Acoustics Australia (2022) 50:373–381
https://doi.org/10.1007/s40857-022-00271-8

TECHNICAL NOTE

A Scoping Review of the Effects of Classroom Acoustic Conditions on Primary School Children's Physical Health

Kiri Mealings[1]

Received: 4 May 2022 / Accepted: 8 June 2022 / Published online: 8 July 2022

Abstract
The aim of this scoping review was to synthesize research assessing the effect of classroom acoustic conditions on children's physical health and identify areas for future research. This scoping review followed the PRISMA-ScR protocol. A comprehensive search of four online databases (ERIC, PubMed, Scopus, and Web of Science) was conducted using the search term *classroom AND (acoustic* OR noise OR reverb*) AND health.* Peer-reviewed journal articles were included if they were written in English, included children in the primary school age range (i.e. 5–12 years), and included a measure of children's physical health. Eight papers out of the 407 papers returned in the search met the criteria to be included in the review. The results were analysed according to the effect of traffic noise, aircraft noise, and internal classroom noise on children's physical health. The results were somewhat mixed, but overall they suggest that noise may have a negative effect on children's physical health by inducing a stress response that results in asthma, fatigue, and headaches. Future research avenues are proposed to better understand the relationship between classroom acoustic conditions and children's physical health.

Keywords Health · Classroom acoustics · Noise · Children

1 Introduction

The impact of noise on human health has been of growing concern. The World Health Organization (WHO) has been particularly worried about the effect of noise on health. Berglund and Lindvall [1] critically reviewed the adverse effects of community noise on humans for the WHO in the 1990s which fed into the WHO Guidelines for Community Noise [2]. Noise can cause permanent hearing loss or a temporary threshold shift, sleep disturbance, fatigue, and increases in blood pressure, heart rate, and vasoconstriction [1]. Studies specifically looking at the effects on environmental noise on children have found that chronic exposure can affect systolic and diastolic blood pressure and catecholamine hormone secretion, but the effects are not always consistently shown (see [3] and [4] for reviews).

The potential for these adverse health effects have led to the WHO Regional Office for Europe to devise guidelines for environmental and leisure noise exposure [5]. These guidelines published in 2018 followed a systematic review process with the intention to update the 1990s document based on the studies since that time. These guidelines include recommendations for external noise such as road traffic noise, railway noise, aircraft noise, and wind turbine noise, as well as leisure noise which may be at outdoor or indoor events, or from personal listening devices. The recommendations are based on minimizing negative effects on health and sleep [5]. It is strongly recommended that average day, evening, and night noise levels should be below 53 dB L_{den}, 54 dB L_{den}, 45 dB L_{den}, and 45 dB L_{den} for road traffic, railway, aircraft, and wind turbine noise, respectively. At nighttime, it is strongly recommended that road traffic, railway, and aircraft noise levels are below 45 dB L_{night}, 44 dB L_{night}, and 40 dB L_{night}, respectively. For leisure noise, it is recommended that the yearly average from all leisure noise sources is less than 70 dB $L_{Aeq,24\,h}$. These guidelines are helpful to note; however, they are mostly based on external average day, evening, and night noise levels (i.e. 24 h period), so it is important to review the impact of noise entering the classroom during the school day (5–6 h) on children's physical health.

For occupational noise, Safe Work Australia [6] states that the national standard for maximum occupational exposure to

✉ Kiri Mealings
kiri.mealings@mq.edu.au

[1] Department of Linguistics – Audiology Section, Level 1 Australian Hearing Hub, 16 University Avenue, Macquarie University, Sydney, NSW 2109, Australia

noise is an average daily exposure level of $L_{\mathrm{Aeq,8\,h}} = 85$ dB as above this level poses a risk to the person's hearing. The national standard for peak exposure is $L_{\mathrm{Cpeak}} = 140$ dB. This noise level is for external and internal noise in the workplace.

It has been established that high noise levels from environmental noise, recreational activities, or at work can have an adverse effect on people's health. However, what about noise in the classroom environment? The classroom environment is where children spend a substantial amount of time. Therefore, it is vital to understand how the classroom acoustic environment impacts on children's physical health.

