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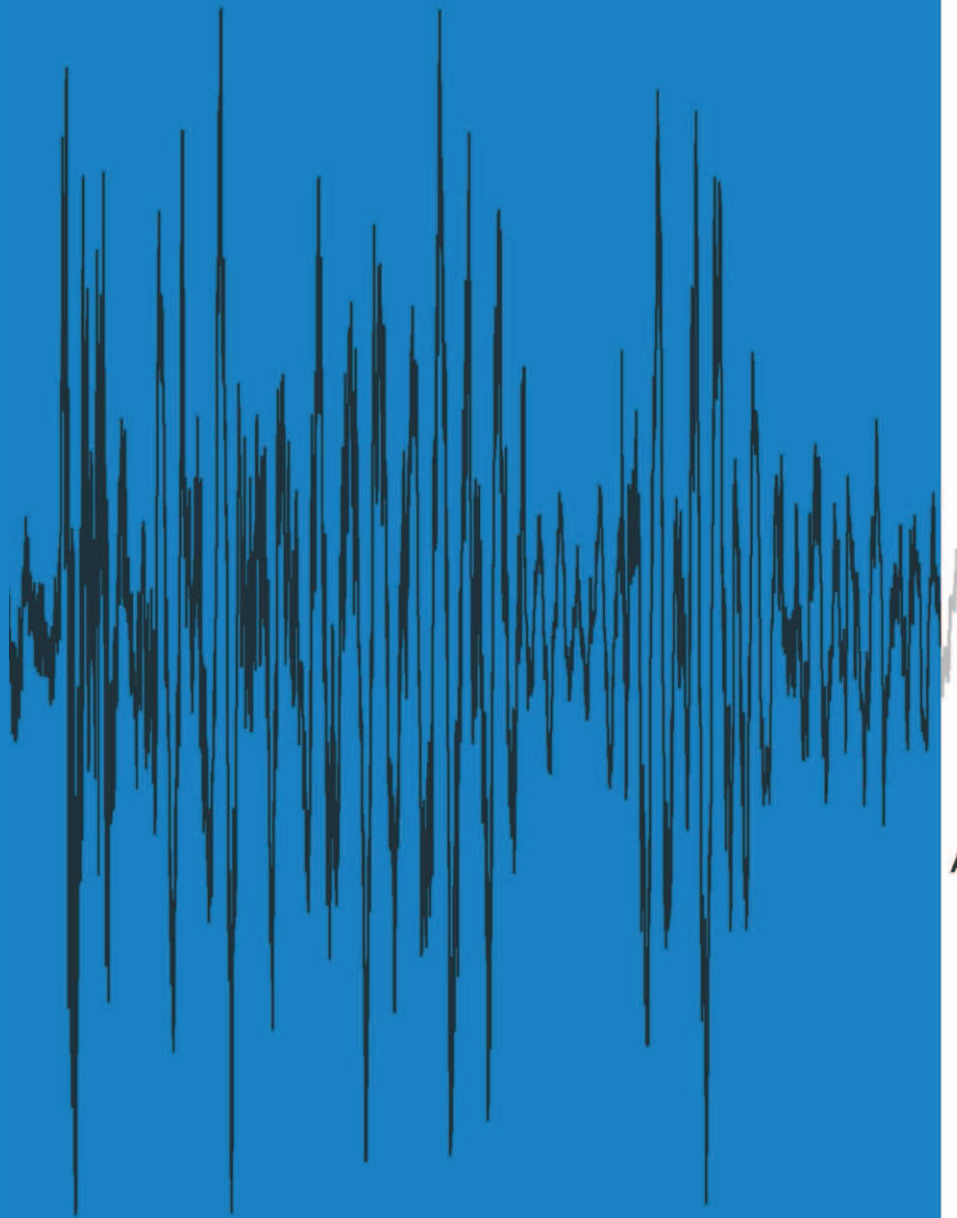

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Original Article

Sound Exposure During Outdoor Music Festivals

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Abstract

Most countries have guidelines to regulate sound exposure at concerts and music festivals. These guidelines limit the allowed sound pressure levels and the concert/festival's duration. In Norway, where there is such a guideline, it is up to the local authorities to impose the regulations. The need to prevent hearing-loss among festival participants is self-explanatory, but knowledge of the actual dose received by visitors is extremely scarce. This study looks at two Norwegian music festivals where only one was regulated by the Norwegian guideline for concert and music festivals. At each festival the sound exposure of four participants was monitored with noise dose meters. This study compared the exposures experienced at the two festivals, and tested them against the Norwegian guideline and the World Health Organization's recommendations. Sound levels during the concerts were higher at the festival not regulated by any guideline, and levels there exceeded both the national and the Worlds Health Organization's recommendations. The results also show that front-of-house measurements reliably predict participant exposure.

