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UMBRELLA+ REVIEW AND DISCUSSION OF THE EVIDENCE, GAPS, & RESEARCH NEEDS FOR QUANTIFYING TRANSPORTATION NOISE IMPACTS ON ALL-CAUSE MORTALITY

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ABSTRACT

Research on noise impacts on mortality has emerged recently, in the past 5-10 years. As such, there has been growing interest in incorporating these impacts into noise burden of disease and health impact assessment models to better inform policy and planning across Europe. To support these efforts in the UK and with work commissioned by the UK Health Security Agency, we conducted an Umbrella+ review of studies investigating the exposure-response relationships (ERRs) of road, rail, and aircraft noise exposures and all-cause mortality. This review followed a systematic, pre-registered protocol (PROSPERO: CRD42024613900), involving comprehensive searches within databases and grey literature of articles published since January 1st 2015 up to November 1st 2024. Articles were screened independently by two reviewers, and the studies meeting inclusion criteria were assessed for quality using the AMSTAR2 or the ROBINS-E framework. This paper provides a discussion of the existing epidemiological literature on transportation noise and all-cause mortality, highlight gaps in the evidence, and propose areas of focus for future research.

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1. INTRODUCTION

Over the past decade, epidemiological and mechanistic evidence on the non-auditory health effects of long-term exposure to environmental noise has grown significantly, particularly in relation to noise from road, rail, and aircraft transportation. Applying this evidence to estimate attributable disease burdens is a valuable tool for prioritizing noise management strategies, shaping policies, and guiding public health actions at both national and local levels. For example, the European Environment Agency (EEA) publishes noise burden of disease estimates for European countries, finding that in 2017 approximately 1 million healthy life years were lost in Europe due to environmental noise exposures [1]. In the UK, research conducted at granular spatial scales (local authorities) in England [2] estimated that exposure to road, rail, and aircraft noise resulted in the loss of approximately 97,000, 13,000, and 17,000 Disability-Adjusted Life Years (DALYs), respectively. These losses were estimated from the effects of transportation noise on annoyance, sleep disturbance, ischemic heart disease, stroke, and diabetes.

A commonly used metric for quantifying and comparing disease burdens is the Disability-Adjusted Life Year (DALY), which accounts for both mortality and morbidity by summing the Years of Life Lost (YLL) due to premature death and the Years Lived with Disability

(YLD). Traditionally, noise burden of disease assessments estimated the mortality component of DALYs by evaluating the downstream mortality impacts from an increased cause-specific disease incidence. This approach differs, for example, from many air pollution burden assessments (e.g., $PM_{2.5}$), which often focus on all-cause mortality directly, using mortality-specific exposure-response relationships [3, 4].

Over the past 5 to 10 years, a growing body of epidemiological research in Europe has examined the relationship between transportation noise and all-cause mortality. As a result, there is increasing interest in incorporating these findings into noise burden of disease and health impact assessment models to better inform policy and urban planning efforts across Europe [5].

To support these efforts in the UK, and as part of work commissioned by the UK Health Security Agency, we conducted an Umbrella+ review of reviews and original epidemiological studies. This review focused on investigating exposure-response relationships (ERRs) between road, rail, and aircraft noise exposure and all-cause mortality.

2. METHODS

2.1 Approach

An "Umbrella review" is a review of systematic reviews and was used to first identify the newest review on the topic of suitable quality. The "+" allows for the possibility to include very new original (i.e., primary research) studies in addition to the identified review(s). A protocol for the review was published in advance on PROSPERO (CRD42024613900).

2.2 Search strategy

We carried out an initial search (Search 1) to identify systematic review papers, including meta-analyses, umbrella reviews, and key reports. Following the search and synthesis of information from the reviews identified in Search 1, a second search (Search 2) was conducted to identify additional original studies that had been published since the literature search concluded within the most recently identified review from Search 1.

2.3 Inclusion criteria

We defined the inclusion criteria using the PECOS approach which is a framework adapted to be suitable for studies of environmental exposures [6].

Table 1. Inclusion and exclusion criteria.