There are several noise sources heard in the classroom. These include external environmental noise present when the classroom is unoccupied (or occupied) such as traffic, railway, and aircraft noise. However, there are also internal noises when the classroom is occupied such as talking and from movement of the children themselves. These noises can be exacerbated by the reverberation time of the classroom.

There are acoustic recommendations for classrooms, largely based on what is needed for accurate speech perception. Generally, the unoccupied noise level should be kept below 35–45 dBA [7] and the occupied noise level should be below 50 dBA [8]. However, the actual acoustic conditions experienced in the classroom by children are often suboptimal [8]. Classrooms are often built near busy roads or railway lines, or under flight paths. Noise levels when the children are in the classroom can also be louder than recommended especially due to the growing amount of time spent in group work activities which can make up around 50% of teaching time [9, 10]. Group work noise levels have been shown to be higher than the noise levels during whole class teaching or independent work due to groups of children speaking at the same time [11, 12]. Additionally, more open plan innovative learning environments are becoming popular [10] which have higher intrusive noise levels from the other classes sharing the same space [12].

The aim of this investigation was to conduct a scoping review to systematically map the research on the impact of classroom acoustic conditions on children's physical health, as well as to identify existing gaps in knowledge to be investigated in future research. Scoping reviews are a relatively new approach for synthesizing research evidence and were the method chosen for this paper rather than a systematic review as it fitted the criteria of a scoping review as outlined by Munn et al. better (i.e. "to identify the types of available evidence in a given field; to clarify key concepts/ definitions in the literature; to examine how research is conducted on a certain; topic or field; to identify key characteristics or factors related to a concept; as a precursor to a systematic review; and to identify and analyse knowledge gaps" (p. 2)) [13]. Systematic reviews have more of a focus on informing practice and policy which was not the purpose of this paper [13]. The following research question was formulated: What is known from the literature about the effect of classroom acoustic conditions on primary school children's physical health?

2 Method

2.1 Protocol

The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) [14] was the protocol used for this scoping review. The PRISMA extension for scoping reviews website can be found at: http://www.prisma-statement.org/Extensions/ScopingReviews.

2.2 Eligibility Criteria

To be included in the review, peer-reviewed journal articles needed to include a measure of children's physical health taking into account the classroom acoustic environment. Peer-reviewed journal articles were included if they were written in English, included children in the primary school age range (i.e. 5–12 years), and included a measure of children's physical health. No restrictions were made on the publication dates or the type of study (i.e. quantitative, qualitative, or mixed-method studies).

2.3 Information Sources

To identify potentially relevant documents, the following bibliographic databases were searched: ERIC, PubMed, Scopus, and Web of Science. The final search results were exported into.csv files where duplicates were removed.

2.4 Search

The database search was conducted on the 21st April 2022. The search term used for all databases was *classroom AND (acoustic* OR noise OR reverb*) AND health*.

2.5 Selection of Sources of Evidence

All publications identified in the searches were evaluated by the titles, and then abstracts and full text when needed for potentially relevant publications.

2.6 Data Charting Process

Data charting refers to how relevant information from the papers was extracted. Data from eligible studies were charted to capture the relevant information on key study characteristics and detailed information on all metrics used to measure children's physical health.

2.7 Data Items

Data were abstracted on the following characteristics: the types of acoustic conditions that have been assessed, the types of measures used to assess physical health, and the effect of the acoustic conditions on children's physical health.

2.8 Synthesis of Results

Studies were grouped by the acoustic conditions explored and summarized according to the effect of the acoustic conditions on children's physical health.

3 Results

3.1 Selection of Sources of Evidence

The search and selection process of the studies to be included in the review is shown in Fig. 1. After duplicates were removed, a total of 407 references were identified from searches of electronic databases. Based on the title and/or the abstract and full-text, 399 papers were excluded for the following reasons: 358 did not assess the effect of classroom acoustics on children's physical health, 36 did not assess children in the primary school age range (the majority of these assessed teacher's vocal health), three did not have the full text available in English, one was not a peer-reviewed journal article, and one reported the results poorly and could not be properly interpreted.

3.2 Characteristics and Results of Sources of Evidence

A summary of the studies included in the review is shown in Table 1. A synthesis of the results follows.

