Noise and health in vulnerable groups: a review

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ABSTRACT

Vulnerable or susceptible groups are mentioned in most reviews and documents regarding noise and health. But only a few concrete and focused studies address this issue. Groups at risk most often mentioned in the literature are children, the elderly, the chronicly ill and people with a hearing impairment. Another distinction encountered is that of sensitive people, shiftworkers, people with mental illness, people suffering from tinnitus, schizofrenia or autism and foetuses and neonates. The mechanism for this vulnerability has not been clearly described, and relevant research has seldom focused on the health effects of noise in these groups in an integrated manner. This paper summarizes the outcomes and major conclusions of a systematic, qualitative review of studies over the past five years. The full review will be published elsewhere. Evidence is descibed along effects and groups assumed to be at risk.

INTRODUCTION

In the recently pusblished guideline by WHO (2011) for the burden of disease from environmental noise it is concluded that future epidemiological noise research will need to focus on vulnerable groups; some noise exposures may be worse for particular subgroups than for others such as children, older people and lower socioeconomic groups. This conclusion supports the notion that noise effects can and should be differentiated between subgroups. In most recent reviews (Clark & Stansfeld 2007; Berry & Flindell 2010; Davies & van Kamp 2008; WHO 2000, 2011) on noise and health, this topic has been touched upon, but evidence is still scarce or scattered. There are conceptual problems and the mechanism for this vulnerability has not been clearly described, nor are the mechanisms necessarliy the same for different groups at risk.

METHODS

Data sources and searches

Medline and Scopus were searched to detect relevant peer reviewed studies published between January 2006 and April 2011. There was a language restriction for English, French and German papers. A wide range of keywords was used, related to noise exposure, vulnerable goups and health outcomes, which are presented in Table 1. In addition, the reference sections of previous systematic reviews, key papers, conference proceedings and international reports on vulnerable groups as well databases of websites dealing with the issue of noise and vulnerability (WHO, PINCHE, ENNAH) were checked for potentially relevant references.

Inclusion and quality criteria

All studies were selected that concern environmental quality in relation to noise and susceptible groups. Studies which did not explicitly deal with effects were in most cases excluded.

Table 1: Key search terms

Health outcomes	**adverse effects, health**./ or health status/ or mental health/ or public health/ **stress related effects** or asthma or respiratory or blood pressure or heart rate* or cardiovascular). stress, psychological/ or stress, physiological/ or emotions/ or asthma/ or child behavior/ or blood pressure/ or heart rate/ **cognitive effects, performance or cognitive impairment** cognitive development, memory, recognition, pre-reading or school performance or performance or comprehension or annoyance or (disturbance adj3 daily activity*) or emotion* or stress or speech or intelligibility).tw. cognition/ or cognition disorders/ or memory/ or reading/ or mental recall/ or recognition, psychology/ or loudness perception/ or comprehension/ or speech intelligibility/ or hearing disorders/ (**sleep or insomnia or awakening***).tw. or exp sleep/ or exp sleep disorders/ or sleep deprivation/ or wakefulness/ (reproductive outcome or pregnancy outcome or birth weight).tw. or pregnancy outcome/ or birth weight/ **vulnerable group*** or vulnerability or frail or child* or infant* or adolescent* or preschool or school* or students or newborn or neonat* or perinat* or prenatal or foet* or fetal or fetus or pregnant or pregnancy or elderly or old people or elder people or mentally ill* or mentally handicapped or mentally disabled or chronic disease* or chronic illness* or shiftworker* or shift worker*). vulnerable populations/ or child/ or infant/ or adolescent/ or students/ or schools/ or pregnancy/ or aged/ or frail elderly/ or disabled persons/ or mentally disabled persons/ or mentally ill persons/ or hearing impaired persons/ tinnitus/ or hearing impaired persons/ or autism/ or (hearing impairment* or hearing impaired or hearing ability or noise sensitiv* or tinnitus or autism).
Exposure:	noise/ traffic or transport* or road or road-traffic or road-transport or automobile* or vehicle* or vehicular movements or motorcycle* or tram or train or trains or railway* or railroad* or airplane* or aeroplane* or aircraft* or airport* or air-traffic or nightflights or night flights).
Design	No restrictions
Time period	2006 – 2011

