ACOUSTIC ANALYSIS OF NOISY TOYS

Análise acústica em brinquedos ruidosos

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ABSTRACT

Purpose: to analyze the levels of noise emitted by nationally-sold toys for use by children from 1 to 5 year old; to compare the values among the toys with and without the seal of Inmetro (National Institute of Metrology, Standardization and Industrial Quality) and to analyze the sound spectrum of toys, in order to identify the area of the cochlea that may be more affected by these noises. **Method:** measurements were performed on 20 sound toys (10 with the seal of the Inmetro and 10 without the seal) with the use of digital sound level meter in an acoustically treated room, and the sound analysis was performed using the Praat program. **Results:** toys placed at 2.5 cm from the equipment with the seal of the Inmetro had an intensity ranging from 61.50 to 91.55 dB (A) and from 69.75 to 95.05 dB (C), positioned at 25 cm ranged from 58.3 to 79.85 dB (A) and from 62.50 to 83.65 dB (C). The results of the toys without warranty stamps placed at 2.5 cm ranged from 67.45 to 94.30 dB (A) and 65.4 to 99.50 dB (C) and the distance of 25 cm recorded from 61. 30 to 87.45 dB (A) and 63.75 to 97.60 dB (C), so that the findings demonstrated that there are noisy toys that go beyond the values recommended by the current legislation in both groups, with and without warranty stamps . **Conclusion**: the toys without the seal of Inmetro showed intensities values significantly higher than the other group, offering more risk to the children's hearing health.

KEYWORDS: Play and Playthings; Noise; Children; Hearing Loss

INTRODUCTION

The portuguese word for noise (ruído) is derived from the Latin *rugitu*, which means burst. Acoustically, noise consists of several sound waves with amplitude and phase relation, anarchically distributed, causing a unpleasant sensation[1]. Although commonly only occupational noise is treated as harmful, all sounds with sound pressure levels exceeding 85 dB (A) can be harmful to hearing, and therefore this is the maximum limit established for exposure during an 8-hour workday[2, 3].

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Recently new studies were performed to evaluate the risk of hearing loss in the case of exposure to music with high sound pressure levels[4]. Sounds with high intensity can also cause non-auditory impairments, such as emotional problems, like stress, sleep disorders, anxiety, oral communication and also language disorders, which may cause a delay in the acquisition of oral language and problems in the acquisition of reading skills [5-7].

The literature shows few studies related to acoustic analysis of non-verbal sounds. The acoustic analysis of noise emitted by toys, as well as any further comparison, is also seldomly performed. A study conducted at the University of Aveiro made the spectral and temporal analysis of verbal and nonverbal sounds using the Praat software (version 4.3.11), and as a result found that the spectrum of non-verbal sounds have characteristics of noise, showing sound energies distributed across the frequency range [8].

Currently, with easy access to a wide range of toys, most children have at least one sound toy, which are increasingly noisier. Researchers studied inner ear damage in 53 children who were exposed

to noise from toys that replicate firearms and fireworks, and observed that 39 children (74%) had a large unilateral sensorineural hearing loss while 14 (26 %) had bilateral hearing loss. Of these 14 children, 8 had a symmetrical loss and 6, asymmetric [9].

There are several studies on hearing loss due to harmful noise level of toys, many of which go beyond the limits of tolerance of the inner ear. Researchers analysed noise levels in toys and found between 95 and 122 dB (A) positioned at 2.5cm from the source of noise and between 86 and 110 dB (A) at 25cm from the source of noise[10]. When performing an acoustic analysis of toys, researchers obtained results intensities between 82 and 130 dB (A), and warned about a possible hyperstimulation which may occur in the inner ear if there is a long enough exposure to this type of noise[11].

Modifiable risk factors related to NIHL include the voluntary exposure to loud noise and lack of use of hearing protectors. These factors can cause or intensify the loss of hearing in children and teenagers[12]. Children and youth are two groups that are particularly vulnerable to hearing loss induced by noise and to numerous other adverse systemic effects of exposure to noise. The main sources of exposure of children and adolescents to noise include Neonatal Intensive Care Unit (NICU) incubators, noisy toys (rattles, musical toys and guns), fireworks, concerts and personal stereos[13]. Another study in this line of research, identified sound pressure levels between 70 and 94 dB(A) in noisy toys[14].

