 2)

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Diarrhoea										
13 (Abu Mourad 2004, El-Gilany 2005, Etiler 2004, Ferrer 2008, Harper 2015, Kyle 2011, Mohan 2017, Monasta 2008, Okour 2012, Perry 2015, Pezzani 2012, Quigley 2006, Ramani 2017)	Cohort: 4 (Etiler 2004, Kyle 2011, Mohan 2017, Perry 2015) Case-control: 2 (Ferrer 2008, Quigley 2006) Cross-sectional: 7 (Abu Mourad 2004, El-Gilany 2005, Harper 2015, Monasta 2008, Okour 2012, Pezzani 2012, Ramani 2017)	Moderate	Inconsistent	Direct	Imprecise	Studies were in 204 infants (<1 year) in Turkey (Etiler 2004), 24,481 children (<14 years) in the UK (Kyle 2011), 1737 children (<2 years) (22,646 surveillance and 7440 diarrhoeal specimens) in Bangladesh, Brazil, India, Nepal, Peru, Pakistan, South Africa and the United Republic of Tanzania (Mohan 2017), 5015 children (<18 years) in the USA (Perry 2015), 3364 children (<10 years) with and without diarrhoea in Brazil (Ferrer 2008), 304 infants (<1 year) with and without diarrhoea in the UK (Quigley 2006), 1655 people in West Bank and Gaza Strip	Cohort studies: 31 437 Case-control studies: 3668 Cross-sectional studies: 7191	Cohort studies: studies found an increase in diarrhoea (RR: 1.7, 95% CI: 1.18-1.7) with 3 people per room (Etiler 2004), >2 per room (IRR: 1.401, 95% CI: 1.072–1.830, p=0.014) (Mohan 2017) and another study found no significant impact of overcrowding on emergency admission for diarrhoea (Spearman's rho correlation: 0.21, p=0.267) (Kyle 2011) and another found that ssecondary transmission of gastroenteritis was more common if a child shared a bed with someone with gastroenteritis (OR: 2.0, 95% CI, 1.5-2.60) (Perry 2015). Case-control studies: one study found an increase in diarrhoea with ≥3 persons per room (OR: 1.73, 95% CI: 1.45-2.06) (Ferrer 2008) but the other found a non-significant decrease with >1 per room (OR: 0.94, 95% CI: 0.55-1.59) (Quigley 2006). Cross-sectional studies: diarrhoea was non-significantly more common in three studies, with 3.46-6.74 persons per room (OR: 1.28, 95% CI: 0.93-1.76) or 6.75–	⊕⊕⊕⊖ Moderate	High

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
						(Abu Mourad 2004), 4458 children (<5 years) in Egypt (El-Gilany 2005),1517 Innuit people in Canada (Harper 2015), 165 children (<5 years) in Italy (Monasta 2008), 197 children (<13 years) in Jordan (Okour 2012), 716 children (<17 years) in Argentina (Pezzani 2012), 114 students in India (Ramani 2017).		10.03 per room (OR: 1.96, 95% CI: 0.79-4.87) (Abu Mourad 2004), 1.3-2.5 per room (OR: 9.84, 95% CI: 0.57-170.1) or 2.6-4.0 per room (OR: 13.95, 95% CI: 0.81-240.4) (Okour 2012), and with overcrowding (OR: 1.42, P=0.09) (Ramani 2017). However, the second of those studies also found that diarrhoea was significantly more common with >4 per room (OR: 23.68, 95% CI: 1.31-426.5) (Okour 2012). Other studies also found that diarrhoea was significantly more common during the last two weeks (OR: 1.52. 95% CI: 1.26-1.83) or during the last 24 hours (OR: 1.82, 95% CI: 1.39-2.39) with >3 per room (El-Gilany 2005). In another study, diarrhoea in the last 15 days was decreased with >2.5 per room (OR: 0.63, 95% CI: 0.41 to 0.96) (Monasta 2008)		
Typhoid fever										
1 (Hosoglu 2006)	Case-control: 1 (Hosoglu 2006)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 1222 people with and without typhoid fever in Turkey (Hosoglu 2006)	Case-control study: 1222	Case-control study: typhoid fever was increased in households with above the mean number of persons per room (OR: 3.31, 95% CI: 1.58-6.92) (Hosoglu 2006).	⊕⊖⊖⊖ Very low	Very low
Skin infections										
