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Associations between road traffic noise exposure at home and school and ADHD in school-aged children: The TRAILS Study

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ABSTRACT

It has been hypothesized that environmental noise plays a role in the manifestation and severity of Attention Deficit/Hyperactivity Disorder (ADHD) symptoms, but evidence is limited. We investigated the cross-sectional associations between residential and school road traffic noise exposure and ADHD symptoms and diagnosis. The sample included n=1710 10-12 year old children from the Netherlands who participated in the TRAILS study. Children with diagnosed ADHD (n=229) originated from the TRAILS clinic-referred cohort. Children who screened positive for ADHD symptoms (n=341) in addition to a gender matched screen-negative sample (n=1140) came from the TRAILS population cohort. ADHD symptoms were measured using a DSM-IV based subscale from the Child Behavior Checklist. Road traffic noise (L_{den}) was estimated at the residence and school level, by model calculation. Analyses were adjusted for demographic and socioeconomic factors and known risk factors for ADHD. Risk ratios for ADHD symptoms and ADHD diagnoses, and regression coefficients for symptom severity were estimated separately and simultaneously for residential and school road traffic noise. Adjusted multinomial models with residential road traffic noise showed that residential noise was not associated with ADHD symptoms, but was associated with lower risks for ADHD diagnosis (RR= 0.93; 95% CI 0.89, 0.97). Similar associations were observed for models including school road traffic noise and models including both exposures. No clear exposure response relationship was observed for associations between residential or school noise and ADHD symptom severity. We found no evidence for a harmful association between road traffic

noise and ADHD. The associations between higher noise levels and lower risks for ADHD were observed only in referred cases with a confirmed ADHD diagnosis. The absence of an association with ADHD severity suggests that this is a chance finding.

Keywords: Road Traffic Noise, Attention Deficit/Hyperactivity Disorder, Adolescents
I-INCE Classification of Subject Number: 63

1. INTRODUCTION

Attention Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder with symptoms continuing into adulthood (1,2). ADHD is characterized by a significant impairment in the functioning of a child due to elevated inattention and distractibility on the one hand and excessive hyperactivity or impulsivity on the other. ADHD is among the most common disorders among children with a prevalence of 6-7% (3).

Although the exact causes of the disorder have not yet been identified, it is evident that both biological as well as environmental factors are accountable for the manifestation of the disorder (2). Studies have shown associations between environmental noise and ADHD symptoms. A large cohort study performed in 46,940 children from Denmark found that a 10 decibel increase in road traffic noise exposure from birth to age 7 was associated with a 9% increase in borderline and abnormal hyperactivity/inattention subscale scores (4). Similar conclusions were taken from a relatively small cross-sectional German study (n= 872) that reported that higher road traffic noise levels were associated with more hyperactivity/inattention symptoms (5). Road traffic noise at age 8 and during the last 5 years was associated to inattention at age 8 in a sample (n=1384) from Oslo, Norway (6). Most of the previous studies focused on residential road traffic noise exposure, but a cross-sectional study in Barcelona in children aged 7-11 years (n=2897) focused on traffic noise at schools, and found that noise exposure at the school was associated with ADHD symptoms (7).

Other previous studies focused on adverse effects of noise on children´s cognition. Particularly, tasks relying on sustained attention (e.g. reading skills, working memory) were found to deteriorate as a result of exposure to traffic noise (8–13), but more robust evidence is needed (14).

Environmental noise may play a role in the manifestation and severity of ADHD symptoms, but evidence is limited. Most of the previous research solely assessed ADHD symptoms and not clinical diagnosis. They further focused on residential road traffic noise alone, while children spend a large part of their day at school. To address these gaps, we investigated the associations between residential and school road traffic noise exposure (separately and simultaneously) and ADHD symptoms and diagnosis.