Toys sold in Brazil (both domestic and imported) must have an Inmetro (National Institute of Metrology, Standardization and Industrial Quality) certification which confirms that they were subjected to various tests, including noise level tests. The results of such tests must be within the limits established by the law, which is based on the Brazilian Standard *NBR 11786/92* – Toy Safety, published by the Brazilian Association of Technical Standards (*ABNT*). This standard determines that the noise emitted by toys, regardless of age which they are intended to, may not be greater than 85 dB (A) in the case of continuous noise, and 100 dB (A) in the case of instantaneous noise[15].

The aim of this study was to examine the levels of noise emitted by toys designed for use by children aging from 1 to 5 years-old; to compare the values among the toys with and without Inmetro accreditation and to analyse the sound spectrum of those toys, in order to identify the area of the cochlea that may be more affected by these noises.

METHODS

For this study, 20 noisy toys were selected (10 certified by Inmetro and 10 that were not). Uncertified toys were chosen because they are easly found in the parallel market and are cheaper, thus presenting an appeal to many potential buyers. Inmetro--certified toys are the ones used in public university clinics during speech therapy. All toys tested emitted continuous noise, did not display any warnings about the intensity of the sound produced and and are sold as suitable for children 1 to 5 years-old. The toys with Inmetro-certified are: Bi-bi-Fon Fon ®, Tomy Penguin ®, Electric Guitar ®, Hippo ®, Musical Little Car ®, Cell Phone ®, Rattle Birdie ®, Star Musical ®, One Day In The Park ® and Musical Ark®. The toys without Inmetro-certified are: Cell Phone # 2, Little Mouse, Drum, Guitar, My First Sound Book, Shuttlecock Musical, Cart Mail, Little Piano, Police and Little Train.

Measurements of sound intensities were performed in an acoustically-treated room, with a MINIPA digital sound level meter, model MSL-1350. We used the weighting circuit – "A" (which has the largest attenuation for frequencies lower than 1000 Hz) and the "C" (having the smallest attenuation); feedback loop set to slow, calibrated for 65-130 dB. The noise levels were measured in two distances, one simulating having the toy by the ear (2.5 cm) and the other simulating a child's arm's length (25 cm)[10].

To investigate the acoustic spectrum, we used a portable DAT recorder connected to a stereo Sennheiser microphone. The recordings were digitized at a sampling rate of 44,000 Hz with the use of CSL Kay Elemetrics, and the sound analysis was performed using the spectral slice visualization in the Praat software, thus obtaining the frequency spectra of each toy.

We followed up with an analysis of the cochleogram (psychoacoustics projection of auditory sensation), also present in the same program. This analysis details how the sound reaches these children's inner ears, thus allowing a better visualization of the impact of the noise in the areas that may be affected. The cochleogram results were converted from the Bark scale to Hertz[16].

The data was analysed in two ways: an acoustic analysis and by psychoacoustics. The acoustic analysis shows the acoustic intensity values specified in the results section and the psychoacoustic analysis takes into account the frequencies that are usually more affected by hearing loss (e.g. 3000 Hz, 4000 Hz, 6000 Hz).

After data collection, a comparative analysis was performed aiming to identify possible differences

between noise levels in toys with and without Inmetro certification. Nonparametric Mann-Whitney statistical test was used in this comparison, with a significance level of 5% ($p < 0.05$) and confidence statistical interval with 95%.

RESULTS

In the measurements performed at distance of 2.5 cm, using the A circuit-weighted, eight toys showed an average intensity greater than 85 dB, and among them, only one had the Inmetro certification (Electric Guitar 91.55 dB). The results from the other toys were as follows: Little Mouse 93.25 dB, Drum 94.3 dB, My First Sound Book 91.7 dB, Shuttlecock Musical 91.65 dB, Mail Cart 90.55 dB, Police 93.35 dB and Little Train 85.55 dB. At distance of 25 cm, only three toys exceeded the limit, all of which lacked Inmetro accreditation: Little Mouse 87.45 dB, Drum 86.75 dB and Little Train 85.7 dB (Figure 1, Figure 2).

