BARN OCH TRAFIKRELATERADE LUFTFÖRÖRENINGAR

-En översyn av riskfaktorer associerade till astma och pip ljud

CHILDREN AND TRAFFIC RELATED AIR POLLUTION

-A review of risk factors associated with asthma and wheezing
SAMMANFATTNING

Titel: Barn och trafikrelaterade luftföroreningar - En översyn av riskfaktorer associerade till astma och pip ljud

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Sammanfattning

ABSTRACT

Title: Children and traffic related air pollution - A review of risk factors associated with asthma and wheezing

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Summary

INTRODUCTION: Traffic related air pollution is a global problem which causes mortality and morbidity mainly in developing countries and large cities where the problem is largest. Asthma is one of the diseases associated with traffic related air pollution and is globally the most common non-communicable disease among children, who are an especially vulnerable group since they are growing and developing. A global estimation by World Health Organization shows that about two billion children live in areas where air pollution exceeds the global guideline values. PURPOSE: The purpose is to identify risk factors associated with traffic related air pollution which may lead to asthma and wheezing among children. METHODS: A systematic literature review of 15 articles. RESULTS: Results from this study identified risk factors such as proximity to roads, pollutants and parental history of allergy. Furthermore, modifiers such as seasons, traffic volume and traffic density were identified. DISCUSSION: Traffic related air pollution is a big problem which can lead to several diseases on respiratory systems. It is a complex problem where risk factors and modifiers interact with each other where some of the risk factors cannot be addressed by individuals and that is why policymakers must act now.
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INTRODUCTION

Air pollution, which has traffic related air pollution as a part of it, counts for a large part of morbidity and mortality in developing countries and especially in cities (Moore, Gould & Keary, 2003). World globalization is resulting in increasingly more people moving into cities, which will increase the problems with traffic related air pollution (World Health Organization [WHO], 2005a). Numbers from WHO reveal that 54% of the global population year 2014 was living in urban areas and this number is expected to increase by 1.84% yearly between 2015 and 2020 according to WHO’s projection (WHO, 2017a). As a consequence of this 63.2% of the world population will be living in urban areas by the year 2020. World Health Organization further estimates that about 2 billion children are living in areas where air pollution exceeds the allowed international limits for air pollution (WHO, 2017a & Unicef, 2016), where 300 million of those children live in areas where the air pollution is six times over the allowed international limits regarding air pollution (Unicef, 2016). Being exposed to traffic related air pollution has several adverse health effects such as increased mortality, increased non-allergic respiratory system diseases, increased allergic diseases like asthma, cardiovascular disease, and cancer (WHO, 2005a). Children are an at-risk group because they are still developing and growing and therefore are more susceptible to traffic related air pollution and other sources like bacteria (Unicef, 2016). Therefore, it is of importance to identify risk factors associated with traffic related air pollution which may lead to asthma and wheezing to raise awareness of the problem, which hopefully will result in action being taken by politicians and policymakers to give the children prerequisites for a healthy upbringing, to ensure that they get the best opportunities to live their lives free from disease and illness, which ultimately can lead to a good quality of life for them.

BACKGROUND

Traffic related air pollution

Traffic related air pollution generated by motor vehicles is a major source of pollutants which contain particles and gases that are known to increase the risk of developing asthma and wheezing among children (Brunst et al., 2015). Furthermore, the development of asthma
exacerbations is significantly associated with traffic related air pollution for children who are suffering from recurring wheezing or asthma (Esposito et al., 2014). Although emissions from motor vehicles has decreased because of technical improvements in the past decade the pollutants associated with it remains a factor for children developing asthma and wheezing (Brunst et al., 2015 & WHO, 2005a). One major reason for this is traffic jams in urban areas, where traffic during rush hours contribute to elevated levels of emissions from motor vehicles. Furthermore, houses and schools in near proximity of roads are identified as areas where air pollution is higher than in other areas, and as a consequence the people living in those areas are exposed to increased levels of traffic related air pollution compared to other areas and thus increasing the risk of morbidity and mortality from traffic related air pollutants (Rice et al., 2015 & WHO, 2005a).

The pollutants

Traffic related air pollutants consist of several components such as PM$_{2.5}$, PM$_{10}$, NO$_X$, NO$_2$ and CO which all are considered to have adverse effects on people’s health if exposed to them (WHO, 2005 & Unicef, 2016). There are other possible sources for these pollutants such as industries which can do the work to plot the health effects of the pollutants more difficult (Mortimer, Neas, Dockery, Redline & Tager 2002). Geographically traffic related air pollution is more severe in socioeconomic weaker countries and larger cities, see figure 1 (WHO, 2005a & WHO, 2018a).

Figure 1.
World Health Organization has global guideline values for these traffic related air pollutants and if exceeded, the pollutants can have adverse effects on people’s health. The guideline values for fine particulate matter PM$_{2.5}$, which originates from motor vehicle generated fossil fuels, industrial production, power plants and from natural sources and are the size of 1/30 of a human hair, have guideline values of 10μg/m$^3$ annual mean and 25 μg/m$^3$ in a 24-hour mean (Unicef, 2016 & WHO, 2018a). These PM$_{2.5}$ particles can enter deep in the lungs and in the blood (Unicef, 2016), which can cause heart diseases and cardiovascular problems and has been reported to be an increased risk for cardiovascular health (Chen et al., 2018). Elevated levels of PM$_{2.5}$ has been significantly associated with increased hospitalization rates for asthma among children in Hong Kong and in comparison, with the older population the relative risk of hospitalization for children 14 years and younger was higher for each 10 mg/m$^3$ increase in NO$_2$, PM$_{10}$ and PM$_{2.5}$ (Ko et al., 2007a). World Health Organization’s guideline values for the coarse particulate matter PM$_{10}$, which is 1/7 in diameter of a human hair and can block and inflame nasal and bronchial passages in humans (Unicef, 2016) have guideline values of 20 μg/m$^3$ annual mean and 50 μg/m$^3$ in a 24-hour mean (WHO, 2018a). This pollutant is known to cause problems for the respiratory functions which may lead to illness or even death (Unicef, 2016).

