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Did You Know How Loud Balloons Can Be?

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ABSTRACT
Importance: Noise exposure is a cumulative and insidious preventable condition.
Objective: In this paper, we investigate the level and potential hearing risks associated with balloon explosions.
Design: We measured balloons that were 1) inflated to rupture, 2) crushed to pop, and 3) popped with a pin.
Results: We found that, in the inflated to rupture condition, the average impulse level was more intense than a 12-gauge shot gun and nearly as intense as a 357 magnum.
Conclusions and Relevance: These results and their implications are put into a broader context for the reader and a case is made for changing the way we talk about and consider cumulative noise exposure throughout our lives.

Introduction

The bag of party balloons in front of me has the following warning labels: “this bag is not a toy,” “choking hazard” and “to protect eyes from possible damage, the use of a balloon pump is recommended (Unique Industries©, Inc., Philadelphia, PA).” There is no mention of hearing protection or the risk of intense sounds. There is a growing literature on the potential hazards of high-intensity impulse noises, the kinds that occur from gunshots and explosions.[1–4] While we suspect the general public would have no difficulty imagining that firecrackers and gunshots are potentially hazardous to hearing, we were interested in the risks of what might be considered a much more benign and child-friendly item: the party balloon. Specifically, we sought answers to the following three questions:

1. What are the peak sound pressure levels of exploding balloons?
2. How do the levels of exploding balloons compare to other high-intensity impulse noises?
3. Are the levels intense enough to warrant concern about potential long-term hearing damage from impulse noises?

Recently the World Health Organization (WHO) reported that 1.1 billion children and teenagers are at risk for long-term hearing loss as a result of noise exposure.[5] They cite the use of personal audio systems/smartphones and other recreational activities such as nightclubs, bars and sporting events as the main culprits. Data from the National Health and Nutrition Examination surveys in the United States revealed that the prevalence of hearing loss in teenagers has increased nearly 5% from 1988-1994 to 2005-2006.[6] Determining a direct cause for this increased prevalence is not trivial; however, a potential link is noise exposure from leisure or fun activities.

In the workplace, there is a much greater understanding (and acceptance) of the risk of temporary or permanent hearing loss from noise exposure. If the workplace environment is sufficiently noisy, there are laws that require employers to provide solutions (e.g., hearing protection, limited exposure time, signage etc.) for their workers.[7] These laws vary slightly from state to state or province to province; however, many jurisdictions use an 85 dB (A-weighted) limit for 8 hours with a 3 dB exchange rate. This means that if the level of the environment is 85 dBA then it is considered safe to be in that environment for 8 hours without the need for hearing protection and with limited long-term risk of hearing loss. However, as the level increases by 3 dB, the amount of time that it is safe to be in that environment (the maximum allowable daily noise dose) is halved. In other words, at 88 dB, the recommended safe time drops to 4 hours. At 91 dB, the time drops to 2 hours and so on. It is the combination of level of exposure and the time allowed that determines the maximum allowable daily noise dose for an individual.

Several researchers have taken the workplace approach to calculating maximum permissible daily noise doses for leisure activities. For example, Hodgetts and Liu[8] found that during the Stanley Cup hockey finals in 2006, the levels in the Edmonton Hockey Arena reached a maximum allowable daily noise dose of around 6 minutes; however, the games lasted about 3 hours each. Other researchers have used similar calculations to assess the listening levels of smartphones and other personal music devices.[9,10] One criticism of this approach is that the safe listening recommendations are based on data from cumulated noise exposure over many years in an industrial context. Many leisure activities are short lived and non-recurring. For example, while hockey noise is significant and disconcerting, an argument can be made that, unless you are a full-time employee who attends every game, the occasional exposure is likely not the same as the cumulative exposure over the lifetime of an employee in a noisy factory. Therefore, it has been argued that risk estimates derived from industrial noise should be interpreted with some caution when applying them to leisure noise.[10]

So far, we have been discussing noise exposure that is more or less continuous over a period of time. Another noise type, impulse noise, is characterised by a sudden burst of high intensity energy. The impulse noise creates an intense air pressure change that can have a significant impact on the auditory system. Impulse noises (typically explosions) have the potential to create large waves in the basilar membrane of the inner ear causing damage to the delicate hair cells.[11] Recent research has also shown that noise damage can occur even beyond he cochlea in the synaptic gaps between the inner ear and the VIIIth nerve.[11]