2 (Bailie 2005, Hegab 2015)	Cross-sectional: 2 (Bailie 2005, Hegab 2015)	Low	Inconsistent	Direct	Imprecise	Studies were in 161 children (<7 years) in Australia (Bailie 2005), and 2104 children in Egypt (Hegab 2015).	Cross-sectional studies: 2265	Cross-sectional studies: skin infection was non-significantly increased in households with >4 people per room (OR: 1.61, 95% CI: 0.61-4.21) (Bailie 2005) and >1.5 per sleeping room did not affect the risk of scabies (OR: 0.892, 95% CI: 0.456–1.743) (Hegab 2015).	⊕⊕⊖⊖ Low	Low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Meningococcal disease										
7 (Al Jarousha 2014, Alemayehu 2017, De Wals 2005, Deutch 2004, MacLennan 2006, Norheim 2014, Olea 2017)	Cohort: 1 (Norheim 2014) Case-control: 3 (De Wals 2005, Deutch 2004, Olea 2017) Cross-sectional: 3 (Al Jarousha 2014, Alemayehu 2017, MacLennan 2006)	Low	Inconsistent	Direct	Precise	Studies were in a general population of 35 million in Norway, Sweden, Denmark and the Netherlands (Norheim 2014), in 74 children (<12 years) with and without meningococcal disease in Canada (De Wals 2005), in 25 771 children (<6 years) with and without meningococcal disease in Denmark (Deutch 2004), 753 people with and without meningococcal disease in Chile (Olea 2017), 1853 children in West Bank and Gaza Strip (Al Jarousha 2014), 240 people in Ethiopia (Alemayehu 2017), and 14 057 students (15-19 years) in the UK (MacLennan 2006).	Cohort study: 35 000 000 Case-control studies: 26 524 Cross-sectional studies: 16 150	Cohort study: meningococcal disease was significantly, but slightly, higher if >2 per room (RR=1.05-1.07, 95% CI: 1.03-1.09) (Norheim 2014). Case-control studies: one study found that meningococcal disease was more common with >4 young people (<21 years of age) in the household (OR: 3.7, 95% CI: 1.5 -9.1) (De Wals 2005) and the other studies found that meningococcal disease was significantly higher if <20 m² per person (OR: 1.5, 95% CI: 1.1-1.9) (Deutch 2004) and with >2.5 persons per bedroom for children <5 years (OR: 2.4, 95% CI: 1.3–4.5) and for persons >5 years (OR: 2.4, 95% CI: 1.2–5.1) (Olea 2017). Cross-sectional studies: one study found that risk factors for meningitis were higher with >3.0 per room (OR: 1.66, 95% CI: 1.01-2.74) (Al Jarousha 2014), another study found significant increases with >1 per room (OR 1.268, 95% CI: 1.186-1.355, p=0.006) (Alemayehu 2017) but the other study found that meningococcal carriage (confirmed colonies of N. Meningitidis) was non-significantly lower with >3 people per sleeping room (OR: 0.91, 95% CI: 0.57-1.43) (MacLennan 2006).	⊕⊕⊕⊖ Moderate	Moderate

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Rheumatic fever and rheumatic heart disease										
5 (Jaine 2011, Mirabel 2015, Okello 2012, Phillips 2014, Riaz 2013)	Cohort: 2 (Jaine 2011, Phillips 2014) Case-control: 3 (Mirabel 2015, Okello 2012, Riaz 2013)	Low	Consistent	Direct	Precise	Studies were in 1249 cases of acute rheumatic fever in New Zealand (Jaine 2011), 37 321 deaths from rheumatic heart disease in the UK (Phillips 2014), 341 children with and without RHD in French Pacific Islands (Mirabel 2015), 486 people (15-60 years) with and without rheumatic fever in Uganda (Okello 2012), and 309 people with and without rheumatic fever in Bangladesh (Riaz 2013).	Cohort studies: 38 570 Case-control studies: 1136	Cohort studies: both studies found increases with crowding. One found that acute rheumatic fever increased with the proportion of crowded houses in the census area (IRR: 1.07, 95% CI: 1.05-1.08) (Jaine 2011) and the other found that deaths from rheumatic heart disease increased with persons per room (RR: 1.07, 95% CI: 1.05-1.09) (Phillips 2014). Case-control studies: studies found that rheumatic heart disease was more common with >8 per household giving <90ft^2 per person (OR: 1.98, 95% CI: 1.4-2.5) (Okello 2012) and with ≥3 per bedroom (OR: 8.27, 95% CI: 1.67–41.08, p<0.01) (Mirabel 2015). The other study found that rheumatic fever was non-significantly lower with ≤3 per room (OR: 0.74, 95% CI: 0.5-1.2) and rheumatic heart disease was higher with >3 per room (OR: 1.7, 1.1-2.7) (Riaz 2013).	⊕⊕⊕⊖ Moderate	Moderate
