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Evaluation of the noise exposure of symphonic orchestra musicians

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Abstract

For musicians, the impact of noise exposure is not yet fully characterized. Some inconsistencies can be found in the methodology used to evaluate noise exposure. This study aims to analyze the noise exposure of musicians in a symphonic orchestra to understand their risk for hearing loss, applying the methodology proposed by ISO 9612:2009. Noise levels were monitored among musicians during the rehearsal of eight different repertoires. Test subjects were selected according to their instrument and position in the orchestra. Participants wore noise dosimeters throughout the rehearsals. A sound meter was used to analyze the exposure of the conductor. The results showed that musicians are exposed to high noise levels that can damage hearing. Brass, woodwind and percussion and timpani musicians were exposed to noise levels in excess of the upper exposure action level of 85 dB (A), while the other instrumental groups had a lower exposure action level of 80 dB (A). Percussion musicians were exposed to high peak noise levels of 135 dB (C). Sound levels varied by instrument, repertoire and position. Octave frequency analyses showed differences among musicians. This study suggests that musicians are at risk for hearing loss. There is a need for more effective guidelines applicable to all countries, which should define standardized procedures for determining musician noise exposure and should allow exposure level normalization to the year, including different repertoires.

Keywords: Hearing loss, musicians, noise exposure, symphonic orchestra

Introduction

Exposure to loud environments is widely recognized as one of the most relevant and frequent risk factors in occupational environments, especially in industrial settings.^[1] Such exposure can result in several effects on worker health, including the development of noise-induced hearing loss (NIHL), which is the most frequent occupational disease in Europe.^[2] There are also some non-industry professional groups at risk for noise exposure due to their professional activities and typical exposure profiles. Professional orchestra musicians are one of these groups.^[3-6]

Previous studies have shown that orchestral musicians are frequently exposed to loud music,^[3-6] which can lead

to selective hearing loss at some frequencies,^[7-9] tinnitus, hyperacusis and diplacusis.^[8-11] Other effects can also occur, such as difficulty distinguishing changes in pitch from changes in intensity, recruitment and the cocktail-party effect.^[12] Tinnitus and hyperacusis are reported as the most common ear disorders.^[10,11] These disorders can result in difficulties with musical perception.^[13]

Despite the relevance of this issue, it seems that the problem of noise exposure is still not well characterized. Moreover, strategies for noise exposure assessment are not well established. Occupational noise legislation in some European countries, such as Portugal (Decree-Law n.º 182/2006^[14]), does not provide specific orientations for musicians. There is only a code of conduct provided in accordance with Directive 2003/10/CE^[15] that establishes general guidelines about how musicians should be protected from noise exposure. This is particularly critical considering that the hearing ability of musicians is crucial to their professional activity and performance.^[9,16] Without a reliable risk assessment for musician noise exposure, it is not possible to compare sound pressure levels with the current guidelines. It is also very difficult to define and implement an effective strategy to reduce the risk of NIHL.^[1]

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Previous studies involving orchestral musicians have revealed some important issues relevant to musician noise exposure characterization. During rehearsals and performances, sound pressure levels are high and vary according to the instrument.^[3-6,17] For example, using a large sample population, O'Brien *et al.*,^[6] measured average equivalent continuous sound pressure levels ($L_{p, A, eqT}$) from 81.2 to 88.8 dB (A) for strings, 86.2-89.4 dB (A) for woodwinds, 85.7-90.7 dB (A) for brass, 88-89.7 dB (A) for percussion and 86.2-88.6 dB (A) for timpani. The same authors observed high values for peak sound pressure level ($L_{p, Cpeak}$) for percussion and timpani. Other variables, including instrument type, repertoire,^[4,6] position in the orchestral structure and venue,^[6] also had significant impacts on the measured $L_{p, A, eqT}$. All these variables need to be considered to characterize musician noise exposure. Studies need to: (i) consider the differences among musicians in an orchestra according to their instrument and position in the orchestral structure, (ii) use a large sample size and (iii) cover the variability related to the range in type and level of noise in the repertoire, venue, rehearsal format and orchestral setup, individual variations and personnel.^[6,18]

This study aims to characterize the noise exposure levels of symphonic orchestral musicians applying the methodology proposed by ISO 9612:2009. Previous studies were inconsistent with respect to the methodology applied to evaluate the noise exposure of musicians. Furthermore, legislation does not consider the specific case of musicians. In this context, this study attempts to analyze the applicability of ISO 9612:2009 to musicians. A more in depth analysis of the influence of repertoire on noise levels is also performed. The intent is to provide some insight to guide future evaluations of the noise exposure of orchestral musicians.