Keywords: Concert guidelines, music festival, sound exposure level

Introduction

Concert attendees often complain about ringing sounds and that everything sounds "muffled" after an event.[1] These phenomena generally disappear within the next day or days. The muffling sensation is more formally known as a *temporary threshold shift* (TTS). If the hearing threshold does not restore completely, it becomes a *permanent threshold shift* (PTS), also known as *noise-induced hearing loss* (NIHL). The ringing is called *tinnitus*, and is a sound experienced by the person in the absence of any external stimulus. Previous research shows that loud music can cause TTS, PTS/NIHL, and tinnitus,[2,3] although conflicting evidence exists.[4]

Most of the research on the impact of loud music on hearing focusses on concerts, discotheques, and portable media players.[5–8] Music festivals have lately become increasingly popular throughout the world. These festivals have multiple stages and often last for several days. With only one published study on the sound exposure of a festival's audience,[9] knowledge of this topic is severely limited. Lack of information on the unique dose received by festivalgoers inhibits evaluation of the impact of these events on hearing.

Current regulations for festivals (if existent) are, in many European countries, often based on the international standard (International Organization for Standardization – ISO 1999[10]) and/or the European Directive (2003/10/EC – noise[11]) that regulate occupational noise exposure. The ISO standard states that an employee can be exposed to 85 dBA for 8 h, each day, for his/her entire work career, without suffering from noise-induced hearing damage. The European Directive limits the exposure of employees to 87 dBA per 8 h workday, and sets lower ("hearing protection must be made available") and upper ("hearing protection must be worn") action limits at 80 and 85 dBA, respectively. The Norwegian occupational noise legislation[12] is based on ISO 1999, but additionally sets an action limit of 80 dBA for an 8 h workday. This means the employer must take action if the noise level at work exceeds this limit.

ISO 1999 also relies on the *equal energy hypothesis* (EEH), which assumes that an equal amount of sound energy always has the same damaging potential. A consequence of this hypothesis is that one can change the noise exposure's

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distribution and/or increase the level while reducing the exposure time, or vice versa, without affecting the damaging potential, as long as the energy remains constant.

The Norwegian Directorate of Health has made a guideline for local authorities in Norway to help them set limits for concerts and festivals.[13] To prevent hearing damage among the visitors, the guideline sets critical limits of $L_{p,A,30\,min} = 99$ dB and $L_{C,peak} = 130$ dB. $L_{p,A,30\,min}$ is for the A-weighted equivalent level over a 30 min period, and the limit applies to the loudest 30 min of the concert. $L_{C,peak}$ is the C-weighted peak-level, and this limit is equal to the peak limit used in the Norwegian occupational noise legislation. These limits are derived from occupational noise exposure regulations using the EEH.[13]

The World Health Organization (WHO) also gives recommendations regarding the sound-level exposure at ceremonies, festivals, and entertainment events.[14] The WHO sets the limit at $L_{p,A,4\,h} = 100$ dB, and also restricts the number of such exposures to less than five per year. They also recommend that the sound level should never exceed $L_{A,Fmax} = 110$ dB. Table 1 shows some examples of guidelines and recommendations for concerts as used in other European countries.

All the guidelines are comparable because they are based on the 80/85 dBA work legislation limits, but small variations in the interpretation of these limits give rise to somewhat different values. We only focus on the Norwegian and the WHO guideline in this study.

Although the WHO recommendation is slightly more liberal for single concerts, it restricts the number of events per year, whereas the Norwegian guideline does not.

Following the Norwegian guideline, and assuming 1.5 h long concerts with the allowed equivalent level, the total dose over the entire year will exceed the WHO recommendation if you attend more than 13 concerts.

There are several differences between single concerts and festivals. Most notably, the length of the exposure differs. A single concert can last from less than an hour to perhaps 3 h. The sound exposure during such a concert is rather constant, possibly with a warm-up band before the main attraction. Music festivals are different. Many artists play rather short concerts, often less than an hour, but they typically play one after another. This gives a completely different exposure pattern, lasting for almost 12 h, with periods of loud music and pauses that depend on how many concerts the participant choose to attend. In addition, many festivals cause sound exposure on sequential days. This is rarely true for attendants of single concerts, unless they are extremely dedicated spectators.

