



UK Health  
Security  
Agency

Heathrow Noise and Airspace Community Forum

# The relationship between aviation noise exposure, noise annoyance and other health effects

What is the evidence telling us?

25 September 2024

Benjamin Fenech PhD

# Noise and health – mechanisms

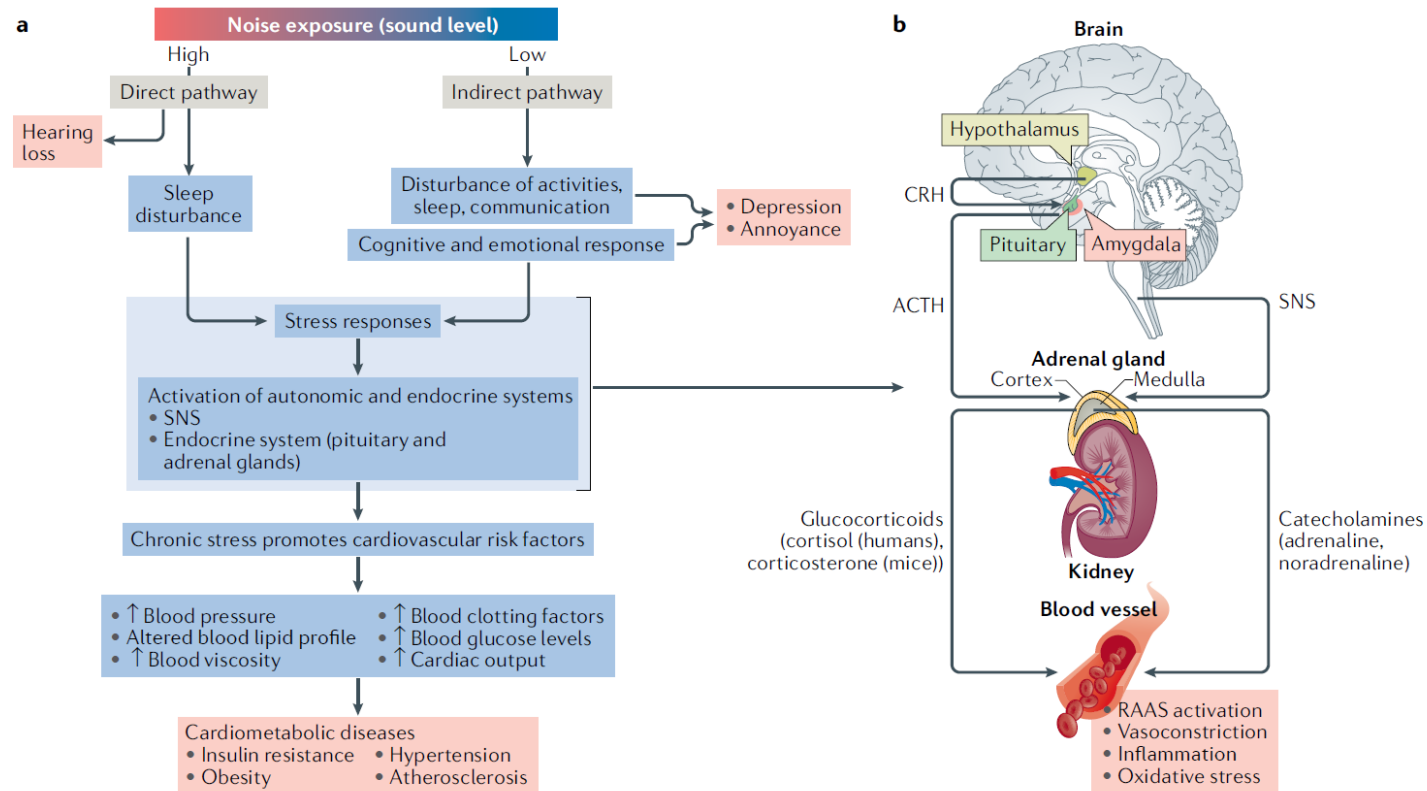
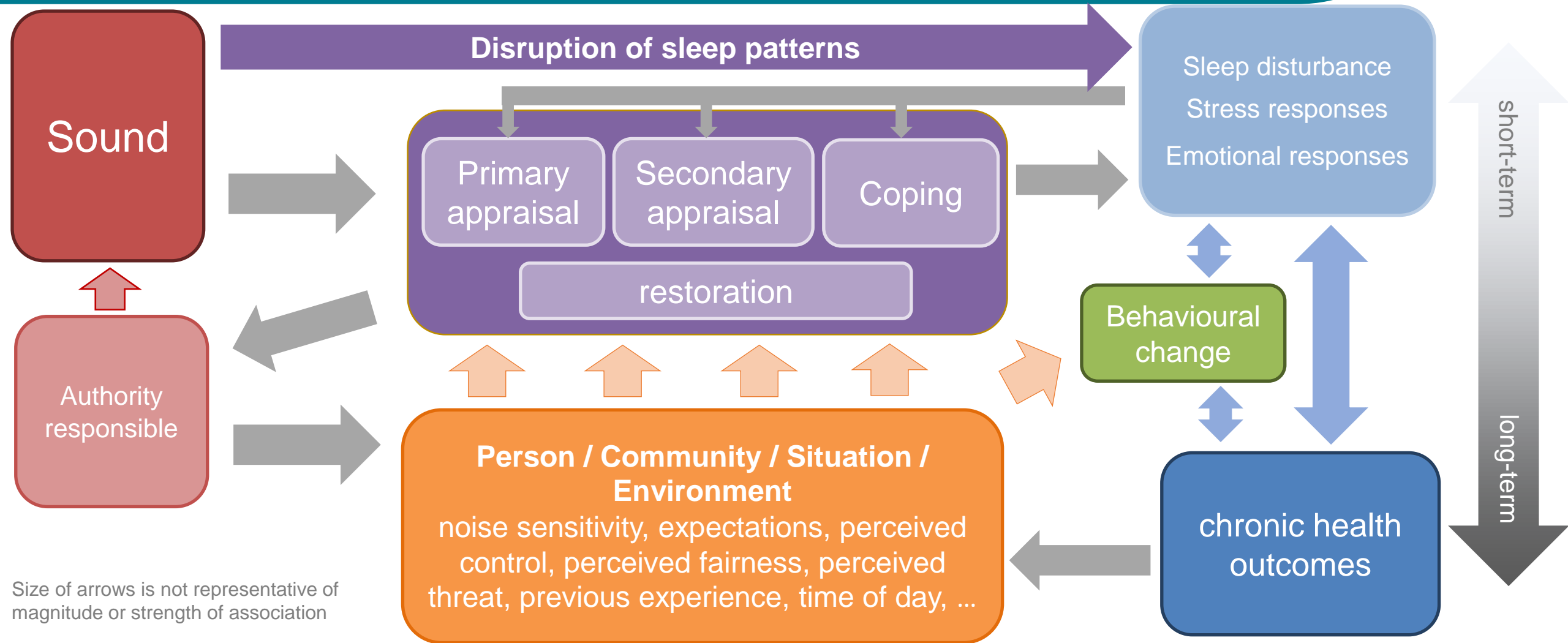


Fig. 3 | **Noise–stress concept and the adverse health consequences in humans.** **a** | Noise reaction model for the direct (auditory) and indirect (non-auditory) effects of noise exposure<sup>173</sup>. **b** | Neuronal activation (arousals) induced, for example, by noise exposure triggers signalling via the hypothalamic–pituitary–adrenal axis and sympathetic nervous system (SNS). In the hypothalamic–pituitary–adrenal axis, the hypothalamus releases corticotropin-releasing hormone (CRH; also known as corticoliberin) into the pituitary gland, which stimulates the release of adrenocorticotropic hormone

(ACTH) into the blood. ACTH induces the production of glucocorticoids by the adrenal cortex, and the activation of the SNS stimulates the production of catecholamines by the adrenal medulla. The release of glucocorticoids and catecholamines in turn leads to the activation of other neurohormonal pathways (such as the renin–angiotensin–aldosterone (RAAS) system) and to increased inflammation and oxidative stress, which can ultimately have adverse effects on cardiovascular function and molecular targets. Panel **a** reprinted with permission from REF.<sup>173</sup>, Oxford University Press.

Münzel, T., Sørensen, M. & Daiber, A. Transportation noise pollution and cardiovascular disease. *Nat Rev Cardiol* **18**, 619–636 (2021). <https://doi.org/10.1038/s41569-021-00532-5>

# Noise and health – mechanisms



Conceptual model by B. Fenech. Model informed by Lazarus' transactional stress model (Lazarus and Folkman 1984; Lercher 1996), the links between stress and restoration (Ulrich et al. 1991; von Lindern et al. 2016), the noise effects reaction scheme (Babisch 2014), non-acoustic factors (Fenech et al. 2021) and associations with the wider determinants of health (Peris and Fenech 2020).