Nitrogen oxide NOx and nitrogen dioxide, NO$_2$ originate from fossil emissions, which occur near roads, industries and indoors from gas ovens used in cooking (Unicef, 2016). The characteristic for NO$_X$ is that it can cause pneumonia, asthma, bronchial symptoms, and impaired lung function (Unicef, 2016), whereas long term NO$_2$ exposure is known to cause bronchitis in asthmatic children and can besides that be a cause for reduced lung function (WHO, 2005a). World Health Organization’s guideline values for NO$_2$ is 40 μg/m$^3$ annual mean and 200 μg/m$^3$ 1-hour mean (WHO, 2018a).

Carbon monoxide, CO is an odorless gas which stems from mainly motor vehicles, and the associated symptoms of carbon monoxide are headache, vision impairment, reduced cognitive
abilities and reduced ability to carry out complex tasks (Unicef, 2016). Furthermore, studies have found associations between childhood asthma and exposure to carbon monoxide among schoolchildren aged 6 to 15 years. (Hwang, Lee, Lin, Jaakkola & Guo, 2005). Previous studies and reports show that all of these traffic related air pollutants are known to be modified by seasonal changes, where the cooler weather increases the emission rates from motor vehicles (Ko et al., 2007a & Unicef, 2016), which subsequently can make the problems worse.

**Children and asthma**

Asthma is a chronic disease which is characterized by symptoms such as heavy breathing or tiredness, when conducting physical activity and wheezing or hissing sounds when breathing (1177 vårdguiden, 2018). Currently, asthma is the globally leading non-communicable disease among children and WHO estimates that 235 million people suffer from asthma. Furthermore, asthma can be triggered by exposure to particles such as airborne substances, pollen, dust mites, pet dander and traffic related air pollution. Other possible triggers include cold air and strong emotions and stress to name a few. Some of the known risk factors which can increase chances of developing asthma include, exposure to exhaust fumes and having a parent with asthma. (1177 vårdguiden, 2018 & WHO, 2017b). Consequences of asthma and wheezing among children are that they might have difficulties being active and participating in physical activities because of loss of breath and tiredness which are typical triggers for asthma. These problems can be treated with various medicines, and with the right treatment the children can live and function without any obstacles (1177 vårdguiden, 2018).

**Health effects and consequences of traffic related air pollution**

Several studies have reported that traffic related air pollution have adverse effects on health (Brunst et al., 2016; Chen et al., 2018; Esposito et al., 2014; Ko et al., 2007a; Ko et al., 2007b; Mortimer et al., 2002 & Nishimura et al., 2013). Children exposed to traffic related air pollution can be subject to reduced lung functionality, which can result in wheezing and later development of asthma (Baroni-Adesi et al., 2015 & Brunst et al., 2015). Further evidence for the adverse effects of traffic related air pollution is shown by Nishimura et al. (2013), who found causal associations between the pollutants and childhood asthma, the study concluded that exposure to traffic related air pollution during the three first years of living was associated
with developing asthma, where children and elderly people were considered belonging to the most vulnerable groups. According to research by Asher et al. (2006) there is an increase of asthma prevalence globally in children. There are several reasons for that, where one factor which is mentioned is exposure to traffic related air pollution (Moore et al., 2003). Consequences of developing asthma in childhood is associated with a lower quality of life for the children because of the hospital visits associated with asthma problems (Ko et al., 2007a). Other consequences associated with traffic related air pollution is increased mortality, which WHO estimates to be 7 million deaths every year, and more than 90% of these mortalities occur in low- and middle-income countries (WHO, 2018a).

**Problem statement**

Traffic related air pollution is increasing in urban areas because of increasingly more people moving into cities resulting in more traffic. The effect of this is that more people are exposed to traffic related air pollution, which is associated with increased morbidity and mortality. Children are a vulnerable group because they are still developing and the fact that many of the children in this world lives in areas where air pollutants exceed international guideline levels. This literature study aims to raise the knowledge of risk factors associated with traffic related air pollution, which can cause asthma and wheezing in children for decision makers to aid them in creating new policies that can help reduce the risks of exposure to traffic related air pollution.

**Purpose**

The purpose of this study is to identify risk factors associated with traffic related air pollution which may lead to asthma and wheezing among children.
METHODS

This study was conducted as a systematic literature review within the defined research area. A systematic literature review indicates that the research process is scientific, transparent and can be replicated (Bryman, 2014). There are a few reasons why a systematic literature review is a relevant method, and the first reason is because a systematic literature review provides a large pool of knowledge of available studies within the field of research. The second reason is because potential bias better can be avoided. (Bryman, 2014). This study has followed the 7-step recommendations written by Bryman (2014), on how to perform a systematic review. This study has therefore been conducted in a structured and systematic way, which makes it replicable.

