3.1 Cardiovascular Diseases

Over the last twenty years, there has been a substantial shift of the major risk factors that contribute to the global burden of disease. Previously, important risks presented communicable childhood diseases, which were with substantial advances from that period and aging of a population in Western societies, replaced with non-communicable adulthood diseases. While the shift is not equally visible in the whole World because of different socioeconomic status, this stands true for Western Europe (WHO, 2007). Globally, of all-cause diseases and mortality, cardiovascular risk factors (arterial hypertension and smoking) and diseases (ischemic heart disease and cerebrovascular disease) represent the top four causes of death and reduced life quality due to illness (disability-adjusted life years, or DALYs) in humans. Among those, high blood pressure is the leading risk factor for all-cause mortality and has the most pronounced impact on life years spent with significant illness and disability in the population worldwide (Münzel et al., 2018).

Although the strength of the association varies significantly across studies, there is substantial evidence of the adverse effects from environmental noise exposure on the cardiovascular system (Münzel et al., 2018a; Münzel et al., 2014; Münzel et al., 2017; van Kempen et al., 2018). Studies of chronic traffic noise exposure are investigating the relationship with cardiovascular health outcomes such as elevated blood pressure, hypertension, ischaemic heart disease (including myocardial infarction), stroke, heart failure, and atrial fibrillation (Münzel et al., 2018a; Münzel et al., 2014). Also, some of the studies have evaluated the health burden of medical and economic implications from environmental noise (Münzel et al., 2014; Harding et al., 2013).

The aim of this section is to present key risks to the cardiovascular system arising from aircraft noise exposure. First, we will present the WHO's position on the exposure-response relationship between diseases of the cardiovascular system and exposure to aircraft noise. We then present supporting conclusions of the studies, which have not yet been included in the WHO review.

3.1.1 Brief summary of the WHO review on the impact of aircraft noise on cardiovascular system

In 2018, the WHO commissioned a new systematic review to evaluate the latest studies on the impact of environmental noise (noise from air, road and rail traffic and wind turbines) on the cardiovascular and metabolic system. The purpose of this review was to provide input to the new environmental noise guidelines for the European Region, as the new guidelines should be based on the latest scientific knowledge (van Kempen et al., 2017; van Kempen et al., 2018).

The WHO review included studies with an observational study design that were published in the period between 2000 to August 2015. The main cardiovascular health effects under investigation were hypertension, ischaemic heart disease and stroke. In order to retain the link with the European Environmental Noise Directive 2002/49/EC (END) and for the meta-analysis implementation, all non-L_{den} metrics from the evaluated studies were transformed into L_{den} (European Parliament and Council of the European Union, 2002).

Hypertension is an important medical condition, which is also a significant risk factor for other cardiovascular diseases and is the leading cause of cardiovascular mortality (WHO, 2013). In their review, the WHO observed that though increased risk for hypertension was associated with increased exposure to road traffic noise, no significant increase of the risk associated with increased aircraft noise exposure was observed. They stated that other meta-analysis came to similar conclusions. On the other hand, they assessed the quality of evidence supporting estimated associations between hypertension and environmental noise to be very low, meaning this estimate of effect is very likely to be changed in the future (van Kempen et al., 2018).

From the reviewed studies, the WHO observed that the increased risk for **ischaemic heart disease** (IHD, also known as coronary artery disease) was statistically associated with increased exposure to aircraft noise. It was observed that aircraft noise was associated with the prevalence, incidence and mortality caused by IHD. However, only the association with the incidence of IHD was found to be statistically significant. The review authors conclude that even though the evidence of this finding is considered as very low quality - and as such these estimates are very likely to be changed in the future - these findings are consistent with recent longitudinal studies, which report positive associations between aircraft noise and mortality due to IHD (van Kempen et al., 2018).

