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Noise risk assessment and health surveillance in the Italian state police band musicians: A cross-sectional study

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Abstract

Introduction: The State Police Band musicians are subjected to high levels of sound exposure during rehearsals and performances. This study assesses the noise risk among these musicians, employing various measurement and calculation methodologies to understand their exposure and propose preventive measures.

Methods: A cross-sectional study was conducted with authorization from the Central Health Directorate of the Italian State Police Health Service. The study population included 93 musicians, divided into Acoustically Homogeneous Groups (GAO). Phonometric and dosimetric measurements were taken on July 25-26 and October 24, 2022, in both combined and separate sections. The methodologies used included evaluations based on GAO, Recurring Week of Maximum Risk ($L_{EX,w}$), and task-based daily exposure ($L_{EX,8H}$). The attenuation provided by hearing protection devices (HPDs) was also assessed using the OMB method. Audiometric tests were conducted to evaluate the musicians' hearing capabilities.

Results: The results indicated that the $L_{EX,W}$ exceeded the exposure limit in all GAOs during the Recurring Week of Maximum Risk. Task-based daily exposure $L_{EX,8H}$ showed that some GAOs in both combined (trombones, euphonium) and separate sections (clarinets, trumpets, oboe, tubas,

trombones) exceeded the limit value of 87 dB(A). The HPDs provided to the musicians were found to offer acceptable protection. No values exceeded the lower action peak value of 135 dB(C). Audiometric tests revealed that 28% of musicians had hearing deficits, predominantly sensorineural, with the highest incidences in the trumpet, trombone, percussion, and euphonium GAOs.

Discussion and Conclusion: Task-based daily exposure assessment provided more realistic individual noise exposure values, highlighting the importance of considering the acoustic properties and size of rehearsal spaces. Larger spaces with better acoustics, such as the renovated large music hall, resulted in lower exposure levels compared to smaller practice rooms. Despite acceptable HPD attenuation, some GAOs still experienced high exposure levels, necessitating further preventive measures. Key preventive and protective measures include practicing in larger spaces, reducing the number of activities, increasing breaks, rotating musicians' positions, and using customized HPDs. Regular phonometric surveys and adequate training and information for musicians are essential for effective noise risk management. Further research is needed to explore the impact of other health factors and improve HPD compliance among musicians.

Keywords: Audiometric tests; musicians; noise exposure; hearing protection; occupational health; phonometric measurements; State Police Band; task-based strategy.

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INTRODUCTION

The assessment of noise risk among musicians in the State Police Band is crucial for safeguarding the health of these orchestral performers who are exposed to high sound levels during both rehearsals and performances. Generally, police officers are exposed to noise risks in various work circumstances, such as urban traffic or public events. However, specific groups, like firearms instructors and musicians, face higher risks due to the nature of their activities.

The Italian State Police Band, consisting of approximately 90 musicians from prestigious conservatories, plays a significant role in promoting music through numerous events in Italy and abroad. Their activities mainly involve daily rehearsals and seasonal concerts, resulting in continuous and variable exposure to sound, which puts musicians at risk of auditory damage.

Factors such as hypertension, smoking, alcohol consumption, ototoxic medication use, leisure noise exposure, and past acoustic traumas can significantly affect auditory performance. Nonetheless, age, the extent, and the duration of noise exposure are critical factors influencing hearing damage [1,2]. Specifically, professional musicians are regularly exposed to high sound levels, with certain instruments capable of producing sounds exceeding 100 dB(A), especially when played at high intensity [3].

Musicians' exposure to noise does not end with their work hours. Continuous practice is necessary for maintaining and refining their musical technique, contributing to significant "extra-occupational" noise exposure. Instruments vary widely in their sound levels and frequencies, from 40 dB(A) for a

very soft sound to over 100 dB(A) for a very loud sound [4]. Smaller, high-pitched instruments like flutes generally produce less sound than larger, low-pitched instruments. However, the human ear is more sensitive to mid-high frequencies (1 kHz - 4 kHz), which are commonly produced by instruments played close to the musician's ear, such as violins.

Given these factors, musicians can be considered at risk from a noise exposure perspective, as they are subjected to high-intensity sounds not only from their instruments but also from those nearby. Additionally, reflected sound due to poor absorption by rehearsal room walls can exacerbate this exposure. Therefore, comprehensive noise risk assessment, including sound level measurements, is crucial for accurate prevention and health protection [5].

Mitigating noise exposure for musicians is more challenging compared to other noise-exposed professions. Standard noise reduction measures used in industrial settings, such as reducing sound production at the source, are impractical for musical instruments designed to produce sound. Efforts can be made to limit sound propagation in rehearsal rooms, balancing the need for acoustically suitable environments without excessive reverberation, which is critical for both rehearsals and performances [6].

The essential acoustic parameter for a rehearsal room is the reverberation time, defined as the duration for sound to decay by 60 dB after the source stops. An optimal rehearsal room should have a moderate reverberation time to avoid elevated sound levels and ensure sound clarity. In contrast, a concert hall should have a higher reverberation time to provide an immersive listening experience for the audience [7].