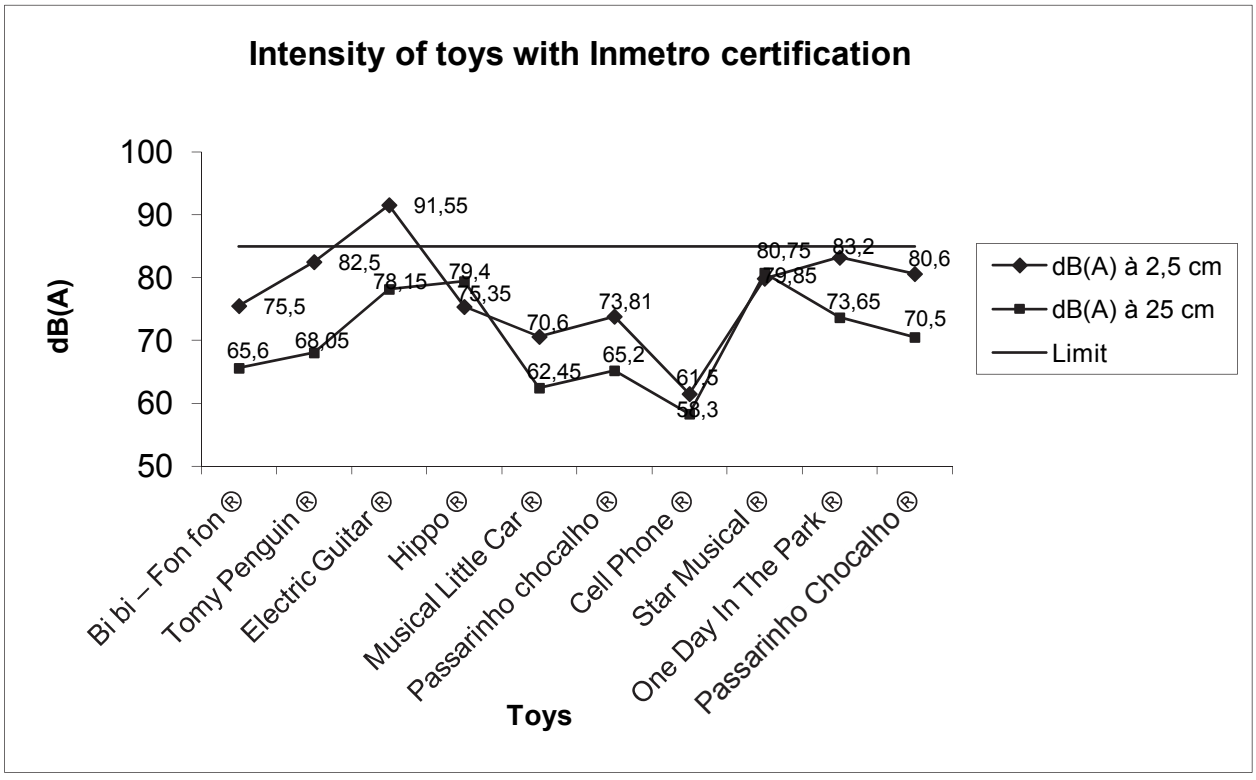

Figure 1 – Average of sound pressure levels (dB) measured from toys with Inmetro certification, at a distance of 2.5 cm and 25 cm (frequency weighting A)