PECOS	Inclusion	Exclusion
Population	General human population in residential settings	Non-human populations in vivo in vitro
Exposure	Transportation noise exposure from road, rail, and aircraft Studies should either measure or calculate noise exposure levels expressed in decibels at an appropriate location for the study participants' residence.	Community, neighbour, occupational or leisure noise Noise annoyance
Comparator	No noise exposure or a lower level of noise exposure measured in decibels	
Outcome	All-cause mortality	
Study design	Search 1) Systematic reviews with and without meta-analysis, Umbrella(+) reviews, and key reports. Reviews that are published (or accepted for publication) between 1 January 2015 to Oct 28th 2024 written in English. Search 2) New primary research studies that have a longitudinal cohort design, published since the literature search concluded within the most recently identified review from Search 1.	Narrative reviews Qualitative studies Intervention studies Controlled exposure studies Studies with a focus on exposure only Notes, editorials, letters and unpublished data

2.4 Search Strings

The following search terms and strings were adapted and applied to the following databases: PubMed(Medline), EMBASE, Global Health, PyscINFO, Web of Science. As applicable, terms were either searched through title and abstract or as MeSH terms. Additional filters were applied

to the data range for study publication search (Jan 1 2015 – October 28 2024) and language (English).

(humans OR adult OR adult* OR aged OR man OR men OR woman OR women OR child OR children) AND ("Noise, Transportation" OR (noise AND traffic) OR (noise AND transportation) OR (noise AND road) OR (noise AND road-traffic) OR (noise AND (airplane OR aircraft)) OR (noise AND rail*) OR (noise AND environment*)) AND (Mortality OR death OR 'all-cause mortality')

Additional strings identifying study design were added for Search 1 and Search 2 as applicable: ("systematic review" OR "meta-analysis" OR "meta analysis" OR review)) OR (cohort stud* OR cohort OR "Cohort studies").

We additionally ran searches through Google Scholar to check for any missing articles and through Government websites to identify any relevant grey literature (e.g., reports) (UK Health Security Agency, Defra, European Environment Agency (EEA), Swiss Federal Office of Public Health, RIVM, Norwegian Institute of Public Health.

2.5 Study selection and analysis

Papers were reviewed in two stages. All the titles and abstracts of the identified papers were reviewed by two reviewers to assess suitability for inclusion in the review using Covidence (software for organizing literature review workflows), based on the inclusion criteria specified above. Studies were marked as included (take through to full text screening), uncertain, or excluded. Uncertain records were discussed and marked as included or excluded. The second stage involved screening of full text of potentially eligible papers. For each excluded paper a clear reason or reasons for the exclusion was provided.

We collected the following information for each included review / original study in excel spreadsheets: Author/publication date; Study design; Population; Exposure; Comparator; Confounding factors controlled for; Analysis; Outcome; Findings; Additional comments. Data was extracted by one researcher and subsequently checked by another.

2.5.1 Study assessment

We assessed the quality of the reviews identified in *Search 1* using the AMSTAR2 Checklist [7]. We assessed the quality of additional original studies identified in *Search* 2 using the ROBINS-E checklist [8]. To note that we *a priori* decided to amend the AMSTAR2 rating score to make the criteria more aligned with reviews of environmental epidemiological studies. Specifically, critical items were adapted from Shea et al. (2017) [7], however, updated by the authors to better reflect the weaknesses which were determined to be critical for reviews of observational environmental epidemiological studies as opposed to reviews of Randomized Controlled Trials (RCTs). Specifically, we removed the critical classification from number 15 and added it to number 8.

2.5.2 Evidence rating

We considered and reported the strength of the evidence across studies. If an evidence rating was provided with an identified review, we adopted that assigned rating and specified which rating framework was used. For any potential additional original studies, we applied the criteria used within the development of the WHO Environmental Noise Guidelines (ENG) as well as the approach adopted in Engelmann et al. (2023) [5].

3. RESULTS

PRISMA Flow diagrams illustrating the search and study selection processes in detail (Search 1 and 2) are in the appendices (Appendix Figure 1 and 2), as well as a simplified summary can be found below in Table 2.

Table 2. Umbrella+ review study search record

	Search 1 (reviews)	Search 2 (original research articles)
Retrieved through search	125	42
Duplicates	33	15
Screened on title/abstract	92	27
Screened on full text	9	4
Included within the review	3	1

In Search 1, three review papers were screened in for inclusion in the study: A systematic review and meta-analysis by Cai et al. (2021) [9]; an Umbrella review of reviews by Chen et al. (2023) [10]; and an Umbrella+ review and meta-analysis of original research studies

(all-cause mortality) by Engelmann et al. (2023) [5] (details of studies included in the Appendix - Table 4).