RESULTS

Study characteristics

The original literature search has yielded 212 papers, of which 71 were a priori eligible to be included in the review, based on the crude criteria described above. Eventually, several papers were not inlcuded because they did not give any information on effects. Thirty seven of these studies pertained to primary school children, fifteen to (young) adolescents, two to preschool schildren and four to neonates. A few papers concerned effects of noise in specific patient groups such as children with autism (2) Asthma (1) and ADHD (1). The eldery were addressed in four papers and another four addressed all age groups and/or life span exposures. Remarkably few studies dealt with noise sensitivity, while this may be key to understand susceptibility, sensitive moments of the day, sensitive places and sensitive periods in the life course. An additional search in MEDLINE and Scopus yielded eight studies on these related topics for the past five years.

Definitions

Vulnerability refers to the susceptibility of a person, group, society or system to physical or emotional injury or attack. It has also been described as the degree to which people, property, resources, systems, and cultural, economic, environmental, and social activity is susceptible to harm, degradation, or destruction on being exposed to a hostile agent or factor.

Noise sensitivity refers to the internal states (be they physiological, psychological and attitudinal, or related to life style or activities) of any individual, which increase their degree of reactivity to noise in general. Noise sensitivity has a strong genetic component as was shown by Heinonen et al. (2005). Noise sensitivity can also be caused by physical illness such as: constant migraine headaches and sudden trauma, such as a head injury. Severe panic disorder may also be accompanied by oversensitive hearing, which in turn facilitates panic attacks. Ear infections, surgery, and the use of some prescribed medications can also lead to this heightened reaction to noise.

In epidemiology **a high risk group** has been defined as a group of people in the community with a higher-than-expected risk for developing a particular disease, which may be defined on a measurable parameter, an inherited genetic defect, physical attribute, lifestyle, habit, socioeconomic and/or educational feature, as well as environment (McGraw-Hill Concise Dictionary of Modern Medicine 2002).

Noise sensitive areas: An area or place is defined as noise-sensitive if noise interferes with normal activities associated with the area's use. Examples of noise-sensitive areas include residential, educational, health, and religious structures and sites, and parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites where a quiet setting is a generally recognized feature or attribute (FAA).

Who are at risk and at risk for what?

Most often mentioned risk groups in the literature are: children, older people, chronic ill people, and hearing impaired people. Groups potentially also at risk are noise sensitive people, people suffering from tinnitus, shift-workers, mentally ill people (schizophrenia, autism) and foetus and neonates. Health effects most frequently described are annoyance, sleep disturbance, cardiovascular disease and cognitive effects. The overview of evidence is structured along these endpoints and per theoretical risk group.

Annoyance

Van Kempen et al. (2009) showed that the exposure–annoyance curve of schoolchildren (aged 9-11) for aircraft noise, overall has the same pattern as in adults. However, children score lower on annoyance at the high end of the scale and somehwat higher at the lower end. These findings confirm the conclusion of Babisch (PINCHE, 2006). In a recently published study Babisch et al. (2010) concluded that German children between 8 and 14 were considerably less frequently annoyed by road traffic noise at home than adults.

Very few studies are available on annoyance reaction in older people. There is no evidence that people above 60 respond differently to environmental noise (van Kamp et al. 2009). Based on analysis of a large meta data set of TNO (N=62,983) van Gerven et al. (2009) found evidence of a non-linear relation. Results revealed an inverted U-shaped pattern for both road and air traffic noise. The largest number of highly annoyed individuals was found in the middle-aged segment of the sample. With a peak around 45 years and the lowest percentages of highly annoyed in both the youngest and oldest groups. These effects were independent of noise levels and noise sensitivity.