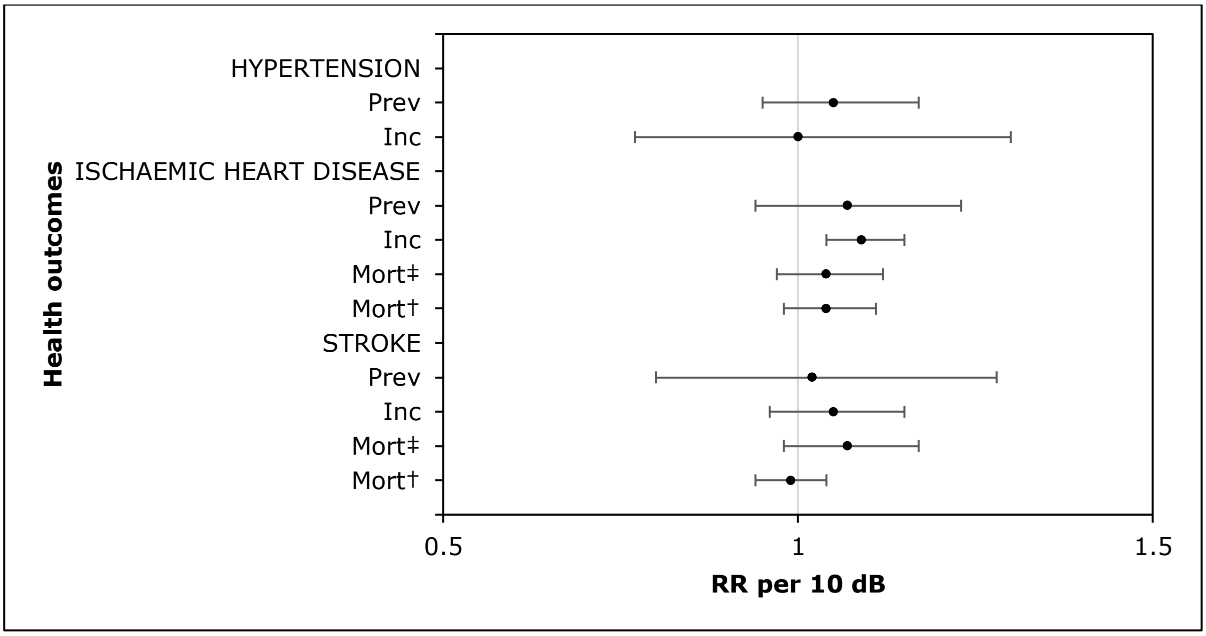
Stroke was identified to be associated with an increase in both prevalence and incidence of stroke. None of these associations seen in ecological and cross-sectional studies were statistically significant. The observations found the prevalence and the incidence of stroke were supported only by the results of the ecological studies on the association between air traffic noise and mortality due to stroke. No such association was observed in the evaluated cohort study. These results are consistent with recent longitudinal studies, which showed no clear indications of association (van Kempen et al., 2018).

The evaluated estimates for the investigated cardiovascular health outcomes are presented in Table 1 and Figure 2.

Outcome		No. of studies/ Design	RR per 10dBA (95% CI)	No. of participants (cases)	QoE*
Hypertension	Prev	9 CS	1.05 (0.95 – 1.17)	60,121 (9,487)	++
	Inc	1 CO	1.00 (0.77 – 1.30)	4,721 (1,346)	++
Ischaemic Heart Disease	Prev	2 CS	1.07 (0.94 – 1.23)	14,098 (340)	+
	Inc	2 ECO	**1.09 (1.04 – 1.15)**	9,619,082 (158,977)	+
	Mort	2 ECO	1.04 (0.97 – 1.12)	3,897,645 (26,066)	+
		1 CO	1.04 (0.98 – 1.11)	4,580,311 (15,532)	++
Stroke	Prev	2 CS	1.02 (0.80 – 1.28)	14,098 (151)	+
	Inc	2 ECO	1.05 (0.96 – 1.15)	9,619,082 (97,949)	+
	Mort	2 ECO	1.07 (0.98 – 1.17)	3,898,645 (12,086)	+
		1 CO	0.99 (0.94 – 1.04)	4,580,311 (25,231)	+++

Bold *– stat. significant association; Prev – prevalence; Inc – incidence; Mort – mortality; CS – cross-sectional; CO – cohort; ECO – ecological; QoE – quality of evidence; RR – relative risk; * – GRADE Working Group of evidence, ++++ – high quality, +++ – moderate quality, ++ – low quality, + – very low quality.*

Table 1: Aircraft noise exposure and the risk of cardiovascular disease as estimated by van Kempen et al. (2017, 2018)



Prev – prevalence; Inc – incidence; Mort – mortality; ‡ - from ecological study; † - from cohort study

Figure 2: Pooled exposure-effect estimates of aircraft noise exposure on cardiovascular diseases from van Kempen et al., (2017, 2018)

3.1.2 Updated review on aircraft-noise related cardiovascular disease

A detailed description of the approach to the literature search used in the current review in relation to cardiovascular disease is described in Annexes 7.1.1. and 7.1.2.

For the purpose of this review, we evaluated 10 studies investigating the impact of aircraft noise exposure on the risk of different cardiovascular health outcomes. Table 2 presents the main characteristics of the evaluated studies of the current review. The estimated risks for the observed health outcomes of evaluated studies are presented in the Table 3 and Table 4.

