Recent progress in the field of non-auditory health effects of noise – trends and research needs

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ABSTRACT

With the aim to identify recent research achievements, current trends in research, remaining gaps of knowledge and priority areas of future research in the field of non-auditory health effects of noise, recent research progress was reviewed. A search was performed in PubMed (search terms “noise AND health”), for peer reviewed journal articles, published between 1 January 2014 and 1 January 2017 in English. Resulting references were screened for relevance by title and abstract where needed in case of doubt. Inclusion criteria: Original research papers on health effects of environmental or occupational noise exposure. Studies on auditory health effects (hearing loss) and animal studies were excluded. The search resulted in over 3000 references. A total number of about 150 papers was included in the review, 18 papers addressed mental health effects, a majority focused on (a wide range of) physiological health effects. A wealth of new research on non-auditory health effects of noise has been published over the last 3 years. Current trends, knowledge gaps and priority future research areas will be discussed.

INTRODUCTION

ICBEN Team 3 focuses on the non-auditory effects of noise. This review provides an overview of recent research progress in this area, with a focus on recent trends in research, gaps in knowledge and challenges for future research. This review shows a giant leap in non-auditory health effects research has taken place over the last 3 years.

METHODS

We performed a systematic search in PubMed. As search terms “noise AND health” were entered, to identify peer reviewed journal articles, published between the 1st of January 2014 and the 1st of January 2017, in the English language. The resulting references were screened for relevance by title, and secondly by abstract, where needed in case of doubt. All articles on
non-auditory health effects of environmental noise or occupational noise exposure were included in the review. The references identified through this initial search, where subsequently complemented with missing papers identified through other pathways, including: authors' own archive, reference lists of identified papers, online suggestions of related papers, journal notifications of new publications in the field, and expert suggestions. Studies on auditory health effects (hearing loss), and animal studies were excluded.

RESULTS AND DISCUSSION

The PubMed search resulted in 3087 references, amongst which 134 papers on non-auditory health effects of environmental noise or occupational noise were identified. These were complemented with 10 papers identified otherwise. This resulted in 144 papers in total [1-144]. In addition, 6 papers presenting Health Impact Assessment calculations based on existing relationships were identified [145-150]. Thus, in total 150 publications on non-auditory health effects of noise were identified, published within the search period (1 Jan 2014- 1 Jan 2017). This high number illustrates the wealth of new research in the field of noise and non-auditory health effects that has been coming available in recent years. Prominent trends and key issues in non-auditory noise effects research are discussed below.

Recent trends in non-auditory health effects research

*Epidemiological studies*

In recent years, the number of large epidemiological studies coming available has been rapidly increasing. As compared to the last decades, within the last 3 years an impressive number of epidemiological studies on health effects of noise has been published. More than half of the total amount of studies (>75) identified in this review consists of epidemiological investigations.

*Reviews and meta-analyses*

The large number of epidemiological studies published on long term health effects of noise, underlines the growing knowledge base. New studies have increased insight in relationships confirmed. This trend is complemented with reviews of evidence and pooled analyses consolidating this knowledge. The number of recent reviews on noise and health is noteworthy, with about 30 reviews published recently within the search period [13, 16, 19, 23, 24, 28, 30, 31, 35, 53, 56, 58, 59, 60, 62, 82, 86, 89, 94, 105, 106, 115, 121, 124, 129, 130, 132, 138, 139]. These reviews included a number of meta-analyses, providing pooled risk estimates [19, 24, 56, 58, 60, 86, 124, 139]. The findings from these meta-analyses will be briefly described hereafter.