Engelmann et al. (2023) is the most recent review, having completed their search for studies in July 2023, and includes the largest number of prospective cohort studies for both road, railway, and aircraft noise sources (n=7 road, n=2 rail, n=1 aircraft) compared with Cai et al. (2021) (n=4 road, n=1 rail). Engelmann et al. (2023) also restricted inclusion of studies in their meta-analysis to prospective cohort study designs and studies which were conducted in European countries. The Umbrella review by Chen et al. (2023) does not provide additional information on noise all-cause mortality impacts beyond what is presented in Cai et al. (2021). The Engelmann et al. (2023) study evaluated and reported that the certainty of the evidence for road-traffic noise was 'high', for railway noise was 'low' and for aircraft noise was 'very low'. The certainty of evidence rated in Cai et al. (2021) across noise sources was either 'low' or 'very low'. The Engelmann et al. (2023) also provided insight into threshold effects for the ERRs, recommending a lower exposure threshold for all-cause mortality to be 45 dBA L_{den}. All risk estimates from the cohort studies included in the Engelmann et al. (2023) meta-analysis were controlled for confounders in the statistical models, including air pollution ($PM_{2.5}$ or NO_x) (except for one study). The Engelmann et al. (2023) review is a European Topic Centre (ETC HE Report 2023/11) publication on the new 'methodology for assessing health risks using data reported under the Environmental Noise Directive'. The authors of the report recommended the pooled relative risk (RR) estimate for road-traffic noise and all-cause mortality for use in the new European Environment Agency (EEA) noise burden of disease assessment for European countries (upcoming).

We assigned an AMSTAR2 rating of overall confidence in the three reviews as 'Low'. Though to clarify, the AMSTAR2 rating applied to Engelmann et al. (2023) is only in relation to the reporting of the methodology and results relating to reviewing original studies on all-cause mortality and is not applied to the entire Umbrella+ review which covers other outcomes. Both Engelmann et al. (2023) and Cai et al. (2021) did not fulfill the criteria for Item 2 which is listed as a critical (*) item, relating to publishing a protocol for methods or explicitly stating they were established prior to conducting the review. Not meeting a critical item automatically moves the rating down to 'low' overall confidence. Furthermore, Engelmann et al. (2023) did not meet non-critical items 5, 10, 12, 14, and 15, while Cai et al. (2021) did not additionally meet items 5, 10, and 12 and Chen et al. (2023) did not meet items 7 (*), 10, and 14 (More information AMSTAR2 criteria can be found in Shea et al. (2017) [7]). Furthermore, all reviews did not meet item 10 ('report on sources of funding of each study included in the review'), which while important to consider for observational epidemiological studies, we feel is more critical for assessing reviews of RCTs.

Considering our assessment of the three review papers above - which included factors such as publication recency, sample size, study designs (of the original research), and AMSTAR2 ratings - we selected the study by Engelmann et al. (2023) to provide the basis and risk estimates (Table 3) for the next step in the review process (Search 2). Following Search 1, we conducted a second search to identify additional original research studies that had been published since Engelmann et al. (2023) concluded their search in July 2023. We searched for studies conducted anywhere in the world (Global scope) but restricted the epidemiological study design to longitudinal cohort studies (Table 1). Through this process, one research study was included in this Umbrella+ review (Table 2): A prospective cohort study of the effect of aircraft noise exposure on all-cause mortality in the USA by Grady et al. (2023) [11]. This study was included within the Engelmann et al. (2023) review but excluded from their meta-analysis because it was conducted outside of Europe. As we did not have geographical restrictions for our review, we decided *a priori* to include this study in the Search 2 process despite it being outside of our publication date range (July 4th 2023 – November 1 2024).

In brief, the Grady study was a prospective follow-up of nurses in the Nurses Health Study (n=53,306) and the Nurses Health Study II (n=60,058) in the USA from 1994-2014 (20 years. Aircraft noise was modelled for 90 airports. The study reported relative risk (RR) estimates from minimally confounder adjusted and fully confounder adjusted cohort-specific cox-proportional hazard models which subsequently had results pooled using random effects meta-analysis. Adjusted models controlled for air pollution. We assessed the study using the ROBINS-E risk of bias (RoB) framework. While the majority of the RoB criteria was rated as having 'low risk of bias', some concerns were raised with regards to the selection of participants into the study, which is elaborated on further by the study authors themselves in

the publication. As per the ROBINS-E criteria, if any of the domains are rated as having 'some concerns', then that becomes the overall RoB rating.