Due to the wide variety of different cardiovascular diseases investigated in the evaluated studies, we sorted studies depending on the group of cardiovascular disease under observation. These groups are hypertensive heart disease, ischaemic heart disease (including myocardial infarction), other forms of heart disease and cerebrovascular disease (including stroke).

In general, evaluated studies observed a positive association between exposure to aircraft noise and increased risk of mortality due to cardiovascular disease (Evrard et al., 2015; Heritier et al., 2017). Heritier et al (2017) observed that the effects of aircraft noise exposure on the cardiovascular system were less pronounced than those observed for other traffic noise sources. They attributed this to the ban on night-flights and the possibility that people who may not have been able to cope with aircraft noise may have moved away.

Empirical evidence illustrates a link between aircraft noise exposure and risk of mortality due to cardiovascular disease.

Study, pub. Year	Design, Period and location	Population	Outcome (ICD-10)	Noise assessment Noise indicator; noise range	Follow-up	Analysis	Adjustments	Description of the expos-resp relationship (dBA)
Evrard et al., 2015	ECO (2007-2010); France	Total = 1.9 million	CVD (I00-I52), Ischaemic heart disease (I20-I25), Myocardial infarction (I21-I22), Stroke (I60-I64, excluding I63.6);	Modelling (INM); L_{den} AEI; 42.0 – 64.1dBA	n/a	Poisson regression (MRR)	A, G, SES, lung cancer mortality, NO_2	Trend per 10dBA
Seidler et al., 2016a	CC (2005-2010); Germany	Total/cases = 1,026,670	Acute myocardial infarction (I21);	Digital landscape model; $L_{pAeq24h}$; $L_{pAeq,night}$; 40 – 65dBA	n/a	Logistic regression (OR)	A, G, SES	Trend per 10dBA and Noise categories (reference: 24-hour continuous noise level <40dBA)
Seidler et al., 2016b	ι0); Germany	Total/cases = 1,026,670	Heart failure (I50); Hypertensive heart disease (I11, I13.0, I13.2); Insurance billing register	Digital landscape model; L_{Aeq24h}; 40 – 65dBA	n/a	Logistic regression (OR)	A, G, SES	Trend per 10dBA and Noise categories (reference: 24-hour continuous noise level <40dBA)
Zur Nieden et al., 2016a	ECO (2012-2014); Germany	Total/cases = 844/132	Hypertension (I10); Physical examination of the subject	Field meas.; $L_{pAeq,18\text{-}06h}$	n/a	Logistic regression (OR)	A, G, SES, S, PA	Noise categories
Zur Nieden et al., 2016b	ECO (2012-2014); Germany	Total = 844	Systolic and diastolic blood pressure; Physical examination of the subject or laboratory measurement	Field meas.; $L_{pAeq18\text{-}06h}$	n/a	Logistic regression (OR)	A, G, SES, S, PA	Noise categories

CO-cohort study; CS-cross-sectional study; CC-case control study ECO-ecological study; CVD-cardiovascular diseases; AEI – average energetic index; INM; Integrated Noise Model; A-age; G – gender; S-smoking; SES-socio-economic status; NO_2- nitrogen dioxide; PA-physical; OR – odds ratio; MRR - mortality rate ratio

Table 2: Study characteristics of the updated review

Study	Design	Population	Outcome (ICD-10)	Noise assessment	Follow-up	Analysis	Adjustments	Noise categories (dBA)
Dimakopoulou et al., 2017	CO (2013); Greece	Total = 420	Hypertension (I10), Cardiac arrhythmia (I49.9), Myocardial infarction (I21-22), Stroke (I60-64)	Modelling (INM); L_{Aeq16h}, L_{night}; 30 – 60dBA	9 yrs; HYENA study	Multiple Logistic regression (OR)	A, G, S, BMI, E, PA, Al, Sa	Trend per 10dBA
Evrard et al., 2017	ECO (2013); France	Total = 1244;Male	Prev. of hypertension (I10);	Modelling (INM); L_{den}, L_{Aeq16h}, L_{night}; 50 – 60dBA	4 yrs; DEBATS Longitudinal study	Multiple Logistic Regression (OR)	A, G, BMI, PA, E, Al	Trend per 10dBA
Heritier et al., 2017	CO (2000-2008); Switzerland	Total/cases = 4.41 million	All CVD (I00-I99), IHD (I20I25); Stroke (I60-I64), Isch. stroke (I63), Hemorr. stroke (I60-I62), MI (I21-I22), Heart failure (I50), BP related death (I10-I15)	Modelling FLULA2; L_{den}; 30 - 60dBA	8 yrs; SiRENE project	Cox Proportional Hazards model (HR)	G, SES, MS, E, MT, N, NO_2	Trend per 10dBA
Zeeb et al., 2017	CC (2005-2010); Germany	Total/cases = 1,026,670/ 137,577	Morb. for hypertension (I10), Hypersensitive heart disease (I11)	Digital landscape model; $L_{pAeq24h}$; L_{night}; 40 - 60dBA	n/a	Logistic Regression (OR)	G, A, E, SES	Trend per 10dB and Noise categories (reference: 24-hour contin. noise level <40dBA)
Seidler et al., 2018	CC (2005-2010); Germany	Cases/controls = 25,495/ 827,601	Prim. hosp. discharge/ osec. diagnosis of stroke: I61-intracerebral haemorr. I63 –cerebral infarct. I64- stroke not specified as haemorr. or infarct.	Modelled: $L_{pAeq24h}$; $L_{pAeq,night}$; 40 - 70dBA	n/a	Logistic Regression (OR)	G,A, E, J, REB	Trend per 10dBA And Noise categories (reference contin. sound pressure level below 40dBA)