3.3 Publication Years

The publication years of the eight studies included in the review are shown in Fig. 2.

3.4 Populations

All eight studies were carried out with children typically found in mainstream classrooms. No studies directly assessed special populations.

3.5 Acoustic Exposure

Three studies assessed the effect of traffic noise, two assessed aircraft noise, and four assessed internal classroom noise.

3.6 Measures and Methods

3.6.1 Questionnaires

Six studies used questionnaires as the physical health data collection method. Akhtar et al. [15] developed a questionnaire specifically for the study that assessed if children are negatively impacted on different performance indicators by noise. The questionnaire was filled out by the children. Not many details were given about the questionnaire.

Chowdhury et al. [16] also developed a questionnaire for the study that assessed children's attitude towards traffic induced noise at school and the adverse impacts on their physical and mental health. The questionnaire was filled out by the children.

Stansfeld et al. [17] developed questionnaires filled out by the children and parents on the perceived health of the child. The questions were based on adult questionnaires of perceived health.

Taborda et al. [18] developed a questionnaire for the study filled out by the child that assessed symptoms such as headaches and tinnitus experienced by the child in the classroom.

Klatte et al. [19] used the KINDL-R [20] filled out by the child's parents to assess children's physical wellbeing. There were three questions, e.g. "during the last 4 weeks, my child suffered from stomachache or headache". Ratings were made on a five-point scales ranging from "never" to "almost always".

Walinder et al. [21] developed a questionnaire for the study that assessed the frequency that children experienced different symptoms due to noise in the classroom including headaches and fatigue on a five-point scale.

3.6.2 Interviews

Two studies used interviews as the physical health data collection method. Lin et al. [22] and Palumbo et al. [23] used interviews where the children were asked if they had experienced 40 different health symptoms in the last week and the location where those symptoms occurred (home, school, or other). These were then categorized into whether the child had experienced asthma-like symptoms (Yes/No); allergy-like symptoms (Yes/No); flu-like symptoms (Yes/No); and/or any respiratory symptoms (Yes/No).

3.6.3 Physiological Assessments

One study used physiological assessments as the physical health data collection method. Walinder et al. [21] took physiological measurements of the children's blood pressure, heart rate, and salivary cortisol.

Table 1 General information for the eight papers included in the review and effect of noise on children's physical health

Authors	Aim	Population/age	Acoustic conditions	Physical health measure	Exposure		Effect of louder noise		
					Chronic	Acute	Negative	None	Positive
Akhtar et al. [15]	To investigate and assess negative impacts of noise on students and teachers	Children aged 10–13 years ($n = 100$)	Schools exposed to traffic noise (mean = 57.2 dBA). No control schools	Questionnaire designed for the study filled out by children	x		x[a]		
Chowdhury et al. [16]	To investigate traffic induced noise and assess people's attitude towards traffic induced noises and its adverse impact on their physical and mental health	Children in schools and colleges including one primary school ($n = 40$ per school)	Schools exposed to traffic noise (59.73–65.84 dB for primary school)	Questionnaire designed for the study filled out by children	x		x[a]		
Klatte et al. [19]	To investigate the effects of aircraft noise on cognition and quality of life	Children in Grade 2 ($n =$ 1243)	Schools with varying exposure to aircraft noise (39.10–58.90 dBA)	KINDL-R Fragebogen zur Erfassung der gesundheitsbezogenen Lebensqualität bei Kindern und Jugendlichen [20] filled out by parents	x		x		
Lin et al. [22]	To examine indoor home and school environments in relation to health outcomes using machine learning methods and logistic regression	Children aged 6–11 years ($n = 280$)	Typical schools in Romania (internal noise levels not reported)	Interviews about health symptoms conducted with children	x		x		
Palumbo et al. [23]	To assess children's allergy, asthma-like symptoms, and flu-like symptoms in relation with classroom comfort and environmental factors	Children aged 6–11 years ($n = 280$)	Typical schools in Romania (internal noise levels not reported)	Interviews about health symptoms conducted with children	x		x[b]	x[b]	
Stansfeld et al. [17]	To assess the effect of exposure to aircraft and road traffic noise on cognitive performance and health in children	Children aged 9–10 years ($n = 2844$)	Schools with varying exposure to aircraft noise (30–77 dBA) and road traffic noise (32–71 dBA)	Questionnaire designed for the study filled out by children and parents	x			x	