A study in Beijing (Li et al. 2008) among students revealed, that the extremely high levels of exposure to traffic noise (64.0 dBA - 79.2 dBA resulted in a percentage highly annoyed of up to 39 % on the ISO verbal annoyance scale, and 50 % according to the numerical scale.

Sleep disturbance

Evidence has indicated (Öhrström et al. 2006) that children are less sensitive for awakenings and sleep cycle shifts, but more sensitive for physiological effects such as blood pressure reactions (Muzet 2007; Bruni et al. 2011) and related motility (WHO, 2009).

Muzet (2007) concluded in his review, that there is only anecdotal evidence that older people are more at risk for sleep disturbance due to noise. Other potential vulnerable groups are people with a somatic or mental disorder, and shiftworkers (Muzet 2007). Earlier suggestions that long term health effects of sleep disturbance depend on the person's vulnerability and/or sensitivity (WHO 2000; van Kamp et al. 2004; Staatsen et al. 2004) are not supported by more recent evidence.

Cardiovascular effects

Analysis on the pooled data set (Heathrow, Schiphol) of the Ranch study (van Kempen et al. 2006) indicated that aircraft noise exposure at school was related to a statistically non-significant increase in blood pressure and heart rate in children. Road traffic noise did show an unexplained negative effect. Babisch & van Kamp (2009) concluded on an inconsistent association between aircraft noise and children's blood pressure. In their recent review Paunovic et al. (2011) conclude on a tendency towards positive associations, but observed large methodological differences between studies. A review of UK studies (Stansfeld & Crombie 2011) again concluded on inconsistent associations of aircraft noise with systolic blood pressure in children. In a study among children aged 8-14 by Babisch et al. (2009) concluded that road traffic noise at home as stressor could affect children's blood pressure. There is some evidence that short term cardiovascular reactions during sleep are more pronounced in children (Griefahn et al. 2008). Lepore et al. (2010) concluded that compared to quiet-school children, noisy-school children had significantly lower increases in blood pressure, when exposed to either acute noise or non-noise stressors, indicative of a generalized habituation effect. Studies in Servia (Belojevic et al. 2008, 2011) among schoolchildren and preschool children indicated a raised BP among children from noisy schools and quiet residences, compared to children from both quiet environments. There is no consistent evidence that the effect of traffic noise on cardiovascular diseases is greater in older than younger people (Griefahn & Basner 2008). Bodin et al. (2009) found strong evidence for an age effect in the noise BP association, with a stronger relation in the middle aged; age group-specific models could account for differences in prevalence in future studies.

A study among 30 male and female participants aged 18-32 (Chang et al. 2009) concluded that environmental noise leads to a significant increment in both systolic and diastolic blood pressure. The effects were significantly associated with an increment of 5 dBA both in transient as well as sustained effects (lag time > 30-60 minutes) especially in females.

There is a differential, but inconclusive effect regarding gender differences in cardiovascular effects of noise (Davies & van Kamp 2008; Babisch 2006). Babisch (2006) showed that people with prevalent chronic diseases run a slightly higher risk of heart diseases as a result of traffic noise than those without.

Physiological effects and quality of life

A study in France (Mir 2008) among 10 year old schoolchildren showed that school noise exposure was associated with fatigue, headaches and higher cortisol level indicative of a stress reaction. These finding are supported by a Swedish study (Wålinder et al. 2007) who found increased prevalence of fatigue, headache and reduced diurnal cortisol variability in relation with classroom Leq during schoolday levels between 59 to 87 dBA. A cross sectional study in Nigeria (Ana et al. 2009) among children frequenting a school near a major road (noise range: 68 – 85 dBA) found at least some disturbance in 70 % of the children. Fatigue and lack of concentration came forward as the most prevalent noise related health problems.

Parra et al. (2010) report that in people over 60 living in Bogota, among other neighbourhood features, road traffic noise was negative related with both the physical and mental dimension of the HR quality of life.