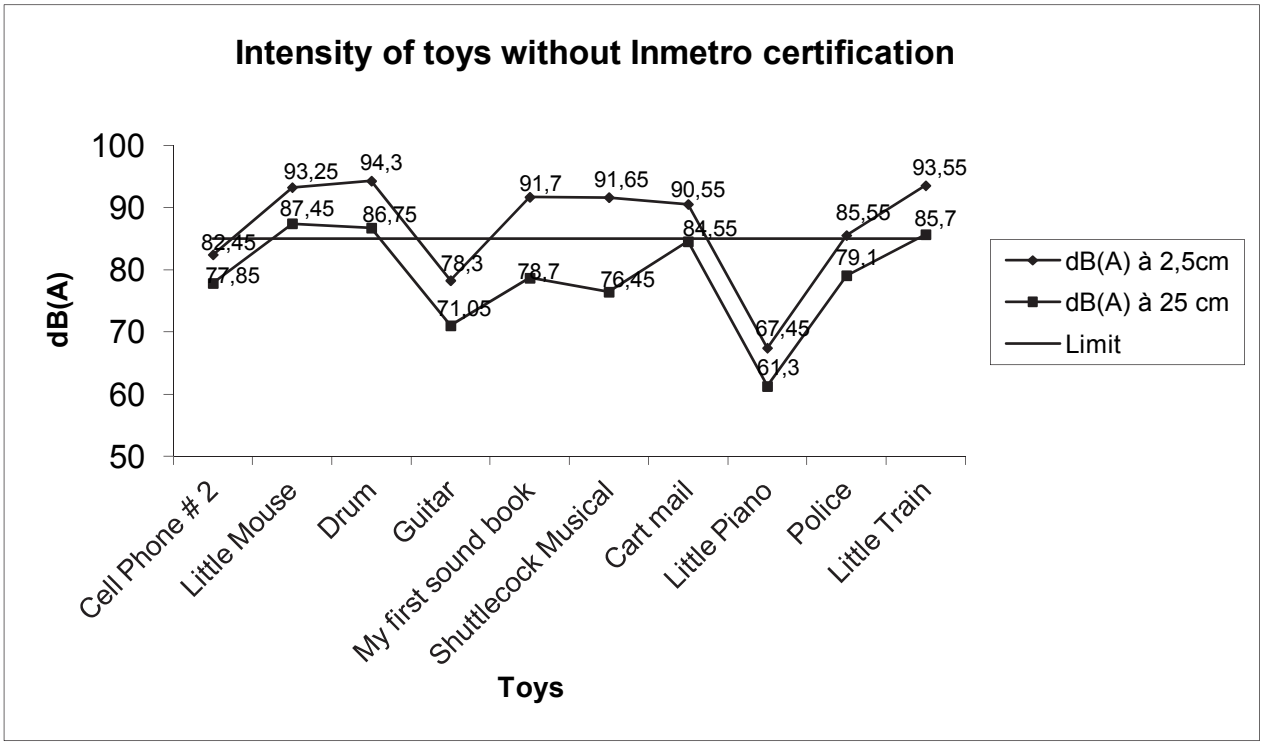

Figure 2 – Average of sound pressure levels (dB) measured from toys without Inmetro certification, at a distance of 2.5 cm and 25 cm (frequency weighting A)

When measured at distances of 2.5 cm with C circuit-weighting, nine toys recorded an average intensity greater than the limits established by law, of which two have the Inmetro certification (Electric Guitar 95.05 dB and One Day In The Park 85.85 dB). The others were: Little Mouse 94.45 dB, Drum 99.95 dB, Sound My First Sound Book 92.55 dB, Mail Cart 90.55 dB, Shuttlecock Musical 91.2 dB, Police 87,85 dB and Little Train 97.6 dB. At the distance of 25 cm, only four toys exceeded 85 dB, all of which lack the Inmetro certification: Little Mouse 85.9 dB, Drum 97.6 dB, Mail Cart 85.2 dB and Little Train 86.1 dB (Figure 3, Figure 4).