Table 1 continued

Authors	Aim	Population/age	Acoustic conditions	Physical health measure	Exposure		Effect of louder noise		
					Chronic	Acute	Negative	None	Positive
Taborda et al. [18]	To evaluate the effectiveness of physical, organizational, and educational interventions to achieve noise reduction in a school	Children aged 6–15 years (*n* not reported)	Classroom with physical, organizational, and educational interventions implemented to achieve noise reduction. Unoccupied noise levels were $L_{min} = 46.6$ dB pre-intervention vs. 44.6 dB post-intervention, $L_{max} = 76.0$ dB pre-intervention vs. 58.3 dB post-intervention, $L_{eq} = 56.4$ dB pre-intervention vs. 48.9 dB post-intervention. Occupied noise levels were $L_{min} = 58.0$ dB pre-intervention vs. 47.1 dB post-intervention, $L_{max} = 86.7$ dB pre-intervention vs. 81.4 dB post-intervention, $L_{eq} = 70.3$ dB pre-intervention vs. 71.4 dB post-intervention	Questionnaire designed for the study filled out by children		x		x[c]	x[c]
Walinder et al. [21]	To assess if classroom noise is related to stress reactions among primary school children	Children in Grade 4 ($n = 57$)	Classrooms with naturally occurring fluctuations in internal noise (range 59–87 dBA)	Questionnaire designed for the study filled out by children Physiological measurements of blood pressure, heart rate, and salivary cortisol		x	x[d]	x[d]	x[d]

[a]No control schools but overall negative effect of noise in noise-exposed schools
[b]Negative effect for noise and asthma, no effect for allergy or flu-like symptoms
[c]No effect for headaches, positive effect for tinnitus
[d]Higher noise correlated with more frequent headaches and fatigue and decreased cortisol variability, blood pressure not related to noise levels, pulse level negatively correlated with noise level