Data collection

For this literature review two of the following databases were used, PubMed and WorldCat Discovery. PubMed is a medical database which consists of over 26 million citations in the medical area and was the main source of scientific articles included in this systematic literature review. WorldCat Discovery was the secondary database, which was used to retrieve articles that were not freely available in PubMed. For the selection of the included articles relevant search terms were gathered from articles retrieved from the initial background search for this study. Furthermore, abstracts were read to identify potential articles for selection, which was followed by a deeper reading of selected articles to acquire an understanding if they held the information needed to answer the study purpose and thus be included in the final selection. The selected articles were reviewed using the STROBE guidelines for observational studies (Strobe-statement.org, 2017) to identify if the articles were following the guidelines for good research. Using this procedure 15 articles were chosen for this systematic literature review with the help of the chosen inclusion and exclusion criteria. The decision to not include Boolean operators and truncation in the search terms was because it was thought to not be needed in the PubMed database. Furthermore, the choice of not using synonyms for search terms such as wheezing was to limit the results of the article search to only include wheezing and thus eliminating unnecessary results with other respiratory sounds that could appear in the search results. Since PubMed does not have an option to verify that articles are peer reviewed the process to ensure that selected articles were peer reviewed was conducted as follows, each of the selected articles
publishing journal was searched to ensure that it clearly stated the articles were peer reviewed. Furthermore, Ulrichsweb database was used to validate that the selected articles were peer reviewed in case the journals did not clearly state this.

**Inclusion criteria**

- Articles in English language
- Study population 18 years or younger
- Peer reviewed

**Exclusion criteria**

- Article older than 5 years
- Review articles
- Meta analyses
- Missing ethical statement

**Table 1. Search results**

<table>
<thead>
<tr>
<th>Date</th>
<th>Database</th>
<th>Search terms</th>
<th>Hits</th>
<th>Abstracts read</th>
<th>Chosen articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-10-31</td>
<td>PubMed</td>
<td>Air pollution, children, asthma, wheezing, traffic, epidemiology, environmental</td>
<td>11</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>2017-11-07</td>
<td>PubMed</td>
<td>Air pollution, children, asthma, wheezing, traffic</td>
<td>17</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2017-11-28</td>
<td>PubMed</td>
<td>Air pollution, children, asthma, traffic, epidemiology, environmental</td>
<td>70</td>
<td>30</td>
<td>4</td>
</tr>
</tbody>
</table>
Analysis

The method used for compiling the data was a thematic analysis. In practice by using this kind of method, it is possible to distinguish different themes in a text, which helps make the general content becoming clear (Bryman, 2014). In this study the chosen articles have been read multiple times. The initial purpose was to get a general understanding of the content of the articles and continuing by identifying similarities and differences which were written down on paper to acquire a better overview of the findings. The analysis was an ongoing process where the four themes pollutants, risk factors and modifying factors, sociodemographic and socioeconomic factors, and correlations to other diseases and symptoms were identified to answer the purpose of the study. These themes were marked with different colors to better maintain track of the different themes during the analysis process. This analysis method made the process of identifying themes manageable.

Ethical considerations

For this systematic literature review the Swedish research council’s guidelines (Vetenskapsrådet, 2017) for good research were used to ensure all selected articles complied with the guidelines. It is important that research is conducted in a trustworthy manner and that no people got hurt during the research. This systematic literature review includes children as
the study population and thus it is extra important to ensure that the selected articles were ethically approved. For research to be ethically correct it needs to fulfill four criteria which are information requirements, compliance requirements, confidentiality requirements and usage requirements. Therefore, the study population must be given full information always and guaranteed full confidentiality, and finally the study population additionally must give their own consent for participation.

Research ethics

All the chosen articles have as stated in the inclusion criteria been published in scientific journals and are peer reviewed, which means that ethical approval is likely to have been done for the selected articles. The population in this study consists of children aged 0 to 18 years, which is considered a vulnerable group. Consequently, this is why it was of utmost importance to make sure that all included articles complied with ethical guidelines. In this study all included articles have been ethically approved. The methods used for this systematic literature review are transparent and the process how it was conducted is documented in this study, where the steps taken are explained which makes this study replicable. As the Swedish research council’s guidelines explained it is important to report the process and results accurately and openly to be considered an ethically correctly conducted study (Vetenskapsrådet, 2017).
RESULTS

The results are based on the 15 analyzed and STROBE quality assessed articles from studies conducted in 12 countries. The studies included are presented in a table below where the main characteristics of the studies included are presented. The majority of the studies in this literature review confirm the findings and knowledge from earlier studies that have shown associations with traffic related air pollution and respiratory health.