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2. METHODS

2.1 Sample

Participants were a subsample from the population (n=2230) and clinic-referred (n=543) cohorts of TRAILS (Tracking Adolescents' Individual Lives Survey). Details about this cohort and the recruitment of participants have been published previously (15,16). In brief, TRAILS is a prospective study of Dutch adolescents with bi- and triennial measurements since age 11 (16). Our analysis was cross-sectional and focused on data from the first measurement wave. Children in the population sample were recruited through schools in urban and rural areas in the North of the Netherlands. Children in the clinic-referred cohort had been referred to the Groningen University Child and Adolescent Psychiatric Outpatient Clinic at any point in their life (20.8% ≤5 years, 66.1% 6-9 years, 13.1% 10-12 years) for consultation or treatment. For the present study we sampled children with a lifetime diagnosis of ADHD and currently elevated ADHD symptoms (i.e., not in remission; n=244) at age 11 from the TRAILS clinical cohort. In the population cohort, we identified a subsample who screened positive for possible ADHD, and randomly drew a gender matched reference sample from those who screened negative (male-female ratio 2:1 in all subsamples; this ratio coincided for the diagnosed and screen-positive subsamples) (see Figure 1 and further description of this selection, as based on the ADHD measurement instruments, below). This sampling strategy allowed us to compare manifestations of ADHD symptoms in a clinical and population sample. The study was approved by the Dutch Central Committee on Research Involving Human Subjects (CCMO). The study was carried out in accordance to the Declaration of Helsinki and all measurements were carried out with their adequate understanding and written consent.

2.2 Attention Deficit/Hyperactivity Disorder

In the TRAILS clinical cohort, information on the presence or absence of ADHD was a assessed with the Diagnostic Interview Schedule for Children (DISC-IV parent version) (17). In addition, parental and teacher ratings were used from the DSM-based ADHD scale of the Child Behavior Checklist (CBCL) and a short version of the Teacher Rating Form (TRF) (18,19) to ensure the presence of current symptoms (as based on the 80^{th} percentile of scores on either parent or teacher scale in the population cohort). This subscale consists of 7 items (attention problems: fails to finish; can't concentrate, inattentive; hyperactive-impulsive problems: can't sit still; impulsive; talks too much; loud), which were averaged. The CBCL and TRF are questionnaires for assessing behavioural and emotional problems in the past 6 months in 4-18 year olds. The response format is 0=not true, 1=somewhat true, and 2=very true or often true. (18).

In the TRAILS population cohort, the diagnostic interview DISC was not administered. Therefore, we identified children who screened positive for possible ADHD, based on a score on the ADHD subscale of the CBCL or short version of the TRF above the 90^{th} percentile. Average symptom levels in the diagnosed ADHD group from the clinical sample were similar to those in the ADHD screen positive group from the population sample. From the population cohort, a gender matched sample (i.e. with the same male/female ratio as the diagnosed and screen positive groups) of n=1222 was selected and added to the final study sample. Finally, 121 individuals were excluded due to missing data on traffic noise exposure or covariates yielding a final sample of n=1710 (Figure 1; 229 confirmed children with ADHD and 341 who screened positive for ADHD symptoms from the clinical and population cohort, respectively).

2.3 Road traffic noise exposure

Road traffic noise was calculated at the residence and school level. Calculations were done at the most exposed facade of the building using the STAMINA (Standard Model Instrumentation for Noise Assessments) in accordance with requirements of the European Environmental Noise Directive (END). The noise model was based on 2011 data and included information on traffic intensity, speed, composition, type of road surface, building data and surface type. We used the EU standard noise metric L_{den}. L_{den} is the average 24 h sound level, with a 10 dB penalty added to the levels between 23.00 and 07.00 hours and a 5 dB penalty added to the levels between 19.00 and 23.00 hours to reflect people's extra sensitivity to noise during the night and the evening. Noise exposure was calculated at 4 metres above the ground of the dwelling facade of the exposed subject (20).

2.4 Covariates

The covariates were chosen a priori based on previous studies (4–7). Data on age, sex, the number of parents in the household, whether parents were foreign born, maternal smoking and alcohol use during pregnancy, problems during pregnancy and child delivery, mothers age at child birth, pregnancy duration (weeks), and birth weight, were obtained from the parent questionnaire. Parental education, parental job title, and parental income were obtained with questionnaires and combined into a z-score reflecting parental socioeconomic status (SES). Children’s use of psychostimulant medication was likewise reported by their parents. Lifetime parental psychopathology with respect to depression, anxiety, substance dependence, persistent antisocial behaviour, and psychosis was assessed with an interview. For each spectrum, each parent was assigned to one of the following categories: 0= (probably) never had an episode, 1= (probably) yes, or 2= yes and treatment and/or medication. Two z-scores were computed reflecting parental internalizing problems and parental externalizing problems (21).