Table 3. Included source-specific relative risk ratios for all-cause mortality from *Searches 1* and *2* in the Umbrella+ review

Noise source	**Relative risk [95% Confidence Interval] per 10 dB L_{den}**	**Source (Certainty of Evidence rating)**
Road-traffic	1.055 [1.026 – 1.084]	Engelmann et al. (2023) meta-analysis [5] (High) *
Railway	1.004 [1.001 - 1.007]	Engelmann et al. (2023) meta-analysis [5] (Low) *
Aircraft	1.03 [0.94 – 1.12]	Grady et al. (2023) original research study [11] (Very low) *

*Certainty of evidence rating provided by the Engelmann et al. (2023) review

4. DISCUSSION

Our Umbrella+ review identified 3 review papers and 1 original research study, published between January 1st 2015 and November 1st 2024, providing evidence from 8 prospective cohort (longitudinal) epidemiological studies on the effects of transportation noise on all-cause mortality (7=road, 2=rail, and 1=aircraft). Because we conducted an Umbrella review, and did not undertake a full-scale literature search for primary research, there may be omitted studies due to the way previous reviews were conducted, which we didn't have control over. Seven of the original research studies underpinning this Umbrella+ review were conducted in Europe (Table 5 in the Appendix), with three of the studies having been conducted in Denmark. One study on aircraft noise exposure and all-cause mortality (Grady et al. (2023)) was conducted in the USA. The sample sizes for the combined risk estimates pooling across studies is large, with an overall sample size of almost 18 million (17,712,661) for road traffic noise, 13 million (13,100,000) for railway noise, and just over 100 thousand (117,364) for aircraft noise. Furthermore, while there was variation in cohort participant follow-up times across studies (5 years – 36 years), most studies had over 10 years of follow-up. Studies of road-traffic noise were rated as providing a 'high' certainty of evidence within the Engelmann et al. (2023) review, providing new opportunities for burden of disease assessments to be conducted on all-cause mortality impacts, particularly from road-traffic noise exposure. While we applied an AMSTAR2 rating of 'low' to the review of all-cause mortality, we also note that the AMSTAR2 rating framework was developed for review studies of healthcare interventions (including RCTs) which includes criteria not always applicable or critical for assessing the confidence of reviews of observational environmental epidemiological studies. Whilst further primary research studies, and subsequent reviews are necessary, the issues identified by the AMSTAR2 rating do not preclude the identified meta-analysis from being used for health risk assessments to inform policy.

All risk estimates included in the meta-analysis by Engelmann et al. (2023), and the addition from Grady et al. (2023), were estimated from models which controlled for key confounding variables and measures of socioeconomic status. Additionally, the risk estimates from studies chosen for inclusion in the Englemann meta-analysis were additionally controlled for air pollution ($PM_{2.5}$ adjusted models were primarily selected). However, we do note that while the Hao et al. (2022) paper from the UK did not have a risk estimate selected which controlled for air pollution in the Engelmann et al. (2023) meta-analysis, there was one presented in Hao et al's original publication, which was a null result (see Table 5 in the appendix). Furthermore, none of the studies controlled for exposure to other types of noise sources or other transportation noise. This may present challenges for estimations of the combined burden of disease from multiple transportation sources, as well as non-transportation sources, as there may be some degree of double counting of the attributable health impacts if exposures were co-occurring for some of the cohort populations but not controlled for in the epidemiological models. Therefore, we recommend that summing the attributable health burden estimates for all-cause mortality across transportation noise sources should be done with caution using current pooled risk estimates.

Most of the evidence on all-cause mortality has been published on road-traffic noise exposures, and there is a gap in the literature for more evidence on impacts from aircraft and railway noise exposures. There is also a major gap in evidence on impacts for countries outside

of Europe. For a robust evidence base we recommend future research on all-cause mortality impacts to be conducted on other types of transportation noise exposures and in countries and communities around the world.

