Noise exposure of physical education and music teachers

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For teachers, as well as for many other non-industrial categories of workers, noise exposure was for a long time considered a negligible risk. In the last decade, however, many researchers have investigated the problem. These have underlined that physical education and music teachers can subsist not only uncomfortable, but also unacceptable and risky noise exposures which can induce hearing problems and stress. The noise exposure levels are nevertheless very variable both for physical education teachers and for music teachers and depend on many factors. In this article an analysis of the noise exposure levels on 75 physical education teachers of 18 schools and of 9 music teachers of an academy of music are presented. The results show that a percentage of 20–25% PE teachers can reach a weekly noise exposure higher than 80 dB(A) while for 7 of the 9 music teachers the noise exposure during a normal working week can exceed the limit value of 87 dB(A).

1. INTRODUCTION

Noise has been worldwide recognized as a risk agent to human health. In the Member States of the European Union, NIHL (noise induced hearing loss) is one of the most recognised occupational diseases[1] and its percentage on the total cost of compensation for occupational diseases (1999-2001)[2] represents about 10 %. The effect of the noise on the hearing is mainly the result of the combination of sound intensity and time exposure. Permanent damage to the inner ear can be caused by loud noise for sufficient time, but lower noise exposure has also a detrimental cumulative effect on the hearing mechanism during all the human life that, with a continuous exposure, cause slowly irreversible threshold shift in the frequency range between 3000-6000 Hz extending through the other frequencies. The consequences of NIHL are very large and involve many aspects of the individual life such as personals aspects (e.g. anxiety, irritability, self-esteem), social aspects (e.g. isolation and difficulty of communication) and economic (e.g. loss of productivity, expenses for workers' compensation, hearing aids)[3].

Schools are complex environments that must meet different requirements for the different functions to be carried out in them. Speech communication, study, music, sport activities and recreational activities need different levels of concentration and involvement for both pupils and teachers. The acoustic conditions in school environments are also very complex and depend on both the environmental noise caused by external noise sources of the school buildings, such as the transport infrastructure[4,5] and on noise produced internally by electric and mechanical systems (e.g. HVAC systems, personal computer, printer, etc.)[6]. Several national and international regulations and guidelines[7-10] recommend to limit the background noise and suggest and/or require minimum values of sound insulation between rooms and for the façades; they also suggest optimal reverberation times and noise emissions of equipment. The acoustic conditions have influence on the way teachers and pupils perform their specific activities.

The physical education (PE) teachers as well as music teachers represent teacher's category to which special attention should be payed for several reasons.

Gymnasia and swimming pools are generally built with acoustically poor materials (facing concrete and/or plaster), sport activities can be very noisy (rebounds of balls, calls, cries, run, etc.) and more classes can occupy and perform their sport activities at the same time[11-15]. As a consequence of the combination of long reverberation times and high background noises, speech intelligibility in these environments is rather poor. Physical education (PE) teachers are then forced to use blowing whistles to communicate with gymnasia and swimming pool users.

Equally also the music teachers can be most exposed to noise. This is due mainly to the fact that they work directly using the sound source responsible to their own sound exposure. The types of musical instrument, the way to play it, the contemporary playing of more than one musical instrument (by teachers and students) as the type of music played, can produce sound exposure levels that can easily exceed the limits recommended by the standards with a consequent risk for NIHL[16,17,18].

In this paper the results of two campaigns of measurements, made on 75 PE teachers of 18 schools[19] and on 9 music's teachers of an academy of music[20], are presented and discussed.

2. EU NOISE EXPOSURE REGULATION

In Europe, the Directive 2003/10/EC[21] of the European Parliament and the Council fixes the minimum health and safety requirements regarding the exposures of workers to the risk arising from noise. This Directive constitutes the key document to ensure the minimum health and safety requirements regarding the risk of noise exposures for workers.