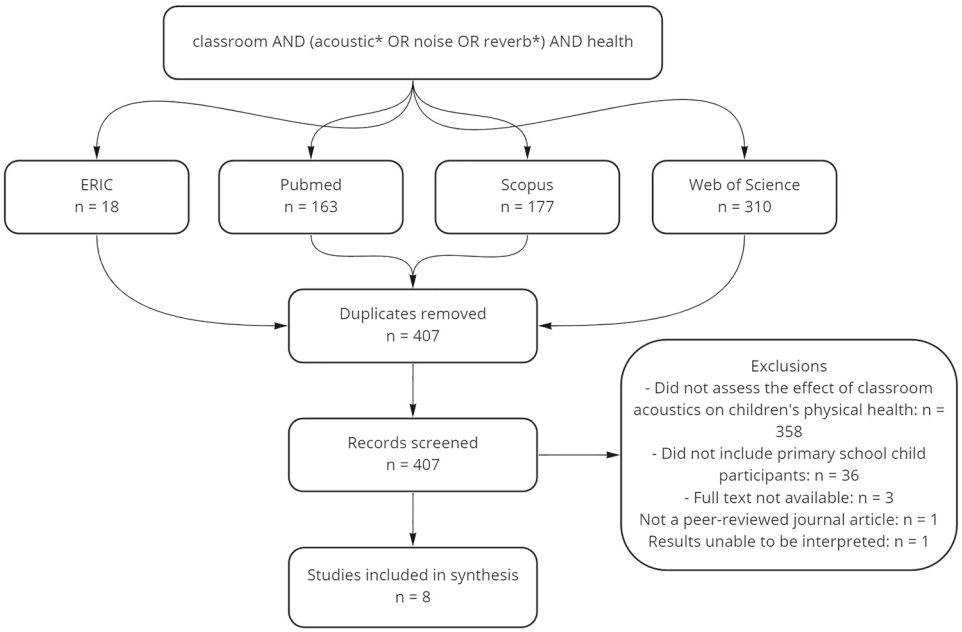

Fig. 1 Search strategy and results

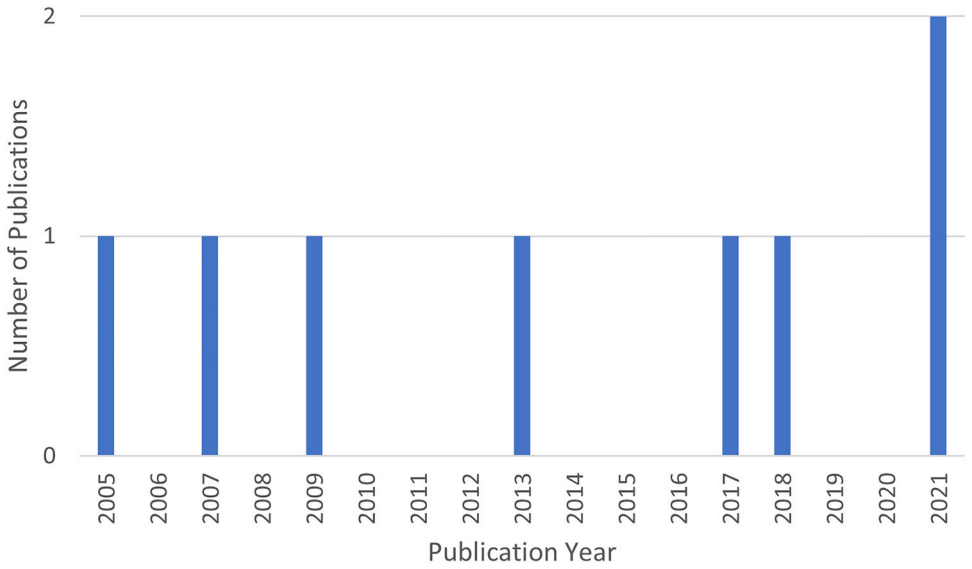

Fig. 2 Publication years of the eight journal articles included in the review

3.7 Outcomes

A summary of the overall outcomes of the studies is shown in Table 1. These findings are described further below categorized by the type of noise assessed.

3.7.1 Traffic Noise Heard in the Classroom

Akhtar et al. [15] reported that 65% of children felt tiredness due to high traffic noise and 64% of children experienced headaches due to exposure to high traffic noise. The mean traffic noise in the classrooms studied was 57.2 dBA which is well above that recommended [7].

Chowdhury et al. [16] found that 79% of respondents experienced headaches, 8% experienced earaches, 7% experienced tiredness, 4% experienced deafness, and 2% experienced respiratory distress. Note that these results are combined for the primary, high school, and college results—the primary school results were not reported separately.

Traffic noise ranged from 59.73 to 65.84 dB for the primary school which is well above that recommended [7].

Stansfeld et al. [17] found no effect of increased road traffic noise on children's self-reported health. Road traffic noise in the schools assessed ranged from 32 to 71 dBA so many of the schools would have had noise levels well above that recommended [7].

3.7.2 Aircraft Noise Heard in the Classroom

Klatte et al. [19] found that children's physical wellbeing dropped by 0.12 points on the five-point rating scale for a 10 dB increase in aircraft noise levels which corresponds to a decrease of one sixth of a standard deviation. The noise levels in the schools ranged from 39.10 to 58.90 dBA so several of the schools would have had noise levels well above that recommended [7].

Stansfeld et al. [17] found no effect of increased aircraft noise on children's self-reported health for schools exposed to levels ranging from 30 to 77 dBA so many of the schools would have had noise levels well above that recommended [7].

3.7.3 Class-Generated Noise

Lin et al. [22] found that the child feeling that it was noisy in the classroom came fourth out of 16 factors in the model of the most important features for respiratory symptoms. A different analysis on the same data found a negative effect of noise on asthma (almost a triple risk), but no effect for allergy or flu-like symptoms [22, 23]. The internal noise levels of the classrooms studied were not reported; however, there was a yes/no rating by the parent about whether the child feels there is noise in the classroom during activities.