Methods

Sound level measurements were made for musicians from a Portuguese symphonic orchestra. Due to orchestral dynamics, it was only possible to assess the noise levels during group rehearsals and general rehearsals for each repertoire in the analysis. Considering the variability related to the type and level of noise with changes in repertoire, rehearsals from eight different repertoires were analyzed. The repertoires were selected by the orchestral manager to be representative of the typical noise exposure. These repertoires are presented in Table 1.

Instruments

Measurements were performed using dosimeters and a sound level meter. Two Quest NoisePro dosimeters were used to measure $L_{p, A, eqT}$ and $L_{p, Cpeak}$. Seven CESVA DC112 dosimeters and one CESVA SC-310 sound level meter provided the $L_{p, A, eqT}$, $L_{p, Cpeak}$ and octave frequency data. All equipment was verified before and after each series of

measurements at 94 dB (A) with a sound calibrator, according to ISO 9612:2009.^[17]

After the field measurements, the data were transferred to the Capture Studio Editor Software (CESVA Instruments, S.L.U., Barcelona, Spain) and QuestSuite™ Professional Software (Quest Technologies, Oconomowoc, USA) for processing.

Measurement procedure

The aim of this study and the procedures were explained to all of the musicians. Each week, the orchestra manager sent to researchers the repertoire, the orchestra structure and the name of each musician. Based on this information, test subjects were selected in accordance with their instrument and position in the orchestra. For each repertoire, nine musicians and the conductor were simultaneously evaluated. To analyze the variability among rehearsals and repertoires, six of the musicians participated in every repertoire. The others musicians were different so that the data included the greatest possible number of situations. However, it was not always possible to measure the same musicians every time due to the absence of some instruments/musicians in different repertoires. In repertoire A, two violin I and two cello musicians were assessed at the same time to analyze position effects.

Noise levels were measured according to ISO 9612:2009.^[17] The assessment included daytime sampling conducted in a discreet manner so as not to disturb the normal behavior of the musicians. Participants wore noise dosimeters

Table 1: Repertoires assessed

Repertoire code	Repertoire
A	C. Carneiro: "Memento"; W.A. Mozart: "Symphony No. 41"; L. van Beethoven: "Symphony No. 7"
B	C.-M. Schonberg/B. Lowden: "Les Misérables"; F. Loewe/J. Green: "Gigi"; Y. Tiersen: "La Valse d'Amélie Poulain"; G. Gershwin: "An American in Paris"; G. Verdi: "La Traviata Prelude to Act 1"; A. Lloyd-Webber/C. Custer: "Phantom of the Opera"; J. Offenbach: "Les contes d'Hoffmann: Barcarolle" and "Orphée aux enfers"
C	A. Khachaturian: 3 excerpts from the ballet Gayane; S. Rachmaninoff: "Symphony No. 3"
D	D. Moreira: From Dawn to Twilight over Zabriskie point; L. van Beethoven: Symphony No. 4; E. Elgar: Concert for violin and orchestra
E	D. Shostakovich: Symphony No. 15; W.A. Mozart: concert for piano and orchestra No. 20; G. Rossini: William Tell Overture
F	H.W. Henze: "La Selva Incantata"; C. Saint-Saëns: "África, Op. 89"; C. Franck: "Symphonic variations"; Richard Strauss: "Alpine Symphony"
G	F. Lopes-Graça: Sinfonietta in memory of Haydn; J. Haydn: Symphony Concertante and "Symphony No. 99"; B. Martinů: Symphony Concertante
H	L. van Beethoven: "Leonora n° 3"; J. Brahms: "Symphony No. 3"; C. Saint-Saëns: "Symphony n° 3"

throughout the rehearsal. The microphone was located at a height of 4 cm above the shoulder of the test subject, without restricting movement. For string instruments, the microphone was positioned on the opposite shoulder of the instrument (i.e. the microphone was placed on the right side for string instruments). Musicians were instructed to be careful with the equipment, especially not to touch it, remove it on their own or speak directly into the microphone to prevent measurement errors. If a touch occurred, the musicians reported the situation. These disturbances were excluded from the data analysis. A sound meter was used to assess the noise exposure of the conductor. It was fixed on a support 10-30 cm from the ear.

