

Extra-auditory effects of noise exposure in school workers and preventive measures: a systematic review

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Abstract. – OBJECTIVE: Noise is still today one of the main causes of occupational diseases; in fact, in Italy in the three-year period 2019-2022, hearing loss represented 15% of all occupational diseases recognized by the National Institute for Insurance against Accidents at Work. The extra-auditory effects related to noise exposure also require particular attention, because they can interfere with mental activities that require concentration, memory and ability to deal with complex problems, causing sleep and learning disorders. For this reason, acoustic comfort is considered a fundamental requirement for obtaining an optimal degree of well-being in closed environments. In schools, a high degree of noise pollution not only makes it difficult for students to listen and learn, but also affects school workers. The aim of this study was to perform a systematic review of international literature and analysis of the preventive measures of extra-auditory effects among school workers.

MATERIALS AND METHODS: The presentation of this systematic review is in accordance with the PRISMA statement. The methodological quality of the selected studies was assessed with specific rating tools (INSA, Newcastle Ottawa Scale, JADAD, JBI scale and AMSTAR). Only publications in English were selected. No restrictions were applied for the publication type. We excluded articles not concerned with the extra-auditory effects of noise exposure in school workers and preventive measures, findings of less academic significance, editorial articles, individual contributions, and purely descriptive studies published in scientific conferences.

RESULTS: Online research indicated 4,363 references: PubMed (2,319), Scopus (1,615) and Cochrane Library (429) have been consulted; 30 studies were included in this review (5 narrative or systematic reviews and 25 original articles).

Regarding the scores of narrative reviews, the INSA score showed an average and a median value of 6.5, thus indicating an intermediate/high quality of the studies. Regarding the scores of systematic reviews, the AMSTAR score showed an average of 6.7 and a median and a modal value of 6, thus indicating a high quality of the studies. The scores assigned to the original articles have an average and median value of 7 and a modal value of 6 and this demonstrates an intermediate/high quality of the studies.

CONCLUSIONS: We can assume that, as it is highlighted by this study, to date these consequences are not considered at the legislative level for the protection of exposed workers. The extra-auditory effects impacting health afterward environmental noise exposure are many and widespread. Therefore, there is a need for interventions to be carried out by institutions and that the physician of the schools, during health surveillance, investigates the effects and clinical manifestations, in order to prevent disorders and deficits highlighted by our study.

Key Words:

Extra-auditory effects, Noise exposure, Preventive measures, School workers.

Introduction

It has been demonstrated by many studies¹ that classrooms, gymnasiums, canteens, music rooms are often characterized by high levels of noise and excessive reverberation, resulting in a reduced quality of listening, teaching and training in general, and in some cases, they do not comply with the minimum acoustic requirements.

In Italy, in the three-year period between 2019 and 2022, hearing loss represented 15% of all occupational diseases recognized by the National Institute for Insurance against Accidents at Work (INAIL)².

In all countries, therefore, noise in the workplace is one of the main causes of occupational illness³. The effects of noise on the auditory and non-auditory systems are directly proportional to sound level and duration of exposure, in such a way that when certain limits are exceeded, the risk of irreversible damage significantly increases. This risk also depends on other factors such as individual susceptibility, interpersonal variability, subject's age, previous and/or concomitant diseases. When the noise is particularly violent, even a single event may be sufficient to cause the damage³. In scientific literature^{4,5}, it is also well known that extra-auditory effects are concerned with cardiovascular disorders and mental well-being.

Today, however, with the enactment of the Legislative Decree 81 of 2008 as amended, the legislator has determined the minimum health and safety requirements relating to the exposure of workers to risks arising from noise exposure during work performance⁶. National regulations require schools to be distributed over the territory in such a way as to reduce the distance between students' houses and the school itself⁷. This condition, however, limits the choice of location of schools, so that those located in urban centers are exposed to external noise caused by transport infrastructure and all other possible anthropogenic sources. In fact, traffic represents the main cause of noise nuisance in Europe and is primarily present in densely populated areas⁹.