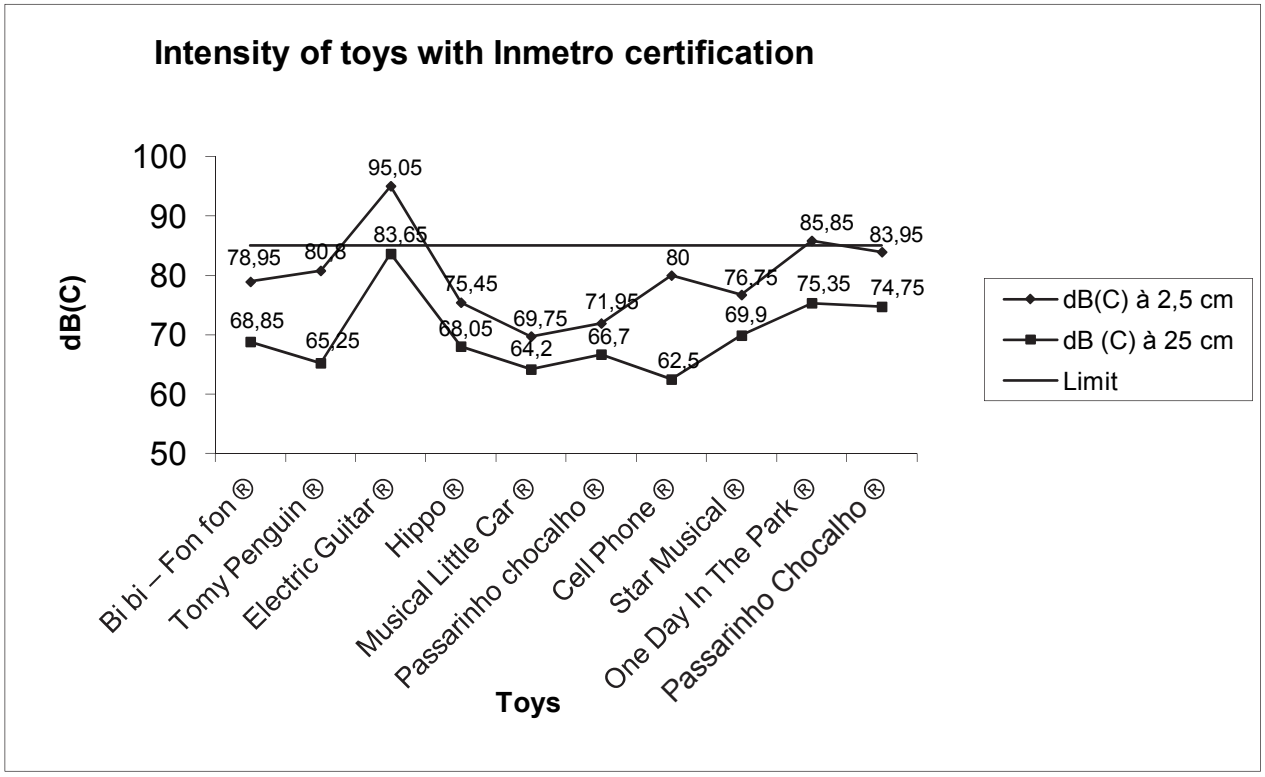

Figure 3 – Average of sound pressure levels (dB) measured from toys with Inmetro certification, at a distance of 2.5 cm and 25 cm (frequency weighting C)

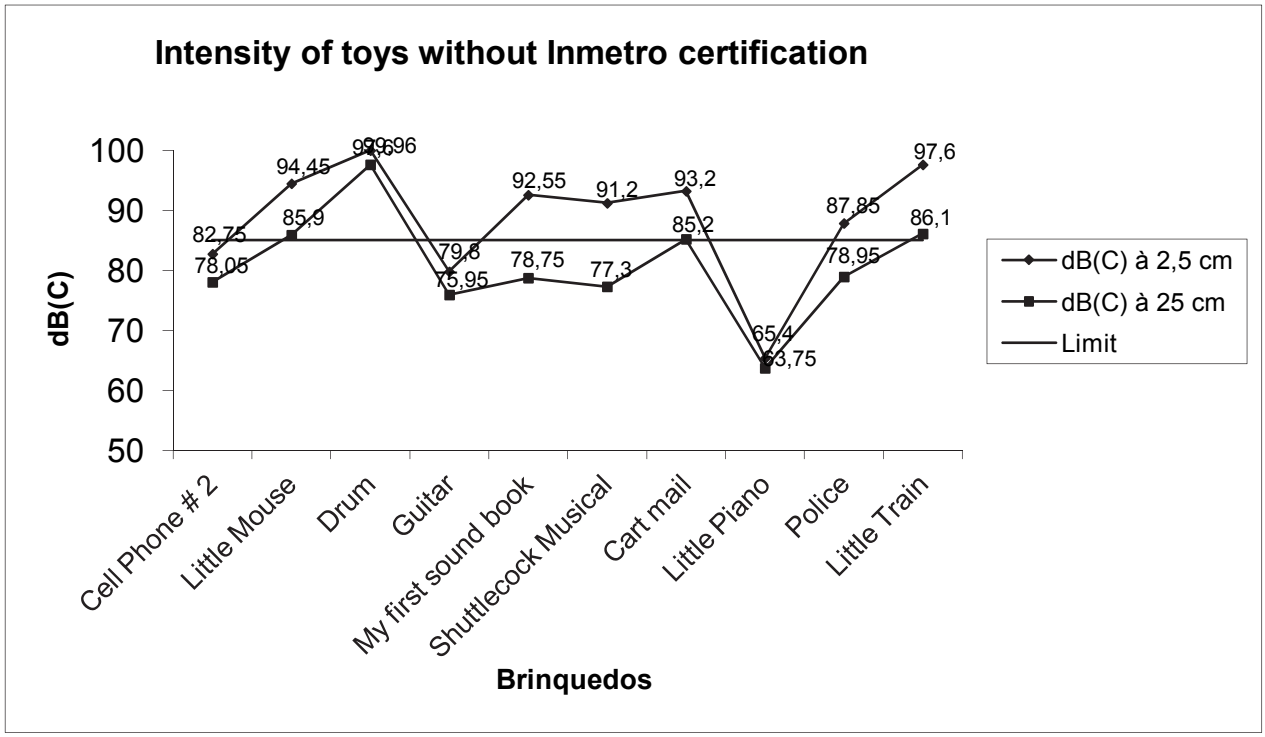

Figure 4 – Average of sound pressure levels (dB) measured from toys without Inmetro certification, at a distance of 2.5 cm and 25 cm (frequency weighting C)