CO-cohort study; CC-case control study ECO-ecological study; CVD – cardiovascular diseases; IHD – Ischemic heart disease; MI – myocardial infarction; BP – blood pressure; INM – Integrated Noise Model; A – age; G – gender; S – smoking; SES – socio-economic status; J – job title; REB – local proportion of people receiving unemployment benefits; MT – mother tongue; N – nationality; BMI – body mass index; E – education; NO_2 – nitrogen dioxide; Sa – salt intake; PA – physical activity; MS – marital status; Al – alcohol.

Table 2(continued): Study characteristics of the updated review

3.1.2.1 Hypertensive diseases

We, like the WHO, found that there are clear indications from the evaluated studies that aircraft noise exposure may increase the risk of hypertension (van Kempen et al., 2018).

Zur Nieden (2016b) observed a small, non-significant association between systolic blood pressure and aircraft noise exposure $Lp_{Aeq,18h\text{-}6h}$. However, the same population did not demonstrate increased risk of hypertension due to increased aircraft noise exposure (zur Nieden et al., 2016a, 2016b). Contrary to the findings of zur Nieden et al (2016a), Dimakopoulou et al (2017) did find an elevated risk for hypertension with increasing aircraft noise exposure levels and that the risk for hypertension in this follow-up study is higher than the initial HYENA study (Hypertension and Exposure to Noise near Airports, conducted by Babisch et al in 2013). The authors suggest that the reason for this discrepancy may lie in the study design, as the previous HYENA study was more prone to biases, and also in the fact that the population in this cohort is now older and have lived much longer in the vicinity of the airport (Dimakopoulou et al., 2017).

Evrard et al (2017) observed a rise in OR (odds ratio) of hypertension with increasing exposure for day-evening-night aircraft noise exposure (L_{den}) and for night-time noise exposure (L_{night}) in men, but not in women. No such trend was observed for daytime noise exposure (L_{Aeq16h}). A significant increase in diastolic and systolic blood pressure was also observed only among men. In women, a significant increase in systolic but not in diastolic blood pressure was observed for L_{den} and L_{Aeq16h} (Evrard et al., 2017). Observed gender differences might be due to unmeasured confounding factors, which are more prevalent among men than women.

On the contrary, Zeeb et al (2017) did not observe any association between continuous air traffic noise exposure (per 10dB $L_{pAeq24h}$) and hypertension, but observed a significantly increased risk for individuals exposed to aircraft noise levels of 50-54dB $L_{pAeq24h}$. Zeeb et al (2017) also observed significant positive associations in people with an initial hypertension diagnosis and subsequent hypertensive heart disease. Aircraft noise exposure showed the highest increase in risk in comparison to other traffic noise sources (13.9% per 10dB $L_{pAeq24h}$). The authors debated whether noise exposure is associated with more severe forms of sustained hypertension, or whether non-differential disease misclassification for hypertension without complications in the insurance data obscures exposure-disease association (Zeeb et al., 2017).

Seidler et al (2016b) observed that cases with hypertensive heart disease showed a statistically significant association in the highest noise category of aircraft noise exposure between 55 to <60dB L_{Aeq24h} (OR 1.26; 95% CI 1.18 – 1.35) (Seidler et al., 2016b).

Evaluated studies indicate that aircraft noise exposure may increase the risk of hypertension.