Taborda et al. [18] found no significant difference in the number of children reporting headaches pre- and post-intervention of noise control (44.7% vs. 38.4%), but there was a significant increase in children with tinnitus post-intervention (12% vs. 26.5%). Unoccupied noise levels were L_{min} = 46.6 dB pre-intervention vs. 44.6 dB post-intervention, L_{max} = 76.0 dB pre-intervention vs. 58.3 dB post-intervention, L_{eq} = 56.4 dB pre-intervention (above that recommended [7]) vs. 48.9 dB post-intervention (still above that recommended [7]). Occupied noise levels were L_{min} = 58.0 dB pre-intervention vs. 47.1 dB post-intervention, L_{max} = 86.7 dB pre-intervention vs. 81.4 dB post-intervention, L_{eq} = 70.3 dB pre-intervention (above that recommended [8]) vs. 71.4 dB post-intervention (still above that recommended [8]).

Walinder et al. [21] found that higher noise correlated with more frequent headaches and fatigue and decreased cortisol variability in children. Blood pressure was not related to noise levels, but interestingly pulse level negatively correlated with noise level. The naturally occurring fluctuations in internal noise ranged from 59 to 87 dBA (above that recommended [8]).

4 Discussion

This scoping review aimed to determine what is known about the effect of classroom acoustic conditions on primary school children's physical health. Eight papers met the criteria to be included in the review. The results of the studies were analysed according to the effect of different types of noise on children's physical health.

4.1 Summary of Findings

Three studies examined the effect of traffic noise heard in the classroom on children's physical health. Two of these studies assessed the impact of noise in noise-exposed schools on children's physical health and found that children reported symptoms such as headaches, earaches, tiredness, deafness, and respiratory distress [15, 16]. However, these studies did not include control schools with low traffic noise to compare these results to. Stansfeld et al. [17] who assessed children's self-reported health in schools with traffic noise ranging from 32 to 71 dBA found no effect of increased road traffic noise on children's self-reported health. However, the definition of self-reported health and what exactly was asked in the questionnaires was not specified. The results of these studies suggest that higher levels of traffic noise heard in the classroom may negatively affect children's physical health; however, given these mixed results and limitations, future research is needed to better understand the effect of traffic noise on children's physical health.

Two studies examined the effect of aircraft noise heard in the classroom on children's physical health. Although Klatte et al. [19] found that children's physical wellbeing dropped by 0.12 points on the 5-point rating scale for a 10 dB increase in aircraft noise levels, this change is very small. Stansfeld et al. [17] found no effect of increased aircraft noise on children's self-reported health, but again the definition of self-reported health and what exactly was asked in the questionnaires was not specified. The results of these studies suggest that aircraft noise heard in the classroom may have a small negative effect on children's physical health; however, more research is needed to better understand the effect.

Four studies assessed the effect of internal classroom noise on children's physical health. Lin et al. [22] and Palumbo et al. [23] found that noise could be associated with respiratory symptoms such as asthma. The authors suggest, taking into account findings from other studies, that the noise can induce stress which increases cortisol levels which can exacerbate asthma. Taborda et al. [18] did not find a significant difference in the number of children reporting headaches

pre (44.7%) and post (38.4%) noise control intervention; however, interestingly there was a significant increase in children with tinnitus post-intervention. The authors, however, believe that this result was due to children at first not understanding what tinnitus was rather than the result being directly related to the noise level. Also, it is important to note here that post-intervention the noise levels were still high and above those recommended for classrooms [7, 8] (although these recommendations are more for speech perception and not specifically health-related) which is why there may not have been a significant decrease in the number of children reporting headaches despite a trend in this direction. In contrast, Walinder et al. [21] found that higher noise levels were associated with higher levels of fatigue and headache alongside reduced cortisol variability which indicates a stress response. Taken together, these results suggest that increased classroom-generated noise may induce stress in children which manifests in physical health symptoms such as asthma, fatigue, and headaches.

4.2 Limitations of the Studies

In addition to the limitations of individual studies mentioned above, there are a couple of limitations across studies that need to be raised. These include the use of subjective measures of physical health, determining the exact cause of physical health problems, and separating the noise source under investigation from other sources.