# In simpler terms...

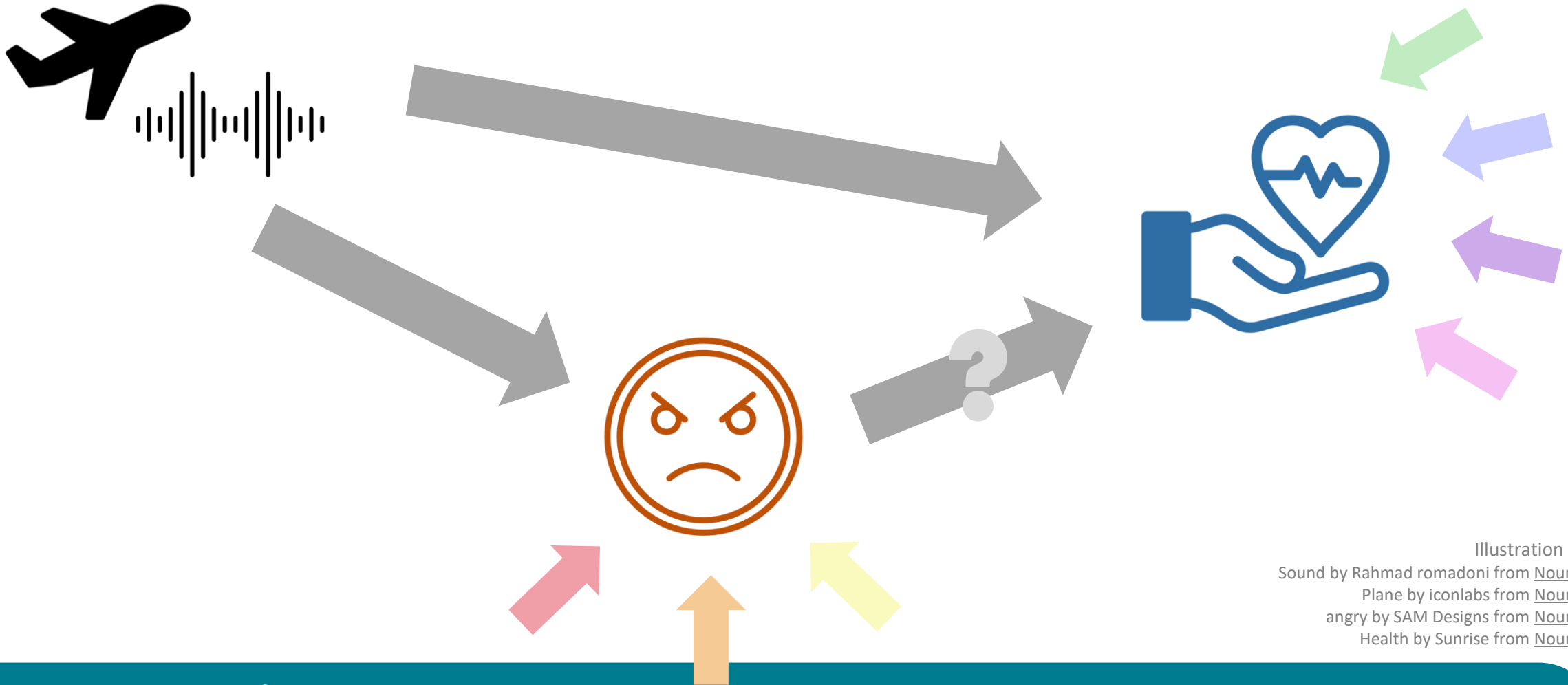
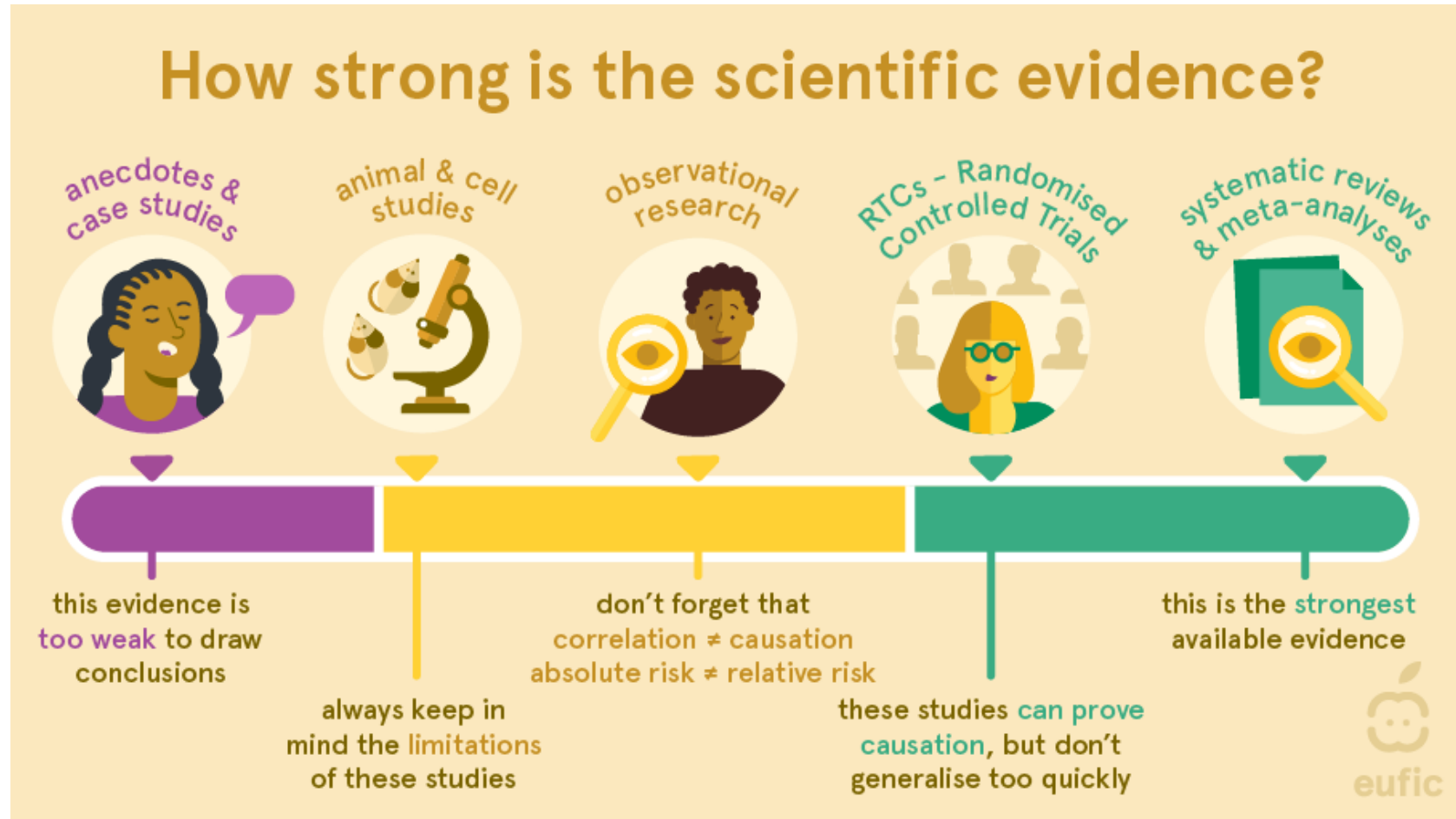


Illustration by B. Fenech 2024  
Sound by Rahmad romadoni from [Noun Project](#) (CC BY 3.0)  
Plane by iconlabs from [Noun Project](#) (CC BY 3.0)  
angry by SAM Designs from [Noun Project](#) (CC BY 3.0)  
Health by Sunrise from [Noun Project](#) (CC BY 3.0)

# Types of evidence



<https://www.eufic.org/en/understanding-science/article/the-levels-of-evidence-in-nutrition-research>