Assessment criteria

In Europe, there is no specific legislation regulating musician noise exposure. Directive 2003/10/EC of the European parliament and of the council of 6 February 2003^[15] fixed the exposure limit values and exposure action values with respect to daily noise exposure levels ($L_{EX,8h}$) and peak sounds for all Member States as follows:

- Exposure limit values: $L_{EX,8h} = 87$ dB (A) and $L_{p,Cpeak} = 140$ dB (C), respectively
- Upper exposure action values: $L_{EX,8h} = 85$ dB (A) and $L_{p,Cpeak} = 137$ dB (C), respectively
- Lower exposure action values: $L_{EX,8h} = 80$ dB (A) and $L_{p,Cpeak} = 135$ dB (C), respectively.

Treatment of results

In this work, it was only possible to assess group and general rehearsals. We did not have access to performances. However, considering that performances are carried out in the same room and in the same conditions as the general rehearsals, we assumed that the noise levels were similar. Thus, noise exposure level determination was considered for the entire time the musicians spent with the orchestra.

According to some European legislation (e.g., Portugal), it is only possible to determine the level of daily exposure or weekly average exposure. Consequently, the average sound exposure level for a year, as presented in previous works, is beyond the scope of legislation. Therefore, exposure levels were normalized to a nominal week of five 8 h working days $\bar{L}_{EX,8h}$, in accordance with ISO 9612:2009.^[17] This included time spent at group and general rehearsals, as well

as in performances (using the same values obtained for the general rehearsal). Because no one is exposed to zero sound levels, $L_{p,A,eqT} = 70$ dB was used for the remaining periods as a conservative estimate, as specified in ISO 9612:2009.^[17]

Results

The orchestra was divided into five groups: Strings, woodwinds, brass, percussion and timpani. The conductor was also monitored. The strings included violin I and II, viola, cello and contrabass. The woodwinds comprised bassoon, saxophone, flute, clarinet, oboe, recorder and piccolo. Brass instruments included trombone, tuba, trumpet and French horn.

For each repertoire, the values for $L_{p,A,eqT}$ and $L_{p,Cpeak}$ were measured. Because rehearsals for each repertoire were carried out over 1 week, the was used for each repertoire. Table 2 summarizes the results for all repertoires for various instruments. It is important to note that in repertoire H, there was a technical problem with the dosimeters, so only five musicians were assessed. Furthermore, some measurements were eliminated due to irregular values.

The sound levels varied by instrument type from 78.9 to 89.7 dB (A) for strings, 84.9-96.8 dB (A) for woodwinds, 87.0-97.4 dB (A) for brass, 85.9-95.4 dB (A) for percussion and timpani and 77.2-86.3 dB (A) for conductors. In general, brass players were exposed to substantially higher sound levels than other musicians (92.7 ± 2.77), followed by woodwinds (90.5 ± 3.45) and percussion and timpani (90.0 ± 2.93). Lower noise levels were measured for strings (85.4 ± 3.40) and conductors (82.1 ± 2.56). For conductors, the noise levels were lower than for most of the musicians. This result suggests that noise levels decrease with distance from the brass section. Within the same group of instruments, the noise levels varied considerably. This result was related to different instruments within the group, as well as to the influence of the musician's position and the repertoire.

The results presented in Table 2 show higher levels for $L_{p,Cpeak}$ for percussion and timpani (129.6-135.0 dB (C)), achieving the lower exposure action level of 135 dB (C).

Table 2: Summarized data for $L_{p,A,eqT}$, $L_{p,Cpeak}$ and $\bar{L}_{EX,8h}$ by instruments groups

Instrument	$L_{p,A,eqT}$ dB (A)				$L_{p,Cpeak}$ dB (C)				$\bar{L}_{EX,8h}$ dB (A)				Number of measurements
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	
Strings	78.9	89.7	85.4	3.40	101.2	129.4	120.7	5.35	75.05	84.2	79.7	2.93	78
Woodwinds	84.9	96.8	90.5	3.45	115.4	131.1	122.6	4.30	80.29	91.9	85.0	3.25	42
Brass	87.0	97.4	92.7	2.77	120.1	133.4	128.2	4.44	82.29	92.6	87.7	2.97	40
Percussion and timpani	85.9	95.4	90.0	2.93	128.8	135.0	131.44	2.15	81.24	87.0	84.3	2.42	24
Conductor	77.2	86.3	82.1	2.56	107.7	120.4	114.5	3.92	72.07	81.6	76.5	2.67	24

SD = Standard deviation

To assess the risk of hearing loss, the noise exposure levels were determined and compared with legal requirements. Table 2 also presents the $\bar{L}_{EX,8h}$ for the instrument groups. The $\bar{L}_{EX,8h}$ of every instrument group in the orchestra exceeded the lower exposure action level (i.e., 80 dB (A)). Furthermore, the higher exposure action level (85 dB (A)) was exceeded by brass, woodwinds and percussion and timpani for some repertoires. Brass players suffered the most exposure (87.7 ± 2.97). Conductors and strings never exceeded the limits ($\bar{L}_{EX,8h} < 81.6$ dB (A) and $\bar{L}_{EX,8h} < 84.2$ dB (A), respectively).