The frequency spectrum of the noise recorded showed peaks of high and low frequencies (345 to 4640.98 Hz), however the majority of the measurements did not exceed the frequency of 3000 Hz. Despite this, when the psychoacoustic analysis performed with the Praat software is taken into account, the concentration of energy observed in most toys is in the range of 3150 to 5300 Hz.

In the tables 1 and 2 below, we can observe the frequency peaks as well as the psychoacoustic analysis results. The result shows that toys that generate noise intensities over 85 dB can damage areas of the cochlea responsible for capturing medium and high frequencies.

Table 1 – Frequency peaks and psychoacoustic analysis of toys with Inmetro certification

Toys with certification	Higher peak of frequency (Hz)	Psychoacoustic analysis (Hz)
Bi-bi Fon-fon	1060,58	1270
Tomy Penguin	1197,09	1270
Eletric Guitar	3466,64	4400
Hippo	1286,26	4400
Musical Little Car	3889,79	4400
Cell Phone #1	3711,10	4400
Rattle Birdie	2326,61	3700
Star Musical	991,09	1720
One Day In The Park	404,45	770
Musical Ark	484,81	630

Table 2 – Frequency peaks and psychoacoustic analysis of toys without Inmetro certification

Toys without certification	Higher peak of frequency (Hz)	Psychoacoustic analysis (Hz)
Cell Phone #2	1715,76	2320
Little Mouse	3327.32	4400
Drum	1365,53	1480
Guitar	345	510
My First Sound Book	2713,02	3150
Shuttlecock Musical	1144,37	4400
Cart Mail	2000,75	3700
Little Piano	4640,98	5300
Police	3692,95	3700
Little Train	655,4	770

Figures 5 and 6 show the frequency spectrum and psychoacoustic analysis for the toy Cart Mail. This toy is not Inmetro-certified and generated sound pressure levels above the expected in both weightings at distance of 2.5 cm and 25 cm.