# Interpreting findings from observational research

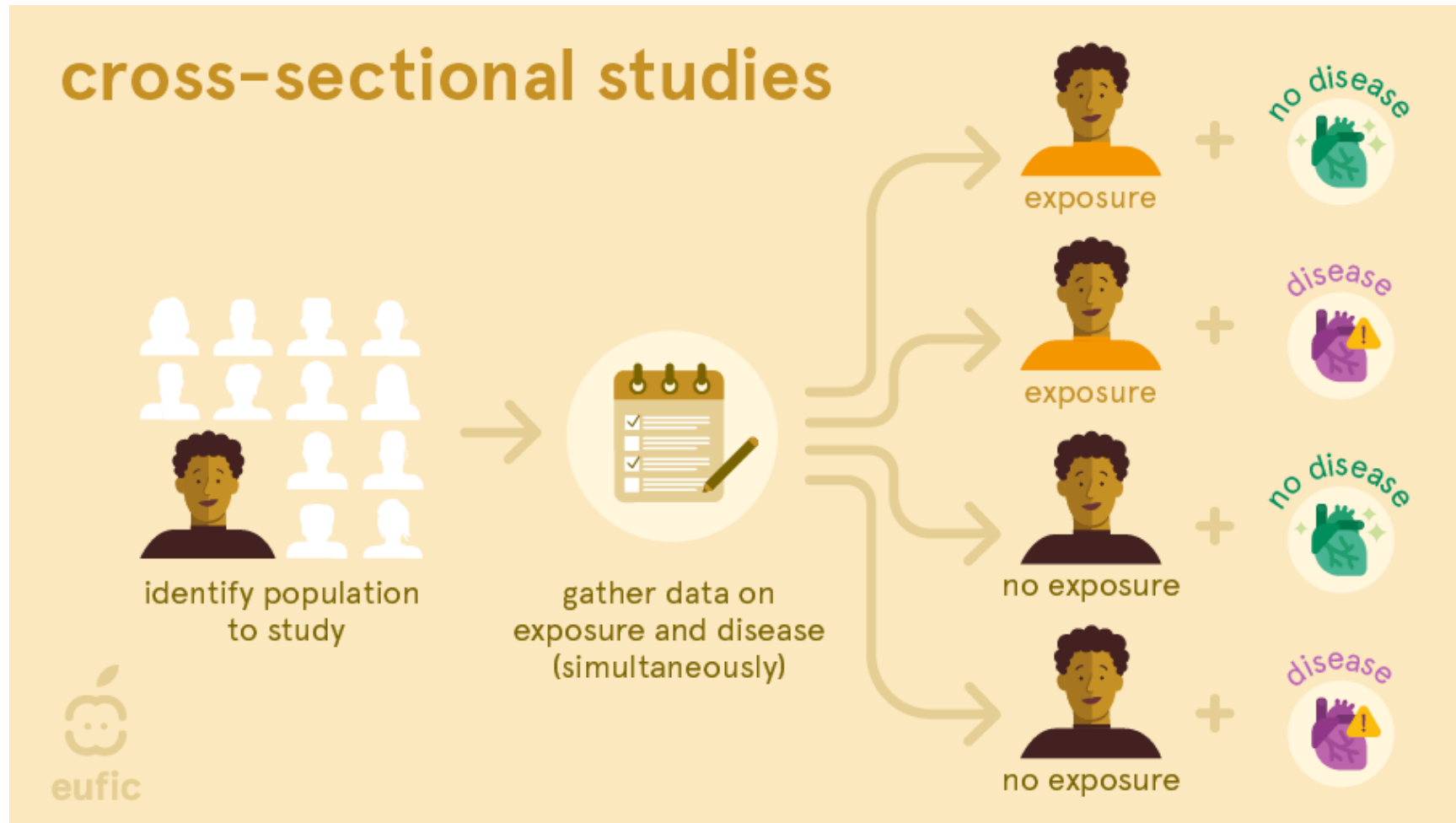
- ❑ Internal validity – is the study believable?
- ❑ External validity – are the results relevant to my situation?
- ❑ Are statistical associations spurious, or a result of an indirect or direct effect?
- No single study is perfect



Photo by [Ross Sneddon](#) on [Unsplash](#)

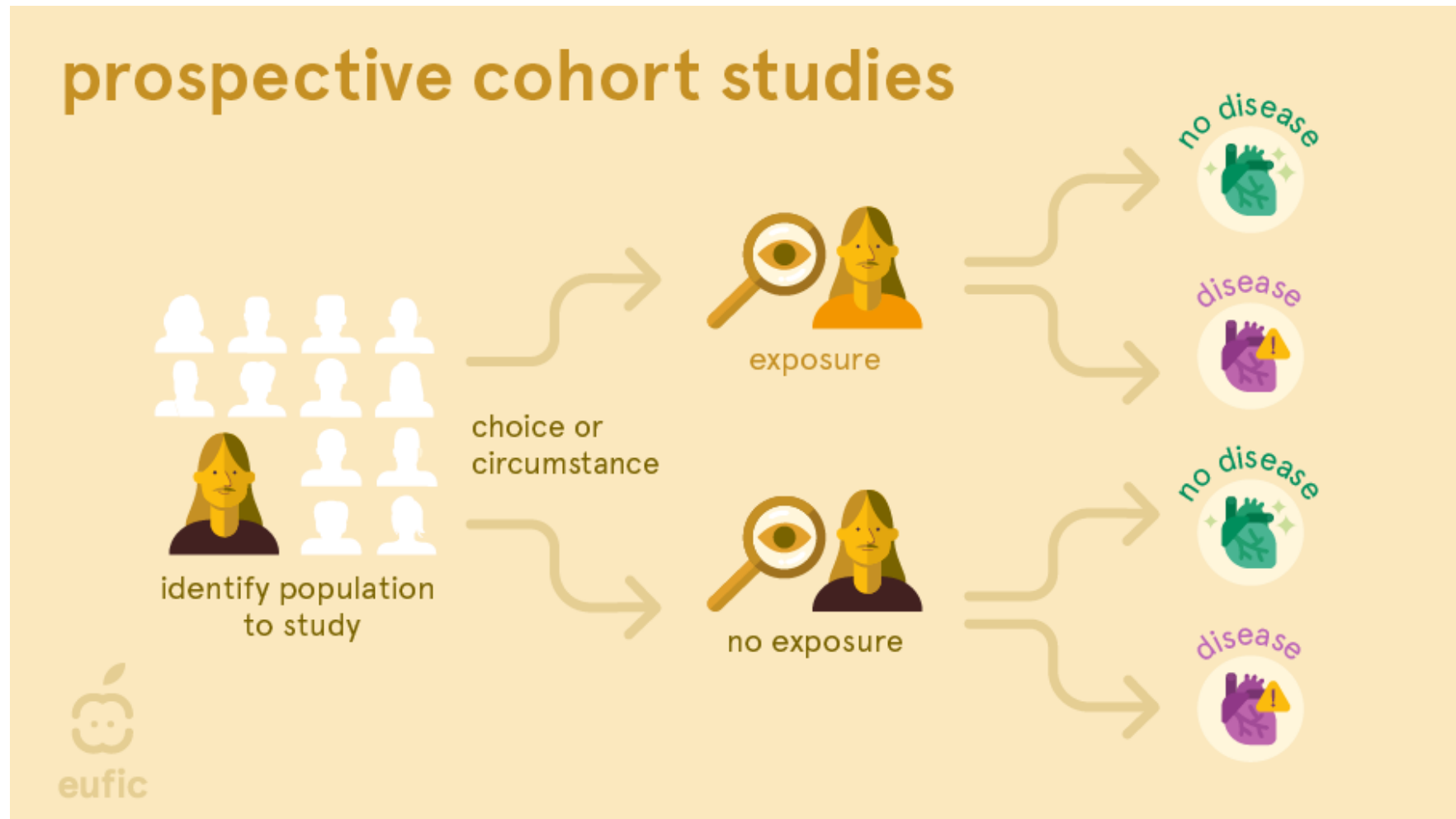
# Noise annoyance and health:

Why is it a difficult topic to study?



# Noise annoyance and health:

Why is it a difficult topic to study?



<https://www.eufic.org/en/understanding-science/article/the-levels-of-evidence-in-nutrition-research>

# Self-reported health

# Self-reported health

Table 8. Associations between aircraft noise exposure at daytime ( $L_{Aeq,16h}$ ), aircraft noise annoyance, noise sensitivity, and health variables (Odds ratios [OR] per unit and  $\pm 95\%$  confidence interval [CI]).

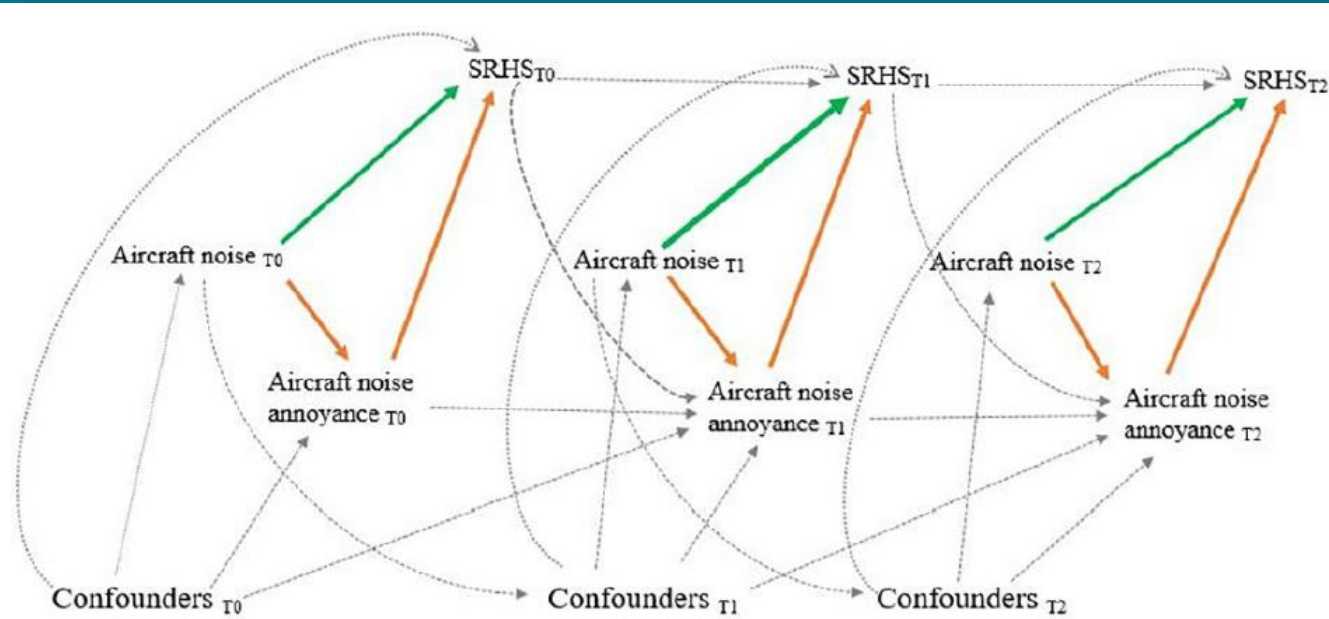
Health variables	Aircraft sound level $L_{Aeq,16h}$ <sup>#</sup>			Aircraft noise annoyance			Noise sensitivity		
	OR	CI-	CR+	OR	CI-	CR+	OR	CI-	CR+
<i>Health-related quality of life (SF36/12 scores &lt; median)</i>									
Vitality (SF36)	<b>0.95</b>	0.93	0.97	<b>1.25</b>	1.13	1.37	<b>1.13</b>	1.02	1.26
Mental health (SF36)	<b>0.96</b>	0.94	0.98	<b>1.13</b>	1.03	1.24	<b>1.40</b>	1.26	1.55
Mental health (SF12)	<b>0.96</b>	0.94	0.98	1.06	0.97	1.17	<b>1.22</b>	1.10	1.36
Physical health (SF12)	<b>0.97</b>	0.95	0.99	<b>1.13</b>	1.01	1.26	<b>1.19</b>	1.06	1.34
<i>GSCL-24 health complaints (above 50% = average of population in Germany)</i>									
Exhaustion	<b>0.98</b>	0.96	1.00	<b>1.36</b>	1.23	1.51	<b>1.40</b>	1.26	1.56
Stomach complaints	0.99	0.97	1.01	<b>1.12</b>	1.02	1.24	<b>1.18</b>	1.06	1.30
Limb complaints	<b>0.96</b>	0.94	0.98	<b>1.22</b>	1.10	1.34	<b>1.48</b>	1.33	1.65
Cardiac complaints	<b>0.96</b>	0.94	0.98	<b>1.32</b>	1.19	1.47	<b>1.35</b>	1.21	1.50
Total score	<b>0.96</b>	0.94	0.98	<b>1.41</b>	1.27	1.56	<b>1.53</b>	1.37	1.71
<i>Sleep quality (bad sleep quality: PSQI score &gt; 5)</i>									
Bad sleep quality	<b>0.95</b>	0.93	0.97	<b>1.45</b>	1.29	1.63	<b>1.42</b>	1.25	1.61