The effect of repertoire was assessed for six musicians [Table 3]. The results correspond to noise levels for general rehearsals of different repertoires. Violin I and II, cello, flute, trombone and French horn were included in this assessment. Some results are not presented in Table 3 because the repertoires did not include all of the instruments or because of the absence of a specific musician. Moreover, in repertoire H, some regular musicians were not assessed due to technical problem with the dosimeters (only 5 musicians out of 10). The conductor was also assessed. Even though the conductor was different for each repertoire, he or she was always in the same position. Although there were no significant differences among rehearsals (Kruskal-Wallis test, $P > 0.05$ for all instruments), the results showed that there were important differences in noise levels among repertoires. Table 3 shows the difference between the highest and lowest $L_{p,A,eqT}$ values achieved for different repertoires. The differences in $L_{p,A,eqT}$ values among repertoires were greater than 3 dB (A), with 11.8 dB (A) obtained for flute.

Table 4 presents an analysis of two rehearsals for repertoire a using the same violinists and cellists, considering the instruments were most representative of the orchestra structure. There appears to be differences between the musicians for both instruments analyzed. The first musician was located at the periphery, and the second musician was located near the center of the orchestra. Musicians located at the periphery were exposed to less noise. According to Table 4 the difference in $L_{p,A,eqT}$ for the same musician between rehearsals was less than 3 dB (A), demonstrating that the exposure does not change significantly between rehearsals.

Given the limitations of our equipment, the octave frequency was analyzed only in some musicians, and the results of all assessed repertoires are summarized in Table 5. The results show differences in octaves frequency among the instruments

types. In general, strings, brass and percussion and timpani were more affected by frequencies of 500 Hz and 1000 Hz. The woodwinds were more affected by 1000 Hz and 2000 Hz frequencies. The conductor was more affected by 125 and 500 Hz frequencies.

Discussion

Studies that determine the noise exposure of musicians are scarce.^[3,4,6,17] This is likely due to a lack of knowledge about the number of hours that musicians are exposed to noise, as well as the need to assess different repertoires. With this in mind, we attempted to characterize the noise exposure levels of musicians, considering all the time that musicians practice with the orchestra, and using the methodology proposed by the ISO 9612:2009, analyzing its applicability to the specific case of musicians.

The results suggest that symphonic orchestral musicians are exposed to high noise levels, putting them at risk for developing hearing problems, such as tinnitus, hyperacusis and diplacusis,^[8-11] or even NIHL,^[7-9] that may constrain their performance. All instrument groups exceeded the lower exposure action level of 80 dB (A), and some of them presented levels of exposure above the higher exposure action level of 85 dB (A). In relation to the peak sound level, only percussion and timpani musicians were particularly at risk because the

Table 3: Influence of repertoire on noise exposure

Repertoire	$L_{p,A,eqT}$ dB (A)								Difference dB (A)
	A	B	C	D	E	F	G	H	
Violin I	88.1	89.4	86.2	85.0	84.2	83.9	81.1	85.9	8.3
Violin II	91.9	88.3	84.8	86.0	86.9	NA*	82.0	89.0	9.9
Cello	83.2	88.7	NA*	82.8	NA*	78.9	79.4	84.2	9.8
Flute	87.6	93.4	NA*	NA*	96.7	93.6	84.9	92.8	11.8
Trombone	NA*	94.5	93.1	92.3	90.7	95.7	NA*	NA*	3.4
French horn	91.8	95.1	89.3	87.0	NA*	96.2	NA*	NA*	9.2
Conductor	82.9	84.3	86.3	78.9	81.3	83.0	77.2	81.5	9.1

*No data due to the absence of the instrument in the repertoire or of the usual musician, NA = Not applicable

Table 4: Influence of position on noise exposure

	$L_{p,A,eqT}$ dB (A)		Difference dB (A)
	Musician 1	Musician 2	
Violin I 1 st rehearsal	84.2	87.6	3.4
Violin I 2 nd rehearsal	81.9	89.7	7.8
Cello 1 st rehearsal	81.8	83.8	2.0
Cello 2 nd rehearsal	82.8	84.4	1.6