Despite the challenges, effective prevention for musicians includes regular medical surveillance, incorporating audiometric tests and specialist evaluations as needed. Personalized hearing protection devices (HPDs) designed for musicians, which reduce sound levels uniformly across frequencies, can also help preserve sound quality and instrument timbre [8].

This study aims to measure noise exposure among the musicians of the Italian State Police Band during rehearsals, both in combined and separate sections, and to compare these findings with available audiometric data. This comparison is essential for supporting targeted medical surveillance and implementing technical preventive measures to reduce the risk of hearing damage among musicians.

METHODS

Study design and ethical considerations

This cross-sectional study was conducted with the authorization of the Central Health Directorate of the State Police Health Service. Ethical considerations were strictly adhered to, ensuring that the study aligned with the principles of the Declaration of Helsinki. Informed consent was obtained from all participants, and confidentiality of the data was maintained throughout the study

Study population

The study population consisted of a convenience sample of 93 musicians from the State Police Band, including 80 men and 13 women, who are subject to health surveillance. Table 1 shows the distribution of the population by age group.

Table 1. Study population by age group.

Age Group	Total	Men	Women
20-30 years	7	5	2
31-40 years	26	24	2
41-50 years	25	22	3
51-60 years	35	29	6
Total	**93**	**80**	**13**

The musicians were divided into Acoustically Homogeneous Groups (GAOs: Saxophones, Oboes, Clarinets, Euphoniums, Tubas, Trombones, Trumpets, Percussion, and Conductors) likely subjected to similar noise exposures during their workday. The number of musicians in each homogeneous group is shown in Table 2.

Table 2. Study population by GAO.

Homogeneous Group	Total
Saxophones	10
Oboes	1
Clarinets	26
Euphoniums	15
Tubas	8
Trombones	5
Trumpets	7
Percussion	9
Conductors	2
Total	**83**

In addition to the GAOs listed above, 8 other musicians were not included in the homogeneous groups due to the heterogeneity of their instruments (e.g., piano, harp, guitar) and were not subjected to sound level measurements.

Measurement procedure

On July 25-26 and October 24, 2023, INAIL technicians conducted sound intensity measurements during the State Police Band's performances to verify the musicians' and conductors' noise exposure levels. The equipment used included a Class I integrating sound level meter and analyzer with 8 Real-Time Sound Book channels, Panasonic CF19 PC, Bruel & Kjaer microphone cables, SVANTEK dosimeters, and a Bruel & Kjaer calibrator.

Phonometric measurements were performed during musical activities in both combined and separate sections. In the large music hall, the band performed pieces representing high sound intensity to simulate a concert ("The Pines of the Appian Way," "Tribute to Duke Ellington," "Libertadores," "Capriccio," and "Australian Variant Suite"). Separate section rehearsals included pieces like "Giocondità," "Tarantella," "Fulgida," "The Three Dots," "Stars and Stripes," "Fribourg," and "Just a Closer Walk."

The measurement and calculation strategy followed the UNI EN ISO 9612:2011 standard and INAIL. Italian Guidelines for the music and recreational sector (March 7, 2012). Each musical piece was considered a distinct work activity with specific sound intensity and duration. Daily exposure ($LEX_{,8h}$) was calculated as the sum of the number of pieces performed during a concert rehearsal and separate section rehearsals, according to formulas in UNI EN ISO 9612:2011.

To simplify noise risk assessment, the average Leq,A value of three high-intensity pieces, each lasting 15 minutes, was considered typical for combined section rehearsals. Similarly, a 5-minute piece was considered typical for separate section rehearsals. The actual exposure for both combined and separate rehearsals was the sum of all pieces performed, excluding breaks. Background noise was not significant for musicians' exposure.

After determining the $LEX_{,8h}$ for each GAO, the weekly exposure ($LEX_{,w}$) was calculated. The evaluation was based on the Recurring Week of Maximum Risk (SRMR) concept, considering the third worst week of exposure in the previous year, expected to recur in future years. During the SRMR, musicians followed a schedule of combined section rehearsals (four days per week) and separate section rehearsals (two days per week), with varying rehearsal durations.

SRMR schedule for band musicians

- **Monday**
  - Morning: Combined Section Rehearsals (9:00-10:20)
  - Afternoon: Separate Section Rehearsals (14:30-17:30)
    - Woodwinds: 14:30-15:30
    - Saxophones and Low Reeds: 16:00-17:00
    - Brass: 14:30-17:30
    - Trumpets, Soprano Cornets: 14:30-15:30
    - Horns, Tenor Cornets: 16:00-17:00
    - Percussion: 14:30-15:30
- **Tuesday**
  - Morning: Combined Section Rehearsals (9:00-10:20)
- **Wednesday**
  - Morning: Separate Section Rehearsals
    - Woodwinds: 9:00-10:30
    - Brass and Percussion: 10:30-11:50
- **Thursday**
  - Morning: Separate Section Rehearsals
    - Brass and Percussion: 9:00-10:20
    - Woodwinds: 10:30-12:00
- **Friday**
  - Morning: Combined Section Rehearsals (9:00-10:20)
- **Saturday**
  - Morning: Combined Section Rehearsals (9:00-10:20)
- **Sunday**
  - Rest

Instrumental measurements were performed under normal working conditions, randomly, during the SRMR, considering representative pieces as individual tasks and including work pauses. Peak (C) levels were recorded during the three most intense pieces. Peak values were found to be non-impulsive, based on frequency analysis and effective dB(C) values. The attenuation level of custom-made ear protectors (Elacin brand, with ER9, ER15, and ER25 filters) was calculated using the OBM method, considering a high-intensity piece performed during combined section rehearsals.