Throat, eye and skin infections										
1 (Firdaus 2013)	Cross-sectional: 1 (Firdaus 2013)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 1896 households in India (Firdaus 2013).	Cross-sectional study: 1896 households	Cross-sectional study: non-significant small increase in infections with decreasing floor space per room (OR: 1.04, 95% CI: 0.91-1.18) (Firdaus 2013).	⊕⊖⊖⊖ Very low	Low
Risk factors for water, sanitation and hygiene										
1 (Rao 2010)	Cross-sectional: 1 (Rao 2010)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 701 people in Guatemala (Rao 2010).	Cross-sectional study: 701	Cross-sectional study: risk factors for WASH problems were greater with crowding (PR: 1.24, p=0.049) (Rao 2010).	⊕⊖⊖⊖ Very low	Low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Dengue fever										
1 (Vincenti-Gonzalez 2017)	Cross-sectional: 1 (Vincenti-Gonzalez 2017)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 1985 people in Venezuela (Vincenti-Gonzalez 2017)	Cross-sectional study: 1985	Cross-sectional study: Dengue was non-significantly higher with >1.5 per room in non-hot-spot housing (OR: 1.18, 95% CI: 0.70-1.98, p=0.637) but significantly higher in hot-spot housing (OR: 2.32, 95% CI: 1.64-3.26, p <0.001) (Vincenti-Gonzalez 2017).	⊕⊖⊖⊖ Very low	Very low
Epstein Barr virus										
1 (Gares 2017)	Cohort: 1 (Gares 2017)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 12,457 children (<14 years) in the UK (Gares 2017).	Cohort study: 12,457	Cohort study: EBV was more common with >1.5 per room (aOR: 1·14, 95% CI: 1.00–1.31) (Gares 2017).	⊕⊖⊖⊖ Very low	Very low
Helicobacter pylori										
1 (Krueger 2015)	Cross-sectional: 1 (Krueger 2015)	Moderate	Not applicable (one study)	Direct	Imprecise	Study was in 7398 people (>3 years) in the USA (Krueger 2015).	Cross-sectional study: 7398	Cross-sectional study: elevated IgG antibodies against Helicobacter pylori were associated with >1 per room (aOR 1·7, 95% CI: 1.3–2.2) (Krueger 2015).	⊕⊖⊖⊖ Very low	Very low
Methicillin-resistant staphylococcus aureus										
2 (Auget 2016, Vieira 2016)	Case-control: 1 (Vieira 2016) Ecological: 1 (Auget 2016)	Moderate	Consistent	Direct	Imprecise	Studies were in a setting with nearly 900,000 residents in the UK (Auget 2016), and 117 HIV-infected youth (<25 years) in Brazil (Vieira 2016).	Case-control study: 117 Ecological study: nearly 900 000 residents	Case-control study: MRSA colonization (p=0.018) and persistent MRSA colonization (p=0.037) were more common with ≥5 per household (Vieira 2016). Ecological study: MRSA was more common with bedroom deficit of 1 (RR: 1.84, 95% CI: 1.24–2.73) (Auget 2016).	⊕⊖⊖⊖ Very low	Very low
1 (Alvarado-Esquivel 2016)	Case-control: 1 (Alvarado-Esquivel 2016)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 375 miners with and without parasite Toxoplasma gondii in Mexico (Alvarado-Esquivel 2016).	Case-control study: 375	Case-control study: antibodies to Toxoplasma gondii were more common with >3.5 per room (OR: 5.83, 95% CI: 1.49-22.8, p=0.01) (Alvarado-Esquivel 2016).	⊕⊖⊖⊖ Very low	Very low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
1 (Mitra 2018)	Cohort: 1 (Mitra 2018)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 30,267 newborns in Bangladesh (Mitra 2018).	Cohort study: 30 267	Cohort study: in this study (which was a randomized trial where the intervention was not relevant to crowding) neonatal infections were significantly more common with ≤ 0.5 bedrooms per person (aRR 1.14, 95% CI: 1.04–1.25) (Mitra 2018).	⨁⨁⨀⨀ Low	Low