Table 2. Compilation of analyzed articles included in the literature review.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title, Country, Publication year</th>
<th>Purpose</th>
<th>Study design and methods</th>
<th>Study population</th>
<th>Main findings</th>
<th>Ethics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brokamp, C., LeMasters, G. K. &amp; Ryan, P. H.</td>
<td>Residential mobility impacts exposure assessment and community socioeconomic characteristics in longitudinal epidemiology studies. USA, Year 2016.</td>
<td>To find out if residential mobility during early childhood will lead to significant misclassification bias for both the estimated exposure levels and the association with asthma diagnosis at age seven.</td>
<td>Cohort study, n=762 children 0 to 7 years of age.</td>
<td>Moving to a new house during childhood is associated with less exposure to TRAP.</td>
<td>Approved by the University of Cincinnati institutional review board. Informed consent obtained.</td>
<td></td>
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<tr>
<td>Cakmak, S., Hebbern, C., Cakmak, J. D. &amp; Vanos, J.</td>
<td>The modifying effect of socioeconomic status on the relationship between traffic, air pollution and respiratory health in elementary schoolchildren. Canada, Year 2015.</td>
<td>To test the hypothesis that indicators of socioeconomic status modify the respiratory health effects of gaseous and particulate pollution. Also, the effect of roadway or traffic density on children’s respiratory health.</td>
<td>Cross sectional, Questionnaire Results presented with odds ratios based on interquartile range.</td>
<td>n=2 328 children 9–11 years of age.</td>
<td>Pollutants were significantly associated with respiratory symptoms across all incomes and education levels.</td>
<td>Approved by the Research Ethics committee of Health Canada.</td>
</tr>
<tr>
<td>Authors</td>
<td>Title</td>
<td>Methodology</td>
<td>Study Details</td>
<td>Approval Details</td>
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<tr>
<td>Delfino, R. J., Wu, J., Tjoa, T., Gullessierian, S. K., Nickerson, B. &amp; Gillen, D. L.</td>
<td>Asthma Morbidity and Ambient Air Pollution – Effect Modification by Residential Traffic-Related Air Pollution</td>
<td>USA, Year 2014.</td>
<td>To study the relationship between daily ambient air pollution and daily hospital morbidity for asthma in individual children will be enhanced by higher chronic exposure to TRAP near the subject’s homes.</td>
<td>Approved by the Institutional Review Boards of the Children’s Hospital of Orange County and the University of California Irvine.</td>
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<tr>
<td>Hasunuma, H., Sato, T., Iwata, T., Kohno, Y., Nitta, H., Odajima, H., … Shima, M.</td>
<td>Association between traffic-related air pollution and asthma in preschool children in a national.</td>
<td>Nested case control study with survey and interview. Results presented with odds</td>
<td>Baseline n=63266 at 1.5 years of age. Follow up</td>
<td>Approved by the ethics committee of the Ministry of the Environment Government of Japan. Consent</td>
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<tr>
<td>Study Title</td>
<td>Authors</td>
<td>Year</td>
<td>Study Objective</td>
<td>Study Design</td>
<td>Sample Size</td>
<td>Key Findings</td>
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<tr>
<td>Japanese nested case-control study</td>
<td>Jung, D. Y., Leem, J. H., Kim, C. H., Kim, J. H., Hwang, S. S., Lee, J. Y., …Kwon, H. J.</td>
<td>2015</td>
<td>To evaluate the relationship of living near main roads to allergic disease, airway hyperresponsiveness, allergic sensitization, and lung function in Korean children.</td>
<td>Cross-sectional study with the use of questionnaire surveys. Results shown as prevalence ratios (adjusted).</td>
<td></td>
<td>Both diagnosed asthma and lifetime wheezing within roads 200m from home were significantly associated with increased prevalence.</td>
</tr>
<tr>
<td>Mentz, G., Robins, T. G., Batterman, S. &amp; Naidoo, R. N.</td>
<td>Acute respiratory symptoms associated with short term fluctuations in ambient air pollutants among schoolchildren in Durban, South Africa. Year 2017.</td>
<td>To investigate and compare associations between daily respiratory symptoms and daily variability in ambient pollutants exposures.</td>
<td>Cross sectional study with interviews. Results reported with odds ratios.</td>
<td>Location was significantly associated with increased wheezing. Schools in the south showed higher measured pollution compared to the south.</td>
<td>Approved by the University of KwaZulu-Natal’s Biomedical Research Ethics committee and the University of Michigan’s Institutional Review Board. Consent given by guardians.</td>
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<tr>
<td>Newman, C., Ryan, P. H., Huang, B., Beck, A. F., Sauer, H. S. &amp; Kahn, R. S.</td>
<td>Traffic-Related Air Pollution and Asthma Hospital Readmission in Children: a Longitudinal Cohort Study. USA, Year 2014.</td>
<td>To assess the association between TRAP exposure and hospital readmission within 12 months</td>
<td>Prospective cohort study, results presented as odds ratios</td>
<td>White children exposed to Trap higher odds of asthma readmission than white with less exposure. African American children significantly more hospital admission (lower household income).</td>
<td>Approved by the CCHMC Institutional Review Board.</td>
<td></td>
</tr>
<tr>
<td>Norbäck, D., Lu, C., Wang, J., Zhang, Y., Li, B., Zhao, Z., …Deng, Q.</td>
<td>Asthma and rhinitis among Chinese children – Indoor and outdoor air pollution and indicators of socioeconomic status. China, Year 2018.</td>
<td>To study associations between diagnosed asthma, diagnosed rhinitis and current respiratory symptoms among pre-school children across China + selected indoor and outdoor exposure of SES.</td>
<td>Retrospective cohort study done with a questionnaire. Results presented with odds ratios.</td>
<td>Living near traffic was significantly associated with doctor diagnosed asthma and wheezing among children aged 3 to 6 years.</td>
<td>Study approved by the Medical Research Ethics committee of School of Public Health, Fudan University, Shanghai. Consent received from parents and participants.</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Authors</td>
<td>Study Objective</td>
<td>Study Design</td>
<td>Sample Size</td>
<td>Findings</td>
<td>Ethical Approval</td>
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<tr>
<td>Porebski, G., Wozniak, M. &amp; Czarnobilska, E.</td>
<td>Residential proximity to major roadways is associated with increased prevalence of allergic respiratory symptoms in children. Poland, year 2014.</td>
<td>To study the influence of the distance on prevalence of allergic respiratory symptoms.</td>
<td>Crossectional study with the use of questionnaire. Results showed with percentage comparisons and odds ratios.</td>
<td>n=4081 children aged 7 and 16 years</td>
<td>Shorter distance to roads showed increased rates of asthma and wheezing.</td>
<td>The study was approved by the Bioethics Committee of the Jagiellonian University.</td>
</tr>
<tr>
<td>Rancière, F., Bougas, N., Viola, M. &amp; Momas, I.</td>
<td>Early Exposure to Traffic-Related Air Pollution, Respiratory Symptoms at 4 years of Age, and Potential Effect Modification by Parental Allergy, Stressful Family Events, and Sex: A Prospective Follow-up Study of the PARIS Birth Cohort. France, Year 2017.</td>
<td>(a) to investigate the association between TRAP exposure in early life and the history of respiratory symptoms and asthma during the preschool years, and (b) to explore whether certain groups of preschool children are more prone to develop respiratory symptoms and asthma in relation to TRAP exposure, focusing on parental allergy, stressful family events, and sex.</td>
<td>Prospective cohort follow up study. Interviews and questionnaire. Results presented with odds ratios.</td>
<td>n=2015 Children from 0 to 4 years</td>
<td>TRAP showed significant association with increased OR for asthma. Children from High SES families were more exposed to TRAP.</td>
<td>Approved by the French Ethics Committee. Written consent obtained from parents.</td>
</tr>
<tr>
<td>Yi, S. J., Shon, C., Min, K. D., Kim, H. C., Leem, J. H., Kwon, H. J., …Kim., S. Y.</td>
<td>Association between exposure to Traffic-Related Air Pollution and Prevalence of Allergic Disease in Children, Seoul, Korea. South Korea, Year 2017.</td>
<td>Assess association between exposure to TRAP and prevalence of allergic diseases.</td>
<td>Cross sectional study with the use of questionnaire. Results presented with odds ratios.</td>
<td>n=14 765 children aged between 1 and 12 years of age</td>
<td>Slightly more asthma prevalence for low income families and proximity to roads but nothing significant, Road density does not increase asthma prevalence.</td>
<td>Ethical approval given by the institutional review board.</td>
</tr>
</tbody>
</table>
Pollutants