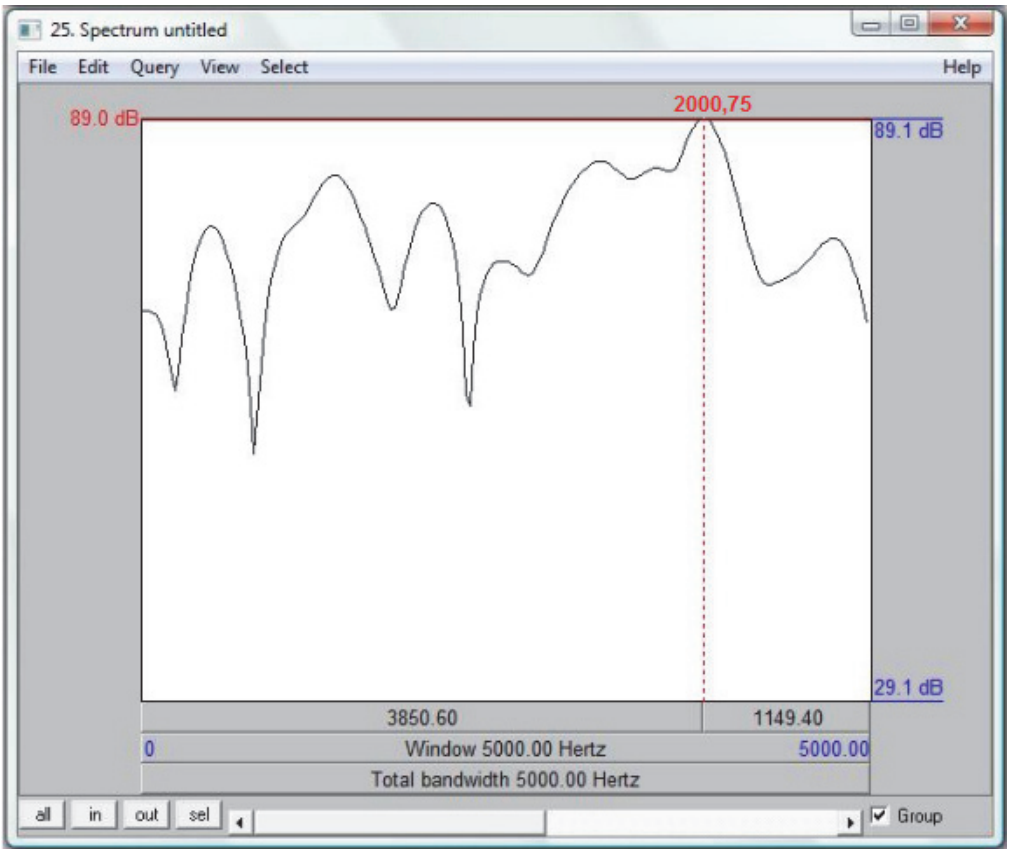

Figure 5 – Higher peak spectrogram toy Cart Mail recorded in 2000.75 Hz

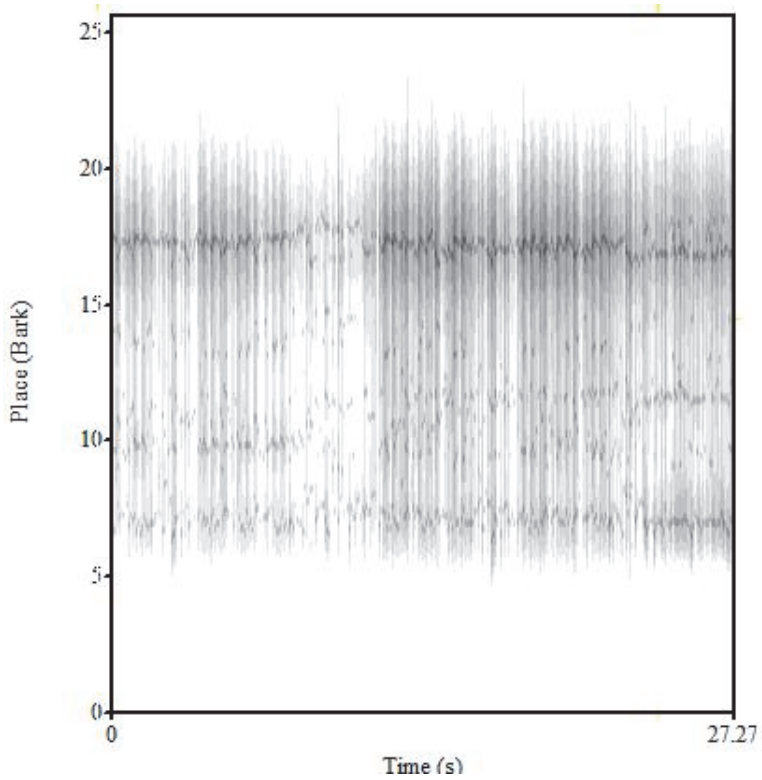

Figure 6 – The psychoacoustic analysis toy Cart Mail with higher energy range in 17 Bark, corresponding to 3700 Hz

The statistical analysis of the averages The statistical analysis of the averages between the toys with and without Inmetro certification (Table 3), measured at distances of 2.5 cm and 25 cm in both weightings (A and C) shows a significant difference in all modalities measured, demonstrating the highest loudness of toys that are not certified by Inmetro.

Table 3 – Descriptive statistics and comparative analysis between the averages of toys with and without Inmetro certification, considering the weights A and C, measured at distances of 2.5 and 25 cm (Mann-Whitney Test)

		dB (A)	dB (A)	dB (C)	dB (C)
	Statistics	2,5 cm	25 cm	2,5 cm	25 cm
Toys with Inmetro certification	Averege and Standard Deviation	77,44±8,13	69,90±7,90	79,85±7,29	69,92±6,37
	Median	77,67	69,27	79,47	68,45
Toys without Inmetro certification	Statistics	86,89±8,65	78,52±7,90	87,83±9,79	80,40±9,20
	Averege and Standard Deviation	91,20	78,9	90,17	78,85
p-value		0,021*	0,045*	0,045*	0,007*

*Significant for $p < 0,05$.