Table 1: Examples of guidelines and recommendations for continuous exposure at concerts

Country	Limit
Austria	$L_{p,A,1\,min} = 100$ dB[15]
Belgium	$L_{p,A,60\,min} = 100$ dB or $L_{p,A,15\,min} = 102$ dB[16]
Germany	$L_{p,A,60\,min} = 99$ dB, $L_{C,peak} = 135$ dB[17]
Netherlands	$L_{p,A,15\,min} = 103$ dB[18]
Norway	$L_{p,A,30\,min} = 99$ dB, $L_{C,peak} = 130$ dB[12]
Sweden	$L_{p,A,T} = 100$ (97) dB, $L_{A,Fmax} = 115$ (110) dB[19]. Numbers in parenthesis apply for events open for children below 13 years of age.
Switzerland	$L_{p,A,60\,min} = 100$ dB, $L_{A,Fmax} = 125$ dB[20]
United Kingdom	$L_{p,A,Event} = 107$ dB, $L_{C,peak} = 140$ dB[21]
WHO	$L_{p,A,4\,h} = 100$ dB, $L_{A,Fmax} = 110$ dB[14]

The differences between concerts and festivals raise the question whether the guidelines for concerts are suitable for such exposures or not. This paper will elucidate this problem and show sound exposures for random participants at two music festivals. The hypothesis is that it is effective to regulate the sound exposure at festivals with guidelines. Additionally, the reliability of front-of-house (FOH) measurements as indicator of visitor dose will be evaluated.

Materials and Methods

Two music festivals held in Norway during the summer of 2014 were selected for the study, because of their long lengths. Hove festival outside Arendal lasted 7 days, and Øya festival outside of Oslo lasted 5 days.

Hove festival

Hove festival, or just "Hove", lasted from 28 June to 4 July 2014, with an increase in the number of artists during the last 4 days. It was one of the largest music festivals in Norway, but it went bankrupt in September 2014. The festival had several camping sites near the concert area, where a majority of the participants could stay. This made the festival popular for people from all over Norway and even Northern Europe.

Hove was arranged on an island called Tromøy, outside Arendal. This island has a bridge connection to the mainland and is a recreational area for people living nearby.

The concerts started around 1 pm each day, but the number of stages used increased throughout the day and night, with the big headliners at the end. Since the festival area was rather isolated from private homes and other noise-sensitive buildings, concerts did not have to end at 11 pm, but continued until between 2 am and 3 am each night.

Øya festival

In 2014, the Øya festival, also "Øya", lasted from 5 to 9 August 2014. The first day's concerts took place in clubs and discotheques in Oslo, while the last four days' concerts were held in a park. Only the concerts in the park were used in this study. There are no camping sites associated with the concert area at this festival. Most of the visitors are therefore from the Oslo region.

At Øya, the concerts started around 2 pm, except for the last day when it started at 1 pm. The festival was located in downtown Oslo, and surrounded by residential buildings. The local authorities therefore put restrictions to the organizers to follow the Norwegian guideline for concerts and festivals. This meant that all concerts had to end at 11 pm, and that there were sound-level restrictions as mentioned above.

The guideline also states that the organizer has to monitor the sound exposure level at the festival area. All but one scene was monitored at FOH. These measurements were done by a consultant and the festival organizers made the results available for this study.

Table 2 shows a summary of details about the two festivals.

Festival communication

Both festivals were contacted beforehand to make sure the experiment could take place. The organizers were informed that the test subjects would carry a noise level dose meter, which could be confused with recording equipment. At Hove, the test subjects were given an approbation certificate they could show the security personnel if required. At Øya, the security personnel were informed about the test equipment to avoid confusion.

Participants

Participants for the study were recruited from students at NTNU, Norwegian University of Science and Technology. Posts on the university's intranet and posters around campus asked people already planning to attend the festivals to participate. No restrictions applied to the participants' age, sex, or hearing ability.

It was important, from an ethical point of view, to only recruit persons already planning to go to the festivals, because the sound exposures at these festivals are potentially damaging to their hearing. The participants were informed about the risks involved in attending concerts and were allowed to wear hearing protection if they wanted to. All participants received NOK 1000 after the festivals as compensation for their participation.

Eight persons were recruited, five male and three female. Four males went to Hove and three females and one male went to Øya. The age was rather equal among all participants, with a mean of 20.8 ± 0.5 years.

The participants signed an informed consent form before the measurements began. They were instructed to act as normal festival participants. In addition to the dose measurements, they also performed audiometric tests that will be presented in a later paper.

Equipment

All participants were equipped with Brüel and Kjær Type 4448 personal noise dose meters. The dose meters were calibrated with a Brüel and Kjær Type 4231 calibrator each day, right before the participants received the equipment. The dose meters were attached to the participants shoulder if possible. Due to differences in clothing, this was not always the case. The dose meters were therefore equipped with a necklace and could hang around the neck of the participant.

The participants were also informed that they should not cover up the dose meters, or protect it from rain, dust, or other exposures.

One-minute equivalent levels with A-weighting were recorded, together with C-weighted peak levels.