All eight of the reviewed studies involved subjective self-report questionnaires or interviews. Only one of the eight studies also included physiological measurements. While self-reports can provide helpful information, they are open to bias from the responder. There can be issues such as how the questions are interpreted by different people and how much insight different people have into their physical health. Questionnaires and interviews that are answered retrospectively can also have the issue of how well the responder can remember the situation or how they were feeling. So, while these subjective measures may provide some helpful insights, physiological measures can better provide objective measures at the time of the noise exposure.

Additionally, it can be difficult to determine the exact cause of physical health symptoms in some of the studies using subjective questionnaires. For example, Klatte et al. [19] asked questions such as "during the last 4 weeks, my child suffered from stomachache or headache". These symptoms could be induced by other aspects of the child's life in different environments such as stress at home or long travel to and from school and not attributed directly to the classroom.

Separating the effect of the afflicting noise source compared to other noise sources is another limitation of the reviewed studies. For example, for the studies that assessed the effect of external noise such as road traffic and aircraft noise, there may have also been classroom noise present, so physical health effects may not solely be able to be attributed to the external noise. The same could be true for class-generated noise where external noise may have also been present and been a contributing factor. Additionally, self-reported health effects may not just be a result of noise exposure in the classroom, but could be influenced by high noise exposure in other aspects of the child's daily life.

4.3 Future Research Needs

Due to the small number of studies assessing the effect of noise on children's physical health, there are plenty of avenues for future research to be conducted to better understand the relationship. More studies are needed with control schools with low noise levels or studies assessing a large range of noise exposure levels so that conclusions can be drawn about what noise level starts to affect children's physical health. This is particularly needed for internal classroom noise as there are no recommendations for what levels affect health like there are for occupational, leisure, and environmental noise [5, 6]. The only recommendations are those that are derived for adequate speech perception [8]. The need for a recommendation is especially relevant due to the growing amount of time spent in noisier group work activities which make up around 50% of teaching time [9–12] and the popularity of open plan innovative learning environments [10] where intrusive noise can be an issue [12]. More studies are needed examining the effect of specific acute noise exposure on the immediate reaction of children's physical health (only researched by two out of eight studies reviewed) in addition to those studies examining chronic exposure to noise.

Additionally, more studies are needed that include physiological measures. Only one of the eight studies included physiological measurements of children's blood pressure, heart rate, and salivary cortisol. All of the other studies used self-report questionnaires or interviews. Using physiological measurements of the children's physical health would help to give more objective insights into how noise affects children's physical health.

Furthermore, all studies reviewed were conducted with children found in mainstream classrooms. It would therefore be interesting to conduct studies with children with special educational needs, such as attention deficit hyperactivity disorder and autism, to see if noise affects their physical health differently to children who are typically developing.

Finally, noise is not the only acoustic variable that could affect children's physical health even though this was the subject of investigation for all eight studies reviewed. It may also be interesting to investigate the effect of the classroom reverberation time as reverberation exacerbates noise so this might also have an effect on children's physical health.

5 Conclusions

This scoping review synthesized information about what is known on the effect of noise in classrooms on children's physical health. Only a small number of studies were identified but the results suggest that traffic noise, aircraft noise, and internal classroom noise may have a negative effect on children's physical health by inducing a stress response that results in asthma, fatigue, and headaches. Given the small number of studies, however, there are plenty of avenues for future research to be conducted to better understand the relationship between classroom acoustic conditions and children's physical health which have been proposed in the paper.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. The author discloses no financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