During combined section rehearsals, sound level meters were placed at various positions in the large music hall, as shown in Table 3.

Table 3. Measurement positions in the large music hall (combined sections).

Position	Location (at ear level)
1	Between Trumpets (1I), Bassoons (5B), and Clarinets (1F)
2	Between Cornets (6K), Tubas, and Saxophones (8G)
3	Between Horns (4H, 1H) and Flutes
4	Between Percussion (3L, 6L) and Trumpets (3I)
5	Between Euphoniums and Tubas

During separate section rehearsals, sound level meters and dosimeters were placed in different positions, as illustrated in Table 4.

Table 4. Measurement positions in the music practice rooms (separate sections).

Microphones	Location (at ear level)
1	Percussion
2	Saxophones
3	Oboes
4	Clarinets
5	Clarinets
6	Trumpets
7	Trombones
Dosimeter 1	Small Clarinet
Dosimeter 2	Conductor

Finally, between July and September 2022, musicians underwent a pure tone audiometry test (air and bone conduction) to assess hearing ability. The tests were conducted in a soundproof booth, with workers in acoustic rest for at least 12 hours. Air conduction testing was performed at frequencies 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz, and bone conduction at 0.25, 0.5, 1, 2, 3, and 4 kHz, following ISO 6189 procedures, preceded by an otoscopic examination.

RESULTS

The phonometric and dosimetric measurements conducted on July 25-26, 2022, and October 24, 2022, yielded the following results.

Combined sections in the large music hall (July 25, 2022)

Measurements were taken during the performance of three pieces: "The Pines of the Appian Way," "Libertadores," and "Tribute to Duke Ellington." Table 11 shows the equivalent levels (Lp,A,eqT,mi) and peak levels (Lp, Cpeak MAX) for each Acoustically Homogeneous Group (GAO).

Table 5. Equivalent levels for three pieces by GAO in the large music hall (combined sections).

GAO	Lp,A,eqT,mi (dBA)	Lp,Cpeak MAX (dBC)	Lp,A,eqT,mi (dBA)	Lp,Cpeak MAX (dBC)	Lp,A,eqT,mi (dBA)	Lp,Cpeak MAX (dBC)	Average L_{Aeq} (dBA) of Three Pieces
Saxophones	91.0	127.7	96.4	117.9	95.8	116.7	94.40
Euphoniums	94.1	125.5	97.0	125.5	98.1	121.6	96.40
Tubas	90.2	124.1	95.6	119.9	93.5	116.2	93.10
Trombones	95.9	130.8	102.2	126.2	100.2	125.0	99.40
Percussion	94.5	128.1	95.7	123.5	94.5	123.8	94.90
Oboe	95.6	119.4	95.1	116.0	94.7	114.6	95.10
Clarinets	94.9	117.5	96.3	117.4	93.6	114.1	94.90
Trumpets	92.7	115.5	95.1	117.0	96.6	118.1	94.80
Conductors	88.7	116.5	89.1	112.0	86.6	111.1	88.10

Separate sections in the music practice rooms

July 25, 2022 (Woodwinds): Pieces performed: "Giocondità," "Tarantella," "Fulgida." Table 6 shows the equivalent levels for the pieces by GAO.

Table 6. Equivalent levels for three pieces by GAO in music practice rooms (woodwinds).

Microphones	Positions	LAeq	LcPeak	LAeq	LcPeak	LAeq	LcPeak
1	Percussion	96.7	126.5	94.5	126.4	91.5	123
2	Saxophones	96.3	121.2	95.8	120.1	93.4	119.3
3	Oboe	97.9	120.8	97.3	119.2	96.6	120.6
4	Clarinet/Bassoon	95.2	119.7	94.8	118.1	93.8	116.5
5	Clarinet	96.1	116.3	97.2	115.2	95.6	116.6
Dosimeter 1	Small Clarinet	95.6	118.9	94.8	118.5	94.3	114.9
Dosimeter 2	Conductor	90.3	110.8	89.8	112.6	88.9	115.6

July 26, 2022 (Woodwinds): Pieces performed: "The Three Dots," "Just a Closer Walk." Table 7 shows the equivalent levels for the pieces by GAO.

Table 7. Equivalent levels for two pieces by GAO in music practice rooms (woodwinds).