Table 5: Summary of frequencies analysis

Instrument	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Strings	45.4-59.0	62.0-70.2	66.1-76.7	73.7-84.6	73.1-86.6	68.7-83.5	58.5-79.6	46.5-64.1
Woodwinds	43.0-55.2	60.7-74.3	67.6-81.5	79.1-88.4	79.6-94.3	76.9-93.8	65.6-76.6	49.7-63.8
Brass	47.4-59.8	65.2-77.4	72.5-84.0	83.2-93.8	82.4-94.7	77.7-91.2	66.8-81.7	48.9-74.2
Percussion and timpani	54.9-57.9	67.7-84.5	80.7-86.9	81.8-88.2	80.5-88.2	76.4-84.5	64.8-80.4	51.3-75.9
Conductor	65.6-76.9	76.2-82.8	72.7-81.7	76.8-83.1	72.6-80.9	67.6-77.7	62.1-71.7	49.1-60.8

$L_{p, Cpeak}$ values achieved the lower exposure action level of 135 dB (C). Our $L_{p, Cpeak}$ results were in line with previous studies.^[6] However, regarding the noise exposure results, our study differs substantially from other studies, in which noise levels were below 85 dB (A).^[4,5,17] Only Laitinen *et al.*^[3] verified that musicians were exposed to dangerous noise levels. These differences can be associated with the way in which $\bar{L}_{EX,8h}$ was determined. In our study, the exposure level was normalized to a nominal week, similar to Royster *et al.*^[13] According to Portuguese legal requirements, no exception exists for musicians. However, some of the studies used the average sound exposure level for a year.^[3,4,17] This method can better characterize a musician's exposure due to variability in the noise exposure level among different repertoires. This suggests that there is a need to consider the particular case of musicians in Portuguese legislation, as well as, in specific guidelines. Another difference was related to the way in which $\bar{L}_{EX,8h}$ was calculated. Previous studies used for the remaining exposure time a value of zero. However, considering that everyone is exposed to some level of sound, particularly musicians who practice alone for long hours, it is important to use $L_{p,A,eqT} = 70$ dB according to ISO 9612:2009^[19] as a conservative estimate. Ideally, the level of noise exposure during individual practice should be included, similar to Laitinen *et al.*,^[3] but this is not always possible. In addition, differences in the measurement strategy may contribute to differences in results across studies, particularly differences in the number of samples, as well as in the microphone location.^[3-5]

We tried to overcome some of the limitations of previous studies related to noise exposure determination, particularly the limitations related to the variability of instrument type, rehearsals and position on stage. We considered several sampling points and assessed a large number of musicians and rehearsals. An analysis of the impact of these variables was carried out. The values of $L_{p,A,eqT}$ varied by instrument type. Higher noise levels were found for brass, woodwinds and percussion and timpani instruments. Conductors and strings were exposed to less noise. The $L_{p,A,eqT}$ values varied greatly within each instrument group. This result was due either to differences in the instruments in the analysis, the influence of the musician's position in the orchestra structure or the repertoire.

The musician position is a very important factor for noise characterization.^[6] Musicians are not only exposed to the noise from their instrument but also to noises from their colleagues.^[20] For the same type of instrument, in particularly violins and cellos, the noise levels varies considerably according to stage position (i.e., the periphery is exposed to lower noise levels than the center). It is important to note that these differences can be related to individual differences during practice. However, considering the differences between the instruments, particularly for the violin I in the second rehearsal (difference of 7.8 dB (A)), the differences are most likely related to the position. There was also a

decrease in the noise levels based on the distance from brass (the noisiest instruments), as previously described by Lee *et al.*^[4] The strings were far from the brass and thus had lower $L_{p,A,eqT}$ values. Conductors are the farthest from the brass and thus had $L_{p,A,eqT}$ values substantially lower than most of the musicians. Therefore, it is important to assess musicians based on their positions within each instrument group, as recommended by O'Brien *et al.*^[6]

We also showed that $L_{p,A,eqT}$ values varied considerably with repertoire. These results can be related to differences in the program, the number of musicians on stage and the type of instruments included in each repertoire.^[6] The conductor can also influence these results. Some conductors prefer the orchestra to play fortissimo in the course of rehearsals. Others request that musicians play more softly.^[12] As a result, it is essential to include different repertoires, as well as to consider several sampling points, to characterize the noise exposure. Otherwise, the data will not be representative.