The pollutants in traffic air pollution are associated with adverse health effects for the children and adolescents exposed to traffic air pollution particles such as PM$_{2.5}$, PM$_{10}$, NOx, CO, NO, NO$_2$ and O$_3$, which have been linked with negative respiratory health effects such as asthma, wheezing, allergic rhinitis, and eczema in majority of the studies (Cakmak et al., 2016; Delfino et al., 2014; Eenhuizen, 2013; Hasunuma et al., 2015; Jung et al., 2015; Kim et al., 2015; Mentz et al., 2017; Newman et al., 2014; Norbäck et al., 2018; Rancière et al., 2017 & Yi et al., 2017). The children and adolescents between 0 to 18 years of age, who were exposed to these pollutants during the cool season were in many cases associated with higher asthma related hospital morbidity, where the changes in hospital encounters could be as high as 29% (Delfino et al., 2014 & Newman et al., 2014). Furthermore, the distribution of ambient air pollution and traffic-related air pollution effects are higher in the cool season where traffic related air pollution emissions from motor vehicles are higher compared to warmer seasons or temperatures. The findings show that seasonal effects vary between different pollutants, where variations in the mean emission values for some of the pollutants such as NOx, PM$_{10}$, SO$_2$, PM$_{2.5}$ and NO, which are associated with asthma, rhinitis and wheezing could range between 23.4 ppb in the warm season for NOx to 63.3 ppb in the cool season. The variations for the pollutant PM$_{10}$ ranged from a mean of 81 µg/m$^3$ in the cool season to 137 µg/m$^3$ in the warm season and for SO$_2$ ranged from 91 µg/m$^3$ during the cool season to 36 µg/m$^3$ in the warmer season, whereas seasonal means during 24-hour for PM$_{2.5}$ were 16.0 µg/m$^3$ in warm season and 19.0 µg/m$^3$ during the cool season (Delfino et al., 2014; Mentz et al., 2017 & Norbäck et al., 2018). These temperatures and seasonal changes affect the volume of exposure to traffic related air pollution and even though the majority of the pollutants affect children’s health negatively and increased hospitalization there were pollutants that did not show any significant effects on some of the associated health effects for children (Hansell et al., 2014; Hasunuma et al., 2015 & Jung et al., 2015).

Risk factors and modifying factors

Most of the studies showed that there are risk factors and modifying factors which can enhance the effects of exposure for traffic related air pollution, such as proximity of road and duration of exposure, which can be classed as risk factors while traffic volume and seasonal changes are
modifiers for the pollutants (Brokamp et al., 2016; Cakmak et al., 2016; Delfino et al., 2014; Eenhuizen et al., 2013; Hansell et al., 2014; Hasunuma et al., 2015; Jung et al., 2015; Kim et al., 2015; Mentz et al., 2017; Newman et al., 2014; Norbäck et al., 2018; Porebski et al., 2014 & Yi et al., 2017). The distance between roads and traffic density interplay with each other and thus modify the effects of traffic related air pollution, and children living in houses or attending the school’s closer to roads are therefore exposed to increased amounts of pollutants which affects the prevalence and incidence of asthma related allergy and respiratory health. (Cakmak et al., 2016). Distance to roads is a risk factor, where living or attending the school’s which are closer than 500 meters result in greater levels of traffic related air pollution, where some of these traffic air pollutants are associated with increased odds and risk of developing asthma, asthma related allergy and other adverse respiratory health diseases, see figure 2 (Jung et al., 2015; Porebski et al., 2014 & Yi et al., 2017) Consequently it is common that children living in areas closer than 500 meters of roads to be experiencing existing asthma and respiratory health morbidity (Jung et al., 2015 & Yi et al., 2017).

