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 after 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).

In all countries, therefore, noise in the workplace is one of the main causes of occupational illness. 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 damage. In scientific literature, 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 performance. 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 itself. 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 areas.

Materials and Methods

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

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) to assess the quality of narrative reviews, the “Newcastle Ottawa Scale” to evaluate cross-sectional and cohort studies, while the “JADAD scale” was applied for randomized clinical trials. The “AMSTAR tool” was used to assess the methodological quality of systematic reviews, and the “JBI tool” 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 review was conducted in the UK (INSA score: 7). The most significant is that 43% of studies detected “voice disturbances and attention deficit”, followed by “stress” (30% of reviews), “sleep disorders and irritability” (27%), “hyper-
tension” (23%), “headache” (17%), “fatigue” and “burnout” (7%) as extra-auditory effects due to noise exposure in schools.

Regarding the preventive measures, in narrative reviews24,45, “Noise awareness campaigns” was deemed as the most useful and effective in preventing extra-auditory effects due to noise exposure in schools.

Regarding the preventive measures, in narrative reviews24,45, “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 reviews23,34,36, 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 reviews23,34,36.

**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>
<thead>
<tr>
<th>Authors</th>
<th>Study Design</th>
<th>Country</th>
<th>Year</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Moreno et al35</td>
<td>Systematic Review</td>
<td>Colombia</td>
<td>2022</td>
<td>A8</td>
</tr>
<tr>
<td>2. Mealings33</td>
<td>Systematic Review</td>
<td>UK</td>
<td>2021</td>
<td>A6</td>
</tr>
<tr>
<td>4. Tomek and Urhahne45</td>
<td>Randomized Controlled Trial</td>
<td>Germany</td>
<td>2022</td>
<td>J2</td>
</tr>
<tr>
<td>5. Jaime et al44</td>
<td>Cohort study</td>
<td>Colombia</td>
<td>2016</td>
<td>N5</td>
</tr>
<tr>
<td>6. Summan et al34</td>
<td>Cohort study</td>
<td>Canada</td>
<td>2020</td>
<td>N7</td>
</tr>
<tr>
<td>8. Stansfeld and Clark47</td>
<td>Narrative Review</td>
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<td>2015</td>
<td>I7</td>
</tr>
<tr>
<td>10. Lin et al38</td>
<td>Cross-sectional Study</td>
<td>USA</td>
<td>2020</td>
<td>N7</td>
</tr>
<tr>
<td>11. Samsuri et al21</td>
<td>Cross-sectional Study</td>
<td>Malaysia</td>
<td>2021</td>
<td>N9</td>
</tr>
<tr>
<td>12. Pillay and Vieira40</td>
<td>Cross-sectional Study</td>
<td>South Africa</td>
<td>2020</td>
<td>N6</td>
</tr>
<tr>
<td>13. De Souza et al38</td>
<td>Cross-sectional Study</td>
<td>Brazil</td>
<td>2020</td>
<td>N8</td>
</tr>
<tr>
<td>14. Nusseck et al38</td>
<td>Cross-sectional Study</td>
<td>Germany</td>
<td>2022</td>
<td>N6</td>
</tr>
<tr>
<td>15. Lia et al39</td>
<td>Cross-sectional Study</td>
<td>Italy</td>
<td>2019</td>
<td>N6</td>
</tr>
<tr>
<td>17. Nedojedlá et al37</td>
<td>Cross-sectional Study</td>
<td>Czech Republic</td>
<td>2018</td>
<td>N7</td>
</tr>
<tr>
<td>18. Minichilli et al36</td>
<td>Cross-sectional Study</td>
<td>Italy</td>
<td>2018</td>
<td>N9</td>
</tr>
<tr>
<td>19. Ana et al37</td>
<td>Cross-sectional Study</td>
<td>Nigeria</td>
<td>2009</td>
<td>N7</td>
</tr>
<tr>
<td>20. Pujol et al41</td>
<td>Cross-sectional Study</td>
<td>France</td>
<td>2013</td>
<td>N6</td>
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<tr>
<td>22. Bitar et al4</td>
<td>Cross-sectional Study</td>
<td>Brazil</td>
<td>2018</td>
<td>N7</td>
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<tr>
<td>23. Dias et al17</td>
<td>Cross-sectional Study</td>
<td>Brazil</td>
<td>2018</td>
<td>N7</td>
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<tr>
<td>24. Lesna and Skrodzka12</td>
<td>Cross-sectional Study</td>
<td>Poland</td>
<td>2010</td>
<td>N8</td>
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<tr>
<td>25. Mendes et al14</td>
<td>Cross-sectional Study</td>
<td>Brazil</td>
<td>2015</td>
<td>N5</td>
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<td>27. Fernandes et al33</td>
<td>Cross-sectional Study</td>
<td>Brazil</td>
<td>2017</td>
<td>N6</td>
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<tr>
<td>28. Cutiva and Burdorf25</td>
<td>Cross-sectional Study</td>
<td>Holland</td>
<td>2015</td>
<td>N8</td>
</tr>
<tr>
<td>30. Gokdogan and Gokdogan27</td>
<td>Cross-sectional Study</td>
<td>Turkey</td>
<td>2016</td>
<td>N8</td>
</tr>
</tbody>
</table>

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

In these articles, 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 have shown voice disorders (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 al, 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 al 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 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 immediately, but also with a time delay. 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 proofreading, for instance, and they also showed reduced frustration tolerance.

### Table IV. Preventive measures.

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