2.4 Statistical analysis

Descriptive statistics were used to characterize the study population, and were calculated for the pooled sample and for those without ADHD, those with ADHD symptoms, and those with an ADHD diagnosis as described above. Equivalence tests were used to test for differences between groups. Risk ratios and regression coefficients for ADHD were estimated for residential L_{den} and school L_{den} as follows:

1. We estimated associations between residential and school road traffic noise (L_{den}) and ADHD with multinomial regression analyses. Participants were classified into three groups: no ADHD symptoms (reference group); ADHD symptoms in population cohort; and ADHD diagnosis in clinical cohort. Models were stepwise adjusted for: (1) age and sex; (2) parental SES, single parenthood, parents born outside the Netherlands; (3) maternal smoking during pregnancy, maternal alcohol use during pregnancy, problems during pregnancy or delivery; and (4, main model) parental internalizing and externalizing problems. Associations were estimated separately for residential and school road traffic noise, but also simultaneously including noise estimated for the residence and school.

2. Linear regression analyses were undertaken with ADHD symptom severity as outcome. This was done (i) in the total sample; (ii) in a sample with those with ADHD symptoms and ADHD diagnosis; and (iii) in only those with an ADHD diagnosis. We furthermore performed linear regression analyses with symptom severity scores for two ADHD subscales: attention and hyperactivity/impulsivity in these groups. In addition to analyses with continuous L_{den}, we also estimated associations with L_{den} categories <50 dBA; 50-60 dBA; and >60 dBA. These models were adjusted for the same set of covariates as specified above (main model).

Data were analyzed for participants from whom we had complete data (n=1710 for residential and n=1538 for school L_{den} analyses). Effect estimates are presented as risk ratios (RR; ADHD symptoms and ADHD diagnosis) or regression coefficients (β; symptom severity), with 95% confidence intervals (CI), per 1 dB(A) or categories of L_{den}. Associations were considered statistically significant if the 95% confidence intervals did not include one (RR) or zero (β). Analyses were performed using the statistical software package STATA version 14.2 (22).

3. RESULTS

Children who screened positive for ADHD symptoms from the population cohort had parents with lower SES, had mothers who were younger during childbirth, and had more often parents that smoked during pregnancy compared to children without ADHD from the population cohort and those with ADHD diagnosis from the clinical cohort. Children with an ADHD diagnosis from the clinical cohort had more often a parent that was born outside the Netherlands and had more often parents with a history of psychopathology compared to the other children. Average residential and school road traffic noise was lower for children with ADHD in the clinical cohort, compared to children from the population cohort (regardless of ADHD symptoms). Residential road traffic noise and school road traffic noise were not correlated (r=0.012), and neither were noise and parental SES (residential road traffic noise r=-0.003; school road traffic noise r=0.081).

3.1 Road traffic noise, ADHD symptoms and ADHD diagnosis

Multinomial regression analyses showed that higher residential road traffic noise levels were associated with lower risks for ADHD diagnosis, but not for ADHD symptoms. The association between noise and ADHD diagnosis remained statistically significant in the fully adjusted model (RR 0.929, 95% CI 0.893, 0.965. Analyses with school road traffic noise and ADHD also showed that higher noise levels were related to lower risks for ADHD diagnosis (adjusted RR 0.945, 95% CI 0.910, 0.981), but not with ADHD symptoms. Results did not change when associations between residential and school road traffic noise and ADHD were analysed simultaneously.

3.2 Road traffic noise and ADHD symptom severity

We observed no associations between residential road traffic noise and ADHD symptom severity in the pooled sample, in the sample with ADHD symptoms and diagnosis, nor in those with an ADHD diagnosis. Coefficients were generally close to zero and were not statistically significant. School road traffic noise >60 dBA (vs. <50 dBA) was associated with -0.113 (95% CI -0.209, -0.018) lower scores for ADHD symptom severity in the pooled sample, but no associations were observed for continuous L_{den} and in the subsamples.