Adjusted for railway and road traffic sound level, age, gender, socio-economical status, home ownership, residential satisfaction, usual window position in the sleeping room at night, number of hours away from home;

<sup>#</sup> $L_{Aeq,8h}$  (10 pm–6 am) for sleep quality,  $L_{Aeq,16h}$  (6 am–10 pm) for all other health variables; bold: OR significant on significance level  $p < 0.05$ .

Schreckenberg, D. et al. Aircraft Noise and Quality of Life around Frankfurt Airport. *Int. J. Environ. Res. Public Health* **2010**, *7*, 3382–3405. <https://doi.org/10.3390/ijerph7093382>

# Self-reported health (DEBATS)



**Fig 1. Causal graph with time-varying aircraft noise levels, time-varying confounders, time-varying aircraft noise annoyance and time-varying self-reported health status.** Green arrows for direct effect, orange arrows for indirect effect and dotted arrows for confounding effect. Some arrows were omitted when no direct effect from a variable on another was hypothesized.

KODJI Mk, et al. (2024) Effects of aircraft noise exposure on self-reported health through aircraft noise annoyance: Causal mediation analysis in the DEBATS longitudinal study in France.

PLoS ONE 19(8): e0307760.

<https://doi.org/10.1371/journal.pone.0307760>

# Self-reported health

*“... no direct effect of aircraft noise levels on SRHS [self-reported health status], but an indirect effect through annoyance. This indirect effect increased as aircraft noise levels increased, with a statistically significant OR [odds ratio] when comparing the highest noise category ( $\geq 60$  dBA) to the lowest ( $< 50$  dBA). Nearly 66% of aircraft noise’s effect on SRHS was mediated by aircraft noise annoyance.”*

KODJI Mk, et al. (2024) Effects of aircraft noise exposure on self-reported health through aircraft noise annoyance: Causal mediation analysis in the DEBATS longitudinal study in France.

PLoS ONE 19(8): e0307760.

<https://doi.org/10.1371/journal.pone.0307760>



Mental health



# Mental health & high noise annoyance

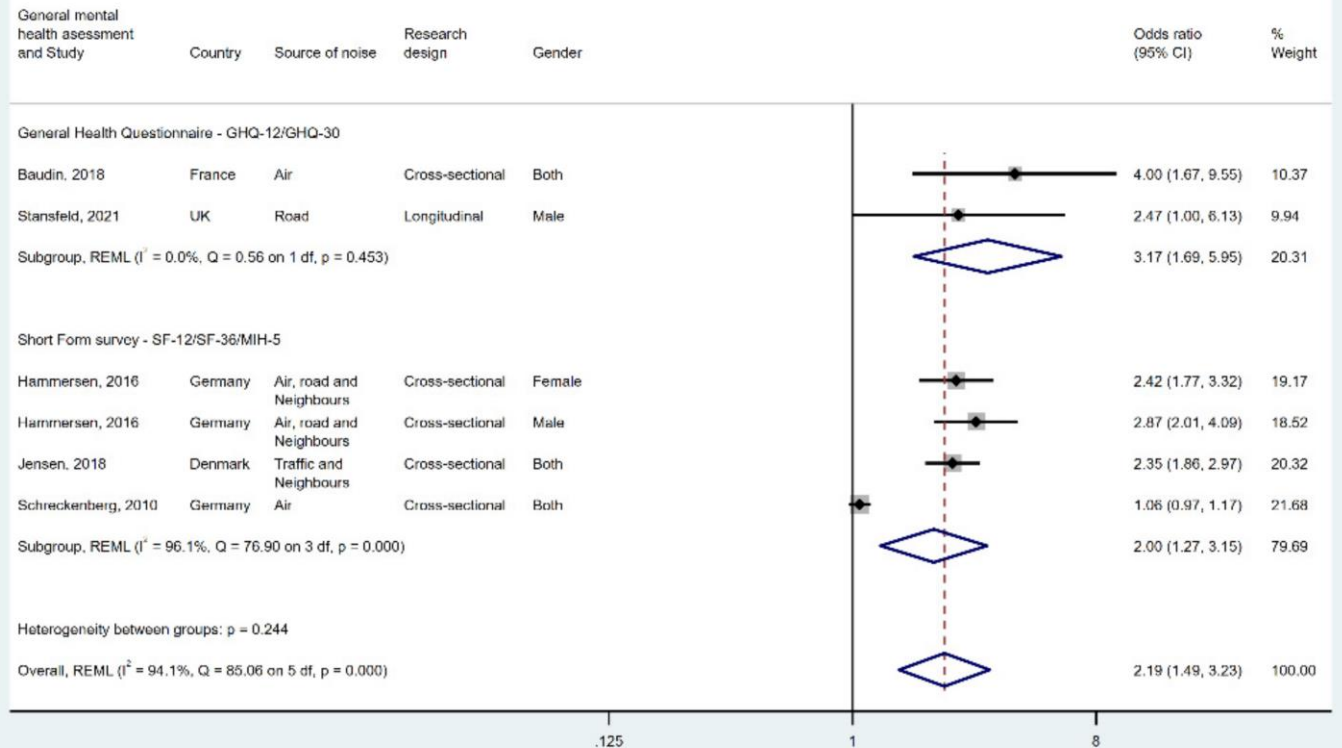
## Depression

Depression assessment and Study	Country	Noise source
<b>SRM</b>		
Eze, 2020	Switzerland	Transportation
Okokon, 2018	Finland	Road traffic
Baudin, 2021	7 European countries	Aircraft noise at night
Subgroup, REML ( $I^2 = 0.0\%$ , $Q = 0.23$ on 2 df, $p = 0.890$ )		
<b>SRD/VQ</b>		
Beutel, 2020	Germany	Traffic, industrial/construction, neighborhood
Maschke, 2007	8 European countries	Traffic, neighbours, commercial and parking
Jensen, 2019	Denmark	Neighbours
Subgroup, REML ( $I^2 = 76.7\%$ , $Q = 8.59$ on 2 df, $p = 0.014$ )		
Heterogeneity between groups: $p = 0.099$		
Overall, REML ( $I^2 = 60.4\%$ , $Q = 12.63$ on 5 df, $p = 0.027$ )		

## Anxiety disorder

Anxiety assessment and study	Country	Source of noise
<b>SRM</b>		
Okokon, 2018	Finland	Road
Baudin, 2021	UK, Germany, Netherlands, Sweden, Italy, Greece, France	Aircraft noise at night
Subgroup, REML ( $I^2 = 0.0\%$ , $Q = 0.04$ on 1 df, $p = 0.835$ )		
<b>VQ/UQ</b>		
Beutel, 2020	Germany	Road, aircraft, industrial/construction, Neighbours
Jensen, 2019	Denmark	Neighbours
Subgroup, REML ( $I^2 = 91.5\%$ , $Q = 11.83$ on 1 df, $p = 0.001$ )		
Heterogeneity between groups: $p = 0.651$		
Overall, REML ( $I^2 = 75.5\%$ , $Q = 12.23$ on 3 df, $p = 0.007$ )		