Cognitive effects

Based on the Ranch study around three major European airports Clark et al. (2006) reported that exposure at home was highly correlated with aircraft noise exposure at school and demonstrated a similar linear association with impaired reading comprehension after adjustment for a range of confounders. Stansfeld et al. (2010) conclude that night exposures does not add to these effects of daytime exposures to aircraft noise. Likewise, Kaltenbach et al. (2008) found exposure to aircraft daytime noise of 50 dBA and over to be associated with learning difficulties in schoolchildren. Road traffic noise exposure at school was not associated with reading comprehension in the RANCH study. Ljung et al. (2009) concluded that road traffic noise impaired reading speed and basic mathematics, but had no effect on reading comprehension or on mathematical reasoning. Irrelevant speech did not disrupt performance on any task. Klatte et al. (2007) did find that serial recall of visually presented digits was severely disrupted by background irrelevant speech. Train noise exposure did not show comparable effects. A later study (Klatte et al. 2010) replicated these findings. Noteworthy is that the children did not consciously realize these detrimental effects.

Shield and Dockrell (2008) related in- and outside noise exposure at school with standard test on literacy, mathematics, and science in children aged 7-11 in London. Results revealed an association between noise and performance on these tests, after adjustment for socio-economic factors, especially in the older children. However, a recent study of Xie et al. (2011) in secondary schools in Greater London did not support these findings.

In a small study (N=20) on the effect of climate, light and noise in the work environment Fosnaric & Planinsec (2008) found a significant effect of noise on work performance of male adolescents.

Hearing disorders and impairment

Studies on hearing loss in children are rare. Within the framework of the PINCHE project Bistrup et al. (2006) do conclude that noise can have auditory effects on children, but most effects are long-term and cumulative. They advise to describe the effects of noise on children in a life-course perspective, in order to illustrate the prospects of cumulative effects. A study (Rocha et al. 2007) among children of highly noise exposed mothers during pregnancy showed no hearing impairment.

In the past five years several studies addressed the issue of hearing disorders and loss in adolescents as a result of recreational noise. Rosanowski et al. (2006) found no pure tone hearing loss, but transient effects on hearing and tinnitus immediately after exposure. Martinez-Wbaldo Mdel et al. (2009) report high frequency hearing loss in 21 % of the highschool students in Mexico, primarily related to frequent exposure to music at discotheques and pop-concerts, the use of personal divices and noise exposure in school workshops. A study in Brazil (Zocoli et al. 2009) among young adults confirmed these findings, indicating that a substantial percentage of the participants reported temporary tinnitus (69 %) after attending disco's, concerts, and listening to music through headphones. Tinnitus complaints were more frequent among females (41 %) than males (27 %). A similar study in Turkey (Bulbul et al. 2009) also found a high prevalence of (transient) tinnitus in young adolescents due to loud music. Noise induced hearing loss at a young age due to recreational music and personal devices was reviewed by Harisson (2008). An American study (Holmes et al. 2007) revealed a prevalence of approximately 6 % perceived hearing loss, and 13.5 % of prolonged tinnitus.

The effects of noise and smoking were studied in a stratified sample of 440 people between 21 and 50 years by El Zir et al. (2009). Results showed an effect of smoking on hearing in all age groups and an interaction effect with noise only in the group older than 40.

In a recent study of Heinonen et al. (2011) noise sensitivity was associated with self-reported hearing disability among all subjects, but especially in women and younger subjects (50 years or less). Baur et al. (2009) reported significant negative effects of noise exposure, painkillers, overweight, and cardiovascular diseases on hearing loss. A positive effect of moderate alcohol consumption was shown in the elderly.