Materials and Methods

The presentation of this systematic review is in accordance with the PRISMA statement¹⁰.

Literature Research

The review included articles published in scientific literature from 2008, the year in which the Consolidated Safety Act came into force, until December 2022, on the major online databases (PubMed, Scopus, Cochrane Library). The search strategy used a combination of controlled vocabulary and free text terms based on the following keywords: noise, non-auditory, extra-auditory, school, preventive, health, preventive measures, students, teachers, annoyance effects (Table I).

All search fields were considered. Additionally, we practiced a hand search on reference lists of the selected articles and reviews for a wider analysis.

Two independent reviewers (SDS and GL) performed the search, reading the titles and abstracts of the articles identified by the search strategy. Relevant reports were selected according to inclusion and exclusion criteria.

Doubts or disagreements were solved through arbitration with two other researchers (NM and VT). Finally, the compatible full texts were independently assessed for definitive eligibility.

Quality Assessment

Three different reviewers (SDS, GL, NM) assessed the methodological quality of the selected studies with specific rating tools. We used the "INSA" method (International Narrative Systematic Assessment)¹¹ to assess the quality of narrative reviews, the "Newcastle Ottawa Scale¹²" to evaluate cross-sectional and cohort studies, while the "JADAD scale¹³" was applied for randomized clinical trials. The "AMSTAR tool¹⁴" was used to assess the methodological quality of systematic reviews, and the "JBI tool¹⁵" was used for case studies.

Eligibility and Inclusion Criteria

Restrictions were applied for the language of the studies: only publications in English were selected. The articles included in this review focus exclusively on articles written in English that deal with the extra-auditory effects due to exposure to noise in schools, on the health of school workers and on the most effective preventive measures used in schools.

Exclusion Criteria

Articles excluded were those that did not deal with the prevention and extra-auditory effects caused by noise exposure in schools, those that resulted of minor importance, editorial articles and purely descriptive studies published in scientific conferences.

Risk of Bias Assessment

In order to reduce the biases of our review, different tools for evaluating the quality of the included studies were used. This evaluation was carried out by two reviewers (SDS and GL) independently and only in the event of disagreement and doubts it was carried out through arbitration with the other authors.

Results

Online research indicated 4,363 references: PubMed (2,319), Scopus (1,615) and Cochrane Library (429). Of these, 2,229 were excluded due to duplication. Furthermore, 1,909 items were excluded because they were unrelated to problems associated with noise in the school environment. Of the remaining 225, 160 items did not meet the inclusion criteria (Figure 1).

Ultimately, 30 studies were included in this review (Table II).

They were 2 narrative reviews (average INSA score: 6.5), 3 systematic reviews (average AMSTAR score: 6.7) and 25 original articles (23 articles with average Newcastle Ottawa scale score: 6.9, 1 article with JADAD score: 2, 1 case series with score: 1). Among the original articles, 1 was a case series study, 2 were cohort studies, 21 were

cross-sectional studies and 1 was another kind of study.

The different extra-auditory effects due to noise exposure and the preventive measures identified through the research were grouped together in order to better summarize the results of the review (Table III-IV).

Narrative and Systematic Reviews

Regarding the scores of narrative reviews, the INSA score showed an average and median value of 6.5 (Table II), thus indicating an intermediate/high quality of the studies. The most appropriate methodological narrative review⁴⁵ was conducted in the UK (INSA score: 7). The most significant is that 43% of studies^{18,21,26,29,30,32-34,36,40-43} detected “voice disturbances and attention deficit”, followed by “stress” (30% of reviews^{21,23,25,27,39,40,42,44}), “sleep disorders and irritability” (27%), “hyper-