Dose calculation

The total sound dose can be calculated using the following equation:

$$\text{Dose} = 10^{L_{eq}/10} \cdot p_{ref}^2 \cdot t,$$

where L_{eq} is the equivalent sound pressure level, $p_{ref} = 20\,\mu\text{Pa}$, and t is the time (e.g., in hours). If the time is given in hours, as in this paper, the unit of the dose measure is $\text{Pa}^2\,\text{h}$ (Pascal squared × hours).

Statistical analysis

All statistical analysis was performed using Minitab 17, version 17.2.1. The dose measure mentioned above was transformed into 1-h equivalent levels (logarithmic transformation) to obtain normal distribution of the residuals during the analysis. This was only needed for the whole day equivalent levels.

Manual selection of single concerts

Some of the concerts are clearly visible in the exposure measurements. This allowed for manual selection of single concerts from the measurements. A concert was defined where the sound level went more than 10 dB above the ambient noise, and stayed high for at least 10 min.

Results

Figure 1 shows an example of a measurement series for one participant from 1 day at the Hove festival. The

Table 2: Details about the two festivals in the study

Festival	Days (days in the study)	Participants	Stages	Camping area	Sound level restrictions
Hove	7 (5)	≈62,000*	Three large, three small	Yes	None
Øya	5 (4)	≈85,000**	Two large, two medium, one small	No	Norwegian guideline for concerts

*This number is from 2007, because the number of participants for 2014 have not been released. **This is an average number for the last years

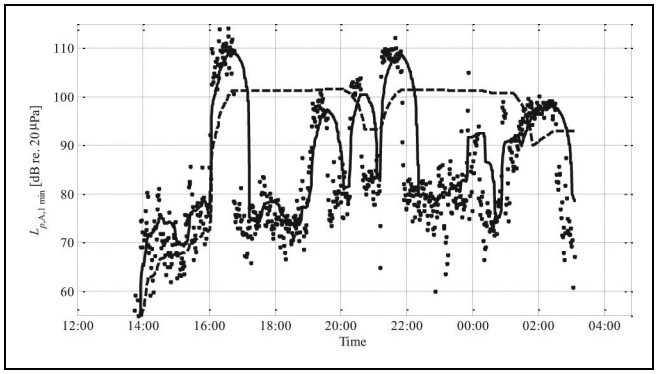

Figure 1: Example of 1-min equivalent level measurements. Dots: 1-min equivalent levels. Solid line: calculated 30-min equivalent levels. Dashed line: calculated 4-h equivalent levels. Both calculated levels use a sliding time window

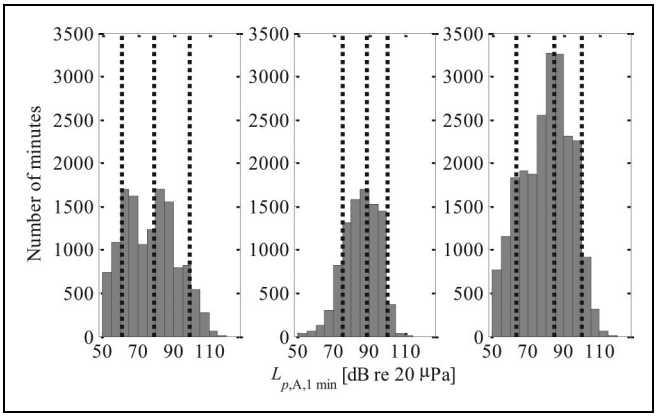

Figure 2: Distribution of 1-min equivalent sound pressure levels during the festivals. The dotted lines in each plot correspond to L90, L50, and L10 from left to right. Left: Hove festival. Middle: Øya festival. Right: Both festivals

Table 3: Statistical measures from the two festivals in the study

Festival	Minutes	Minutes >100 dBA	L10 [dBA]	L50 [dBA]	L90 [dBA]
Hove	13,155	879 (6.7%)	97.0	76.8	58.1
Øya	9291	398 (4.3%)	97.8	86.1	72.8
Both	22,446	1277 (5.7%)	97.5	81.8	60.9

corresponding 30-min and 4-h equivalent levels are plotted in the same figure.

Based on the measurements from each participant, the statistical measures L10, L50, and L90 were calculated. Table 3 shows these values and Figure 2 shows the distribution of the measurements. The figure shows that the data are not normally distributed and one has to take this into account when performing statistical analysis on the data.

Table 4 shows the sound dose in Pa^2 h for each person. An event with $L_{p,A,4\,h} = 100$ dB, as the WHO allows, gives 16 Pa^2 h. This recommendation is exceeded seven times at Hove, and none at Øya. Following the WHO recommendation with maximum four events with such level, the total yearly festival dose becomes 64 Pa^2 h. This is exceeded by two persons at Hove. P1 might also have been overexposed, because 2 days of exposure are missing.