It is important to note that this study has one important limitation. We were only able to measure sound levels in group rehearsals and general rehearsals, the last one as estimate of the performance exposure. Outside individual practice activity was not considered because individual practice was performed in the musicians' homes. Moreover, non-orchestral activities differ among musicians, making it difficult to estimate noise exposure. In fact, exist a clear difficulty for all that is needed to assess the musicians' noise exposure. There has been considerable discussion about the importance of including individual practice noise exposition for over 20 years.^[3,13,21] The sound levels during individual practice can potentially be as damaging as orchestra rehearsals and performances. In some of the cases, practice noise levels may be considerably high, representing a significant source of noise exposure.^[3,13] Factors related to noise exposure during practice include how continuously the musician practices and how often they repeat more difficult louder passages.^[13] Others activities carried out by musicians, such as teaching, can also provide exposure.^[21] It is therefore hypothesized that musician exposure is higher than that observed in our study. Using 70 dB (A) for periods outside of rehearsals and performances helps to compensate for this limitation. However, this value can be lower than reality, as shown by Laitinen *et al.*^[3] Future studies on the impact of individual practice will be important for more accurate characterization of noise exposure.

Another important limitation is related to the dosimeter microphone position for the string instruments. The dosimeters were placed on the right shoulders, close to the ear that receives less exposure. This may have introduced an error factor into the measurements. According to Schmidt *et al.*,^[18] this can lead to a difference of 4.6 dB (A). However, this is a limitation that is difficult to solve due to dosimeter limitations.

The octave frequencies were analyzed for only some musicians. This analysis is not common for studies on

musician noise exposure. Only Emmerich *et al.*^[22] analyzed the frequency spectra. There were differences in octave frequencies among instrument types. Therefore, the characteristics of noise exposure are different for different instrument types. The contribution of octave frequencies analysis is not only important for implementation of noise exposure reduction measures. Frequency data can be also important for understanding adverse health effects in musicians related to noise exposure. Different frequencies can have different effects on individuals.^[23] Consequently, it is important to know not only the levels of a musician's noise exposure but also the characteristics of the sound spectrum to better understand the effects on the musician's auditory and non-auditory systems.^[8-11]

The implementation of noise reduction measures is essential. The use of hearing protectors is the most commonly used measure;^[3-5,7,8] however, musicians are reluctant to use these devices because they change the perception of how an instrument sounds.^[10,11] As a result, there is inadequate use of hearing protection by musicians. The absence of the implementation of a correct Hearing Conservation Program may be related to a lack of use of hearing protection.^[24] Taking breaks during practice, rotating musicians, using screens, increasing the distance among instruments, intervening in performance and rehearsal environments and controlling the health status of musicians are also used to protect hearing.^[4,5,7,8,11,12] However, the efficacy of these measures has not been well studied.

Conclusion

More attention to musician noise exposure is recommended. Orchestral musicians are at risk for hearing damage. There is a need to implement risk reduction measures and to inform musicians of the risk that they are exposed.

It is important to note that musicians are not adequately covered by legislation, as is the case in much of Europe, including Portugal. As a result, measures to reduce noise exposure levels cannot be applied. Musicians may be exposed to dangerous noise levels that may constrain their performance or even make them unable to practice music.

The methodology proposed by ISO 9612:2009^[19] was used to determine musician noise exposure. It was possible to determine the level of noise exposure, providing results different from the majority of the past studies and highlighting the fact that musicians encounter noise levels in excess of legal requirements. There is a need for more effective guidelines applicable to all countries. These guidelines should define standardized procedures for determining musician noise exposure and should allow exposure level normalization to the year, including different repertoires. Previous studies present different measurement strategies and $\bar{L}_{EX,8h}$ calculation methods. This leads to different results,

making it difficult to characterize musician noise exposure. In some cases, musicians can be classified as non-exposed, but in reality, they are highly exposed. In Portugal, only exist a translation of Reid and Holland^[12] guidelines for determining musician noise exposure. However, some aspects, particularly those related to determination, remain unclear. There are also important issues related to individual practice. This is a difficult activity to assess because the number of hours spent practicing varies by musician. Practice location also influences this activity, leading to differences among musicians in the same orchestra. An indicative value to be used for each instrument group could make it easier to determine the level of noise exposure.

Despite studies describing the problem of musician noise exposure, this issue remains poorly characterized. Further studies are needed to relate factors such as individual practice and the effectiveness and applicability of the measures to reduce exposure and increase awareness of risks.

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