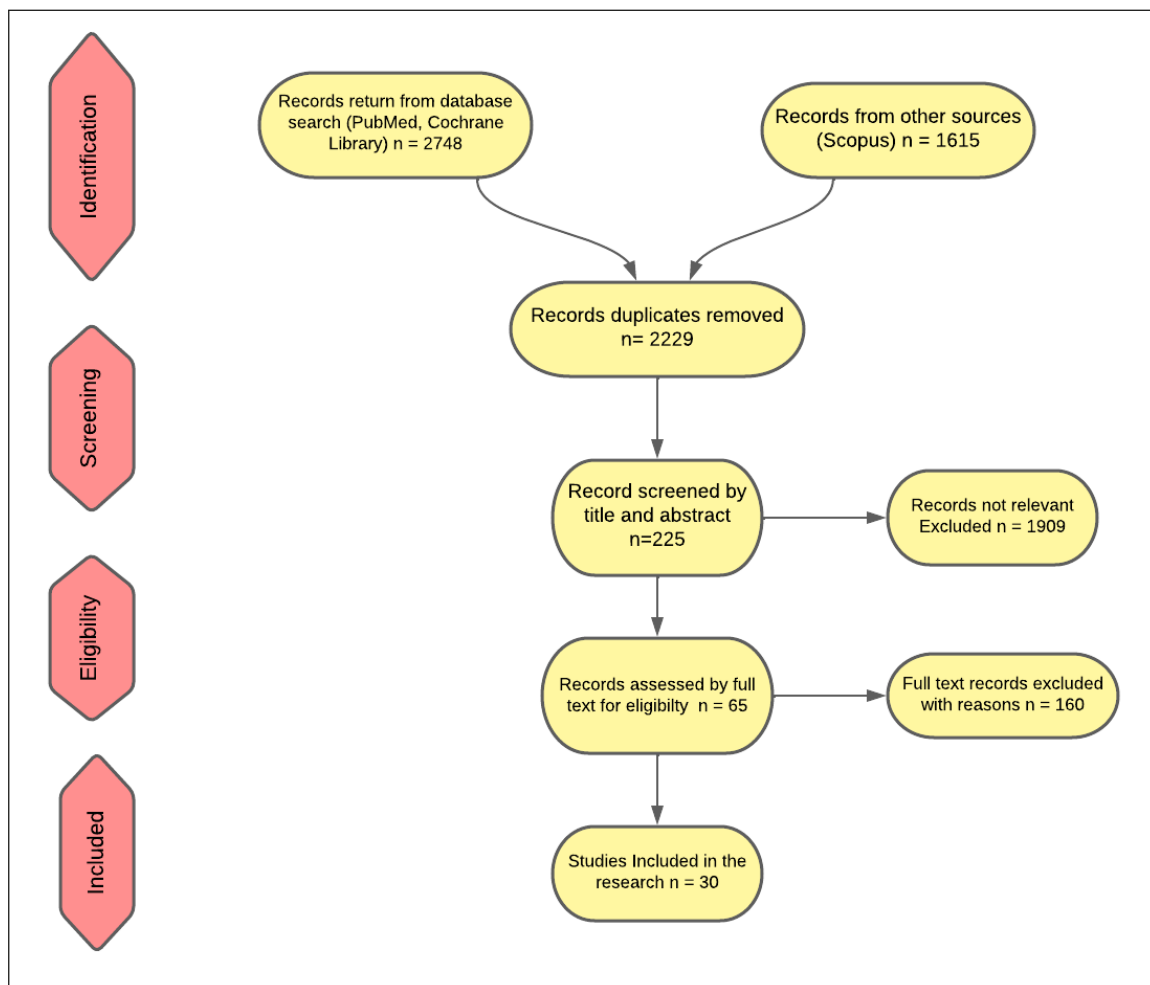


Figure 1. PRISMA Flow Diagram.

Table I. Search strings.

1 Noise and teacher and non-auditory
2 Noise and teacher and extra-auditory
3 Noise and teacher and health
4 Noise and teacher and annoyance
5 Noise and teacher and preventive measures
6 Noise and teacher and effects
7 Noise and school and non-auditory
8 Noise and school and annoyance
9 Noise and school and preventive measures
10 Noise and school and effects
11 Noise and students and non-auditory
12 Noise and students and extra-auditory
13 Noise and students and health
14 Noise and students and annoyance

tension” (23%), “headache” (17%), “fatigue” and “burnout” (7%) as extra-auditory effects due to noise exposure in schools.