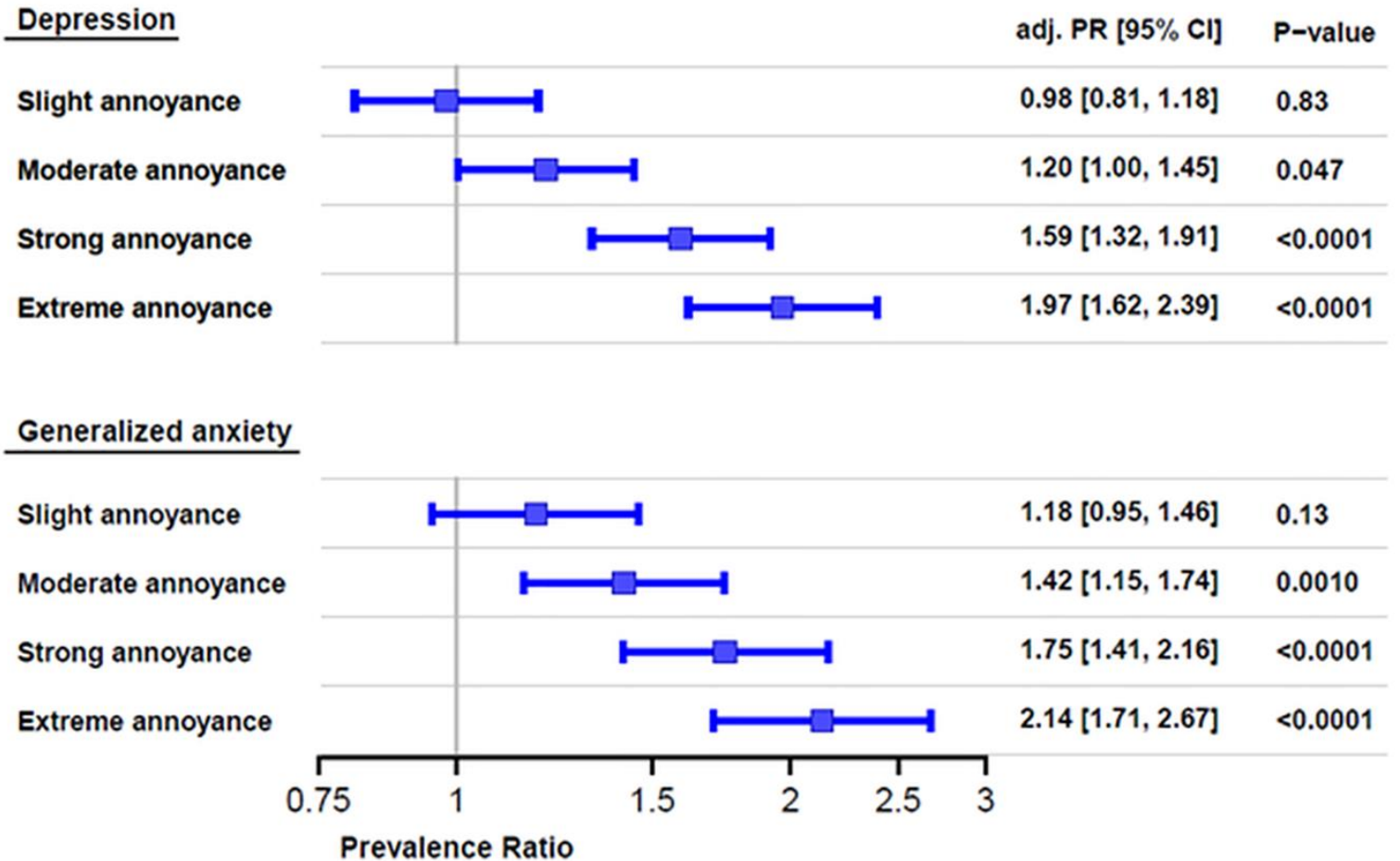
## General mental health



Gong, X.; et al. (2022) Association Between Noise Annoyance and Mental Health Outcomes: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2696. <https://doi.org/10.3390/ijerph19052696>

# Mental health

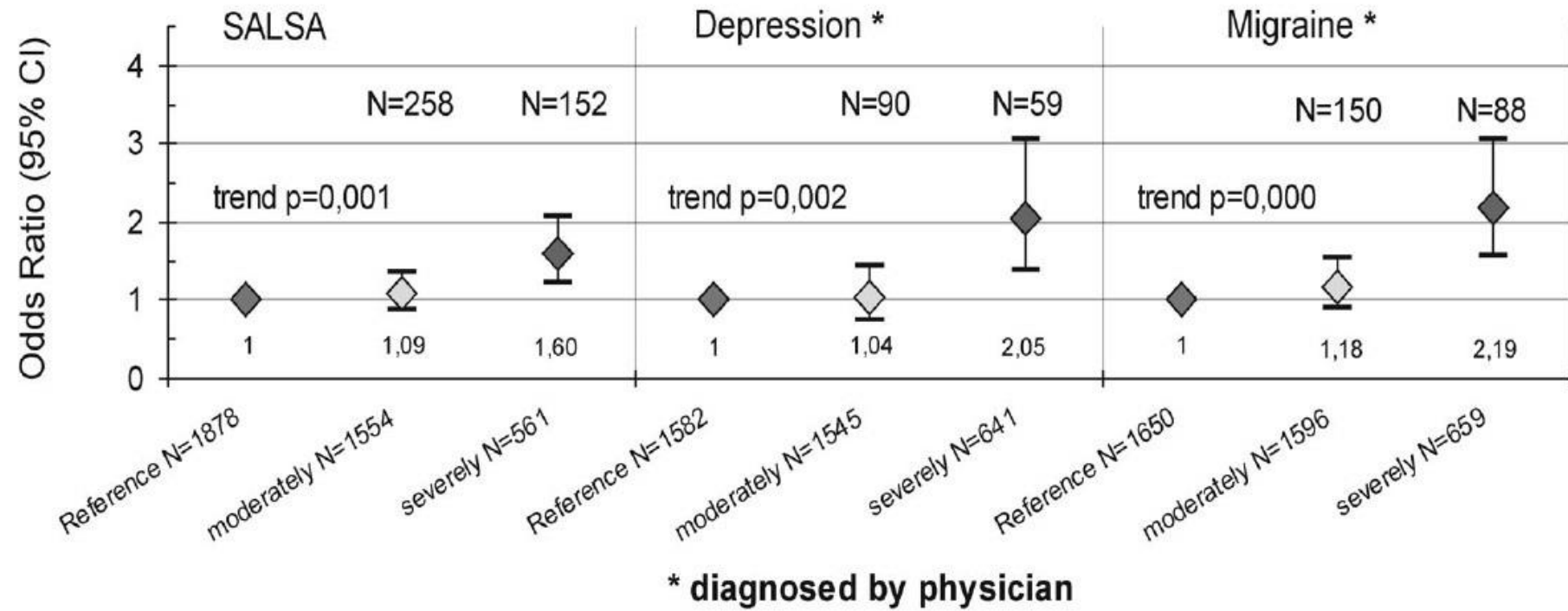
Fig 1. Association between noise annoyance, depression and anxiety.  
 Note. Multiple generalized linear models with a binominal distribution and a log link function adjusted for sex, age and socioeconomic status were used.



Beutel ME, et al. (2016) Noise Annoyance Is Associated with Depression and Anxiety in the General Population- The Contribution of Aircraft Noise. PLoS ONE 11(5): e0155357. doi:10.1371/journal.pone.0155357

# Mental health

**Adults: general traffic noise which bothered or annoyed moderately or severely, related to diseases**



Niemann, H.; et al. (2006) Noise-induced annoyance and morbidity results from the pan-European LARES study. *Noise and Health* 8(31):p 63-79, Apr–Jun 2006. | DOI: 10.4103/1463-1741.33537