There were not a statistical difference between Hove ($M = 11.1$ Pa^2 h, CI = [6.8, 18.2] Pa^2 h) and Øya ($M = 7.0$ Pa^2 h, CI = [5.0, 9.7] Pa^2 h) when looking at the daily exposures; $t(27) = 1.68$, $P = .105$. Nor the persons showed a significant difference ($F_{7,25} = .65$, $P = .70$) when looking at the daily doses.

The mean daily dose for all the participants was 8.9 Pa^2 h. This corresponds to a 4-h equivalent level of 97.5 dBA. It is, however, clear that some of the participants had a considerable higher exposure dose during some days. The fourth day for P4 and fifth day for P2 gave, for instance, total dose around 46–47 Pa^2 h. This corresponds to a 4-h equivalent level of approx. 104.6 dBA.

Single concert exposure

Using the method mentioned above, 99 concerts were found from all the participants; 36 at Hove and 63 at Øya. Table 5 shows the statistical measures for all the 1-min measurements from the concerts. Figure 3 shows the sound level distribution for the same measurements.

The equivalent sound level during each concert was also calculated. Individual concert lengths were used in the calculation. Focusing on the concert exposures only, the difference between Hove ($M = 101.4$ dBA, SD = 4.4 dB) and Øya ($M = 95.8$ dBA, SD = 3.5 dBA) becomes highly significant; $t(60) = 6.65$, $P < .001$. At Hove neither the day ($F_{4,31} = 1.6$, $P = .20$) nor the persons ($F_{3,32} = .31$, $P = .82$) had any significant differences. At Øya the persons ($F_{3,59} = 1.31$, $P = .28$) did not differ significantly, but day 1 ($M = 97.4$ dBA, SD = 1.9 dBA) and 2 ($M = 97.6$ dBA, SD = 3.3 dBA) was significantly louder than day 4 ($M = 93.5$ dBA, SD = 3.3 dBA); $P_{\text{day one}} = .002$, $P_{\text{day two}} = .004$. The multiple comparison was performed using the Games-Howell method.

Front-of-house measurements

Figure 4 shows the measurements done at the FOH. The figure shows the distribution of the $L_{p,A,1\ min}$ values at all the concerts. Concerts were manually selected from these measurements using the same method mentioned above.

Figure 5 shows the distribution of equivalent sound pressure level at all the concerts, measured at the FOH and with the participants. The calculation considered the individual concert lengths using the method described above. Both data sets follow an extreme value distribution. FOH had location 97.5 dB (95% CI: [97.0, 98.0]) and scale 2.15 dB

Table 4: Daily sound dose, in Pa^2 h, during the music festivals for each participant

	Person	Day 1	Day 2	Day 3	Day 4	Day 5	Total dose
Hove	P1	*	19.7	5.7	*	36.5	61.9*
	P2	**	16.8	3.3	12.3	47.0	79.4
	P3	3.4	4.2	5.8	13.8	19.3	46.5
	P4	9.7	2.1	9.0	46.3	25.4	92.5
Øya	P5	11.0	14.0	10.8	5.3		41.1
	P6	11.9	5.5	4.2	5.9		27.5
	P7	7.9	10.5	4.4	4.1		26.9
	P8	9.4	17.0	1.4	6.6		34.4

*: Participant was exposed to loud sound, but data is missing. The total dose is therefore lower than the actual. **: Participant was not exposed to loud sounds, hence not wearing the dose meter. The total dose should be correct

Table 5: L10, L50, and L90 for concert exposures at both Hove and Øya; FOH Øya is the front-of-house measurements done by the organizers

Festival	Minutes	Minutes >100 dBA	L10 [dBA]	L50 [dBA]	L90 [dBA]
Hove	1683	804 (47.7%)	107.8	99.6	90.7
Øya	3143	372 (11.8%)	100.4	95.6	87.9
Both	4826	1176 (24.3%)	103.8	96.7	88.3
FOH Øya	3412	368 (10.8%)	100.2	96.2	88.9

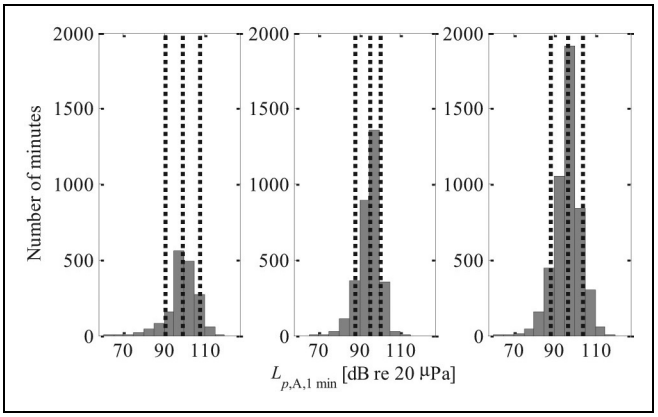

Figure 3: Distribution of 1-min equivalent level at the concerts during the festivals. The dotted lines in each plot correspond to L90, L50, and L10 from left to right. Left: Hove festival. Middle: Øya festival. Right: Both festivals