Regarding the preventive measures, in narrative reviews^{24,45}, “Noise awareness campaigns” was deemed as the most useful and effective in

preventing extra-auditory effects due to noise exposure in schools (9% of reviews).

Regarding the scores of systematic reviews^{23,34,36}, the AMSTAR score showed an average of 6.7 and a median of 6 and a modal value of 6, thus indicating an intermediate/high quality of the studies. The most qualitative systematic review³⁶ was conducted in Columbia (AMSTAR Score: 8) (Table II). Among the extra-auditory effects due to noise exposure in schools in the systematic reviews, attention deficit, vocal disorders and hypertension were the most mentioned. The preventative measures which are vocal training, implementation of sound absorbing materials, and structural modifications, were those proposed in 2 of the 3 systematic reviews^{23,34,36}.

Original Articles

The scores assigned to the original articles have an average value of 6.8, a median value of 7 and a modal value of 6 and 7 (Table II). This

Table II. Included studies and quality assessment score.

Authors	Study Design	Country	Year	Score
1. Moreno et al ³⁵	Systematic Review	Colombia	2022	A8
2. Mealings ³³	Systematic Review	UK	2021	A6
3. Mogas-Recalde et al ²²	Systematic Review	Spain	2021	A6
4. Tomek and Urhahne ⁴⁵	Randomized Controlled Trial	Germany	2022	J2
5. Jaime et al ⁴⁶	Cohort study	Colombia	2016	N5
6. Summan et al ⁴⁴	Cohort study	Canada	2020	N7
7. Basner et al ²³	Narrative Review	USA	2014	I6
8. Stansfeld and Clark ⁴³	Narrative Review	UK	2015	I7
9. Piriälä et al ³⁹	Case Series	Finlandia	2020	JB7
10. Lin et al ³¹	Cross-sectional Study	USA	2020	N7
11. Samsuri et al ²¹	Cross-sectional Study	Malaysia	2021	N9
12. Pillay and Vieira ⁴⁰	Cross-sectional Study	South Africa	2020	N6
13. De Souza et al ²⁶	Cross-sectional Study	Brazil	2020	N8
14. Nusseck et al ³⁸	Cross-sectional Study	Germany	2022	N6
15. Lia et al ¹⁸	Cross-sectional Study	Italy	2019	N6
16. Karjalainen et al ³⁰	Cross-sectional Study	Sweden	2020	N8
17. Nedojedlá et al ³⁷	Cross-sectional Study	Czech Republic	2018	N7
18. Minichilli et al ³⁶	Cross-sectional Study	Italy	2018	N9
19. Ana et al ⁴⁷	Cross-sectional Study	Nigeria	2009	N7
20. Pujol et al ⁴¹	Cross-sectional Study	France	2013	N6
21. Hernandez et al ⁴⁸	Cross-sectional Study	Spain	2016	N6
22. Bitar et al ²⁴	Cross-sectional Study	Brazil	2018	N7
23. Dias et al ¹⁷	Cross-sectional Study	Brazil	2018	N7
24. Lesna and Skrodzka ³²	Cross-sectional Study	Poland	2010	N8
25. Mendes et al ³⁴	Cross-sectional Study	Brazil	2015	N5
26. Simoes-Zenari et al ⁴²	Cross-sectional Study	Brazil	2012	N6
27. Fernandes et al ²⁸	Cross-sectional Study	Brazil	2017	N6
28. Cutiva and Burdorf ²⁵	Cross-sectional Study	Holland	2015	N8
29. Jonsdottir et al ²⁹	Cross-sectional Study	Island	2015	N8
30. Gokdogan and Gokdogan ²⁷	Cross-sectional Study	Turkey	2016	N8

I: INSA Scale. N: Newcastle Ottawa Scale. J: JADAD Scale. A: AMSTARScale. JB: JBI Scale.