# Mental Health

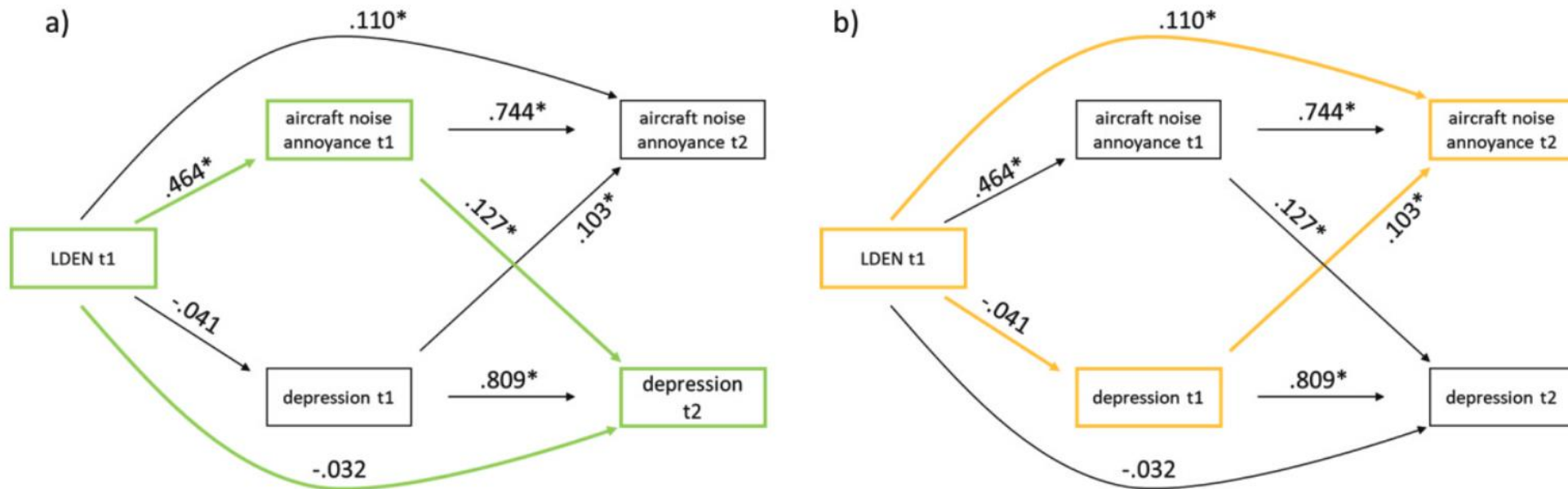


Figure 1 – the effect of aircraft noise exposure in t1 (2012) on a) prevalence of depression in t2, potentially mediated by aircraft noise annoyance in t1, b) on aircraft noise annoyance in t2, potentially mediated by depression in t1.

Benz S, Schreckenberg D (2019). Examination of the causal relationship between aircraft noise exposure, noise annoyance and diagnoses of depression using structural equation modelling. <http://pub.dega-akustik.de/ICA2019/data/articles/001315.pdf>

# Mental health

*“Noise annoyance ... might enhance the impact of noise and take its full effect in contributing to the development of depression.*

*Depression can be confirmed as a potential predictor ... of aircraft noise annoyance, which is in line with evidence for an association of noise annoyance and mental health quality of life.*

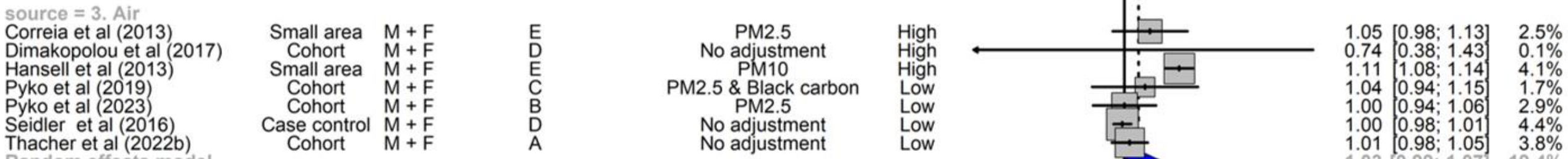
*Depression could result in lower perceived coping capacity and the feeling of lack of control of the noise situation that might lead to more annoyance.”*

Benz S, Schreckenberger D (2019). Examination of the causal relationship between aircraft noise exposure, noise annoyance and diagnoses of depression using structural equation modelling. <http://pub.dega-akustik.de/ICA2019/data/articles/001315.pdf>

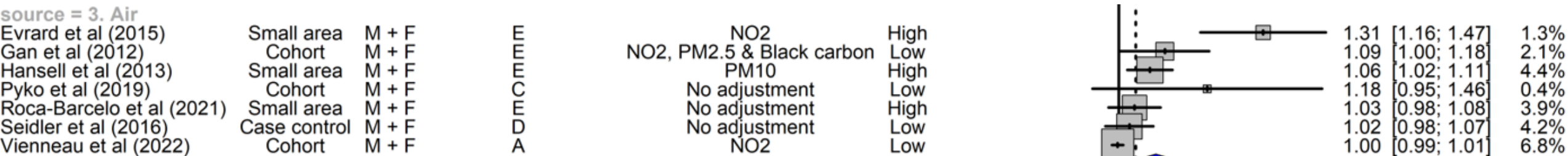
# Cardiovascular disease

# Heart disease – meta analysis

## Incidence



## Mortality



Article submitted for international scientific peer review. Pooled results not shown.

# Cardiovascular – hypertension & annoyance

W. Babisch et al. / Science of the Total Environment 452–453 (2013) 50–57

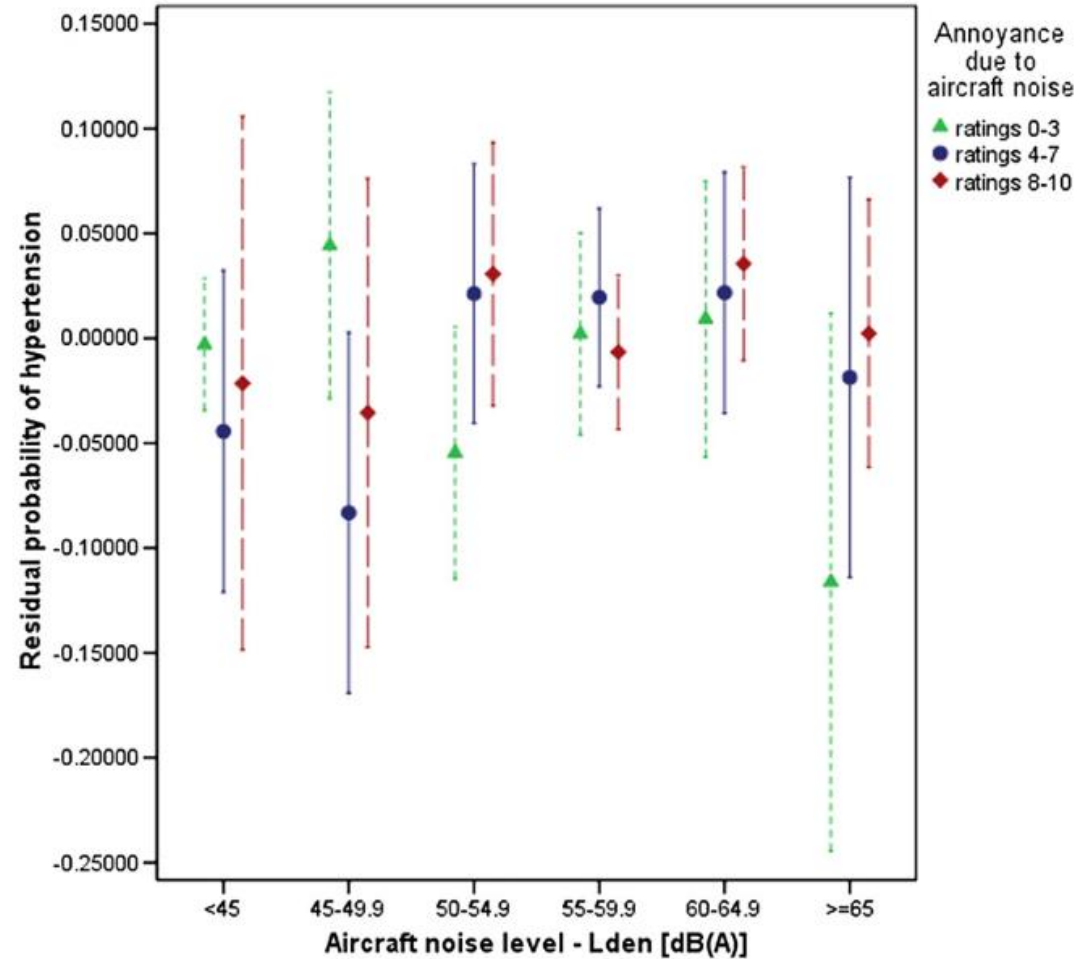
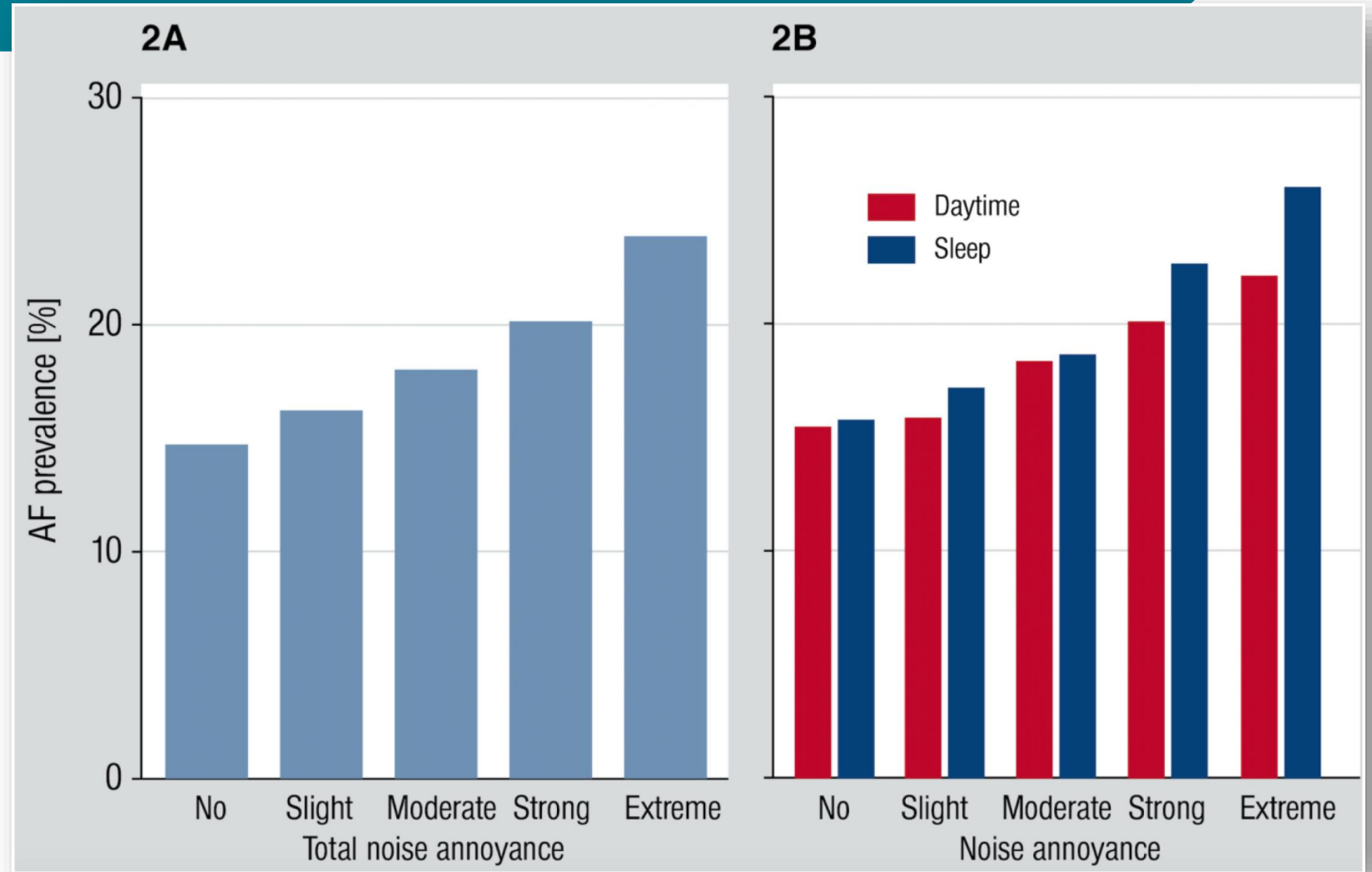