Occupational standards also contain hearing risk estimates based on impulse noise.[7,12] A number of recent studies have looked at various methods of calculating maximum permissible exposure (MPE) based on impulses.[1–4,12–15] These approaches vary in how conservative they are at estimating risk, with some approaches predicting more damage than others. A universally agreed upon method has not been established, but Flamme et al.[2] provided a thorough review of the various approaches. They measured the sound pressure level (SPL) of various firecrackers and found that at 0.5 m the peak SPL was around 171 dB. Given that intensity, the most liberal calculation for MPE estimated that subjects could be exposed to 2 firecrackers at that distance, while the most conservative method of calculating MPE suggested that zero exposures would be safe at that distance. Similarly, Flamme et [2] measured civilian firearms and found that they ranged from 141 dB SPL for a Marlin 60 .22 calibre rifle to 164 dB for a Smith and Wesson .38 calibre handgun. Again, they provide estimates that ranged from a few exposures to zero safe exposures, depending on the method of calculating MPE. The government of Canada has some broad recommendations available on their website indicating that:

"Noise regulations in several jurisdictions treat impulse noise separately from continuous noise. A common approach is to limit the number of impulses at a given peak pressure over a workday. The exact figures vary slightly, but generally the regulations in which the exchange rate is 5 dB permit 10,000 impulses at a peak pressure level of 120 dB; 1,000 impulses at 130 dB; 100 impulses at 140 dB, and none above 140 dB."

With this background in mind, we set out to determine if there was any reason to be concerned about potential hearing risks associated with balloons exploding. Specifically, do balloons produce an acoustic pressure wave on par with other well-known explosive sounds? And if so, should we be concerned about children playing with and popping balloons?

Method

Instrumentation

The authors used standard 9-inch party balloons for all measures (Unique Industries©, Inc., Philadelphia, PA). The measurement setup consisted of a ¼-inch constant-current power (CCP) pressure microphone-preamplifier set (G.R.A.S. Type 46BG) with a sensitivity of 0.2 mV/Pa, and a 2 channel CCP power module (G.R.A.S. Type 12AQ) with adjustable gain (?20 dB – 70 dB in discrete steps of 10 dB) and selectable filter (Linear, High-pass, A-weighting, External) settings. The microphone-preamplifier set has a bandwidth of 3.15 – 70k Hz and dynamic range upper limit of 184 dB SPL. All but the 0 meter measurements (described below) were made at grazing incidence to the sound source, and all measurements were made with the power module set to apply 10 dB gain. Measurements were carried out within a single day; the measurement setup was factory calibrated less than two months from measurement date, which was well within the suggested annual calibration. Data were collected at 250kHz with a 16-bit National Instruments USB-6210 data acquisition (DAQ) module set at +/-10V range. A custom LabView program was used to control all measurement equipment and data collection. Data were saved to text files and post-processed in MATLAB® using custom MATLAB® scripts alongside a US National Institute for Occupational Safety and Health (NIOSH) developed MATLAB® library; this library was also used by the authors in[1–4] to analyze impulse noise data. (We need to talk about the MATLAB script used here to do the calculations and that it was the same script used for the guns that we include in this paper).

Procedures

We were interested in the level of impulse noise at 4 distances from the microphone: 0 meters, 0.5 meters, 1 meter, and 2 meters. We were also interested in the impulse level when "inflated to pop" (blown up to the point of explosion) versus "crushed to pop" versus "pin popped." The authors wore industrial grade ear protection for all measurements.

For the "inflated to pop" condition one of the authors blew air into the balloon to the point it ruptured. This was repeated 10 times at each distance with all post-processed results being averaged to obtain mean values. For the "crushed to pop" and "pin popped" conditions the authors first measured a piece of string to 28.3 inches in length (circumference = 3.14 × 9 inches). This string was then used as a 9-inch guide by inflating the balloon to the point where the largest section of the balloon fitted into the loop of string. We realize that the circumference of a balloon is not a perfect circle; however, we felt this provided us a reasonable calibration for the prescribed 9-inch diameter. We obtained 10 measures of crushed to pop and pin popped at 0 meters from the microphone. These 10 measures were then averaged for a mean peak dB SPL for both conditions.