Table 3. Prevalence ratios for health effects compared to distance, length, and proportion of roads.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Lifetime wheezing (+)</th>
<th>Past year wheezing (+)</th>
<th>Lifetime diagnosed asthma (+)</th>
<th>Past year asthma treatment (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>PR* 95% CIs</td>
<td>%</td>
<td>PR* 95% CIs</td>
</tr>
<tr>
<td>Distance from main road (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>225+</td>
<td>1,800</td>
<td>22.6 1.00</td>
<td>13.3 1.00</td>
<td>10.4 1.00</td>
<td>4.6 1.00</td>
</tr>
<tr>
<td>180-225</td>
<td>399</td>
<td>24.1 1.09</td>
<td>12.3 1.02</td>
<td>11.3 0.81-1.59</td>
<td>4.8 1.12</td>
</tr>
<tr>
<td>75-150</td>
<td>1,263</td>
<td>23.4 1.04</td>
<td>10.2 0.82</td>
<td>11.9 1.23 0.81-1.56</td>
<td>3.9 1.00</td>
</tr>
<tr>
<td>&lt;75</td>
<td>741</td>
<td>27.1 1.17</td>
<td>14.2 1.16</td>
<td>11.2 1.11 0.84-1.46</td>
<td>4.5 1.08</td>
</tr>
<tr>
<td>Proportion of main road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1,934</td>
<td>22.6 1.00</td>
<td>13.1 1.00</td>
<td>10.5 1.00</td>
<td>4.7 1.00</td>
</tr>
<tr>
<td>0.1-1.94</td>
<td>751</td>
<td>23.8 0.99</td>
<td>11.1 0.82</td>
<td>10.3 0.96 0.73-1.36</td>
<td>3.2 0.79</td>
</tr>
<tr>
<td>1.94-3.58</td>
<td>759</td>
<td>25.0 1.14</td>
<td>12.6 1.12</td>
<td>12.1 1.29 1.00-1.67</td>
<td>4.7 1.08</td>
</tr>
<tr>
<td>3.58+</td>
<td>759</td>
<td>25.6 1.14</td>
<td>11.7 0.87</td>
<td>12.4 1.32 1.00-1.74</td>
<td>4.5 1.10</td>
</tr>
</tbody>
</table>

Although overall traffic related air pollution and proximity to roads show an increased risk or odds for asthma related symptoms and development of asthma there are some contradicting findings (Hasunuma et al., 2015; Lindgren et al., 2013 & Yi et al., 2017). Exposure to traffic related air pollution is modified by the duration of the exposure and as a result long-term exposure is associated with increased levels of pollutants and interrupter resistance from traffic related pollution (Eenhuizen et al., 2013), and furthermore with increased hospital readmission and several asthmatic and allergic outcomes (Jung et al., 2015 & Newman et al., 2014), whereas short term exposure to traffic related air pollution during the cool and warm season was associated with several asthmatic symptoms and increased exposure to pollutants (Delfino et al., 2014).

**Sociodemographic and socioeconomic factors**

Socioeconomic factors revealed that both income and education affect children’s health in a negative way, where lower income and education in many cases is associated with health issues such as chest congestion, asthma, asthmatic symptoms, wheeze and chest illness and higher levels of hospitalization (Cakmak et al., 2016; Newman et al., 2014 & Norbäck et al., 2018). Exposure to traffic related pollutants showed that children from higher income families can be exposed to higher levels of PM$_{10}$ and SO$_2$ or equal levels of exposure to other pollutants across all other income groups (Cakmak et al., 2016 & Norbäck et al., 2018), whereas moving to a new location is associated with more greenspace and less exposure for traffic related air pollution (Brokamp, LeMasters & Ryan, 2016). The morbidity of asthma and asthmatic symptoms varies with children from different income and parental education groups, where associations are found between asthma and asthmatic symptoms in both low and high-income and high-education families where a majority of the associations are higher in lower income and education levels (Cakmak et al., 2016; Norbäck et al., 2018 & Rancière, Bougas, Viola & Momas, 2017). Overall findings show that children from lower socioeconomic families have a higher risk of respiratory morbidity (Cakmak et al., 2016 & Yi et al., 2017). Differences between sociodemographic factors like sex was found where males proved to be positively associated with wheezing, whereas girls were not (Norbäck et al., 2018 & Rancière et al., 2017). Furthermore, parental history of allergy was identified as a risk factor for children to develop asthma if they were exposed to traffic related air pollution (Rancière et al., 2017).
**Correlation to other symptoms**

Allergic and respiratory symptoms other than asthma and wheezing are additionally associated with exposure to traffic related air pollution, such as atopic dermatitis (eczema), allergic rhinitis, airway hyperresponsiveness, allergic sensitization, cough, shortness of breath and chest tightness (Hansell et al., 2014; Jung et al., 2015; Kim et al., 2016; Mentz et al., 2017 & Yi et al., 2017). Some of the health effects of traffic air pollutions are modified by distance to roads and specific pollutants where allergic rhinitis, allergic sensitization, and airway hyperresponsiveness showed significant associations when living closer than 75 meters to roads, whereas allergic rhinitis is positively associated with exposure to both black carbon and PM$_{10}$ in a traffic pollution area (Delfino et al., 2014; Hansell et al., 2014; Jung et al., 2015 & Kim et al., 2016). The symptoms follow similar patterns which were found for asthma and wheezing, where risks and odds increase with higher traffic density and volume as with home address and school’s proximity to major roadways (Porebski et al., 2014; Hansell et al., 2014 & Kim et al., 2015). There are a few reports that disagree with these findings where no, or weak associations were found (Hasunuma et al., 2015; Lindgren et al., 2013 & Yi et al., 2017).