The main indicators that this regulation takes into account are:

A. Peak sound pressure (P_{peak}): Maximum value of the "C" frequency weighted instantaneous noise pressure;

B. Daily noise exposure level ($L_{EX,8h}$) in dB(A) re. 20 mPa: time weighted average of the noise exposure levels for a nominal eight-hour working day as defined by international standard ISO 1999:1990[22]. It covers all noises present at work, including impulsive noise. If the work is such that the daily exposure consists of more periods with different sound levels, $L_{EX,8h}$ the combination of periods is ascertained using:

$$L_{EX,8h} = 10Log\left(\frac{\sum_{i=1}^{M} 10^{0,1L_{Aeq,Ti}} T_i}{T_o}\right) \quad (1)$$

where:
M is the number of individual periods in the working day;
T_i is the duration of period "i";
$L_{Aeq,Ti}$ is the equivalent continuous weighted sound pressure level that represents the sound level that the person is exposed to during a period "i";
T_o is 28,800 seconds (8 hours);

C. Weekly noise exposure level ($L_{EX,W}$) in dB(A) re. 20 mPa: time weighted average of the daily noise exposure levels for a nominal week of five eight-hour working days as defined by international standard ISO 1999:1990[22]. $L_{EX,W}$ is used when the exposure of an employee to noise varies markedly from day to day and is ascertained using:

Table 1. Exposure limit values and exposure action values defined in the Directive 2003/10/EC.

	$L_{EX,\,8h}$	P_{peak}
Exposure Limit Values:	87 dB(A)	200 Pa (140 dB (C) re. 20 μPa)
Upper Exposure Action Values:	85 dB(A)	140 Pa (137 dB (C) re. 20 _Pa) Lower
Exposure Action Values:	80 dB(A)	112 Pa (135 dB (C) re. 20 _Pa)

$$L_{EX,W} = 10 Log\left(\frac{1}{5}\sum_{K=1}^{m} 10^{0,1\left(L_{EX,8h}\right)_K}\right) \quad (2)$$

where:

k is the index representative of the working day; m is the number of days of the week;

$(L_{EX,\,8h})_K$ is the value of $L_{EX,8h}$ on the K-th working day.

These levels must be compared with the action values and with the limit values (Table 1) for each worker or group of workers.

3. CHARACTERIZATION OF THE TEACHING ROOMS

In a first phase the main architectural and acoustic characteristics of the teaching room were detected. The analyses on the gymnasia and swimming pools were conducted in 15 gymnasia and 3 swimming pools of primary and secondary schools and university structures (Figure 1).

The teaching rooms were chosen in order to cover all the existing architectural characteristics for sport buildings. For the gymnasia and swimming pools the room volumes varied between 320 m^3 (small gymnasium in a primary school) to 26000 m^3 (a large university swimming pool) and although the gymnasia and the swimming pools construction were not old, only 20% of the them presented sound absorbing material on the ceiling and/or on the walls (Table 2).

For the academy of music,

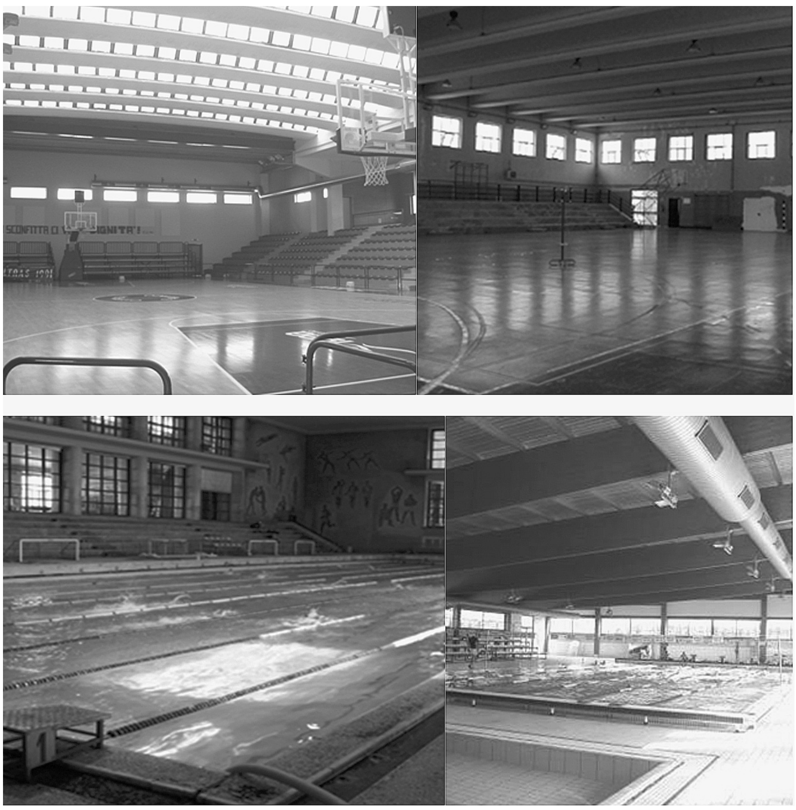

Figure 1. Some gymnasia and swimming pools investigated.