Linear regression coefficients for associations between noise and symptom severity of attentional symptoms were close to zero and not statistically significant, except for school road traffic noise >60 dBA in the pooled sample. Children in this highest school noise category (vs. those in the <50 dBA category) had on average -0.135 (95% CI -0.247, -0.024) lower scores for attention symptom severity. Associations between noise and symptom severity of hyperactive/impulsive symptoms were also close to zero and not statistically significant, except for a small inverse association between residential road traffic noise and hyperactive/impulsive symptoms in the pooled sample (β -0.005, 95% CI -0.011, -0.000).

4. Discussion

In this cross-sectional study of 1710 children, we found no evidence for a harmful association between road traffic noise and ADHD. Higher noise levels at the residence and school were associated with a lower risk of a clinical ADHD diagnosis, but not with ADHD symptoms in the population cohort or with symptom severity. The results were consistent after adjustment for various known risk factors for ADHD and socioeconomic status and for different cut-offs of ADHD symptoms.

Our results differ from previous studies that did observe harmful associations between road traffic noise and ADHD symptoms (4–7). Average noise levels in these previous studies were generally higher than in our study, and these previous studies focused solely on ADHD symptoms and did not assess clinical diagnosis (4–7), potentially explaining the different findings. In line with the results in our study, road traffic noise annoyance (reported by the parent) was not associated with more hyperactivity symptoms in a German study of 1185 children (24). However, since that study used parental noise annoyance as a proxy for children's noise exposure, it is less comparable to our study.

Given the results of previous studies (4–7) and the absence of a plausible mechanism for a protective association between traffic noise and ADHD, we consider it unlikely that our results represent a true protective association between traffic noise and ADHD. This protective association was not observed in the population cohort and neither did we observe a clear association between noise and symptom severity. This suggests that the observed protective association might be a chance finding. The children with a clinical ADHD diagnosis are different than those who screened positive for ADHD symptoms in the population cohort. The group with an ADHD diagnosis was selected based on referral to an outpatient clinic, while the children who screened positive for enhanced ADHD symptom levels were selected from the general population and their problems were not necessarily severe enough to warrant a clinical diagnosis. Those with a clinical ADHD diagnosis might also reflect a group that has access to the healthcare system and selection bias might be present. The children with ADHD diagnoses also differed from children that screened positive for ADHD symptoms in terms of a higher parental socioeconomic status, a lower frequency of a foreign-born parent, and a higher frequency of complications during pregnancy or delivery. While inclusion of these covariates did not alter the results, other unmeasured factors different in the clinical cohort than in the population cohort might have lead to residual confounding. Failing to adjust for factors related to low noise levels and high ADHD diagnoses could be an explanation for the unexpected inverse association between noise and ADHD.

This study was based on a rich dataset that enabled us to adjust for potential confounders and perform a number of sensitivity analyses. Children spend a large part of their time at school, thus having road traffic noise data for both homes and schools was a major advantage. Limitations include that the period of cohort's measurements and the year of the noise model are 10 years apart, and may have lead to exposure misclassification. We had no data on air pollution exposure while this is highly correlated with traffic noise and is potentially a risk factor for ADHD symptoms (25–27), although not consistently (28). Although the TRAILS cohort is longitudinal, our analysis was cross-sectional and only used data from the first measurement wave. We therefore cannot determine the direction of the observed associations and future research should assess the longitudinal association between road traffic noise and ADHD. Lastly, in some cases sample size was low and those estimates should be interpreted with caution.

5. CONCLUSION

This cross-sectional study found no evidence for a harmful association between road traffic noise and ADHD. The associations between higher noise levels and lower risks for ADHD were observed only in referred cases with a confirmed ADHD diagnosis. The absence of an association with ADHD severity suggests that this is a chance finding. Longitudinal studies should focus on the association between traffic noise and ADHD in schools and at home.

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