Outcome; ICD-10 classification		Noise exposure	Assessed Risk (Per 10dBA increase in noise levels)		No. of partic. /cases	Study
Diseases of the circulatory system (ICD-10; I00 – I99)						
All Cardiovascular disease; I00-I99	Mort	L_{den}	**1.18 (1.11-1.25)** 0.994 (0.985-1.002)	RR (95% CI) HR (95% CI)	1,900,000/ 7,450 4,410,000/ 142,955	Evrard et al., 2015 Heritier et al., 2017
Hypertensive diseases (ICD-10; I10 – I15)						
Blood pressure; I10-I15	Mort	L_{den}	1.012 (0.985-1.039)	HR (95% CI)	4,410,000/ 13,438	Heritier et al., 2017
Heart failure and hypertensive heart disease; I50, I11, I13.0, I13.2	Inc	L_{Aeq24h}	**1.016 (1.003-1.030)**	OR (95% CI)	1,030,000/ 104,145	Seidler et al., 2016b
Hypertension; I10	Tot	L_{Aeq16h} L_{night}	**1.45 (1.05-1.99)** **1.69 (1.01-2.82)**	OR (95% CI)	420/265	Dimakopoulou et al., 2017
	Inc	L_{Aeq24h} L_{Aeq16h} L_{night}	0.997 (0.985-1.010) 1.46 (0.89-2.39) **2.63 (1.21-5.71)**	OR (95% CI)	1,030,000/ 137,577 420/71	Zeeb et al., 2017 Dimakopoulou et al., 2017
	Prev	L_{den} L_{Aeq16h} L_{night}	**1.48 (1.00-1.97)†** 1.34 (0.90-1.79) † **1.34 (1.00-1.97) †**	OR (95% CI)	1230/426	Evrard et al., 2017
Hypertensive heart disease; I11	Inc	L_{Aeq24h}	**1.139 (1.090-1.190)** **1.126 (1.107-1.146)**	OR (95% CI)	1,030,000/ 7,031 1,030,000/ 50,681	Zeeb et al., 2017 Seidler et al., 2016b

Tot - incident and prevalent cases; MI – myocardial infarction; † - in men. RR – risk ratio; HR – hazard ratio; OR – odds ratio

Table 3: Exposure to aircraft noise and the assessed risk for cardiovascular diseases from epidemiological studies (bold are statistically significant associations)

Outcome; ICD 10 classification		Noise exposure	Assessed Risk (Per 10dBA increase in noise levels)		No. of partic. /cases	Study
Ischaemic heart diseases (ICD-10; I20 – I25)						
Ischemic heart disease; I20-I25	Mort	L_{den}	0.991 (0.987-1.003) **1.24 (1.12-1.36)**	HR (95% CI) RR (95% CI)	4,410,000/ 60,327 1,900,000/ 7,450	Heritier et al., 2017 Evrard et al., 2015
Myocardial infarction; I21-I22	Tot	L_{Aeq16h} L_{night}	1.03 (0.55-1.92) 0.83 (0.31-2.20)	OR (95% CI)	420/34	Dimakopoulou et al., 2017
	Inc	L_{Aeq16h} L_{night}	0.69 (0.29-1.63) 0.37 (0.10-1.42)	OR (95% CI)	420/18	Dimakopoulou et al., 2017
	Mort	L_{den} L_{Aeq24h}	**1.28 (1.11-1.46)** **1.027 (1.006-1.049)** 0.993 (0.966-1.020)	RR (95% CI) HR (95% CI) OR (95% CI)	1,900,000/ 7,450 4,410,000/ 19,313 1,030,000/ 19,632	Evrard et al., 2015 Heritier et al., 2017 Sidler et al., 2016a
Other forms of heart diseases (ICD-10; I30 – I52)						
Cardiac Arrhythmia I49.9	Tot	L_{Aeq16h} L_{night}	1.28 (0.85-1.94) **2.09 (1.07-4.08)**	OR (95% CI)	420/68	Dimakopoulou et al., 2017
	Inc	L_{Aeq16h} L_{night}	1.33 (0.80-2.21) 1.88 (0.85-4.19)	OR (95% CI)	420/44	Dimakopoulou et al., 2017
Heart failure; I50	Inc	L_{Aeq24h}	0.974 (0.958-0.990)	OR (95% CI)	1,030,000/ 70,012	Seidler et al., 2016b
	Mort	L_{den}	**1.056 (1.028-1.085)**	OR (95% CI)	4,410,000/ 12,345	Heritier et al., 2017
Cerebrovascular diseases (ICD-10; I60 – I69)						
Stroke; I60-I64	Tot	L_{Aeq16h} L_{night}	0.84 (0.36-1.95) 1.30 (0.32-5.31)	OR (95% CI)	420/12	Dimakopoulou et al., 2017
	Inc	L_{Aeq16h} L_{night} $L_{pAeq24h}$	1.02 (0.30-3.54) 1.99 (0.23-17.2) 0.976 (0.953-1.000)	OR (95% CI) OR (95% CI)	420/5 25,498/ 827,601	Dimakopoulou et al., 2017 Seidler et al., 2018
	Mort	L_{den}	1.08 (0.97-1.21) 1.013 (0.993-1.033)	RR (95% CI) HR (95% CI)	1,900,000/ 7,450 4,410,000/ 22,444	Evrard et al., 2015 Heritier et al., 2017
Haemorrhagic stroke; I60-I62	Inc	$L_{pAeq24h}$	0.945 (0.884-1.011)	OR (95% CI)	3236/ 827,601	Seidler et al., 2018
	Mort	L_{den}	0.991 (0.951-1.032)	HR (95% CI)	4,410,000/ 5,354	Heritier et al., 2017
Ischemic stroke; I63	Inc	$L_{pAeq24h}$	0.982 (0.957-1.008)	OR (95% CI)	3236/ 827,601	Seidler et al., 2018
	Mort	L_{den}	**1.074 (1.020-1.127)**	HR (95% CI)	4,410,000/ 2,991	Heritier et al., 2017