Table 2. Architectural and acoustics characteristics of the gymnasia and swimming pools. C: ceiling, W: side walls.

Id	V (m^3)	Form	Type of material	Type of school
Gym 1	2470	rectangular	C – W: reflecting	secondary
Gym 2	9500	rectangular	C – W: reflecting	secondary
Gym 3	10750	trapezoidal	C - W: reflecting	secondary
Gym 4	9200	trapezoidal	C - W: reflecting	secondary
Gym 5	590	rectangular	C - W: reflecting	primary
Gym 6	320	rectangular	C - W: reflecting	primary
Gym 7	356	rectangular	C: Absorbing, W: reflecting	primary
Gym 8	3520	rectangular	C - W: reflecting	primary
Gym 9	7000	horseshoe	C: Absorbing, W: reflecting	university
Gym 10	450	square	C: Absorbing, W: reflecting	university
Gym 11	1675	rectangular	C - W: reflecting	university
Gym 12	7875	rectangular	C - W: reflecting	university
Gym 13	1650	rectangular	C - W: reflecting	primary
Gym 14	6000	rectangular	C - W: reflecting	secondary
Gym 15	3120	rectangular	C - W: reflecting	secondary
Sw. P. 1	26000	rectangular	C - W: reflecting	university
Sw. P. 2	3800	rectangular	C - W: reflecting	primary
Sw. P. 3	5460	rectangular	C - W: Absorbing	university

considering the regularity of the teaching rooms and their characteristics, it was decided to perform the measurements only in one representative classroom, shown in the Figure 2. It has, as most of the other rooms, a dimension of about 100 m^3, masonry walls, roof type sound-absorbing materials, marble floor, two glass windows with wood grid, and a metal door. In its interior there are a piano, a wardrobe and two small tables with their chairs.

For each teaching room the reverberation time "T_{30}" in the central frequencies of 1/3 octave bands was measured according to ISO 3382[23] using the Maximum Length Sequences (MLS) technique. With this technique the cross-correlation function of digitally synthesized binary sequences, generated in the tested room by a loudspeaker, and of the output signal measured in a receiver point gives the impulse response of the room. The measurements were carried out using a

Figure 2. Examples of classroom.

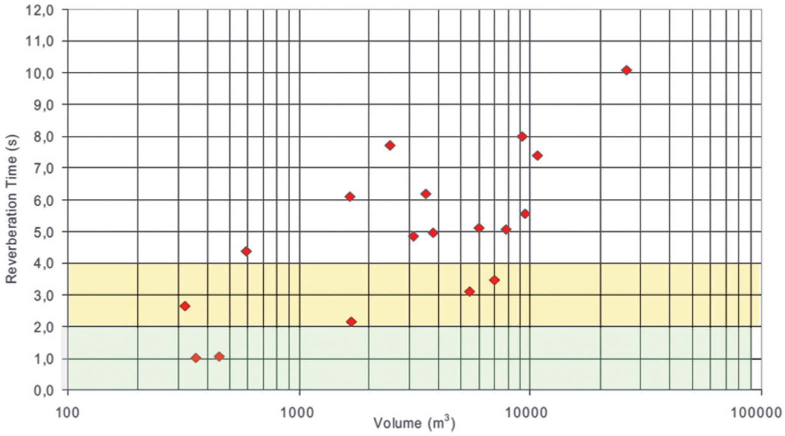

Figure 3. Average T_{30} (250-2000 Hz) as function of the volume of the buildings investigated.

two-channels acquisition unit, a loudspeaker and a software package that allows to perform a complete study of any building according to ISO3382[23]. The loudspeaker was placed in two different room positions, and for each position, the impulse responses were recorded in six different points with a microphone. In Figure 3 the average values of the reverberation time between 250 and 2000 Hz, referred to the volume of the gymnasia and swimming pool, are reported.

The results show that although national and international standards and regulations[8-10] recommend or impose average values of the reverberation time inside school gymnasia and swimming pools lower than 2,0 sec, only two small gymnasia fulfilled this requirement and only 4 others presented an average reverberation time between 2,0 and 4,0 sec. The results are significantly different for the representative teaching room of the music conservatory which average T_{30}, in the same range of frequency (250-2000 Hz), is lower than 1 s as recommended for educational environments (Table 3).