Results

Table 1 shows the main findings from this experiment. As expected, the worst-case scenario was when a balloon was inflated to rupture at the entrance to the microphone. This would be the equivalent of a person blowing a balloon to rupture right beside another person's ear. Mean peak SPL in this scenario was 167.82 dB with a standard deviation of 3.75 dB. At this level, this impulse noise may represent approximately the 8-hour equivalent exposure of 81.35 dB (SD = 2.54 dB). We used the A-weighted 8-hour sound equivalent level (L_{eqA8hr}) method outlined in the Direction

Technique de Armements Terrestres (DTAT) 1983 standard[16] and used in [3-4] to calculate approximate maximum permissible exposures (MPE) for both adults and children. We found that adults may be able to sustain between 2 and 3 exposures of this level before running the risk of permanent damage. However, for the children, not even 1 exposure would be considered safe when a balloon is inflated to rupture near the ear. Predictably, as we moved the exposure further back from the microphone, the average peak dB SPL decreased and the MPEs increased (See Table 1). Both the crushed to rupture and pin popped conditions were found to be lower in average peak dB SPL and MPEs than the inflated to rupture conditions.

Table 1. Experiment Findings

Condition	Distance from Mic	Mean Peak dB SPL	SD (Peak)	Mean LEQA8 dBA	SD (LEQA8)	MPE (Adult)	MPE (Child)
Inflated to Rupture	0.0 M	167.82	3.75	81.35	2.54	2.32	0.23
	0.5 M	157.03	1.50	73.64	1.14	13.68	1.37
	1.0 M	151.26	1.69	70.71	1.76	26.87	2.69
	2.0 M	145.84	0.79	68.41	1.05	45.59	4.56
Crushed to Rupture	0.0 M	159.03	5.13	74.61	3.08	10.95	1.09
Pin Popped	0.0 M	154.99	1.40	72.76	1.62	16.75	1.67

Figure 1 shows a comparison of the inflated to rupture, 0 meter condition in comparison to other recently measured impulse noises.[1,2] While slightly lower than a 357 magnum, the balloon impulse noise was found to exceed that of a 12 gauge shotgun and a 30-06 rifle. Figure 2 shows a capture of the moment of balloon ruptures. As can be seen when inflated to rupture, the entire surface of the balloon ripples and creates a huge disturbance in the air around the balloon. Additionally, for online viewing there is a slow-motion video showing the moment of explosion and the accompanying explosion.

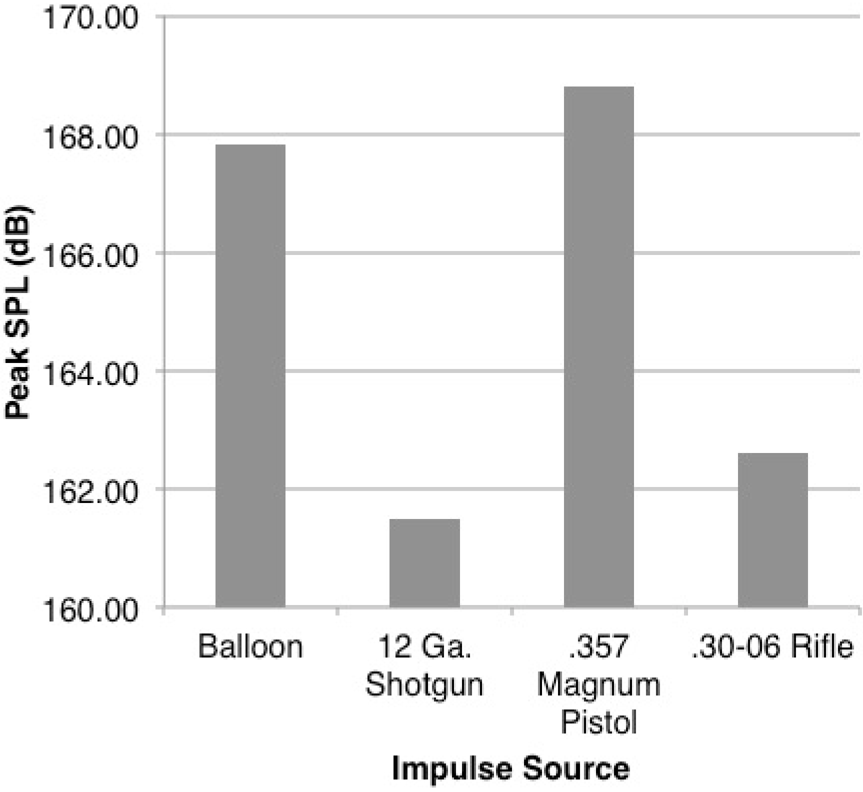

Figure 1. Average peak SPL (dB) for balloons blown to rupture at the measurement microphone. Data from Flamme et al., (2009) is presented for comparison.