Microphones	Positions	LAeq	LcPeak	LAeq	LcPeak
1	Percussion	94.1	128.1	90.6	123.3
2	Saxophones	101.8	124.1	97.6	121.8
3	Oboe	100.6	121.5	98.8	119.6
4	Bassoon	95.1	123.5	92.4	122.7
5	Clarinets	100	120.2	97.8	119.1

July 26, 2022 (Saxophones): Pieces performed: "Stars and Stripes," "Fulgida." Table 8 shows the equivalent levels for the pieces by GAO.

Table 8. Equivalent levels for two pieces by GAO in music practice rooms (saxophones).

Microphones	Positions	LAeq	LcPeak	LAeq	LcPeak
Ch1	Alto Soprano Saxophone	94.4	127.5	91.5	123
Ch2	Tenor Saxophone	95.0	123.7	93.4	119.3
Ch3	Baritone Saxophone	96.3	121.2	96.6	120.6
Ch4	Alto Saxophone	94.6	118.9	93.8	116.5
Ch5	Center of Room	95.2	116.4	95.6	116.5

July 26, 2022 (Percussion): Pieces performed: "Fribourg," "Tarantella." Table 9 shows the equivalent levels for the pieces by GAO.

Table 9. Equivalent levels for two pieces by GAO in music practice rooms (percussion).

Microphones	Positions	LAeq	LcPeak	LAeq	LcPeak
Ch1	Snare Drum	93.1	125.6	101.6	129.3
Ch2	Xylophone	93.7	120.0	98.8	121.3
Ch3	Drum Kit	96.3	120.9	100.3	120.2
Ch4	Timpani	94.5	117.7	97.5	119.9
Ch5	Center of Room	96.7	116.8	97.5	114.9

Combined sections in the large music hall (October 24, 2022)

Measurements were taken during the performance of "Capriccio." Table 10 shows the equivalent levels for the piece by GAO.

Table 10. Equivalent levels for "Capriccio" by GAO in the large music hall (combined sections).

GAO	Lp,A,eqT,mi (dBA)	Lp,Cpeak MAX (dBC)
Saxophones	88.8	117.0
Tubas	86.0	117.0
Trombones	91.1	123.0
Percussion	87.9	125.4
Oboe	90.9	115.7

GAO	**Lp,A,eqT,mi (dBA)**	**Lp,Cpeak MAX (dBC)**
Clarinets	88.8	113.9
Trumpets	87.9	116.9

Daily Personal Noise Exposure Levels (LEX,$_{8H}$) by GAO

Based on the measurements and considering the Recurring Week of Maximum Risk (SRMR), the daily personal noise exposure levels (LEX,$_{8H}$) were calculated for each GAO. Tables 11-13 show the LEX,$_{8H}$ for combined and separate sections rehearsals.

Table 11. LEX,$_{8H}$ for each GAO on Monday (combined and separate sections).

GAO	**Large Music Hall** LEX,$_{8H}$ **(dBA)**	**Practice Room** LEX,$_{8H}$ **(dBA)**	**Total** LEX,$_{8H}$ **(dBA)**
Saxophones	83.77	85.00	84.11
Euphoniums	86.10	-	86.10
Tubas	82.77	91.00	88.50
Trombones	88.70	85.00	87.44
Percussion	84.57	84.00	84.00
Oboe	84.77	87.00	85.75
Clarinets	84.27	86.00	85.11
Trumpets	83.70	90.00	87.70
Conductor	77.77	79.00	78.11

Table 12. LEX,$_{8H}$ for each GAO on Tuesday, Friday, and Saturday (combined sections).

GAO	**Large Music Hall** LEX,$_{8H}$ **(dBA)**
Saxophones	83.77
Euphoniums	86.10
Tubas	82.77
Trombones	88.70
Percussion	84.57
Oboe	84.77
Clarinets	84.27
Trumpets	83.70
Conductor	77.77

Table 13. LEX,$_{8H}$ for each GAO on Wednesday and Thursday (separate sections).

GAO	**Practice Room** LEX,$_{8H}$ **(dBA)**
Saxophones	86.76
Trombones	86.76
Percussion	85.76

GAO	**Practice Room** $LEX_{,8H}$ **(dBA)**
Oboe	89.16
Clarinets	88.16
Trumpets	91.76
Tubas	92.76
Conductor	81.56

Weekly Personal Noise Exposure Levels ($LEX_{,W}$) by GAO

Based on the $LEX_{,8H}$ results, the weekly personal noise exposure levels (**$LEX_{,W}$**) were calculated for each GAO during the SRMR. Table 14 shows the **$LEX_{,W}$** for each GAO and the conductors.

Table 14. $LEX_{,W}$ for each GAO and conductors during the SRMR.

GAO	**$LEX_{,W}$ (dBA)**	**Extended Uncertainty (U)**	**$LEX_{,W}$ + Extended Uncertainty (dBA)**
Saxophones	85.40	1.9	87.30
Trumpets	89.00	1.9	90.90
Trombones	89.20	2.0	91.20
Clarinets	86.00	1.9	87.90
Euphoniums	86.00	1.9	87.90
Oboe	86.90	1.9	88.80
Tubas	90.00	1.9	91.90
Percussion	85.80	1.9	87.70
Conductor	80.20	1.7	81.90

Audiometric Exam Results

Musicians underwent pure tone audiometry (air and bone conduction). The results are summarized in Table 15.