Tot - incident and prevalent cases.

Table 3 (continued): Exposure to aircraft noise and the assessed risk for cardiovascular diseases from epidemiological studies (bold are statistically significant associations)

3.1.2.2 Ischaemic heart diseases

Evrard et al. (2015) observed a positive statistically significant association between weighted average exposure (dBA L_{den}) to aircraft noise and mortality from ischaemic heart disease (RR 1.28; 95% CI 1.11 – 1.46). The estimated risk was higher than the risk estimated in the WHO review (see previous chapter). In the WHO review, statistical significance was reached only for the risk of incidence of ischaemic heart disease (van Kempen et al., 2018).

The evaluated studies mostly investigated aircraft noise regarding the association with myocardial infarction. Evrard et al (2015) observed a positive association between weighted average exposure to aircraft noise and mortality for myocardial infarction. The risk was higher for men than for women (Evrard et al., 2015).

Seidler et al (2016a) also found indications for the relationship between exposure to traffic noise and the occurrence of a myocardial infarction. They observed that the risk indicators tend to be more pronounced for road and rail traffic noise than for aircraft noise. In their study, they observed that the risk for myocardial infarction starts rising at an aircraft noise level of 55dB LpAeq24h. In the highest noise exposure category (>60dB LpAeq24h), OR rises to 1.42 (95% CI; 0.61 – 3.25). The small number of people exposed to high noise levels (>60dB LpAeq24h) might be responsible for inability to reach statistical significance. In their analysis, they observed that the most sensitive noise exposure time is between 5.00 to 6.00 a.m. (Seidler et al., 2016a). On the contrary, Dimakopoulou et al. (2017) did not find an increase in the risk of myocardial infarction with increasing aircraft noise exposure.

The relationship between aircraft noise exposure and risk of myocardial infarction or mortality from ischaemic heart disease needs cautious interpretation. Further research is required on this theme.

3.1.2.3 Other forms of heart diseases

Dimakopoulou et al (2017) observed an elevated non-significant risk between aircraft noise exposure and arrhythmia during the night. Seidler et al (2016b) observed that heart failure was associated with aircraft noise only in the presence of hypertensive heart disease.

3.1.2.4 Stroke

Dimakopoulou et al (2017), like the WHO, observed an elevated non-significant risk for stroke associated with aircraft noise exposure. The association was stronger during the night, but it still did not reach statistical significance, which might have happened due to the small number of people exposed to high aircraft noise levels (Dimakopoulou et al., 2017; van Kempen et al., 2018).

Seidler et al (2018) did not observe an increase in the risk of stroke with increasing aircraft noise levels, but they were faced with the same problems as Dimakopoulou et al (2017), i.e. a small number of cases in the high exposure categories. On the other hand, they observed that nightly maximum sound pressure levels exceeding

50dB L_{max} led to increased disease risk for aircraft noise exposure, even if continuous sound pressure levels were below 40dB $L_{pAeqnight}$, which indicated possible relevance of the maximum aircraft noise level at night on the cardiovascular system (Seidler et al., 2018).

When the elevation of the risk for stroke due to aircraft noise exposure was investigated separately for the ischemic and haemorrhagic stroke, Heritier et al (2017) observed that possible increased risk for ischemic stroke but not haemorrhagic stroke was associated with elevation of aircraft noise levels.