4. ANALYSIS OF THE ACTIVITIES

The physical education teachers as well as those of music have in common that they are exposed to highly fluctuating sound levels depending on the performing lesson. The physical education teachers, for example, can make students perform moderate activities as a warming up and/or they can lead exercises by the rhythmic hand beating or whistling. Other exercises require, instead, the use of balloons with the PE teacher being the referee of the students' match. The music teacher's sound exposure is strictly connected to the types of musical instruments used during the lessons.

Several preliminary meetings with school managements and physical education teachers have been organized to receive information about the weekly programming classes, the number of classrooms and the number of students present during classes in gyms and swimming pools. During the meetings, the name of the teacher, the daily and weekly hours of work, the main activities and the possible use of instruments (e.g. whistles, megaphones, etc.) have been reported. The meetings have permitted

Table 3. Averaged reverberation time (T30) values for the representative teaching room of the music conservatory

Frequency (Hz)	250	500	1000	2000
T30,average (s)	0,63	0,54	0,49	0,42

to identify various operating conditions in terms of types of activities, such as gymnastics with or without music, volleyball, basketball or diving, but also in terms of occupancy, such as the simultaneous presence of more than one class in the gym at the same time. The same approach was followed in the academy of music in which operate 107 teachers in 40 classrooms. Some classes perform activities such as scenic arts, general musical culture but in others musical instrument such as harp, violin, piano, saxophone, percussion and trumpets are played. Therefore, when assessing the exposure of music teachers it was critical to make a classification by type of class (with or without instruments) and instrument categories.

5. NOISE EXPOSURE ASSESSMENT OF PHYSICAL EDUCATION TEACHERS

5.1 IN SITU MEASUREMENTS

During each of the school activities a sound level meter class 1 was used to measure the sound levels $L_{Aeq,1h}$ in proximity of the position occupied by the PE teacher. The type of activities performed, the number of students present, the use of the whistle and other noticeable information were registered.

The continuous equivalent A-weighted sound pressure level $L_{Aeq,1h}$ measured during different lessons was quite variable reaching values between 70 and 87 dB(A) (Figure 4) while the $L_{max,peak}$ varied between 85 and 135 dB.

5.2 NOISE EXPOSURE

Afterwards the sound levels were combined with the relative weekly exposure times to evaluate the weekly noise exposure $L_{EX,w}$. Although the 75 PE teachers are engaged in activities inside gymnasia and swimming pools for less than 35 hours/week (Figure 5), 80% of them have a $L_{EX,w}$ higher than 75 dB(A) and for 25% of them $L_{EX,w}$ exceeds 80 dB(A).

The main factors that influence the noise exposure were then examined. It was found out that the noise exposure levels became higher than 80 dB(A) when at least 3 of the following conditions are present: (a) number of pupils > 30 (presence of more than one