Table 15. Audiometric exam results by gender.

Gender	**Pathological**	**Normal**
Men	25	55
Women	1	12
Total	**26 (28%)**	**67 (72%)**

Of the 93 musicians, 67 audiograms (72%) were considered normal based on the subjects' age. However, 28% showed pathological results. Table 16 shows the distribution of pathological audiometric results by age group.

Table 16. Pathological audiometric results by age group.

Age Group	**Total**	**Men**	**Women**
20-30 years	1	1	0
31-40 years	4	4	0
41-50 years	5	4	1
51-60 years	16	16	0
Total	**26**	**25**	**1**

Among the musicians with pathological audiometric results, the majority (84%) had sensorineural hearing loss (NS), while a smaller percentage had mixed or conductive hearing loss. Table 17 shows the distribution of pathological audiometric results by instrument played and type of hearing loss.

Table 17. Pathological audiometric results by instrument played and type of hearing loss.

Instrument	**GAO**	**Total**	**Normal**	**Pathological**	**Sensorineural**	**Conductive**	**Mixed**
Conductor	-	2	2	0	0	0	0
Brass	Tubas	11	10	1	1	0	0
	Euphoniums	10	6	4	4	0	0
	Trumpets	7	4	3	3	0	0
	Trombones	5	3	2	2	0	0
	Percussion	9	5	4	3	0	1
Woodwinds	Clarinets	26	18	8	5	1	2
	Oboe	3	3	0	0	0	0
	Saxophones	12	9	3	3	0	0
Other	-	8	7	1	1	0	0
Total	-	**93**	**67**	**26 (28%)**	**22 (84%)**	**1**	**3**

Regarding the severity of sensorineural hearing loss, Table 18 shows that most cases were mild, followed by moderate and severe cases.

Table 18. Severity of sensorineural hearing loss by instrument played.

Instrument	**GAO**	**Total**	**Normal**	**Pathological**	**Mild**	**Moderate**	**Severe**
Conductor	-	2	2	0	0	0	0
Brass	Tubas	11	10	1	1	0	0
	Euphoniums	10	6	4	4	0	0
	Trumpets	7	4	3	3	0	0
	Trombones	5	3	2	2	0	0
	Percussion	9	5	4	2	1	1
Woodwinds	Clarinets	26	18	8	6	1	1
	Oboe	3	3	0	0	0	0
	Saxophones	12	9	3	3	0	0

Instrument	GAO	Total	Normal	Pathological	Mild	Moderate	Severe
Other	-	8	7	1	1	0	0
Total	-	**93**	**67**	**26 (28%)**	**22**	**2**	**2**

The results indicate a high prevalence of sensorineural hearing loss among musicians, highlighting the importance of preventive measures and regular monitoring of their auditory health.