An updated meta-analysis on the association between road traffic noise and coronary heart disease, including 14 studies, presenting a significant pooled effect estimate with an RR of 1.08 (95% CI 1.04-1.13) per 10 dB increase in $L_{dn}$ [19]. In addition, a meta-analysis was published on transportation noise and ischemic heart disease, presenting a risk estimate in the same order of magnitude, with a pooled RR of 1.06 (95% CI: 1.03-1.09) [139]. Also, a meta-analysis was presented on cross sectional studies (published between 1980 and 2010) on transportation noise (different sources including road traffic and aircraft noise) and cardiovascular disease, presenting a positive but non-significant risk estimate [24]. In addition, a meta-analysis was published on ‘residential’ and occupational noise exposure and type 2
diabetes, presenting a positive and significant risk estimate for ‘residential noise’, but not for occupational noise [56]. The same authors published a meta-analysis on road traffic noise, aircraft noise and stroke, with a small positive pooled risk estimate for both road traffic noise and aircraft noise, which was significant for aircraft noise only [58]. Furthermore, they performed a meta-analysis on road traffic noise and children’s blood pressure, presenting weak, positive but non-significant pooled effect size estimates for SBP and DBP [60]. A meta-analysis was published on aircraft noise and hypertension, presenting an overall OR for hypertension in ‘residents with aircraft noise exposure’ of 1.63 (1.14-2.33) [86]. In addition, one meta-analysis focused on occupational noise exposure and cardiovascular effects [124]. This meta-analysis concluded that there was a strong association between occupational noise exposure and hypertension, and a weak association for other cardiovascular effects, but the evidence is still limited and the authors note that more longitudinal studies into the effects of occupational noise and cardiovascular effects are needed.

**Air pollution and noise: combined exposure**

A topic that has received increasing interest in recent years is combined exposure to noise and air pollution. A number of health endpoints, e.g. cardiovascular effects, have been associated to both noise and air pollution, while there is support from the scientific literature for a causal role of both exposures. During the last decade, it has become widely recognized that these exposures may confound (or interact with) each other.

Until recently, only a limited amount of studies was available into the long term effects of traffic related exposures, taking both noise and air pollution into account. Amongst the first studies mutually adjusting for road traffic noise and air pollution exposure, were the studies on road traffic noise and hypertension published in 2007 [151] and the study on published in 2009 [152]. Since then, the number of studies including both exposures has been increasing, with 9 studies identified in a first review on this topic, published in 2013 [153]. Since then, the increasing trend of studies coming available on this topic has continued. During the search period of this review an impressive amount of 43 new epidemiological research papers were published taking both exposures into account [7, 20, 21, 27, 32, 33, 37, 39, 42, 44, 45, 49, 50, 52, 55, 65, 69, 70, 73, 77-79, 85, 88, 96, 98, 99, 104, 108, 109, 112, 114, 116, 118, 119, 125-127, 133-136, 144]. In addition, 2 narrative reviews on the topic were published, in 2015 [129] and 2016 [106], respectively. The 2 recent reviews conclude that independent effects of environmental noise and air pollution (mainly in studies on cardiovascular health effects) have been shown [106, 129], while the review published in 2016 also points at recent research suggesting that these two exposures may also interact with each other.

**Study populations (size)**

The noise mapping requirements as prescribed by the Environmental Noise Directive has led to an increasingly wide availability of noise maps for urban areas, as well as to the increased availability of tools developed to perform noise calculations. This trend has led to a broader availability of noise exposure data, which, in combination with large health databases (e.g. cohorts and morbidity and mortality registration databases), has created new opportunities for environmental exposure-effect research. While until fairly recently, the number of large population studies into the health effects of long term noise exposure was still very limited, during the search period an impressive number of large studies have been performed, including over 30 studies with a study population size exceeding 10 000 subjects [1, 2, 4, 5, 7, 9, 10, 12, 27, 33, 37, 39, 43-45, 50, 52, 54, 73, 77, 85, 104, 108, 112, 118, 119, 122, 123, 125, 127, 136, 143, 144], of which at least 7 exceeded 100 000 persons [2, 10, 37, 39, 50, 77, 123]. Although, this includes studies from the same research groups, some of which based
their analysis on the same population database, with articles focusing e.g. on different endpoints. Larger studies can offer a benefit in terms of increased power, if not compromised by limitations in adjustment for confounding and quality (e.g. lower spatial resolution) of exposure assessment.

**Prospective studies**

The need for more longitudinal prospective studies has frequently been expressed. For studying the long term health effects of exposure, a prospective design is preferred above a cross-sectional design, since it has the strength of being capable to take into account the sequence in time, and thereby allows to answer the questions: “Did the exposure precede the health endpoint under study?” and “Are highly exposed persons at higher risk of developing the health effect of interest?”. If the answer to those questions is positive, there is more reason to assume such association may indeed be causal. Until recently, however, large prospective studies in this area of research were still extremely rare. Over the last few years, this is changing rapidly: During the search period over 10 prospective studies were published on non-auditory health effects of noise [2, 3, 8, 33, 39, 43, 63, 70, 104, 118, 119, 125, 136].