5. ACKNOWLEDGMENTS

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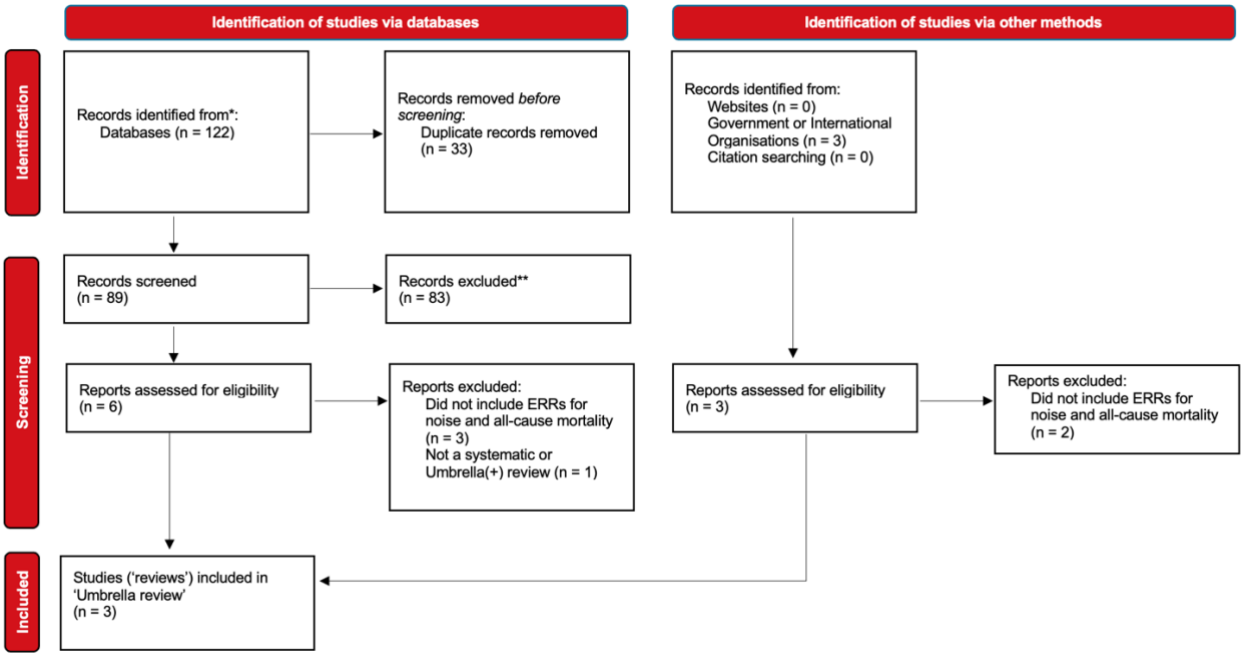
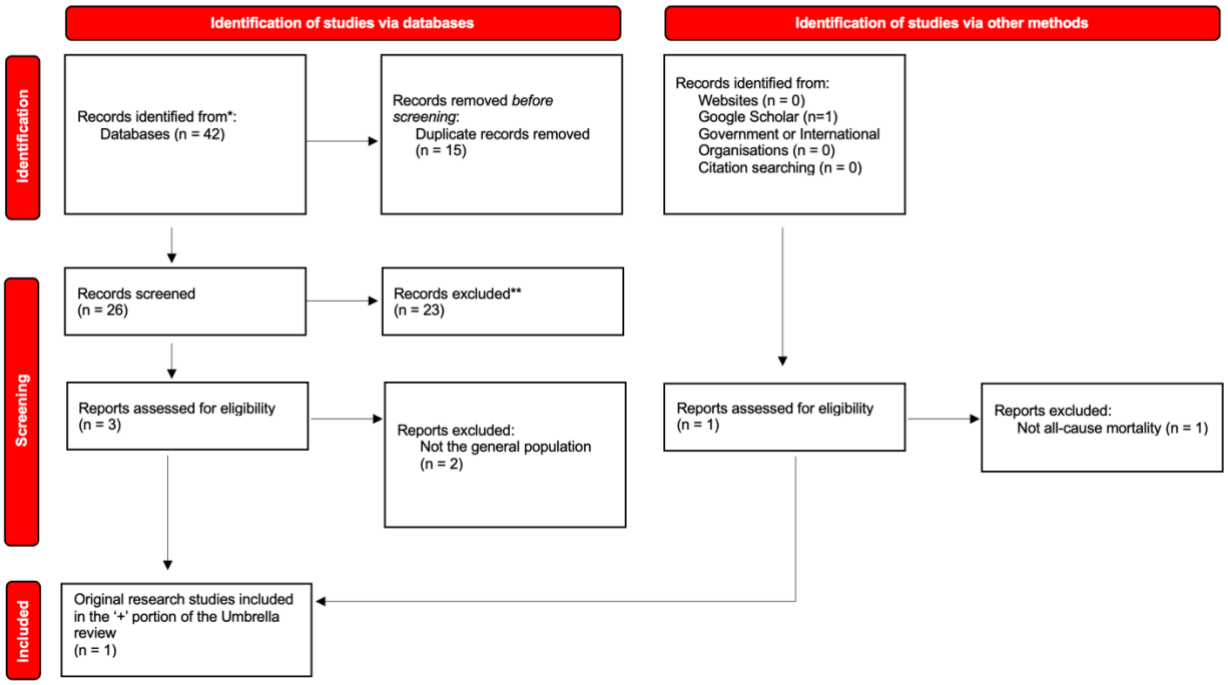
7. APPENDIX (SEE NEXT PAGE)