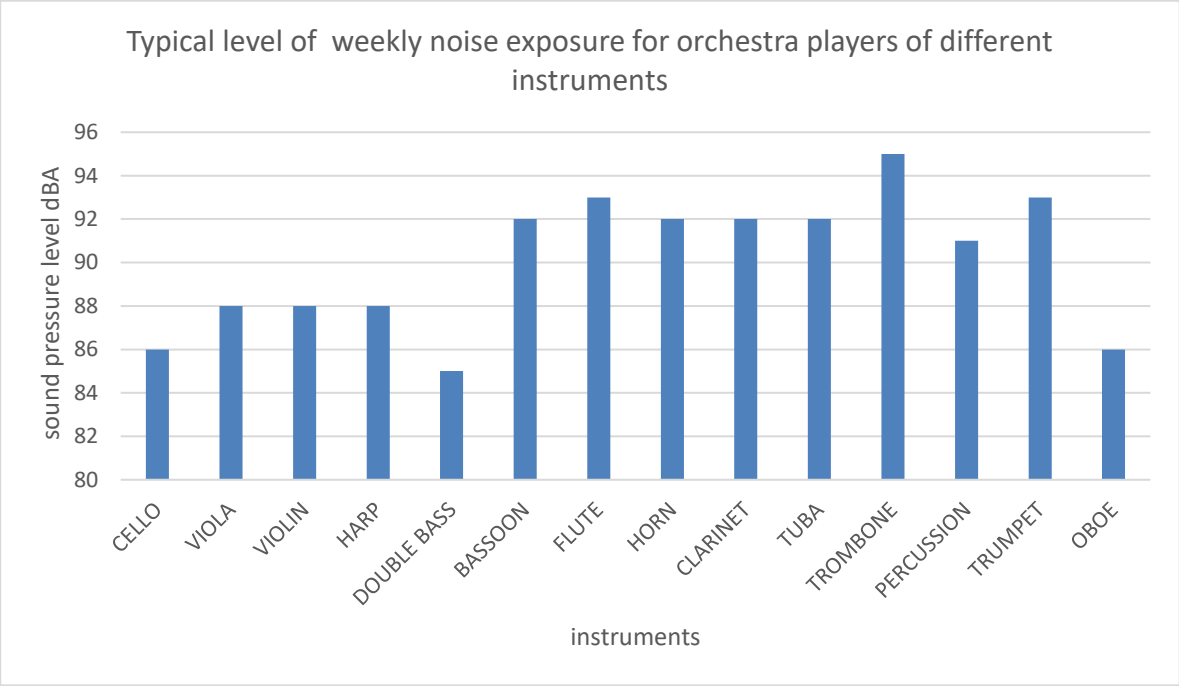
DISCUSSION

The study on sound exposure among the musicians of the Italian State Police Band employed various measurement and calculation methodologies. Specifically, the following methods were used: evaluation by Acoustically Homogeneous Groups (GAO), Recurring Week of Maximum Risk (**LEX**,w), and daily exposure ($LEX_{,8H}$) based on specific tasks.

The results indicated that, during the Recurring Week of Maximum Risk, the $LEX_{,8H}$ in all GAOs exceeded the exposure limit value. Meanwhile, the task-based daily exposure $LEX_{,8H}$ showed that only some GAOs, in both combined sections (trombones, euphonium) and separate sections (clarinets, trumpets, oboe, tubas, trombones), exceeded the limit value (87 dB(A)). Fortunately, the attenuation provided by the hearing protection devices (HPDs) for each GAO, calculated using the OMB method, was found to be "acceptable." Therefore, the HPDs provided to the musicians by the employer are considered adequate.

Additionally, no values exceeded or approached the lower action peak value of 135 dB(C), which protects against the risk of acute acoustic trauma. These results are partially comparable with the available literature data (see Figure 1).

Figure 1. Typical weekly noise exposure level for orchestral players of different instruments.



A detailed analysis of the results shows that focusing solely on the $LEX_{,W}$ could lead to overestimating the risk. The task-based strategy using the daily $LEX_{,8H}$ allows for a more accurate assessment of noise exposure, excluding breaks, resulting in more realistic individual exposure values.

Evaluating the daily $LEX_{,8H}$ with the task-based strategy, both in the large music hall and in the practice rooms, reveals different exposure levels, with only some GAOs exceeding the exposure limit. In the large music hall, only the "trombone" GAO exceeded the limit in combined sections, while in the practice rooms, the "trumpets," "clarinets," "oboe," and "tubas" GAOs exceeded the limit in separate sections. This difference could be attributed to the size and acoustics of the environment. Recent renovations in the large music hall improved acoustic quality by increasing the room volume, replacing and repositioning panels with more sound-absorbing materials, and using new anti-vibration platforms for percussion and brass instruments. This likely reduced sound propagation and reverberation time, decreasing sound exposure levels for musicians. Notably, percussionists benefited from the new setup, which reduced sound reflections.

Another aspect to consider is the influence of musicians' relative positions on personal exposure, even for those playing the same instrument. In larger environments like a large music hall, the distance between musicians and the use of sound-absorbing dividers reduce personal exposure risk compared to smaller practice rooms.

These results should be compared with audiometric exam data collected for health surveillance and categorized by GAO for a better risk assessment. These exams showed that GAOs most affected by sensorineural hearing loss included trumpets, trombones, percussion, and euphonium. In the clarinet GAO, 8 out of 26 musicians (30%) had pathological audiograms, though most had mild sensorineural deficits.

Comparing these findings with literature data on hearing loss in professional musicians, a study by eight Italian researchers analyzed 41 articles from 1978 to 2018 involving 4648 professional musicians (3645 classical and 973 pop/rock) [9]. The study found that pop/rock musicians had a higher incidence of hearing loss (63.5%) than classical musicians (32.8%). Hearing loss primarily affected high frequencies (3000-6000 Hz) and was symmetric in 68% of pop/rock musicians and 44.5% of classical musicians. Asymmetric hearing loss was more significant in classical musicians, likely due to the instruments played (e.g., violin, flute). This study supports our findings of a 28% hearing loss incidence among our musicians.

Our audiometric results further show that the euphonium and tuba GAOs exceeded the exposure limit in both combined and separate sections. However, 40% of euphonium players (4 out of 10) had sensorineural hearing loss (1 mild, 2 moderate, 1 severe), while only one tuba player had a mild sensorineural hearing loss, despite a professional exposure of approximately 91 dB(A). This apparent discrepancy might be explained by frequency analysis in 1/3 octave bands for high-intensity instruments, as shown in a previous study by the Central Health Directorate of the Public Security Department in 2014 (Table 19).

Table 19. Frequency analysis in 1/3 octave bands for high-intensity instruments.

Frequencies (Hz)	**31.5-100**	**100-315**	**315-1000**	**1000-3150**	**3150-10000**	**10000-20000**
Saxophones	□ooo					
Clarinets			oooo			
Piccolo		□ooo		□o		
Tuba			□		□	
Trombone			□		□	
Trumpet			□	□		
Cornet		□	□		□	
Drum Kit	□	□	□	□	□	□
Cymbals			□	□	□	

Note: Symbols in the table indicate the intensity of frequencies in each 1/3 octave band for the respective instruments.