**Summary of results**

Results conclude that traffic related air pollutants have negative effects on children’s health and that these pollutants can vary in strength depending on season. Furthermore, this study identified modifiers such as seasons, traffic volume and traffic density which can enhance the effects of traffic pollution, and consequently result in higher morbidity. Identified risk factors were proximity to roads, parental history of allergy and duration of exposure, which interplays with the modifiers and affects children’s health. There were evidence that socioeconomic and sociodemographic factors such as income, education and sex influence exposure and morbidity among children. Besides these findings, there was evidence on traffic related air pollution to be a cause for more symptoms such as eczema, allergic rhinitis, and chest tightness among others.
DISCUSSION

The purpose of this study was to identify risk factors associated with traffic related air pollution which may lead to asthma and wheezing. The results from this study show that there are several risk factors associated with traffic related air pollution and different health outcomes with a varying degree of strength. The adverse health effects associated with traffic related air pollution and the risk factors are consistent with the majority of the articles. Some results from articles demonstrated different findings where no significant effects were found that could be associated with adverse health effects for children. Furthermore, differences were found for asthma related symptoms where some articles disagreed with other findings in this study.

Methods discussion

Methods

The search strategy for this literature review was set after identifying a few key concepts in the initial reading of background literature for this study. The searches were not limited to a single country or region because of not having a limit the searches would give a more extensive view of the problem, which was considered important since this is a global problem. The disadvantage is that it may lower the transferability of this study, because of the wide variety of different settings in the studies. The inclusion criteria include children between 0 to 18 years was because in the initial searches for articles it became clear that there was a large variation of age groups in the studies and limiting the search for a specific age group would have been difficult to find enough relevant articles for this study. Because the author considered it to be of importance to have the latest research for this study the decision to exclude articles that were 5 years or older was made. Other exclusion criteria are that articles missing clear ethical statement were dismissed and this is particularly important because the study populations consist of children, who are a vulnerable group of people. In the search result table, two results are not shown because no articles were selected in them because of duplicate results. The decision to not include specific pollutants in the search term may have resulted in the exclusion of relevant articles which could have potentially shown different results. All the articles chosen for this systematic literature review were made sure to include ethical permission which is a requirement for good research, and consequently articles in the selection process which did not
meet the requirement of ethics were discarded. Bryman (2014), writes about the importance of using keywords in combination with Boolean operators to get the best search results, and because of the exclusion of Boolean operators and truncation this study can be considered to have lower validity since the searches conducted would most likely had returned more relevant articles to choose from for this study. Even though this study is limited to 15 articles there are some strengths with it. Several of the studies consist of huge populations which give strength to the results.

Results discussion

Pollutants

The different traffic related air pollutants showed that the effects of them are modified by temperature and in most cases, they were above the global guideline values by WHO, although there were some pollutants that which had mean values lower than the global guideline values by WHO (2018a). The findings of this study show that some of the mean values for the pollutants such as PM$_{2.5}$ exposure can be below WHO’s global guideline values during the cool season and is despite that associated with increased asthma related hospital morbidity. Similar findings were further found for the pollutant NO$_{2}$, which furthermore supported other studies (Nishimura et al., 2013 & Perez et al., 2013). These contrasting results may be a result of the use of different methodology or it can be the effects of the specific locations and road layout where the studies have been performed. These findings could indicate that exposure to traffic air pollutants below WHO’s global guideline values may be harmful to children’s health. The contrasting results may as well be indicative of the complexity involved measuring traffic air pollutants, partly due to the other possible sources of traffic air pollution (WHO, 2005a) and possible confounders. Earlier reports have shown that confounders such as other pollutants that are not being measured during the study can be a confounder, and other possible confounder is temperature because of the seasonal variations in temperature (Chen et al., 2018 & Mortimer et al., 2002). The increase in hospitalization rates was linked with cooler seasons and is consistent with what other studies have reported on, where similar findings have been reported for lower temperatures being associated with higher mean values for pollutants (Ko et al., 2007b & Nishimura et al., 2013). One possible explanation for this is that population behavioral patterns are different during cooler seasons, and furthermore there could be differences in time which
they spend outside during different seasons. Effective strategies to reduce traffic air pollution could be investing in better ventilation in homes and schools which would result in overall better air quality and investments in more greenspace could be beneficial, which was reported to be associated with decreased levels of traffic related air pollution, which Esposito et al. (2014) also reported on.

**Risk factors and modifying factors**

This study concludes that road proximity is a risk factor and high traffic volume is a modifier, which are associated with increased risk and odds for developing asthma, asthma related symptoms, and adverse respiratory health. Earlier reports and studies by Esposito et al. (2014); Mortimer et al. (2002); Nishimura et al. (2013); Perez et al. (2013); Rice et al. (2015) and WHO (2005a), concluded that increased traffic is affecting people’s health and wellbeing and living close to roads is associated with higher exposure rates pollutants from traffic, which the findings of this study reported on. These findings highlight the problem of living and attending school close to a busy road where increased levels of asthma related morbidity are measured. The closer the distance the bigger the effects are with increased odds of developing asthma, which is reported in this study and is consistent with findings in earlier studies (Perez et al., 2013; Esposito et al., 2014 & Rice et al., 2015). This is a clear indication that urgent action is needed to assist populations living close to roads or high-density roads to improve their quality of life which is at risk because of increased exposure to traffic air pollutants. It is likely that these exposures will increase the global asthma prevalence among children and it is not good news, since it has been previously reported to be increasing globally by (Asher et al., 2006), and should persuade decision makers to implement new policies and strategies to fight the problems with traffic air pollution and the related adverse health effects. Although most of the results agreed with previous findings on asthma morbidity there were a few reports which yielded different results. There could be several reasons for that. One of the explanations could be the traffic patterns in these areas or that the road layout within the cities are different and affects exposure in a different way, and another potential possibility is the possible variations in traffic volume depending on time of day, location, and difference on how old the vehicle fleet is. World Health Organization has developed tools for assessing the health impacts from various pollutants and walking and cycling interventions. These tools are a result of their sustainable development goals for air quality in cities and are used to help member states getting
information on exposure assessment and health impacts of pollution (WHO, 2018a). It is clear that WHO has the knowledge on how to proceed with these issues and it is therefore important that politicians are aware of this to make the best use of this knowledge and tools available.