Miscellaneous outcomes for specific risk groups and outcomes

Linares et al. (2006) studied hospital admissions of children younger than 10 years old and found an association between road traffic noise levels and admission for respiratory disease, pneumonia and organic diseases after adjustment for air pollution effects, meteorological circumstances, influenza epidemics and pollen concentrations. A SES effect could not be ruled out, based on the presented information. In a birth cohort of 652 children Bockelbrink et al. (2008) found an association between noise annoyance (specifically during the night) and prevalence of asthma attacks (doctor diagnosed) in girls.

The few studies (Lasky & Williams 2009; Byers et al. 2006; Liu 2010) on neonates at the ICU of hospitals have concentrated on noise levels only and potential measures to reduce these. About the short and long term effects no data are available.

Russo et al. (2009) compared speech evoked responses between normal children and children with autism, under a quiet and noisy condition. Normal children showed delayed reaction times under the noisy conditions, whereas autistic children showed delayed times under both conditions; ADS children perform as well under quiet conditions as normal children do under noisy conditions.

Role of noise sensitivity

Berry and Flindell (2009) conclude in their review that evidence shows that noise sensitive people (NS) are more susceptible to cardiovascular effects. This also ties in with the role of annoyance as a mediating factor. Babisch et al. (2009) only found an effect of NS on cardiovascular effects when NS, annoyance and exposure were assessed before the CVD outcomes (prospective studies). White et al. (2010) compared physiological effects of task performance between highly a NS and non sensitive group in opposite direction. Both mean heart rate and sympathovagal balance of LNS subjects were responsive to the change in circumstances between conditions. This was not the case for HNS participants. Shepherd et al. (2010) found that NS was associated with health-related quality of life. Annoyance and sleep disturbance mediated the effects of NS on health. Schreckenberg et al. (2010) conclude that NS people were more critical of their environmental quality, in particular with regard to air traffic. This phenomenon was earlier referred to by Weinstein as “critical tendency” (1980). Fyhri & Klaeboe (2009) concluded that only NS was related to hypertension and chest pain, while no relationships between noise exposure and health complaints were identified. It is concluded that it is conceivable that individual vulnerability is reflected both in ill health and NS. Heinonen et al. (2007) found that cardiovascular mortality was significantly increased only in NS women. Based on this it was concluded that NS may be a risk factor for cardiovascular mortality in women, which is a slightly different interpretation than that suggested by Fyhri & Klaeboe (2006). No main effect of NS was observed by Ljungberg & Neely (2007) in cognitive aftereffects of vibration and noise exposure.

Ryu & Jeon (2011) found NS to have a greater influence on the percentage of highly annoyed by indoor noise than outdoor noise. Marks & Griefahn (2007) report a high correlation between noise sensitivity and subjective sleep quality in terms of decreased restoration and calmness, difficulty to fall asleep, and body movements. The results suggest that noise induced sleep disturbance is mediated by NS.

Role of social economic status

Very few studies addressed the role of social economic factors. Theoretically, this relation would operate via learned helplessness (Evans 2006) and unequal distributions of noise. Low SES groups/areas might be more at risk due to accumulations of exposures at residential level (noise, airpullution etc) and of residential and work exposures. In the USA and UK an association was previously found between income level and exposure levels (Evans et al. 2002). In the NL no such SES differences were confirmed, except for rail noise. Both at higher and lower ends of the gradient more noise exposure were found (Kruize 2007). Likewise Fyhri & Klaeboe (2006) did not find a SES related noise distribution in Oslo, but they did find an income mediated association in a medium size city.