This analysis shows that high-intensity frequencies in tuba do not affect the most sensitive frequencies for human hearing (1K-4K), possibly explaining the health outcomes for this GAO.

Conversely, phonometric measurements and health surveillance results indicated that GAOs for trumpets, trombones, and euphonium had the highest acoustic exposure and the most "affected" musicians.

It is crucial to define what constitutes normal hearing for a proper assessment of audiograms. Hearing normality is represented by a range of values varying with age, gender, race, and noise exposure. Human hearing capacity decreases with age due to presbycusis and socioacusis, considering the current living environment has transitioned from a "natural environment" to an "artificial environment" filled with industrial-era sounds and noises.

Furthermore, a musician's activity is unique, as they are exposed to specific sound intensities during work and must practice daily to prepare pieces for performance and maintain their technique (predominant exposure to their instrument). Therefore, a musician's "extra-occupational" noise exposure is significant.

Given the overall data, phonometric measurements are necessary for proper risk assessment, HPD use is essential to protect musicians from high-intensity sound exposure, and a task-based strategy could further reduce professional exposure.

Preventive and protective measures to reduce exposure significantly should be considered, moving from an unacceptable risk (>87 dB(A)) to a medium risk (≤85 dB(A)) for all GAOs, where HPD use would not be mandatory but only provided by the employer.

Poor compliance with HPD use among musicians remains a common issue. Commonly reported causes include decreased performance efficiency, vibration and rumble effects, and ear canal irritation. Identifying protection devices that better meet musicians' needs is essential. Customized HPDs molded to the external ear canal and new-generation HPDs with filters designed for specific attenuation could be beneficial. A good HPD for musicians should cause a linear frequency reduction in sound level without significantly altering instrument timbre and sound language

comprehensibility. Tolerance and adaptation tests for these devices would increase their acceptance among musicians.

Proposed preventive and protective measures

Organizational measures

- Preferably practice in the large music hall, where exposure is lower than in smaller rooms.
- Reduce the number of activities/pieces performed, as shown in Tables 20 and 21.
- Increase breaks between pieces to allow for acoustic recovery.
- Rotate musicians within the same GAO during performances to provide more acoustic rest.
- Rearrange musician positions within the large music hall to minimize exposure.

Protective measures

- Place plexiglass dividers around highly exposed GAOs to prevent direct sound exposure.
- Periodically apply sound-absorbing treatments to walls in both the large music hall and practice rooms to reduce sound reflections.
- Use mutes on instruments where available.
- Utilize custom-molded HPDs for each musician.
- Professional musicians playing high-volume instruments (e.g., trumpets, trombones) should consider using HPDs during individual practice.

Preventive measures

- Implement health surveillance by the Competent Doctor (MC).

Table 20. Values of the twa8h* based on the number of songs performed of 15' each during the general rehearsals in the music room with combined sections.

GAO (number of musical songs)**	80 dBA	81 dBA	82 dBA	83 dBA	84 dBA	85 dBA	86 dBA	87 dBA	88 dBA	89 dBA	90 dBA	91 dBA	92 dBA
SAXOPHONE	79,3 (1)		82,0 (2)	83,7 (3)		85,0 (4)	86,0 (5)	87,4 (7)					
TRUMPET	79,7 (1)		82,0 (2)	83,7 (3)		85,0 (4)	86,0 (5)	87,4 (7)					
TROMBONE					84,3 (1)			87,0 (2)		89,0 (3)	90,0 (4)		
	79,5		82,0		84,2	85,0	86,0	87,4					

CLARINET	**(1)**		**(2)**		**(3)**	**(4)**	**(5)**	**(7)**					
EUPHONIUM		**81,3 (1)**			**84,0 (2)**		**86,1 (3)**	**87,0 (4)**					
PERCUSSION	**79,8 (1)**		**82,0 (2)**		**84,5 (3)**	**85,0(4)**	**86,1 (5)**						
OBOE	**80,0 (1)**			**83,0 (2)**	**84,7 (3)**								
TUBE	**78,0 (1)**		**82,7 (3)**		**84,7 (4)**	**85,0(5)**	**85,7(6)**						
ORCHESTRA CONDUCTOR	**77,7 (3)**		**82,0 (8)**										

***Twa 8h=** weighted average exposure distributed over an 8-hour work day

****Number of musical songs=** number of songs performed in combined sessions

Table 21. Values of the twa8h* based on the number of songs performed of 5' each during the rehearsals in the rehearsal rooms with separate sections.