1 (Brander 2017)	Cross-sectional: 1 (Brander 2017)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 292 children (6 months to 15 years) in Kenya (Brander 2017)	Cross-sectional study: 292	Cross-sectional study: significant increase in multi-drug non-susceptible enteric infections (aPR: 1.29, 95% CI: 1.08-1.53, p=0.004) with ≥3 persons per room (Brander 2017).	⨁⨀⨀⨀ Very low	Very low

Mental health including stress (outcomes 3 and 5) and sleep disorders (outcome 4)

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Common mental disorders										
1 (Faisal-Cury 2009)	Cross-sectional: 1 (Faisal-Cury 2009)	Low	Not applicable (one study)	Direct	Precise	Study was in 831 pregnant women in Brazil (Faisal-Cury 2009).	Cross-sectional study: 831	Cross-sectional study: mental disorders were more common for 0.76-1.00 per room (PR: 1.78, 95% CI: 1.21-2.60), 1.00-1.75 per room (PR: 1.17, 95% CI: 0.76-1.81) and >1.76 per room (PR: 1.63, 95% CI: 1.11-2.40) (compared to <0.75 per room) (Faisal-Cury 2009).	⨁⨁⨀⨀ Low	Low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Anxiety and depression										
3 (Barnes 2011, Regoeczi 2008, Riva 2014a)	Cohort: 2 (Barnes 2011, Regoeczi 2008) Cross-sectional: 1 (Riva 2014a)	Unclear	Inconsistent	Direct	Precise	Studies were in 6341 people in the UK (Barnes 2011), 1018 people in Canada (Regoeczi 2008) and 3066 people in Greenland (Riva 2014a).	Cohort studies: 7359 Cross-sectional study: 3066	Cohort studies: unhappiness about one's health was significantly increased after 3-5 years living in a crowded house (OR: 4.23, p<0.01) (Barnes 2011) and depression was associated with both very uncrowded and crowded houses (Regoeczi 2008) but there were no significant associations with aggression or withdrawal (Regoeczi 2008). Cross-sectional study: anxiety was non-significantly higher per additional person per room (OR: 1.1, 95% CI: 0.93-1.31) and depression was significantly higher (OR: 1.22, 95% CI: 1.03-1.43) (Riva 2014a).	⨁⨁⨀⨀ Low	Low
Psychiatric disability										
1 (Cabieses 2012)	Cross-sectional: 1 (Cabieses 2012)	Unclear	Not applicable (one study)	Direct	Precise	Study was in 268 873 people in Chile (Cabieses 2012).	Cross-sectional study: 268 873	Cross-sectional study: self-reported psychiatric disability was significantly lower for > 1 per room in Chilean-born people (OR: 0.65, 95% CI: 0.46-0.91) but uncertain for international immigrants (OR: 0.78, 95% CI: 0.04-13.03) (Cabieses 2012).	⨁⨁⨀⨀ Low	Low
Schizophrenia										
1 (Kimhy 2006)	Cohort: 1 (Kimhy 2006)	Unclear	Not applicable (one study)	Direct	Imprecise	Study was in 11 015 people (104 cases) in Israel (Kimhy 2006).	Cohort study: 11 015	Cohort study: schizophrenia was non-significantly associated with crowding for 1-1.99 per room (RR: 1.17, 95% CI: 0.57-2.40), 2-2.99 per room (RR: 0.83, 95% CI: 0.38-1.82) and >3 per room (RR: 0.91, 95% CI: 0.41-2.03) (compared to <1 per room) (Kimhy 2006).	⨁⨀⨀⨀ Very low	Very low
Stress										
1 (Riva 2014b)	Cross-sectional: 1 (Riva 2014b)	Unclear	Not applicable (one study)	Direct	Imprecise	Study was in 839 people in Greenland (Riva 2014b).	Cross-sectional study: 839	Cross-sectional study: stress was increased with >1 person per room (OR: 1.82, 95% CI: 1.14-2.90) (Riva 2014b).	⨁⨀⨀⨀ Very low	Very low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Inattention and hyperactivity										
1 (Kohen 2015)	Cross-sectional: 1 (Kohen 2015)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 1233 children (2-5 years) in Canada (Kohen 2015).	Cross-sectional study: 1233	Cross-sectional study: no significant association of inattention-hyperactivity with >1 per room in adjusted analyses (Kohen 2015).	⊕⊖⊖⊖ Very low	Very low
Emotional symptoms										