Fig. 2. Association between the aircraft noise level  $L_{den}$  and the prevalence of hypertension, stratified by the annoyance due to aircraft noise (3 categories).

Babisch, W et al. (2013) Noise annoyance — A modifier of the association between noise level and cardiovascular health?, Science of The Total Environment, 452–453, <https://doi.org/10.1016/j.scitotenv.2013.02.034>.

# Cardiovascular – atrial fibrillation & annoyance



O. Hahad et al. (2018) Annoyance to different noise sources is associated with atrial fibrillation in the Gutenberg Health Study, International Journal of Cardiology, <https://doi.org/10.1016/j.ijcard.2018.03.126>

# Cardiovascular – atrial fibrillation & annoyance

**Table 4. Association between source-specific combined daytime and sleep annoyance and odds of prevalent atrial fibrillation.**

	<i>Model 1<sup>a</sup></i>			<i>Model 2<sup>b</sup></i>			<i>Model 3<sup>c</sup></i>		
	OR	95% CI	<i>p</i> -value	OR	95% CI	<i>p</i> -value	OR	95% CI	<i>p</i> -value
<i>Total noise annoyance</i> (per point)									
Road traffic ( <i>N</i> = 14,180)	1.11	[1.06;1.15]	< 0.0001	1.07	[1.02;1.12]	0.0028	1.07	[1.02;1.12]	0.0029
Aircraft ( <i>N</i> = 14,178)	1.06	[1.03;1.10]	0.00037	1.05	[1.02;1.09]	0.0039	1.06	[1.02;1.10]	0.0024
Neighbourhood ( <i>N</i> = 14,172)	1.21	[1.16;1.26]	< 0.0001	1.14	[1.09;1.19]	< 0.0001	1.13	[1.08;1.18]	< 0.0001
Industrial ( <i>N</i> = 14,171)	1.15	[1.08;1.22]	< 0.0001	1.11	[1.04;1.17]	0.0012	1.11	[1.04;1.18]	0.00080
Railway ( <i>N</i> = 14,169)	1.09	[1.03;1.16]	0.0036	1.06	[0.99;1.12]	0.090	1.05	[0.99;1.12]	0.11

<sup>a</sup> Model 1: adjusted for age and sex

<sup>b</sup> Model 2: adjustments of model 1 + socioeconomic status, night shift work and depression

<sup>c</sup> Model 3: adjustments of model 2 + medication use, diabetes mellitus, hypertension, smoking, obesity, dyslipidemia and family history of myocardial infarction or stroke

OR = odds ratio

CI = confidence interval

O. Hahad et al. (2018) Annoyance to different noise sources is associated with atrial fibrillation in the Gutenberg Health Study, International Journal of Cardiology, <https://doi.org/10.1016/j.ijcard.2018.03.126>

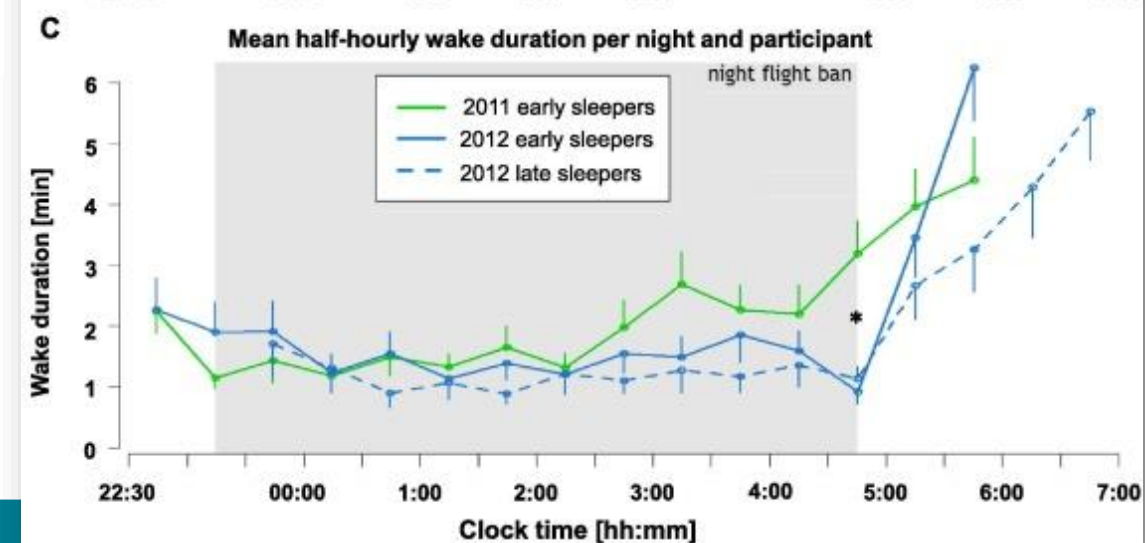
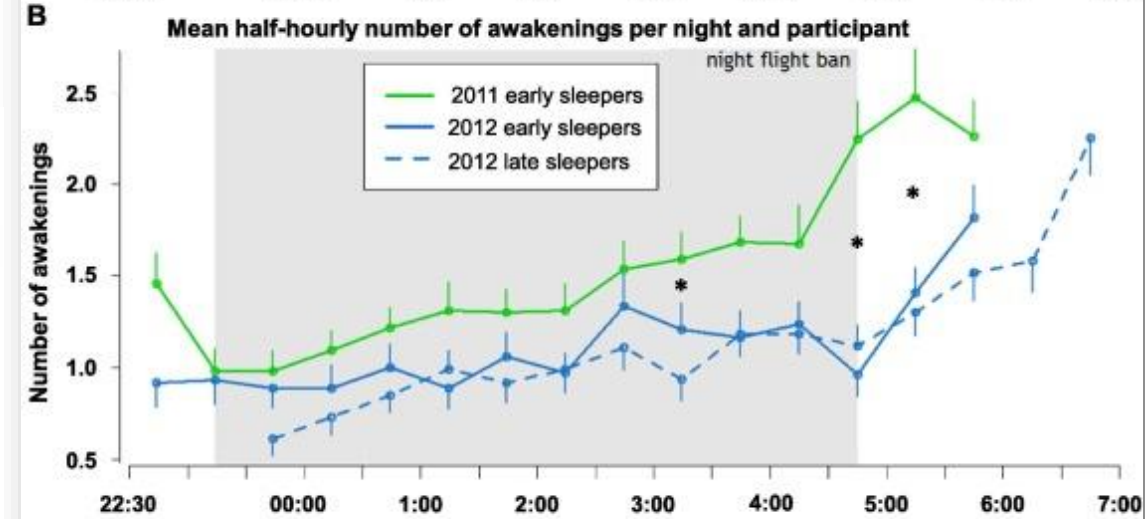
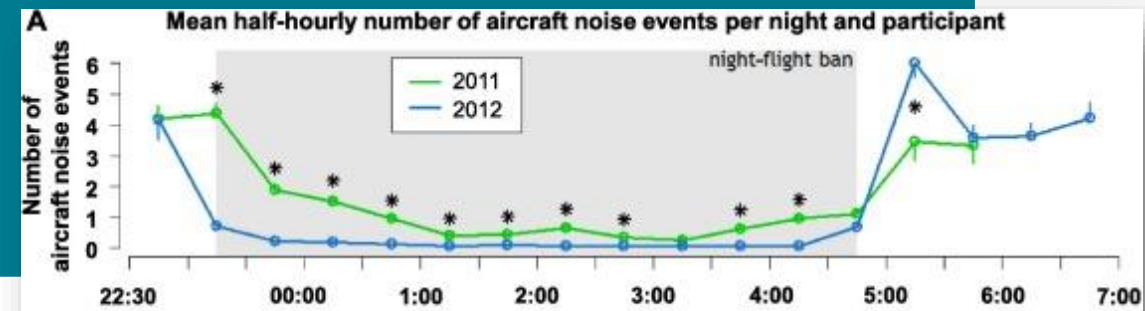
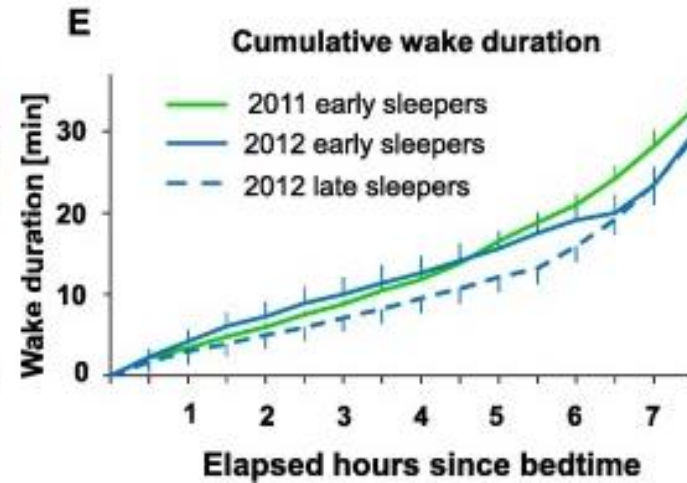
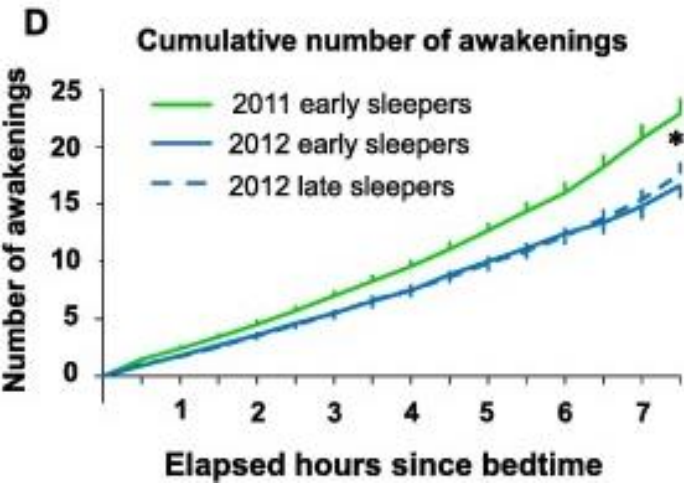
# Cardiovascular (recurrence)