Table III. Extra-auditory effects and percentage of occurrence in articles.

Extra-auditory effects	Occurrence in %
Voice disturbances	43
Attention deficit	43
Stress	30
Sleep disorders	27
Irritability	27
Hypertension	23
Headache	17
Fatigue	7
Burnout	7

demonstrates an intermediate/high quality of the studies. The studies conducted in Italy and in Malaysia obtained the highest values (9).

In these articles^{17,18,21,25-33,35,37,40-44,46,47,51,52,23}, the extra-auditory effects found to be linked to noise exposure in schools were “voice disturbance”, “attention deficit”, “stress”, “irritability”, “hypertension” and “headache”.

In 62% of the original articles, the use of preventive measures, such as “sound-absorbing materials”, “structural and/or architectural modifications” and “voice training for teachers”, were the most used in preventing extra-auditory effects, followed by “noise reduction by modernizing the school’s furniture”, “noise awareness campaigns” and “school’s complete relocation”.

Discussion

This systematic review shows that there are still few studies evaluating the extra-auditory effects caused by noise exposure in the school environment. School workforce is not currently considered to be exposed to noise risk, both indoor and outdoor, so preventive measures are not always put in place. Most of the studies^{16,18,23,26,30-33,36,40-42,44} have shown voice disorders¹⁶ (aphonia

and phonasthenia due to the Lombard effect, in which teachers, as a result of environmental noise unconsciously increase the tone of their voices in order to be heard better), attention deficit, stress, sleep disorders, irritability, hypertension, headache, fatigue and burnout.

About the quality of the studies, the two narrative reviews had “INSA” scores of 6 and 7. Dias et al¹⁷, by measuring sound pressure levels and through a noise self-perception questionnaire, found that 85% of the professors surveyed reported speaking louder because of the noise in the classrooms and 75% reported voice fatigue after class. Another important study conducted in Italy by Lia et al¹⁸ considers the teacher’s profession at high risk for voice disorder also for symptoms of cognitive fatigue after work, attention deficit, anxiety, irritability, stress headache, decreased performance, hypertension, and sleep disturbance. Two original articles had a rate of 9 to the Newcastle Ottawa scale, which is the highest for this study.

Preventive measures were considered in only 16^{17,21,23,24,26,27,30,35,36,37,40-42,46,47,51} of the 30 studies, and the ones that were mostly mentioned were vocal training, structural modifications (such as replacing doors and windows to use more suitable ones), use of sound-absorbing material on walls and ceilings, noise awareness-raising for pupils and school staff, relocation of schools to non-urban areas or away from sources of noise pollution, construction of sound devices between the school and the street, and planting trees around schools to absorb noise from outside.

As an extension of the theory of maximum adaptability, it should be added that the effects of noise can occur immediately¹⁹, but also with a time delay²⁰. Studies showed that when a task is completed under noise, a deterioration in performance occurs only in subsequent tests. In these tests, the participants performed worse in proof-reading, for instance, and they also showed reduced frustration tolerance.

Table IV. Preventive measures.

Preventive Measures	Occurrence in %
Use of sound-absorbing material	36
Structural and/or architectural modifications	45
Voice training for teachers	27
School’s complete relocation	18
Noise awareness campaigns for pupils and teachers	18
Noise reduction by modernizing the school’s furniture	18
Building of sound absorbing devices between school and street	9

Conclusions

We can assume that, to date, as it has been pointed out by this study, these consequences are not taken into account at the legislative level for the protection of exposed workers. The extra-auditory effects that impact health as a result of exposure to environmental noise are manifold and widespread. Therefore, it is desirable that institutions take action and that the occupational physician of the school, when carrying out health surveillance, investigates the effects and clinical manifestations, in order to prevent the disorders, deficits highlighted by our study.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethics Approval

Not applicable.

Informed Consent

Not applicable.

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