# Occupational and recreational noise exposures at stock car racing circuits: An exploratory survey of three professional race tracks[1)]

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**Noise in stock car racing is accepted as a normal occurrence but the exposure levels associated with the sport have not been adequately characterized. Researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an exploratory assessment of noise exposures to drivers, racing team members, and spectators at three stock car racing events. Sound level measurements were conducted using sound level meters, personal noise dosimeters, and a digital audio tape recorder that made sound recordings for later laboratory analysis. Area sound level measurements were made during race preparation, practice, qualification, and competition. Personal dosimetry measurements were conducted on drivers, team members, and spectators. Findings showed time-weighted averages (TWA) that ranged from A-weighted 96 decibels (dBA) for a spectator in the stands during a race to 114 dBA for a driver inside a car during practice. Peak sound pressure levels exceeded the maximum allowable limit of 140 dB during race competitions. Personal exposure measurements exceeded the NIOSH recommended exposure limit of 85 dBA as an 8-hr TWA in less than a minute for one driver during practice, within several minutes for team members, and less than one hour for spectators during the race. Hearing protection use was variable and intermittent among team members and spectators. Among drivers and team members, there was greater concern for communication performance than for hearing protection.**
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## 1 INTRODUCTION

Stock car racing is one of the fastest growing spectator sports in the United States with over 75 million television viewers and more than 8 million spectators attending over 90 racing events each year[1,2]. Thunderous noise is often associated with stock car racing and, to a certain extent, is part of the sport appeal. The growing popularity of the sport has led racing teams to demand more speed and performance from their car engines, which in turn leads to higher noise emissions in and near the car and around the racetrack[3]. There is no verifiable information about the number of people who are occupationally involved in the sport, however, each of the three major racing leagues has between 30–43 racing teams with some of the teams employing as little as ten people while the top teams employ hundreds of workers.

Noise levels at professional stock car racing events have not been empirically documented, however, noise levels at other racing events (i.e. open wheel cars, monster trucks and motorcross) have been recorded from 100 – 140 decibels (dB)[4,5]. It is well known that prolonged and repeated exposure to excessive noise levels may lead to noise-induced hearing loss (NIHL), which is an irreversible, condition caused by damage to sensory cells within the cochlea. Race car drivers, team members and crew, event staff, and employees of the racetracks—and, to a lesser extent, the spectators—are often exposed to noise levels that are considered hazardous to hearing[6,7]. Although professional stock car racing associations have a strong history of safety practices and innovations, they do not require hearing protection to prevent NIHL[8]. Anecdotally, there are reports of widespread hearing loss among professional stock car racing personnel, but there is very

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[1)] Mention of the name of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

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little scientific literature on the extent or severity of auditory damage or impairment[3].

Previously, investigators from the National Institute for Occupational Safety and Health (NIOSH) in partnership with a stock car racing team surveyed and documented area and personal exposure to noise and chemicals at the Bristol Motor Speedway in Bristol, Tennessee[9,10]. The Bristol Motor Speedway is considered a "worst case scenario" for noise and chemical exposure due to its small size ($\frac{1}{2}$-mile track) and bowl-shaped configuration. Results showed personal exposure levels that ranged from 100–125 A-weighted decibels (dBA) for the driver and 95–120 dBA for the racing team and crew members. That initiative was then expanded to include spectator noise exposures at Bristol Motor Speedway, and to survey and document personal and area noise levels at two additional racetracks in Indianapolis, Indiana and Sparta, Kentucky. The Indianapolis and Kentucky tracks are considered to be more representative of standard racing environments.

## 2 METHODS

Noise assessments consisted of (1) area noise level measurements in the pit area, infield, and spectator stands at three race tracks, and an infield garage at the Kentucky Motor Speedway; and (2) personal noise exposure measurements of one driver, team members and crew, and spectators during race preparation, practice, qualifications, and competition.

### 2.1 Stock Car Racing Circuits

The Bristol Motor Speedway in Bristol, Tennessee is reputed by stock car racing teams and spectators to be the noisiest racetrack in the United States. It is a $\frac{1}{2}$-mile track that has a seating capacity for 150,000 spectators. Unlike other tracks, Bristol Motor Speedway grandstands extend upward to form a bowl-shaped configuration similar to football stadiums. Figure 1 displays the stadium-like configuration of the Bristol Motor Speedway. Two other racetracks were selected. The Indianapolis Motor Speedway (Indiana), also known as "the Brickyard," is a 2.5-mile, oval-shaped track, which is the oldest track in the circuit, as well as the largest in terms of its seating capacity of more than 250,000 spectators. The Kentucky Speedway in Sparta, Kentucky represents a new state-of-the-art racing venue. The track is a 1.5-mile tri-oval (3 turns) and offers seating capacity to 75,000 spectators.

Infield areas typically hold team garages, media and information centers, a medical facility, concession stands, and other race support functions. In addition to the racing teams and racing-event employees, some spectators can purchase special admission tickets to enter the infield and pit areas.