1 (Kohen 2015)	Cross-sectional: 1 (Kohen 2015)	Low	Not applicable (one study)	Direct	Imprecise	Study was in 1233 children (2-5 years) in Canada (Kohen 2015).	Cross-sectional study: 1233	Cross-sectional study: no significant association of emotional symptoms with >1 per room in adjusted analyses (Kohen 2015).	⊕⊖⊖⊖ Very low	Very low
Psychological distress										
2 (Firdaus 2017, Pierse 2016)	Cross-sectional: 2 (Firdaus 2017, Pierse 2016)	High	Inconsistent	Direct	Imprecise	Study was in 4326 households in India (Firdaus 2017) and with >13,800 responses to each wave in New Zealand (Pierse 2016).	Cross-sectional study: >13 800 responses and 4326 households	Cross-sectional study: one study found a significant increase in psychological distress with overcrowding (OR: 2.85, 95% CI: 2.49–3.25, p<0.001) (Firdaus 2017) but the other study showed a non-significant association of psychological distress with a one bedroom deficit (Pierse 2016).	⊕⊖⊖⊖ Very low	Very low
Suicide ideation										
1 (Gray 2016)	Cross-sectional: 1 (Gray 2016)	Moderate	Not applicable (one study)	Direct	Imprecise	Study was in 452 Inuit participants (15–30 years) in Canada (Gray 2016).	Cross-sectional study: 452	Cross-sectional study: suicidal ideation was non-significantly increased with 1.9 per room (compared to 0.5 per room) in adjusted analysis (difference in means: +8.8%, 95% CI: −2.1 to +19.6) (Gray 2016).	⊕⊖⊖⊖ Very low	Very low
Self-esteem										
1 (Gray 2016)	Cross-sectional: 1 (Gray 2016)	Moderate	Not applicable (one study)	Direct	Imprecise	Study was in 452 Inuit participants (15–30 years) in Canada (Gray 2016).	Cross-sectional study: 452	Cross-sectional study: self-esteem was non-significantly reduced with 1.9 per room (compared to 0.5 per room) in adjusted analysis (difference in means: −3.3%, 95% Ci: −8.0 to +1.5 (Gray 2016).	⊕⊖⊖⊖ Very low	Very low

Quality assessment							No. of participants	Effect	Quality	Importance
Number of studies	Designs	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Autonomic nervous system reactivity or externalizing behaviour problems										
1 (Waters 2017)	Cohort: 1 (Waters 2017)	Low	Not applicable (one study)	Direct	Imprecise	Study was in children (<7 years) from 99 families in the USA (Waters 2017).	Cohort study: 99 families	Cohort study: overcrowding (>1.5 per room) was not associated with autonomic nervous system reactivity or externalizing behaviour problems (Waters 2017).	⊕⊖⊖⊖ Very low	Very low
Sleep disorders										
3 (Chambers 2016, Johnson 2015, van der Spuy 2017)	Cross-sectional: 2 (Chambers 2016, van der Spuy 2017) Ecological: 1 (Johnson 2015)	Moderate	Inconsistent	Direct	Imprecise	Studies were in 371 low-income adults in the USA (Chambers 2016), 874 people in Canada (van der Spuy 2017), and 1789 patients in the USA (Johnson 2015).	Cross-sectional studies: 1245 Ecological: 1789	Cross-sectional studies: one study found excessive daytime sleepiness with >1 per room (aOR: 2.07, 95% CI: 1.16–3.69, p=0.014) (van der Spuy 2017) and the other study concluded, in general, that living in a crowded household (≥1 per room) is not significantly associated with sleep disturbance but did find a significant relationship between crowding and duration of sleep in some analyses (Chambers 2016). Ecological: this study found that for every one-unit increase in percentage of neighbourhood-level crowding (>1 per room), the apnoea–hypopnoea index increased by 0.40 ± 0.20 (p=0.04) (Johnson 2015).	⊕⊕⊖⊖ Low	Low
Drug and alcohol abuse										
1 (Al-Hemiary 2015)	Cross-sectional: 1 (Al-Hemiary 2015)	High	Not applicable (one study)	Direct	Imprecise	Study was in 2678 youths in Iraq (Al-Hemiary 2015).	Cross-sectional study: 2678	Cross-sectional study: alcohol abuse was significantly associated ($\chi 2$: 4.9, df: 1, p=0.026) and drug abuse was not significantly associated ($\chi 2$: 1.8, df: 1, p=0.17) with ≥2 persons per room (Al-Hemiary 2015).	⊕⊖⊖⊖ Very low	Very low