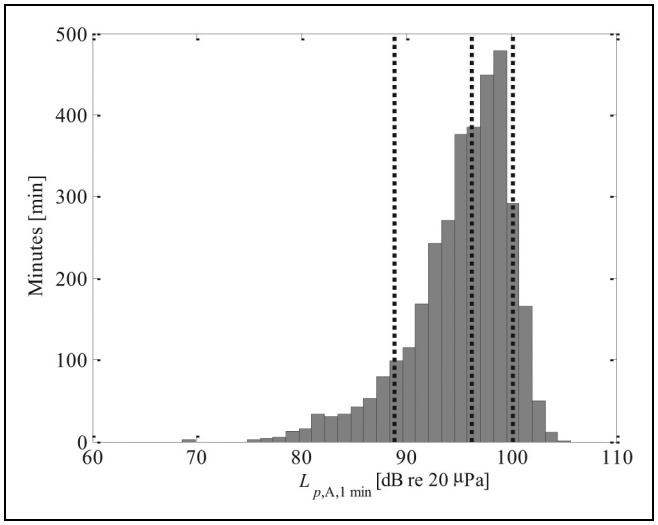

Figure 4: Distribution of $L_{p,A,1\ min}$ at the concerts at Øya, measured at the front-of-house. The dotted lines are, from left to right, L90 = 88.9 dB, L50 = 96.2 dB, and L10 = 100.2 dB

(95% CI: [1.78, 2.60]) and the participants had location 97.4 dB (95% CI: [96.6, 98.2]) and scale 3.05 dB (95% CI: [2.54, 3.67]). As can be seen the location value is similar, but the scale is larger for the participants. The increased scale value indicates that there are larger variations in the participant data, which also is visible in the figure.

The FOH measurements also showed that day 1 ($M = 97.6$ dBA) and 2 ($M = 97.7$ dBA) was slightly louder than day 3 ($M = 96.5$ dBA) and 4 ($M = 96.5$ dBA), but a Kruskal–Wallis test failed to find any significant difference ($H(3) = 3.06$, $P = .38$).

A Mann–Whitney test showed no significant difference between the FOH equivalent levels (Mdn = 96.8 dBA) and the participant concert equivalent level (Mdn = 96.3 dBA); $U = 4752$, $Z = 0.74$, $P = .46$.

Measurement uncertainty

A source of measurement uncertainty was the placement of the dose meters. Because some of the participants wore the dose meter as a necklace during all or part of the measurement, there can be small differences in the measured levels.

During one of the days at Øya, it rained for a few hours. At least one of the participants covered the dose level meter with a raincoat during this rain shower, although this was not necessary. This may have affected the measurements, giving slightly lower sound pressure levels.

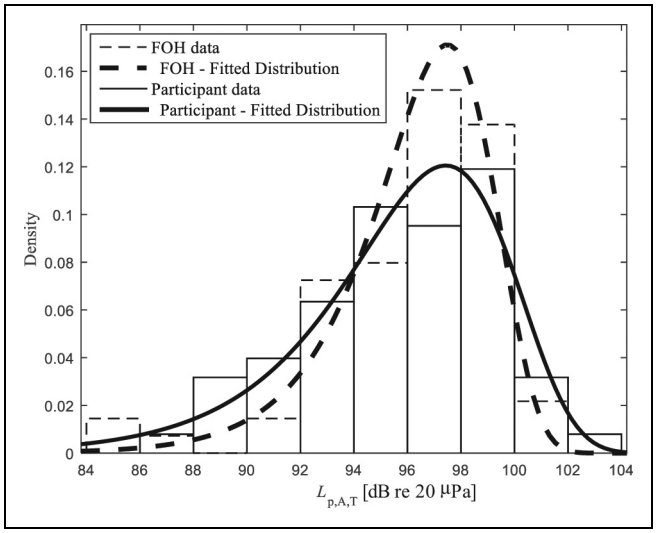

Figure 5: Distribution of equivalent sound pressure levels at the concerts at Øya measured at the front-of-house (FOH) and with the participants. The individual concert length has been used in the calculation of the equivalent levels. Each data set was fitted to an extreme value distribution. FOH data: location = 97.5 dB, scale = 2.15 dB. Participant data: location = 97.4 dB, scale = 3.05 dB

None of the uncertainties have been quantified.