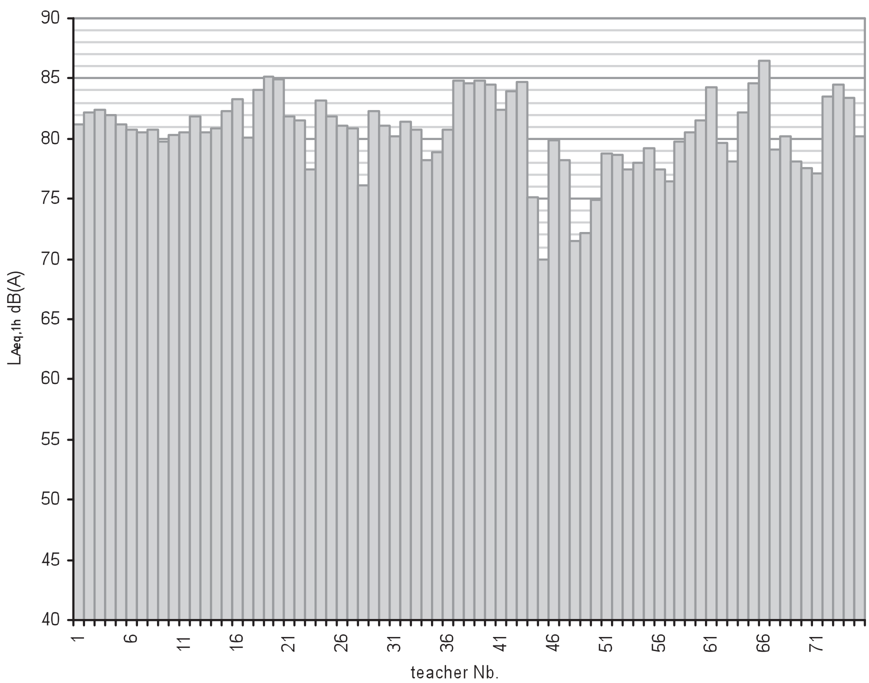

Figure 4. $L_{A,eq,1h}$ measured during the teaching activities of PE teachers

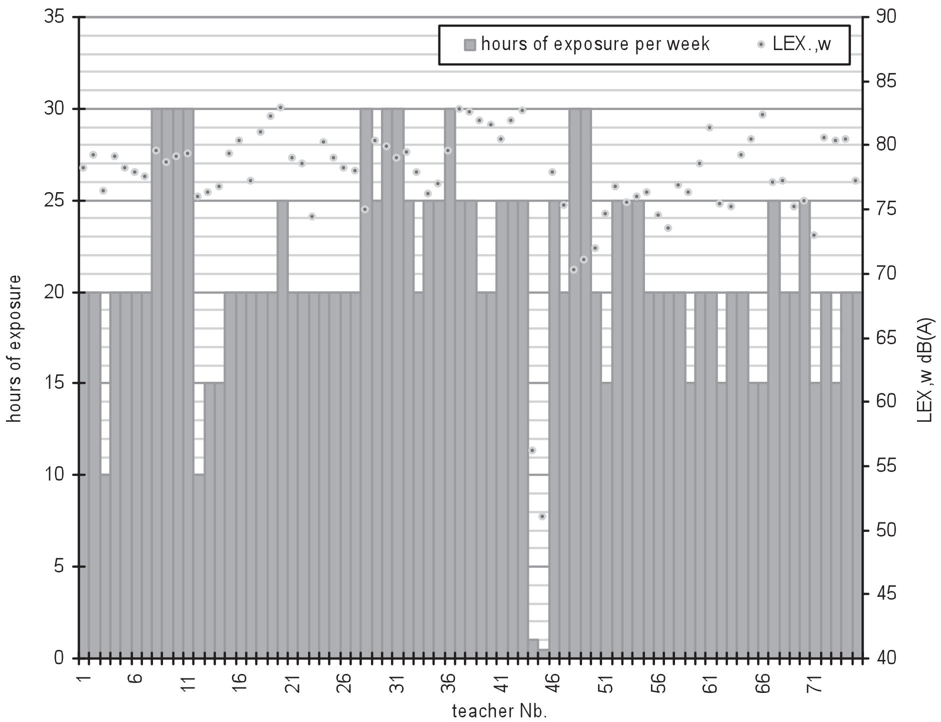

Figure 5. *Weekly exposure times and $L_{EX,w}$ in dB(A).*

class); (b) time exposure > 25 hours per week; (c) rebounds of balls during activities; (d) intensive use of blowing whistles; (e) reverberation time > 5 s. The age of the students seems to have less influence.

These assumptions were then verified conducting controlled tests with the simulation of the different types of exposition situations for the PE teachers[19].

Some measurements were repeated asking the PE teachers to wear a dosimeter (Figure 6). With whistle blowing, the L_{Aeq} measured with the worn dosimeter was 5–7 dB(A) higher than that measured with a sound level meter at 1 m from the position occupied by the teacher. The potential risk of NIHL for PE teachers that often use the whistle can be, therefore, even higher than expected. It was also alarming that

Figure 6. *Measurements with the dosimeter during the activities with the use of the whistle.*

none of the investigated PE teachers wears individual hear protectors during the lessons.

6. NOISE EXPOSURE OF MUSIC TEACHERS

6.1 IN SITU MEASUREMENTS

Several measurements were made in the academy of music during the normal activities using a class 1 sound level meter and a personal dosimeter. The sound level meter was positioned inside the classroom, away from reflective surfaces, at a height of 1,5 meter from the floor and in a position not disturbing teachers and students during the course of the lesson. The dosimeter was worn by the teachers during the lesson.

Nine teachers involved with different types of instruments were chosen. Four of them played the piano, while the others played saxophones, trumpets and trombone, harps, violins and one was a singer.

The A-weighted sound equivalent levels ($L_{A,eq}$) were measured during the different activities (Figure 7). The figure shows how the classes of trumpet and trombone as well as saxophone lead to very high "dosimetrics" levels, reaching respectively 106,6 and 98,8 dB(A). Moreover it can be seen that the differences among the measurements with the dosimeter and the sound level meter range between 9,7 dB(A) (piano 4) and a maximum of 17,3 dB(A) (piano 3), underlining clearly that the music piece and the way it is played, has a strong influence on the overall levels and should be considered during the measurements.