Figure 2. Image of second author blowing up a balloon to the point of structural exhaustion.

/2016/11/Balloon-Explosion-Slow-Motion.mp4"]https://canadianaudiologist.ca/wp-content/uploads/2016/11/Balloon-Explosion-Slow-Motion.mp4

Slow motion video of a balloon explosion.

Discussion

Our initial objective for this experiment was to explore whether two concerned fathers had any justification for their disdain of children's party balloons. While we felt they may be potentially hazardous, we were alarmed to discover that they were capable of producing impulses that were around the same level as a high-powered shotgun or a 357 magnum. For children, in particular, balloons produce an impulse noise that may be considered potentially hazardous, in some cases, even after only 1 or 2 exposures. We are fairly confident that parents would not let their children shoot guns without considering hearing protection.

It is important to point out that risks associated with maximum allowable daily noise doses assume that these exposures will be occurring for a long period in a person's life (e.g., years). It is also true that the calculation of MPE from impulse noises is an area that is not completely understood or agreed upon.[7] However, it is difficult to imagine how we might actually find an answer to these challenges associated with these estimates since it would be unethical to pursue controlled, long-term exposure or impulse noises in humans. However, recent work on animals has shown that ears exposed to only 2 hours of 100 dB demonstrate significantly greater loss as they aged compared to control animals. Additionally, there was a significant interaction between amount of exposure and age of animals. Higher exposures when the animal was young lead to more rapid declines as the animals aged.[17]

Noise is cumulative in the same way that sun exposure is[18] and we need to be thinking of noise exposure in our society like we now think of sun exposure. The intention of this research is not to have balloons banned from society any more it is the intention of cancer research papers to have the society banned from going outside on sunny days. This paper is about raising consciousness about a topic that we do not yet spend enough time discussing. We appreciate that it is fairly easy to consider papers such as this, and the people who write them, to be hyper-concerned parents dedicated to generating yet another warning label that takes away the joys of being a child. In fact, balloons are not banned from play in either author's homes. The children in our houses are aware of balloon noise and are educated about the risks of popping them. That is the important context of this paper. Hearing loss is an invisible problem. We have trouble imagining the impacts of cumulative noise exposure because it happens so gradually. Even if we notice ringing in our ears from a high exposure, the ringing usually subsides and leaves us with a false sense that nothing permanent happened. A recent survey showed how far we have to go to change the way people think about hearing loss and hearing protection. Parker and Dybala[19] asked adults to imagine themselves at an outdoor concert on a day that was forecasted to be sunny, and then rank order the items that they imagined they would need. The results were troublingly predictable. At the top of the list was "bottle of water." We are not arguing that hydration is unimportant. However, at some point in the authors' lives, hydration shifted from being something that happened when you were thirsty, to something that is federally recommended[20] and proactively planned before every outing. The next items were also very important and predictable. Protecting ourselves from the potentially harmful effects of the sun. What had us troubled was the fact that "earplugs" was second from the bottom on this list. In fact, earplugs just edged out "towels" as a consideration for the concert.

We bring this up to underscore the importance of educating an issue into a child's permanent way of thinking. We believe that the "water" and "sunscreen" rankings reflect the changing ways parents, teachers and daycares for young children think about these issues. To be sure, the science and knowledge of these items is critical. Somehow, enough of that knowledge made its way to the "system" to convince the people supporting the healthy development of children that protecting them from dehydration and sun exposure is important. In other words, the idea to keep children hydrated and protected became sticky enough for the behaviours to become automatic and expected. To our children, wearing sunscreen is not a behaviour they will need to learn. It is going to be just what you do when you leave the house on a sunny day. We believe that changing the minds of teenagers and adults about hearing protection is an important challenge. However, we feel that changing the mindset of parents with small children as well as daycares and schools about the impacts of noise on lifelong hearing will probably lead to greater social and societal change in the long-term. This is the context for this paper. This is our hope. We want physicians and audiologists to have an interesting starting point for conversations with parents of young children. We want parents to talk to other parents about noise and how to protect against unnecessarily loud environments for their children. We want daycares and schools to be aware of the long-term hazards of even one larger exposure. If balloons can be one of the tools to get that conversation started, we will have accomplished something with this article. To our children, they just know and accept that sunscreen is important because we have learned enough about it and made it routine for them. Our hope is that by the time our children have children, they will know and accept that hearing protection is important and it will be routine to their children. It all starts with conversations like this: “did you know how loud balloons can be?”

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Declaration of Competing Interests

Neither author has any competing interests to declare.

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