CONCLUSIONS

Vulnerable groups regarding environmental noise have been understudied, are generally underrepresented in study populations, and evidence is still highly anecdotal. Effects of noise in schoolchildren are the best documented. The available evidence shows that children are less vulnerable for annoyance than adults, but more vulnerable for cognitive effects of noise. They are not per se more vulnerable as a group, but more at risk because of less developed coping strategies and they are in a sensitive developmental period. This is indicative of a life phase effect rather than an age effect. Children seem to be less vulnerable for awakenings due to noise but more vulnerable for physiological effects during sleep and related motility. There is some evidence that annoyance from both road- and air traffic noise predict asthma prevalence in children (both self reported and diagnosed). Evidence does not indicate that the elderly are more vulnerable to noise in terms of annoyance and sleep disturbance. Age specific comparisons rather show a U shaped relation and indicate that both young and older people are less at risk as far as annoyance and disturbance are concerned. But possibly the elderly are more vulnerable regarding CVD effects and this may be a combined effect of air pollution and noise. The role of noise annoyance and noise sensitivity in this relation is still inconclusive. Noise sensitivity related effects might be part of a more generic vulnerability effect, which could be psychologically and/or physiologically based. Gender differences in terms of vulnerability for CVD effects should also be further studied. A further distinction between susceptible people, places and periods might be useful for future research. More attention for specific groups at risk is warranted, such as the mentally ill, shift-workers, people suffering from tinnitus. Also the distribution of noise over SES groups deserves more attention, as well as the accumulation of exposures (noise & air), the accumulation of residential and work related exposures and places with less opportunity for recovery from daily stressors (lack of restoration). It may also be fruitful to study differential effects of noise from a more contextual viewpoint and take life course and life phase related aspects into account. This includes looking at studies into the health effects of noise in groups based on e.g. social economic status, working situations and places as well as looking at specific susceptibility for noise during the life stages and an accumulation of risk during the life course. To further this field it is necessary in future studies to present and compare subgroup-specific exposure effect relations. Generic use of the term "vulnerable groups" should be avoided since the mechanisms are quite different and maybe more important: they vary in time, place and across contexts. Groups at risk or susceptible groups, periods or places would in most case be more appropriate terms to use.

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Dose-response relationships between hypertension and several night noise indices of aircraft noise exposure around the Kadena US airfield in Okinawa

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INTRODUCTION

There are a few evidences reported that cardiovascular effects of traffic noise are related to a kind of night noise index (Babisch 2011). Although WHO-EU released a night noise guideline in 2009 (WHO 2009) using L_{night} as the noise index, the causation between the health effects and noise exposure is explained based on indirect relationships among health effects, sleep disturbances and noise exposure. And the index L_{night} is employed as the night noise index in the guideline for mainly practical reasons. However, our study of awakening process based on the neuro-physiological model (Tagusari et al. 2009) suggests that evaluation of night noise exposure by means of L_{night} where sound power is averaged on power basis seems to be inappropriate because it is not sound power the brainstem integrates but awakening potential. Moreover, it would be more understandable if the frequency of sleep disturbances is more related with health effects than the integrated sound power is. This paper reports dose-response relationships between hypertension and noise indices based on the results of the Okinawa study conducted in 1995–1998 around the Kadena and the Futenma US airfields (Okinawa Prefectural Government 1999; Matsui et al. 2004, 2008). To find an appropriate noise index for the evaluation of the risk of hypertension, several noise indices were examined in the analysis. The average number of awakenings per year was applied as an index as well as the conventional noise indices such as L_{den}, L_{day}, L_{night} and the number of night noise events per year. The dose-response relationships were obtained around the Kadena and the Futenma airfields respectively to investigate the validity of the noise indices.

METHOD

Material

Systolic and diastolic blood pressures were obtained from the records of the health examination conducted by the local governments around the Kadena and the Futenma airfields in Okinawa, Japan (see Figure 1) in the fiscal years of 1994 and 1995. The examination covered the residents who were self-employed persons, part-time workers, house wives and unemployed persons, and contained the information about age, gender, weight, height and home address. Table 1 shows the valid sample size of the above examination in each municipality for different classes of L_{den} which is calculated on the basis of the measurement conducted by DFAA (Defence Facilities Administration Agency) in 1977.

Our previous papers (Matsui et al. 2004, 2008) employed the above L_{den} (see Figure 1) to determine dose-response relationships between hypertension and noise exposure. In this paper, the validity of the several noise indices were examined on the basis of the recent measurement conducted by the Okinawa Prefectural Government in 1997 and 1998.