Outcome /ICD-10	Noise exposure		Effect estimate OR (95% CI)	No. of cases/controls	Study
	Indicator	**Categories**			
Hypertensive diseases (ICD-10; I10 – I15)					
Hypertension/ I10	$L_{pAeq24h}$	40 – 44dBA	0.99 (0.97-1.02)	13,319/55,561	Zeeb et al., 2017
		45 – 49dBA	0.99 (0.97-1.03)	7,100/29,488	
		50 – 54dBA	**1.07 (1.02-1.12)**	3,014/11,819	
		55 – 59dBA	0.96 (0.89-1.05)	813/3,575	
		≥ 60dBA	0.68 (0.33-1.40)	9/56	
Hypertension/ I10	L_{night}	40 – 44dBA	**1.02 (1.00-1.03)**	23,217/60,309	Zeeb et al., 2017
		45 – 49dBA	1.00 (0.97-1.02)	10,648/29,711	
		50 – 54dBA	1.01 (0.97-1.05)	4,071/11,087	
		55 – 59dBA	0.81 (0.67 – 0.97)	176/591	
Hypertensive heart disease/ I11	L_{Aeq24h}	40 – 44dBA	**1.18 (1.15-1.21)**	15,895/197,474	Seidler et al., 2016b
		45 – 49dBA	**1.24 (1.21-1.28)**	8,684/106,497	
		50 – 54dBA	**1.19 (1.14-1.24)**	3,302/42,620	
		55 – 59dBA	**1.26 (1.18-1.35)**	979/12,744	
		60 – 64dBA	0.86 (0.45-1.65)	10/172	
Heart failure and hypertensive heart disease/ I50, I11, I13, I13.2	L_{Aeq24h}	40 – 44dBA	1.01 (0.99-1.03)	30,463/197,474	Seidler et al., 2016b
		45 – 49dBA	**1.07 (1.04-1.09)**	16,604/106,497	
		50 – 54dBA	1.00 (0.96-1.03)	6,113/42,620	
		55 – 59dBA	1.03 (0.98-1.09)	1,802/12,744	
		60 – 64dBA	0.97 (0.61-1.53)	24/172	
Ischaemic heart diseases (ICD-10; I20-I25)					
Myocardial infarction/ I21-I22	$L_{pAeq24h}$	40 – 44dBA	1.01 (0.97-1.05)	5,839/249,666	Seidler et al., 2016a
		45 – 49dBA	1.00 (0.95-1.05)	3,029/134,464	
		50 – 54dBA	0.97 (0.91-1.04)	1,151/52,923	
		55 – 59dBA	1.06 (0.95-1.18)	376/15,845	
		60 – 64dBA	1.42 (0.62-3.25)	6/196	
Myocardial infarction/ I21-I22	$L_{pAeqnight}$	40 – 44dBA	0.99 (0.95-1.04)	3,319/140,511	Seidler et al., 2016a
		45 – 49dBA	0.95 (0.89-1.01)	1,382/65,738	
		50 – 54dBA	1.07 (0.98-1.17)	623/24,693	
		55 – 59dBA	0.99 (0.66-1.49)	24/1,142	
Myocardial infarction - fatal/ I21-I22	$L_{pAeq,24h}$	40 – 44dBA	**1.06 (1.01-1.12)**	3,121/24,966	Seidler et al., 2016a
		45 – 49dBA	**1.08 (1.01-1.15)**	1,649/134,464	
		50 – 54dBA	1.03 (0.94-1.12)	605/52923	
		55 – 59dBA	1.09 (0.94-1.27)	198/15845	
		60 – 64dBA	**2.70 (1.08-6.74)**	5/196	
Myocardial infarction - fatal/ I21-I22	$L_{pAeqnight}$	40 – 44dBA	**1.07 (1.01-1.13)**	1,813/140,511	Seidler et al., 2016a
		45 – 49dBA	1.00 (0.92-1.08)	717/65,738	
		50 – 54dBA	**1.14 (1.01-1.28)**	348/24,693	
		55 – 59dBA	1.24 (0.73-2.13)	14/1,142	

Table 4: Exposure to aircraft noise and the assessed risk for the incidence of cardiovascular diseases from epidemiological studies by noise categories (bold are statistically significant associations)