Appendix - Figure 1. PRISMA Flow Diagram (Search Process 1)



Appendix - Figure 2. PRISMA Flow Diagram (Search Process 3)

Appendix - Table 4. Summary of review studies included through Search process 1 (reviews)

First author (date)	Type of study	Literature search period	Population	Sample size	Studies included	Included study designs (n of studies)	Effect sizes (RRs) per 10 dB [95% CIs]	GRADE Assessment of evidence (as reported in reviews)	AMSTAR2 Rating
Engelmann (2023) [5]	Umbrella+ review (Analysis of all-cause mortality was based on original research articles only, therefore classified as systematic review/meta-analysis)	Jan 1, 2015 – July 3rd 2023	Europe (meta-analysis)	17,712,661	7 cohort studies, contributing 7 ERRs for road-traffic and 2 for rail (Table 3.3 in Engelmann et al. (2023))	Prospective cohorts (7)	**Road**: 1.055 [95% CI 1.026, 1.084] **Rail**: 1.004 [95% CI 1.001, 1.007]	**Road**: High **Rail:** Low **Air:** Very low	Low*
Chen (2023) [10]	Umbrella review	? – Nov 2021	Global	Same as reported in Cai 2021	1 systematic review/meta-analysis (Cai 2021)	Meta-analysis	***Road**: 1.01 [95% CI 0.98, 1.05] (Cai 2021)*	***Road**: Very low (Cai 2021)*	Low
Cai (2021) [9]	Systematic review/meta-analysis	Jan 1, 2000 – Oct 5 2020	Global	Road (Cohort, n=4): 1,191,344 Rail (cohort, n=1): 339,633	5 primary studies, contributing 5 ERRs for road-traffic and 1 for rail	Prospective cohorts (4); ecological (1)	**Road**: 1.01 [95% CI 0.98, 1.05] **Rail**: 0.99 [95% CI 0.97 - 1.00]	**Road** (Cohort): Low **Rail**: Low	Low

RR: Relative risks; dB: Decibels; ERR: Exposure response relationship: CI: Confidence interval
*AMSTAR2 rating only applies to the review of all-cause mortality studies and not to the entire review

Appendix - Table 5. Summary of longitudinal cohort studies (original research) published between January 1st 2015 and November 1st 2024 included within the Engelmann et al. (2023) [5] review and identified through the '+' element of this Umbrella+ review .

Noise source	N. prospective cohort studies (original research)	Countries	Cohort follow-up length	N. of studies which controlled for confounders, including socioeconomic status	N. of studies which controlled for air pollution	N. of studies which controlled for exposure to other sources of noise
Road-traffic [12-18]	7	Denmark (x3), Switzerland, UK, Sweden	5 to 36 years	7	6*	0
Railway [13, 16]	2	Denmark, Netherlands	5 to 17 years	2	2	0
Aircraft [11]	1	USA	20 years	1	1	0

*Note that the study by Hao et al. (2022) did provide a Hazard Ratio estimate which additionally controlled for $PM_{2.5}$ (1.00 (95%CI 0.97-1.04)) in their publication, however, this estimate was not included in the Engelmann et al. (2023) meta-analysis.