Discussion

Noise guideline suitability

The Norwegian guideline is easy to interpret when it comes to festival exposures as well as single concerts. The guideline states that the loudest 30-min equivalent level during the event should be used when considering whether the limit is met or not. This means one can use a sliding window of 30 min length during the entire day. Because the guideline does not give any restrictions on the number of events, the length of the exposure becomes irrelevant.

Contrarily, the WHO guideline provides ambiguous limits for long-lasting sound exposures such as music festivals. Because the guideline gives restrictions to the number of events per year, it is not clear whether one should convert the daily exposures to 4-h equivalent levels, use sliding windows, or split the day into separate events that each last for 4 h.

The guideline's reliance on the EEH supports a guideline interpretation where the total yearly sound dose for participants is the guiding limit. The problem is that this is an individual value that depends on how many concerts each participant attends. Therefore, the value is difficult for a festival organizer to use. It also opens up the discussion whether it is acceptable for one festival to fill the allowed sound dose for an entire year, or not.

Furthermore, the authors strongly disagree with the use of a yearly dose, as the WHO recommendation use. It is implausible, based on an understanding of hearing mechanisms, that four concerts on consecutive days will have the same damaging potential as four concerts distributed throughout the entire year. If sufficient restitution is allowed after an exposure, the next sound exposure will be a completely separate happening with no correlation to the previous exposure. It might even be the case that the ear could tolerate more sound after the first exposure, because quiet periods allow the ear to recover after loud exposures, and possibly toughen the ear to actually tolerate louder sound.[22] Therefore, such silent periods are beneficial for the participants' hearing and must be considered when the damaging potential is to be determined.

Validity of front-of-house measurements

The FOH measurements provided by the organizers at Øya and the results from the participants' measurements both follow an extreme value distribution with nearly identical location values (97.5 and 97.4 dB, respectively), but larger scale value for the participants (2.15 and 3.05 dB, respectively). The larger scale value for participants' measurements indicates a larger variation in the measurements. Since the participants were free to move around the festival area, it seems intuitive that the distribution should be similar, but with larger variation. A Mann–Whitney test also did not show any significant difference between the FOH and participant's equivalent levels. This similarity means that it can be possible to use stationary FOH measurements to estimate the sound exposure for the participants at a concert/festival. The increased variation for the participants must then be considered.

Exposure level of festival participants

The equivalent sound levels during rock concerts have previously been measured to be around $L_{p,A} = 100$ dB.[23–25] A music festival study from Switzerland showed somewhat lower levels with an average of $L_{p,A} = 95.1 \pm 3.1$ dBA, with values in the range of 87.3–103.8 dBA.[9] The average daily exposure at Hove was 93.4 ± 1.0 dBA, with values in the range of 87.3–99.4 dBA. At Øya, the average was 92.6 ± 0.7 dBA with values in the range of 85.5–95.9 dBA. The overall levels were slightly lower at the two festivals in this study.

Looking at the L10 values from the two festivals we see that the levels are similar, 97.0 and 97.8 dBA at Hove and Øya, respectively. The statistical analysis of the daily doses also showed no significant differences between the two festivals. The mean average daily dose from all the measurements was 8.9 Pa^2 h. This is less than the WHO recommendation of $L_{p,A,4\,h} = 100$ dB, which gives a dose value of 16 Pa^2 h. There are, however, large variations in the personal dose, and there were participants exposed to around 47 Pa^2 h during 1 day. One should, nonetheless, be careful when assessing the damage risk of these doses, because the exposure time was significantly larger than 4 h as well. The 47 Pa^2 h dose was received during 805 min (almost 13.5 h).

The differences in exposure level become more prominent when focusing on the concerts held at the two festivals. At Hove 47.7% of the concert minutes were above 100 dBA,

while at Øya it was 11.8%. The L10 values were 107.8 and 100.4 dBA at Hove and Øya, respectively. This level difference is also reflected in the equivalent levels of the concerts. The equivalent sound level during all the concerts shows a highly significant difference between the two festivals. Hove had a mean equivalent sound pressure level during the concerts of 101.4 dBA, while Øya had 95.8 dBA. The reason why this is not reflected in the daily doses is that the participants at Hove went to fewer concerts than the participants at Øya.

Number of concerts violating the Norwegian guideline was also counted. At Hove, 26 of the 36 concerts (72%) and at Øya, 18 of the 63 concerts (29%) exceeded $L_{p,A,30\,min} = 99$ dB. The violations at Hove were also significantly higher than the ones at Øya. The maximum 30-min equivalent levels violating the guideline at Hove had a mean value of 104.4 ± 3.5 dBA. The same value at Øya was 100.7 ± 1.6 dBA.

Possible explanations for difference in exposure at different concerts

The following part will discuss possible explanations for the observed differences.