**Sociodemographic and socioeconomic factors**

Socioeconomic factors have historically been linked with poor health for people with lower socioeconomic status, and thus is an important part in public health studies (WHO, 2005a). This study confirms that both sociodemographic factors and socioeconomic status affects children’s health which has been reported before by organizations such as WHO (2005a) to be a risk factor if the children are part of a lower income family. As children of lower income families were found to be at greater risk of respiratory morbidity it is possible that parents income might be an obstacle for them getting the required hospital help and medication they need. Other possibilities are poor housing and ventilation which was reported by Moore et al. (2003) and WHO (2005a). An interesting observation is the finding that children from higher income families could be exposed to more pollutants than other socioeconomic groups. Possible explanations could be location differences which could explain this result, since it is possible that wealthier families prefer to live close to shops and malls, which could be located in areas that generates a lot of traffic and thus could explain this finding. This was an unexpected result since historically public health studies show that socioeconomic weaker populations more often report higher exposure to pollutants than wealthier groups (WHO, 2005a). What is interesting is that other studies have reported similar findings where children from higher income families were exposed to higher levels of traffic related pollutants (Rice et al., 2015). The varying results regarding asthma morbidity and asthmatic symptoms could possibly be because of the limited amount of studies with socioeconomic focus and might therefore not be generalizable to other populations because of that.

**Correlation to other symptoms**

The findings confirm that exposure to air traffic pollution can be modified by several factors and result in several other symptoms other than asthma and wheezing. This makes the problem with traffic air pollution even more important to find solutions for. It has been reported, that symptoms such as cough, shortness of breath are known to be symptoms of developing asthma
among children (1177 vårdguiden, 2018 & Unicef, 2016). Consequently, it is possible considering the results of this study that having these other symptoms might result in increasing levels of asthma prevalence in the future, which Asher et al. (2006) reported on. This might additionally affect the economy in many countries with increasing hospitalization and medication costs, and these events are most likely to affect the poorer populations to a greater extent, which subsequently leads to even worse quality of life for them if exposed to traffic related air pollution. Being exposed to traffic related air pollution can cause many other health issues that are not in this study, and these negative effects on children’s health can later in their lives, even be a cause of mortality, WHO (2005a). World Health Organization reported that transport related air pollution is estimated to be 6% of total mortality in adults 30 years of age or older. Even if there are reports not showing any significant associations with asthma and traffic air pollution, it can be assumed that the pollutants have an effect since overall evidence from other studies are showing otherwise (Brunst et al., 2015; Esposito et al., 2014; Ko et al., 2007a; Mortimer et al., 2002; Nishimura et al., 2013 & Perez et al., 2013).

Summary of findings

This study found evidence of associations with traffic related air pollution and adverse health effects among children, which is supported by other studies and reports. The reported inconsistencies in findings are found in previous studies as well, which gives strength to these findings. The results show how important it is for decision-, and policy makers to be aware of the problem with the ever-growing global pollution rates. World Health Organization has global indicators in place with their sustainable development goals which includes policies to reduce mortality from air pollution, access to clean fuels and technologies, and air quality in cities (WHO, 2018a). One thing that seems to be overlooked is the possible individual exposure to traffic related air pollution and it is important to know this because it is possible that individual activities can affect exposure results, which possibly could be measured by personal sensors. This study clearly shows the implications of exposure to traffic related air pollution and the effects it has on children. Furthermore, it highlights many factors modifying the effects, why it is important to study risk factors and modifying factors in association with traffic related air pollution.
Conclusion

This study concludes that there are elevated risks from traffic air pollution with the different identified modifiers such as seasons, traffic volume and traffic density for asthma, other allergic symptoms, and respiratory diseases. Although not all associations are significant there is enough evidence to support the findings of the existence of several risk factors associated to asthma and wheezing from traffic related air pollution such as the pollutants, proximity to roads and parental history of allergy which are affecting children’s health outcomes. These findings might not be generalizable because of the limited amount of studies included, which is a weakness. Although given the results in combination with the large study populations in many of the included studies this study can be an indication that traffic related air pollution affects children’s health and is a public health problem.

Implications and suggestions for the future

The results from this study show that traffic related air pollution is a public health issue which needs attention. Exposure to traffic related pollutants show adverse health effects for children, which will affect the health care services even more and put a strain on the limited resources available. Further consequences are lesser quality of life for children who develop asthma and wheezing as a consequence of exposure to the different pollutants, which besides that can affect their family’s economy with the increased costs for medicine and hospital visits. The results of this study can help decision makers and people in general to gain knowledge and understand the importance of addressing the problem of traffic air pollution. This information could inspire for new policies to be created for an efficient city planning to minimize risk of exposure to traffic related air pollution, which could protect vulnerable populations. Although there is a lot of research done in this field, it would be important to do more longitudinal studies to better be able to assess causality.
REFERENCES


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