GAO (number of musical songs)**	**80 dBA**	**81 dBA**	**82 dBA**	**83 dBA**	**84 dBA**	**85 dBA**	**86 dBA**	**87 dBA**	**88 dBA**	**89 dBA**	**90 dBA**	**91 dBA**	**92 dBA**
SAXOPHONE	**75,3 (1)**	**81,9 (5)**			**84,0 (8)**	**85,0 (10)**	**86,7 (15)**						
TRUMPET	**80,6 (1)**				**84,7 (3)**		**86,9 (5)**				**90,6 (10)**	**91,7 (15)**	
TROMBONE	**75,5 (1)**	**81,9 (5)**			**84,0 (8)**	**85,0 (10)**	**86,7 (15)**						

CLARINET	**76,4 (1)**		**82,9 (5)**			**85,0 (8)**	**86,0 (10)**		**88,1 (15)**				
PERCUSSION	**80,9 (5)**				**84,0 (10)**	**85,7(15)**							
OBOE	**77,4 (1)**						**86,0 (8)**	**87.0 (10)**		**89,1 (15)**			
TUBE		**81,7 (1)**						**87,9 (5)**				**91,0 (10)**	**92,7 (15)**
ORCHESTRA CONDUCTOR		**81,5 (15)**	**82,0 (20)**										

***Twa 8h**= weighted average exposure distributed over an 8-hour work day

****Number of musical songs=** number of songs performed in combined sessions

Study limitations

This study is not without limitations. First, there was a lack of access to health surveillance medical records to evaluate other concurrent pathologies and medications that could influence and worsen hearing damage. Second, the study lacks comparison with baseline and follow-up audiometric data, as it was impossible to obtain previous health records and instrumental examination data. Regarding point 1, it would have been interesting to identify how many subjects reported extra-auditory symptoms, such as insomnia, tachycardia, hypertension, and musculoskeletal symptoms. These issues could correlate with the need to hold and transport the musical instrument for extended periods, leading to musculoskeletal disorders. Concerning point 2, without baseline and follow-up audiometric data, it is impossible to determine if a musician had pre-existing hearing impairment at the time of hiring or if the condition progressed.

CONCLUSION

In conclusion, despite these limitations, future activities should adopt a task-based strategy to ensure that exposure limits are not exceeded for each GAO while accommodating the musicians' work needs. The use of individual hearing protection devices and strict regulations for time and entity of noise exposure is of paramount importance for the prevention of HL. Furthermore, periodic phonometric surveys in the large music hall and practice rooms should be scheduled as per d.Lgs. 81/08 (every four years) or more frequently if health surveillance data indicate significant changes [10-15].

Achieving greater compliance with HPD use among musicians requires adequate training and information. Given the unique nature of their work, active and concrete participation and collaboration from the music band employees in hygiene and safety initiatives in the workplace are essential.

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References

1. Marinelli P, Monarca S. Occupational Noise Exposure in Police Officers. Occup Med. 2011; 61(8): 604-606.
2. Sataloff RT. Occupational hearing loss (3rd ed.). CRC Press; 2006.
3. Hoffman JS, Cunningham DR, Seitz MR. Sound Exposure Levels in Music Practice Rooms. J Occup Environ Hyg. 2006;3(6): 338-345.
4. Schmuziger N, Patscheke J, Probst R. Hearing in nonprofessional pop/rock musicians. Ear Hear. 2006;27(4): 321-330.
5. O'Brien I, Wilson W, Bradley A. Nature of orchestral noise exposure and hearing loss in musicians. J Occup Health. 2008;50(6):496-502.
6. ISO 1999:2013. Acoustics - Estimation of noise-induced hearing loss. 2013. https://www.iso.org/standard/45103.html.
7. Rossing TD. Acoustics of Concert Halls. Physics Today. 2007;60(7): 38-43.
8. Chesky K, Pair M, Yoshimura E, et al. An Evaluation of Sound-Level Exposures in Music Practice Rooms. Med Probl Perform Art. 2009; 24(1):18-22.
9. Di Stadio A, Dipietro L, Ricci G, et al. Hearing Loss, Tinnitus, Hyperacusis, and Diplacusis in Professional Musicians: A Systematic Review. Int J Environ Res Public Health. 2018 Sep 26;15(10):2120. doi: 10.3390/ijerph15102120.
10. Tikka C, Verbeek JH, Kateman E, et al. Interventions to prevent occupational noise-induced hearing loss. Cochrane Database Syst. Rev. 2017;7:CD006396. doi: 10.1002/14651858.CD006396.pub4.
11. Nelson DI, Nelson RY, Concha-Barrientos M, et al. The global burden of occupational noise-induced hearing loss. Am J Ind Med. 2005;48:446–458. doi: 10.1002/ajim.20223.
12. Sliwinska-Kowalska M, Zaborowski K. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Permanent Hearing Loss and Tinnitus. Int J Environ Res Public Health. 2017;14 doi: 10.3390/ijerph14101139.
13. Jansen EJ, Helleman HW, Dreschler WA, de Laat JA. Noise induced hearing loss and other hearing complaints among musicians of symphony orchestras. Int Arch Occup Environ Health. 2009;82:153–164. doi: 10.1007/s00420-008-0317-1.
14. Chen KH, Su SB, Chen KT. An overview of occupational noise-induced hearing loss among workers: epidemiology, pathogenesis, and preventive measures. Environ Health Prev Med. 2020 Oct 31;25(1):65. doi: 10.1186/s12199-020-00906-0.
15. Ding T, Yan A, Liu K. What is noise-induced hearing loss? Br J Hosp Med (Lond). 2019 Sep 2;80(9):525-529. doi: 10.12968/hmed.2019.80.9.525.