Effectiveness of the sound level restrictions

Hove festival was located well outside urban areas, hence the local authorities did not impose the festival to follow the Norwegian guideline for concerts and festivals. Øya, on the other hand, played at Tøyenparken, in the middle of downtown Oslo. People living nearby the concert area held demonstrations both before and during the festival, and complained about the sound/noise they experienced. Because of the urban location, the local authorities enforced Øya to follow the Norwegian guideline. This meant that the concerts had to end at 11 pm and that the maximum 30-min equivalent level was not to exceed 99 dBA for the participants.

The organizers at the regulated festival at Øya stated that both artists and audience seemed satisfied with the sound level. Increasing the sound level will therefore expose the audience to an unnecessarily higher risk of getting hearing damage.

There are only FOH measurements from one of the festivals, so there are no data available to compare the sound levels of both festivals directly. However, participants of the unregulated festival received a statistically significant higher concert levels than the participants of the regulated festival did. This evidence strongly supports the hypothesis that sound level restrictions are effective. However, study limitations make the evidence inconclusive.

Study limitations

The difference in sound level experienced at the festivals can have several other explanations for which the study did not control.

The sound levels measured depend on meteorological conditions, local topography, numbers of visitors, and particularly the sound spectrum of the music.[9] These variables were likely different for the two festivals, and therefore may have affected the difference in sound exposure measured.

For practical reasons, the participants at Hove got their dose equipment some hours before the first concert began, leading to more time in silence. The participants at Øya got their equipment much closer to the first concert. This contributes to the difference in sound level distribution. It does, however, not influence the daily dose, since the quiet period contributes little to the total value.

No information about participant behavior was collected; hence the position during concerts could not be assessed. One possibility is therefore that the participants at the unregulated festival were closer to the stage/loudspeakers during the concerts. However, it has been shown that the sound level at concerts does not have to increase as one move towards the stage.[9] This is true if you are relatively close to the stage, and not if you are standing very far from the scene. It also depends on the type and placement of the loudspeakers.

The number of minutes during which the participants at Hove attended concerts is less than that of the Øya participants. This may be explained by the presence of camping sites nearby unregulated festival area, while the regulated festival lacked such a quieter area away from the concerts. This means that the participants at the unregulated festival may have selected their favourite bands and only attended these concerts. When they attended these, they may have gotten closer to the stage, resulting in increased exposure. Following the same argumentation, participants of the regulated festival may also have attended concerts with bands they did not know or like that much, and therefore stood further from the stage.

The organizers were aware of the sound measurements, and this could have affected the results. At Øya, however, the organizers also did their own sound monitoring, as required by the Norwegian guideline for concerts and festivals. They used this monitoring to adjust the sound level during the festival. It is therefore unlikely that the measurements done in this study would further affect the sound level.

At Hove, the organizers did not monitor the sound levels themselves, but since the sound level was higher than both the Norwegian and WHO recommendation, it does not seem like they tried to adjust the sound level to meet any limits. Because all the artists have their own sound engineers and none of these were informed about the measurements, this also support that the sound level was not affected by this study.

Since the number of participants in this study was small, it is difficult to generalize to the rest of the participants at the festivals. It is also possible that the participants in this study did not act as "normal festival participants" as they were instructed. They did not give any indications of behaving differently, but this is difficult to settle.

Some participants wore the dose meters as a necklace, and this can have affected the measurements. The use of necklace dose measurements was most prominent at the regulated festival and therefore the FOH measurements can be used as a verification of the measured sound levels. Since no significant difference was found between the FOH measurements, the necklace measurements, and the shoulder measurements, it is assumed that this measurement uncertainty is negligible.

Conclusions

The sound levels measured at individual festival concerts are comparable to those previously measured at normal concerts. However, the total dose received is much higher for festival participants due to the longer duration of these events.

At both studied festivals, sound exposure of participants exceeded Norwegian guideline limits, but this happened more frequently and with more extreme values at the festival where no regulations were enforced. Clearly, it is effective to impose restrictions to the sound levels at both concerts and festivals, and it also seems necessary. Otherwise the sound will be dangerously loud and visitors are at risk of getting hearing loss.

The WHO concert guideline is difficult to apply to multi-day music events. This might also be the reason why few, if any, countries use the WHO guideline as their recommendation. Because it is implausible that four events, as the WHO guideline allows, will have the same damaging potential regardless of how they are distributed throughout the year, guidelines that are event-based are more reasonable. Giving restrictions to the maximum equivalent level over relatively short time (e.g., 30 min or 1 h), are also easier for concert organizers to apply.

Stationary FOH measurements also provide a good estimate for the sound exposure of the participants at the concert; hence the use of such measurements is sufficient to assess how the audience is exposed.

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Conflicts of interest

There are no conflicts of interest.

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