6.2 NOISE EXPOSURE

The evaluation of the noise exposure was done according to equations (1) and (2) of Directive 2003/10/EC considering the sound levels $L_{A,eq}$ measured with the sound level meter and the daily and weekly exposure times of the teachers: 6 hours/day and 12 hours per week. C-weighted peak levels ($L_{C,peak}$) were also considered and compared with noise limit values of table 1.

The time schedule of lessons suggested that, with the typical teachers' employment of 2 days per week, the $L_{EX,8h}$ is not representative for the teachers' exposure, so that the sound exposure level $L_{EX,W}$ must be considered. The results (Table 4) show that the highest level $L_{EX,W}$=101,4

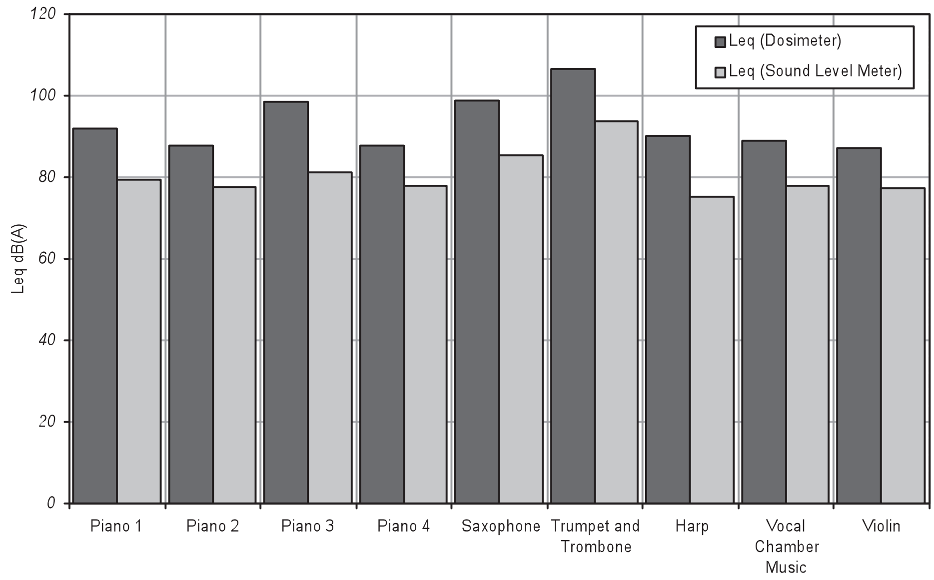

Figure 7. Comparison between the A-weighted sound equivalent levels measured with the dosimeter and the sound level meter.

Table 4. Noise exposure levels of music teachers.

Teacher	Class	$L_{EX,8h}$ dB(A)	$L_{EX,W}$ dB(A)	L_{peak} dB(C)
1	Piano 1	90,6	86,6	126,1
2	Piano 2	86,5	82,5	139,1
3	Piano 3	97,3	93,3	135,9
4	Piano 4	86,5	82,5	127,8
5	Saxophone	97,6	93,6	130,1
6	Trumpet and Trombone	105,4	101,4	133,3
7	Harp	89,0	85,0	126,1
8	Vocal Chamber Music	87,7	83,7	127,9
9	Violin	85,9	81,9	123,0

dB(A) occurs in the class of trumpets and trombones where the teacher and three students were playing in a small room of 48,6 m^3, while the lowest, of 81,9 dB(A) occurs, in a violin class with one student and a larger room (97,2 m^3). The C-weighted peak limits values $L_{peak,c}$ are always respected. The table shows also that, despite the short weekly working time, for all the teachers, the $L_{EX,W}$ exceed the lower exposure action value indicated by the Directive[20] and in three cases exceeds the limits value.

7. CONCLUSION

The noise exposure of PE teachers in school gymnasia and swimming pools is generally underestimated. A study conducted on 75 PE teachers showed that a percentage of 20–25% PE teachers could achieve a weekly noise exposure higher than 80 dB(A). In the survey the specific influence on the global noise exposure of the different activities performed in the gymnasia and swimming pools were identified.

The noise exposure conditions seem to be more alarming for the music teachers for which the weekly noise exposure levels exceed for all the examined subjects the lower exposure action value of 80 dB(A) and for three of them the limits value of 87 dB(A).

The study confirms that PE and music teachers represent a teachers' category to which it should be given special attention in order to reduce the risk of noise exposure.

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