*Fig. 1—Bristol Motor Speedway, Bristol, Tennessee, U.S.A.*

Racing teams are typically comprised of various individuals who carry out different tasks during a race event. Team members include owners, administrators, engineers, race trailer drivers, mechanics, and one or more race car drivers. A subset of this group is called the *crew* or *pit crew* comprised of 7–10 team mechanics that service the car when it comes into a designated area called the *pit* for a *pit stop* during practice, qualifications, or the race. The pit crew is headed by a crew chief, the person responsible for supervising and managing the crew and communicating with the driver during the race. Each racing team is assigned a *pit stall* located on a straight lane road that runs parallel to the race track, called the *pit lane*. In stock car racing circuits, the pit lane is separated from the infield area and the garages by a low concrete wall where team and crew members must remain behind until the car comes in for a pit stop. Race cars enter and exit the pit lane several times during the race for refueling, tire change, mechanical car adjustments, and quick repairs after minor accidents. The typical tire change and refueling pit stop lasts between 13–18 seconds.

Stock car racing events usually start 1–2 days before the race. Activities during a race weekend include *preparation*, which is when car adjustments are made in the infield garage or in the pit; *practice*, which is the designated time allowed by the association for the teams to work on performance details; *qualifications*, which is when the driver makes 2 or more laps at top speeds in order to qualify for the race and the race order placement; and finally *race competition*, which may run 2–4 hours in duration depending on the race mileage, weather conditions, and accident rate.

### 2.2 Instrumentation

*Area noise level measurements* were conducted using the Quest Technologies Model 1800 (Oconomowoc, Wisconsin) and the Larson-Davis System 824 (Depew, New York) type 1 sound level meters. Sound level meters were set to "SLOW" response and A-weighting frequency filter. A Panasonic SV-255 digital audio tape (DAT) recorder was used to capture ambient and engine noise emissions for further frequency and octave band analysis. The sound level meters conformed to the American National Standards Institute (ANSI) S1.4—1983 (R2006) specification[11]. The equipment manufacturers calibrated the instruments before each visit. Field calibrations were conducted before and after measurements using the Larson-Davis CAL250 and the Quest Technologies CA-22 acoustic calibrators.

Data from the Quest Technologies and Larson-Davis sound level meters were downloaded and analyzed using QuestSuite 4.0 and Larson-Davis 824 Utility 3.0 software respectively. Recordings from the DAT were digitally transferred to a computer as WAV files via AUDIOTRAK Waveterminal U2A 24-bit audio card (San Jose, California) and CoolEditPro 6.0 software (San Jose, California). Spectral analysis was performed by MATLAB software (Natick, Massachusetts) routines, which yielded maximum levels, equivalent sound levels ($L_{eq}$), time and frequency spectra, and octave- and 1/3-octave band spectra.

*Personal noise exposure assessments* were conducted using the Quest Technologies M27 (Oconomowoc, Wisconsin) and the Larson-Davis Spark 706 (Depew, New York) personal noise logging dosimeters. The dosimeters conformed to the American National Standards Institute (ANSI) S1.25—1991 (R2007) specification[12]. The equipment manufacturers calibrated the instruments before each visit. Field calibrations were conducted before and after measurements using the Larson-Davis CAL250 and the Quest CA-22 acoustic calibrators. Data from the Quest and Larson-Davis dosimeters were downloaded and analyzed using QuestSuite 4.0 and Blaze V2.0 software. The dosimeters were set to measure noise exposure in comparison to the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) and the NIOSH recommended exposure limit (REL)[4,13]. The OSHA PEL is 90 dBA for an 8-hour time-weighted average (TWA) using a 5-dB exchange rate. The NIOSH REL for noise is 85 dBA for an 8-hour TWA using a 3-dB exchange rate. OSHA and NIOSH state that no unprotected exposure shall be permitted above 140 dB.

## 2.3 Measurements

*Area measurements* locations were selected to provide a sample representation of typical noise emissions in and around the racetracks. However, it is important to note that certain limitations associated with accessibility to restricted team areas, and rules surrounding the operation of electronic equipment at various locations prevented a comprehensive noise assessment.

*Table 1—Number of personal and area measurements.*

| | | | | |
|---|---|---|---|---|
| Area Measurements | | | | |
| *Racetrack* | *Pit* | *Infield/Infield Garage* | *Stands* | *Total* |
| Bristol | 4 | 2 | 6 | 12 |
| Kentucky | 2 | 4 | 2 | 8 |
| Indianapolis | 1 | 1 | 2 | 4 |
| Personal Dosimetry | | | | |
| *Racetrack* | *Pit* | *Infield/Infield Garage* | *Stands* | *Total* |
| Bristol | 3 | 4 | 2 | 9 |
| Kentucky | 2 | 3 | 4 | 9 |
| Indianapolis | 2 | 2 | 2 | 8 |

Area noise level measurements were conducted during preparation, practice, qualifications, and racing competition at all three racetracks. A total of 24 area measurements were obtained at the Bristol Motor Speedway during two races; at the Indianapolis Motor Speedway during two races; and at the Kentucky Speedway during three races. Distance from the racetrack varied from 50 feet for the pit crew at Bristol Motor Speedway to several hundred yards for infield measurements at the Indianapolis Motor Speedway. The spectator stands were limited by the seat assignments and their distance from the racetrack and varied from 50 to 300 feet. Noise level measurements were also obtained inside and around the car while it was idling in the pit area and near the garage.