**Mental health effects**

The focus of research in this area has been on physical health effects: A majority of the identified papers addressed non-auditory physical health effects, while a minority of 17 papers addressed mental health [1-14, 22, 109, 131] (either exclusively, or in combination with other (physical) health endpoints).

Studies addressing mental health effects included in this review reported associations between noise annoyance and depression and anxiety prevalence [1], impaired mental health [5], and with SF-36 mental health score [6], with SF-12 mental health factors [109] and with depressive symptoms and suicidal ideation [12] in adults, and incident mental health problems in children [3]. While in the above mentioned study reported an association between noise annoyance and SF-36 mental health score, however, no significant association with modeled road traffic noise exposure ($L_{dn}$) was found [6], while a weak association with modeled road traffic noise exposure was found in another study, however with a non-clinically relevant magnitude of effect [9]. In a large prospective study ($N \approx 190,000$) road traffic noise during the night ($L_{night}$) was found associated with purchase of anxiolytic-hypnotic medication [2], while a smaller cross-sectional study ($N \approx 15,000$) found no association between road traffic noise ($L_{den}$) and increased use of psychotropic medication [4]. In addition, a prospective study reported an association between road traffic noise exposure and depressive symptoms [8]. In line with this, a large case-control study ($N \approx 650,000$) reported an association between road traffic noise and depression [10]. A large cross sectional study found an association between road traffic noise exposure and behavioral problems in children, particularly with hyperactivity/inattention symptoms [7].

**New and established health outcomes**

A relatively large number of studies addressed the relationship between noise exposure and hypertension [16, 18, 20, 21, 26, 51, 66, 69, 81, 86, 131, 142], long term effects on blood pressure [18, 32, 60, 69, 78, 98, 144], and transient blood pressure elevations [41, 42, 72, 87, 91, 99, 110, 140]. New or more rarely addressed endpoints related to blood pressure were studied as well: hypertension mortality [27], pregnancy induced hypertension (see below) [112], hypotension and hypotension medication use [96]. Cardiovascular morbidity and
mortality was further studies in a range of epidemiological studies [25, 27, 33, 39, 57, 65, 71, 74, 77-79, 92, 104, 111, 116, 122, 123, 125, 132, 135]. Several studies investigated effects of noise on endocrine [61, 75, 76, 101, 140, 141] and metabolic outcomes [17, 127].

An emerging topic in non-auditory effect research is a hypothesized effect of environmental noise exposure on (indicators of) weight gain and obesity, with several studies reporting significant associations [43-45, 54, 63, 108, 114], including two studies with a prospective design [43, 63]. Furthermore, associations with diabetes type II were studied [27, 83, 133].

Relatively new or more rarely studied outcomes included new studies on respiratory outcomes, including asthma prevalence [37], and daily respiratory mortality [134], rheumatoid arthritis [50], and carcinogenic outcomes [118, 119, 126].

Birth outcomes were studied (low birth weight, small for gestational age, head circumference etc.) [49, 52, 73, 85], with inconsistent findings. While an association was found for particulate matter and term low birth weight, results for noise exposure were inconclusive [49]. However, while air pollution exposure was assessed at address level, noise was estimated ‘in buffers of 50m and 250m’ around the address. Different spatial resolution of air pollution and noise exposure may explain differences in results. Another study, however, confirmed the association between air pollution (NO$_2$) and birth outcomes (head and abdominal circumference), while traffic noise did not seem to affect birth size [85]. A negative association was found for community noise and term birth weight, and was largely un-changed after air-pollution adjustment [73]. An association was found between road traffic noise exposure and pregnancy complications (pre-eclampsia and pregnancy induced hypertension) [112].

**Future research needs**

More large prospective studies, and studies with intervention design are needed to further refine exposure response relationships and strengthen evidence, respectively, with specific attention for ‘newer’ endpoints. Larger studies should not compromise on exposure assessment quality. Crude exposure assessment may lead to biased results. High quality exposure assessment is warranted, with specific attention for combined exposure studies, where air pollution and noise should be assessed with a same high quality level and spatial resolution to allow disentanglement of effects.

**REFERENCES**