DISCUSSION

Sound toys and electronic games attract the attention of children, therefore are replacing the more traditional toys such as dolls and toy cars. This causes great concern, given that our study showed that many noisy toys do not comply with standards established by Brazilian law.

Several of these toys, available for purchase at regular stores, are counterfeited and as such are not subjected to the certification tests administered by the Inmetro, which reflects a problem related to the absence of competent governamental supervision.

Based on the recommendations of the report NR-15, from the Ministry of Labour, exposure times should be shortened as noises get louder. These recommendations also apply to noise generated by toys, since high intensity noises can cause physical and psychological damages and consequently affect not only the children's hearing as well as the development of language and speech [5-7].

In accordance with other studies,[10,11,14] our results also show noise levels that exceeded the limits recommended by Brazilian law. Considering this, one may say there is a large possibility that such toys may cause noise-induced hearing loss. This was shown by studies that evaluated the hearing threshold in children and teenagers exposed to noisy toys [9].

Based on the psychoacoustic analysis, we found that the range where most frequent cochlear injury occurred was between 3150 and 5300 Hz. It is interesting to observe that this is the frequency range with greater susceptibility to hearing loss in cases of occupational hearing loss.

In a study performed with police officers, was possible to demonstrate the causal relationship between the noise emitted by the firing of guns and the areas with greater hearing loss on audiometry (4 and 6 kHz) [17].

For the reasons cited above, our study suggests that certain care and attention be taken when purchasing noisy toys, such as: checking the intensity of the noises generated, avoiding toys that offer hearing protections, since the child may forget to use them, avoiding musical instruments and toy guns, which can be hazardous or cause irritation, substituting them by other, less noisy toys [6].

The present study also demonstrated that proximity to the sound source increases hearing discomfort and the risk of cochlear damage, therefore as a precautionary measure it is important that the children keep a safe distance between the noisy toys and their ears. The increase of loudness with the proximity of the sound source was also described by other study with noisy toys [10].

Prevention is thus the best treatment, because it ensures that children are not being exposed continuously to noise-intensive environments. Education

of parents and caregivers is also of extreme importance to minimize exposure of the children to the high levels of noise. Stronger governmental supervision would also be indicated, such as a more stringent examination of the toys sold in the country, ensuring that not only the age indicated in the packaging is adequate, but also the loudness levels of the toys.

CONCLUSION

In conclusion, this study found that the toys without Inmetro certification had higher noise levels, when compared with toys certified by that government agency. Furthermore, it was observed that noisy toys affect predominantly the high frequencies areas in the cochlea. Their action, only insidious at first, may cause irreversible damages to hearing.

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RESUMO

Objetivo: analisar os níveis de ruídos emitidos por brinquedos nacionalmente comercializados, utilizados por crianças de 1 a 5 anos; comparar os valores entre os brinquedos com e sem selo do Inmetro (Instituto Nacional de Metrologia, Normalização e Qualidade Industrial) e analisar o espectro acústico dos brinquedos, com o intuito de identificar a área da cóclea que pode ser mais afetada por esses ruídos. **Método:** as medições foram realizadas em 20 brinquedos sonoros (10 com o selo do Inmetro e 10 sem o selo) com o uso do decibelímetro digital em sala acusticamente tratada, e a análise dos sons emitidos pelos brinquedos foi realizada por meio do programa *Praat*. **Resultados:** a intensidade do ruído dos brinquedos com o selo do Inmetro posicionados a 2,5 cm do equipamento variou de 61,50 a 91,55 dB(A) e 69,75 a 95,05 dB(C) e a referente à distância de 25 cm variou entre 58,30 a 79,85 dB(A) e 62,50 a 83,65 dB(C). A intensidade do ruído dos brinquedos sem o selo do Inmetro a 2,5 cm variou entre 67,45 a 94,30 dB(A) e 65,4 a 99,50 dB(C) e na distância de 25 cm registrou desde 61,30 a 87,45 dB(A) e 63,75 a 97,60 dB(C), portanto os achados demonstraram que existem brinquedos ruidosos que ultrapassam os valores recomendados pela legislação vigente em ambos os grupos, com e sem selo do Inmetro. **Conclusão:** os brinquedos sem o selo do Inmetro apresentaram valores de intensidade significantemente maior em relação ao outro grupo, oferecendo maior risco à saúde auditiva das crianças.

DESCRITORES: Jogos e Brinquedos; Ruídos; Crianças; Perda Auditiva

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