Outcome /ICD-10	Noise exposure		Effect estimate OR (95% CI)	No. of cases/controls	Study
	Indic.	Categories			
Other forms of heart diseases (ICD 10; I30 – I52)					
Heart failure/	L_{Aeq24h}	40 – 44dBA	0.96 (0.93-0.98)	4,664/40,861	Seidler et al., 2016b
		45 – 49dBA	1.02 (0.99-1.05)	19,886/197,474	
		50 – 54dBA	0.92 (0.89-0.96)	10,844/106,497	
		55 – 59dBA	0.93 (0.87-1.00)	3,852/42,620	
		60 – 64dBA	1.12 (0.67-1.88)	1,094/12,744	
Cerebrovascular diseases (ICD-10; I60 – I69)					
Stroke; I61, I63-64	$L_{pAeq24h}$	<40dBA, Max ≥50dBA	**1.07 (1.02 – 1.13)**	10,595/325,613	Seidler et al., 2018
		40 – 44dBA	0.98 (0.95-1.01)	7304/247,877	
		45 – 49dBA	1.02 (0.98-1.06)	3973/133,244	
		50 – 54dBA	0.97 (0.92-1.03)	1470/52,507	
		55 – 59dBA	0.86 (0.77-0.95)	413/15,792	
		60 – 64dBA	1.62 (0.79-3.34)	8/195	
	$L_{pAeqnight}$	<40dBA, Max ≥ 50dBA	1.01 (0.98-1.04)	6707/220,495	Seidler et al., 2018
		40 – 44dBA	1.02 (0.98-1.04)	4209/139,373	
		45 – 59dBA	1.00 (0.98-1.05)	1804/65,201	
		50 – 54dBA	0.99 (0.91-1.07)	741/24,541	
		55 – 59dBA	1.00 (0.68-1.46)	28/1131	
Ischemic stroke; I63	$L_{pAeq24h}$	<40dBA, Max ≥ 50dBA	**1.06 (1.00-1.12)**	1465/52, 373	Seidler et al., 2018
		40 – 44dBA	0.99 (0.96-1.03)	6392/247,876	
		45 – 49dBA	1.04 (0.99-1.09)	3489/133,244	
		50 – 54dBA	1.06 (0.92-1.04)	1273/52,507	
		55 – 59dBA	0.85 (0.76-0.95)	356/15,792	
		60 – 64dBA	1.41 (0.62-3.22)	6/195	
Haemorrhagic stroke;	$L_{pAeq24h}$	<40dBA, Max ≥ 50dBA	**1.16 (1.02-1.33)**	256/52,373	Seidler et al., 2018
		40 – 44dBA	0.90 (0.82-0.99)	874/247,876	
		45 – 49dBA	0.94 (0.84-1.05)	470/133,244	
		50 – 54dBA	0.99 (0.85-1.16)	192/52,507	
		55 – 59dBA	0.91 (0.69-1.21)	53/15,792	
		60 – 64dBA	3.22 (0.79-13.1)	2/195	

Table 4(continued): Exposure to aircraft noise and the assessed risk for the incidence of cardiovascular diseases from epidemiological studies by noise categories (bold are statistically significant associations).

3.1.3 Conclusions

As the WHO review illustrated, the current review shows, that there are some new indications that aircraft noise exposure may increase the risk for cardiovascular diseases, such as hypertension, ischaemic heart diseases, stroke and some other forms of heart diseases.

In some of the evaluated studies it was suggested that the night is a particularly sensitive time for the development of cardiovascular diseases (Dimakopoulou et al., 2017; Seidler et al., 2016b). These findings are supported by suggestions that sleep disturbance due to aircraft noise could mediate the effect of aircraft noise on health, especially cardiovascular diseases (Greiser et al., 2007; Haralabidis et al., 2008).

Though the evidence supporting the association between aircraft noise exposure and cardiovascular health outcomes is substantial, there is still heterogeneity among studies in estimating the effect size (risk in present case). There are many reasons for heterogeneity among epidemiological studies due to different study designs, differences in exposure of observed populations and differences in exposure, confounder and outcome assessment.

Especially unfavourable for the evaluation of the evidence of noise effects exposure is the use of different noise metrics, as the quantification of the noise exposure requires a common unit. The question, regarding which noise indicator is the most relevant in describing the relationship between aircraft noise exposure and health effects, is a recurring theme.

Even though cardiovascular risk estimates for aircraft noise are found to be much lower than the ones found for known individual life-style risk factors for the development of cardiovascular diseases, individual life-style risk factors can be influenced by individual behaviour, and therefore, are not comparable. Also, protection from health consequences of traffic noise exposure is a governmental and management task and an individual does not have a direct influence over it.

As there are still uncertainties in scientific evidence, precautionary principle is recommended. Decisions can be made based on the best available data and future studies should also focus on vulnerable groups, effect modifiers, sensitive hours of the day, coping mechanisms, differences between noise sources, possible confounding with air pollution and differences between objective (noise level) and subjective (noise perception) exposure.

Aircraft noise exposure may increase the risk of cardiovascular diseases, although the evidence available may currently be contested. Subjective and objective factors may influence individual response to aircraft noise. It is through further research that better understanding of the relationship between noise exposure and cardiovascular disease risk and mortality may be revealed.