*“... this is the first prospective cohort study which evaluates **the risk for recurrence in patients diagnosed with an acute coronary syndrome who are exposed to transportation noise at home....** In the present study, **the risk for recurrence including all-cause mortality increased by approximately 20%–30% per 10 dB increase in aircraft noise. This is a substantially higher exposure-response association than observed in previous population-based studies....** This supports the hypothesis that acute coronary heart disease patients, as included in our study, are particularly vulnerable to aircraft noise. ... **The effect was stronger for patients without noise-proof windows in their home.**”*

Olbrich, H-G, et al. (2023), Aircraft noise exposure and risk for recurrent cardiovascular events after acute coronary syndrome: A prospective patient cohort study, Environmental Research, <https://doi.org/10.1016/j.envres.2023.117108>.

Does time of day matter?

# Flight timings & awakenings



Elmenhorst, E-M; et al. (2024), Night-flight ban preserves sleep in airport residents, *Transportation Research Part D: Transport and Environment*, <https://doi.org/10.1016/j.trd.2023.104027>.

# Noise exposure timings and mortality

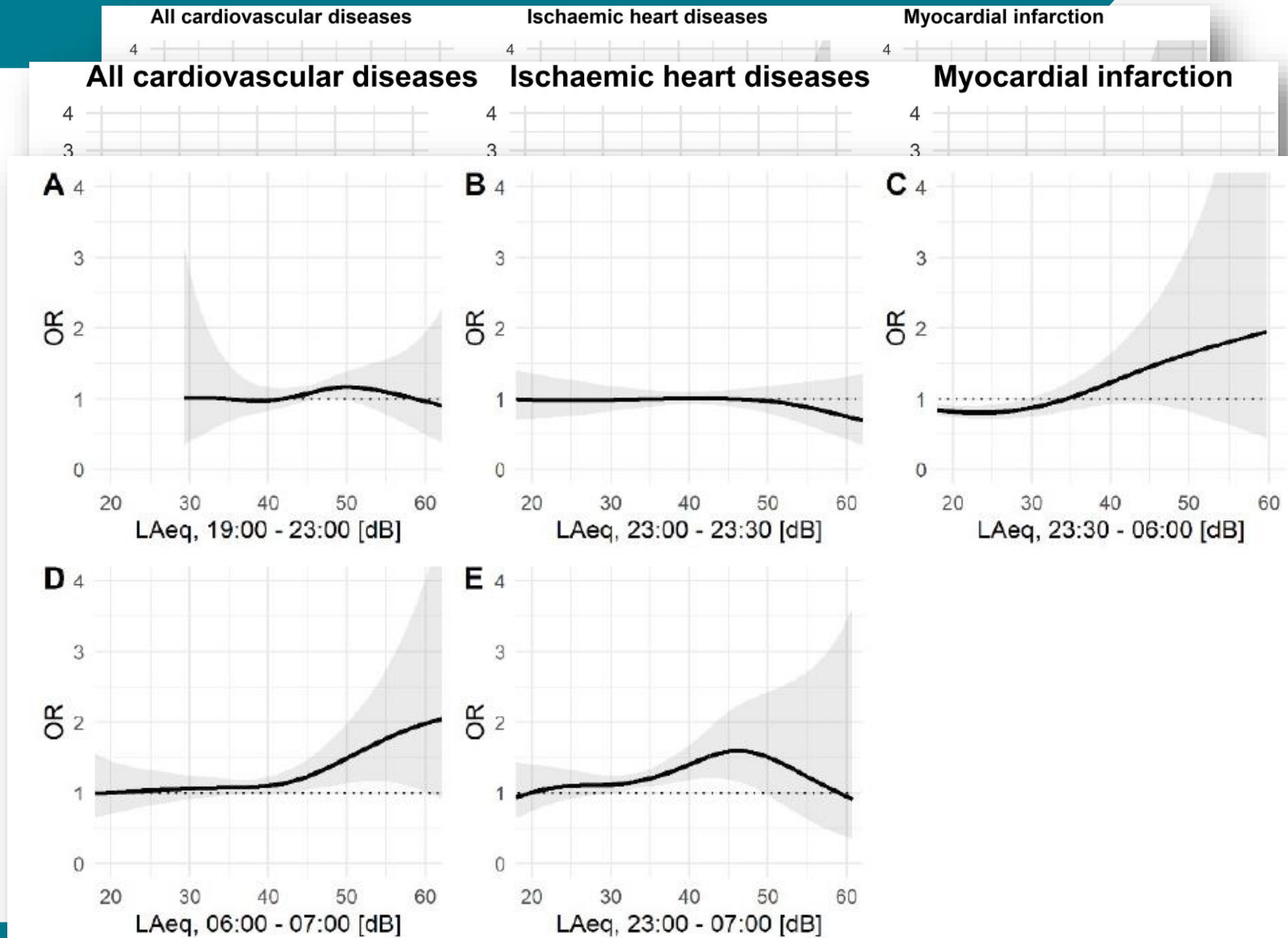
Odds of **night-time mortality** in relation to 2h- $L_{Aeq}$  levels.

Odds of **daytime mortality** in relation to night-time  $L_{Aeq}$  (23:00–07:00) levels of the preceding night.

**Daytime mortality from arrhythmias** in relation to  $L_{Aeq}$  levels for various night-time exposure windows in the night preceding the event

Saucy, A. et al., Does night-time aircraft noise trigger mortality? A case-crossover study on 24 886 cardiovascular deaths, *European Heart Journal*,

<https://doi.org/10.1093/eurheartj/ehaa957>



# Recap



- There are **multiple pathways** through which aviation noise affects long-term physical and mental health
- Current evidence suggests that **efforts to reduce both noise exposure and annoyance** are warranted
- Emerging evidence suggests that **certain individuals are at higher risk of adverse effects**: e.g. people with cardiovascular and psychological diseases
- Still many unknowns – a case for **monitoring & evaluation**
- The health evidence doesn't give us all the answers