References

1. Berglund, B., Lindvall, T.: Community noise. In: Berglund B, Lindvall T (eds) Arch Cent Sens Res. 2(1), 1–195 (1995)
2. Berglund, B., Lindvall, T., Schwela, D., et al.: Guidelines for community noise [internet], vol. 31, Noise & Vibration Worldwide. World Health Organization, pp. 1–141 (1999). http://multi-science.metapress.com/openurl.asp?genre=article&id=. https://doi.org/10.1260/0957456001497535
3. Haines, M.M., Stansfeld, S.A.: The effects of environmental noise on child health and learning: a review of international research. Acoust Aust **31**(1), 17–22 (2003)
4. Stansfeld, S., Clark, C.: Health effects of noise exposure in children. Curr Environ Heal Rep **2**(2), 171–178 (2015)
5. World Health Organization. Environmental Noise Guidelines for the European Region Executive Summary. 8 (2018). http://www.euro.who.int/__data/assets/pdf_file/0009/383922/noise-guidelines-exec-sum-eng.pdf
6. Safe Work Australia. Managing noise and preventing hearing loss at work: Code of practice. Safe Work Australia (2020)
7. Australia/New Zealand Standard. AS/NZS2107:2016, Acoustics: recommended design sound levels and reverberation times for building interiors (2016)
8. Mealings, K.: Classroom acoustic conditions: understanding what is suitable through a review of national and international standards, recommendations, and live classroom measurements. In: 2nd Australasian Acoustical Societies Conference, ACOUSTICS (2016) https://acoustics.asn.au/conference_proceedings/AASNZ2016/
9. Mealings, K.T., Demuth, K., Buchholz, J.M., et al.: An assessment of open plan and enclosed classroom listening environments for young children: part 2 - teachers' questionnaires. J. Educ. Pediatr. (Re)Habilitative Audiol. **21**, 20–38 (2015)
10. Imms, W., Mahat, M., Byers, T. et al.: Type and use of innovative learning environments in Australasian schools ILETC survey no. 1. Technical Report 1/2017. Melbourne (2017). http://www.iletc.com.au/publications/reports
11. Shield, B.M., Dockrell, J.E.: External and internal noise surveys of London primary schools. J. Acoust. Soc. Am. **115**(2), 730–8 (2004)
12. Mealings, K.T., Buchholz, J.M., Demuth, K., et al.: Investigating the acoustics of a sample of open plan and enclosed Kindergarten classrooms in Australia. Appl. Acoust. **100**, 95–105 (2015)
13. Munn, Z., Peters, M.D.J., Stern, C., et al.: Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med. Res. Methodol. **18**(1), 143 (2018)
14. Tricco, A.C., Lillie, E., Zarin, W., et al.: PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann. Intern. Med. **169**(7), 467–73 (2018). https://doi.org/10.7326/M18-0850
15. Akhtar, J., Anjum, N., Iftikhar, N.: Evaluation of the impact of noise pollution on students in congested area of Rawalpindi. Nurture **7**(1), 1–9 (2013)
16. Chowdhury, R.B., Dey, R., Alam, M.S., et al.: Extent of traffic induced noise in the noise sensitive institutions of Chittagong city, Bangladesh. Noise Vib. Worldw. **41**(1), 28–36 (2010)
17. Stansfeld, S.A., Berglund, B., Clark, C., et al.: Aircraft and road traffic noise and children's cognition and health: a cross-national study. Lancet **365**(9475), 1942–1949 (2005)
18. Taborda, R.F., Gomes, R.F., Rocha, C.H., et al.: Evaluation of noise reduction interventions in a school. Folia Phoniatr. Logop. **73**(5), 367–375 (2021)
19. Klatte, M., Spilski, J., Mayerl, J., et al.: Effects of aircraft noise on reading and quality of life in primary school children in Germany: results from the NORAH study. Environ. Behav. **49**(4), 390–424 (2017)
20. Ravens-Sieberer, U., Bullinger, M.: Assessing health-related quality of life in chronically ill children with the German KINDL: first psychometric and content analytical results. Qual. Life Res. **7**(5), 399–407 (1998). https://doi.org/10.1023/A:1008853819715
21. Wålinder, R., Gunnarsson, K., Runeson, R., et al.: Physiological and psychological stress reactions in relation to classroom noise. Scand. J. Work Environ. Heal. **33**(4), 260–266 (2007)
22. Lin, Z., Lin, S., Neamtiu, I.A., et al.: Predicting environmental risk factors in relation to health outcomes among school children from Romania using random forest model - An analysis of data from the SINPHONIE project. Sci. Total Environ. **784**, 147145 (2021)
23. Palumbo, J.R., Lin, S., Lin, Z., et al.: Assessing associations between indoor environment and health symptoms in Romanian school children: an analysis of data from the SINPHONIE project. Environ. Sci. Pollut. Res. **25**(9), 9186–93 (2018). https://doi.org/10.1007/s11356-018-1568-3