*Personal noise exposure measurements* were selected to reflect the major occupational risk hazards encountered in racing. A total of 26 personal dosimetry measurements were obtained on one driver, crew members, team observers, and spectators. Arrangements were made with several willing spectators to wear dosimeters during their attendance of the races. Measurements were collected for seven races spanning a 3-year time period. Dosimeters were typically set to measure the 8-hr TWA starting 2 or 3 hours before the race. Table 1 shows a breakdown of the area and personal measurements at the three racetracks.

The noise exposure metrics provided by the instruments and reported in this study are: 1) equivalent continuous sound level ($L_{eq}$) to indicate the average sound level based on a 3-dB exchange rate; 2) maximum level ($L_{max}$) indicating the highest A-weighted sound level that occurred during the measurement period; 3) peak

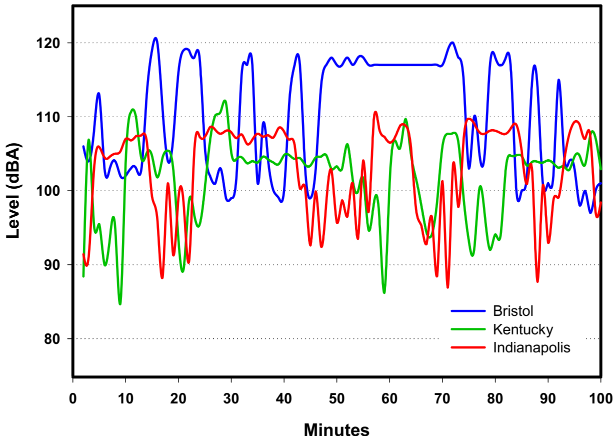


*Fig. 2—Average infield area sound level measurements during first 100 minutes of the races.*

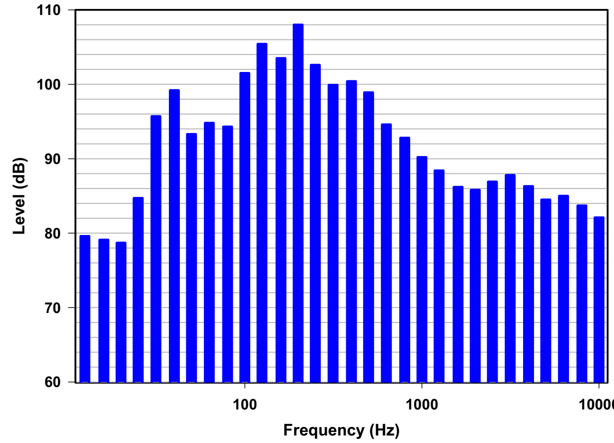


*Fig. 3—1/3 Octave noise spectrum of a stock racing car.*

level ($L_{peak}$) to indicate the highest instantaneous sound pressure (linear or no frequency-weighting); and 4) time-weighted average (TWA) indicating the average A-weighted sound level that is accumulated over an 8-hour time period.

## 3 RESULTS

### 3.1 Area Sound Level Measurements

Figure 2 shows average area noise level measurements taken in the pit area during racing competitions at the three race tracks. The Kentucky Speedway race lasted approximately 2 hours while the Bristol and Indianapolis races lasted over 3 hours. In order to provide a comparative sample of noise levels at these racetracks, the first 100-minute segment of each race was selected for presentation. The transient decreases in noise levels in the tracings are typically the result of the race being run under caution (low speed) after an accident.

Table 2 provides a snapshot of noise levels in the pit area, the infield, and the spectator stands during racing competition at all three race tracks. Pit and infield measurements at the Indianapolis Speedway were collected during a single racing event since access to the infield area was not granted on subsequent visits.

Engine and exhaust noise are the primary contributors of noise during the racing competitions. Figure 3 shows the noise spectrum of a stock car in 1/3-octave band levels. Measurements were obtained approximately 3 feet away with the engine running at full throttle. The figure illustrates that most of the energy content is concentrated in the lower frequencies (100–500 Hz). Knowledge of the noise spectrum associated with car engines and racing is imperative to the selection of appropriate hearing protection and communication devices, and providing effective engineering noise control solutions.

### 3.2 Personal Exposure

Limited access to personnel and certain areas of the race tracks at the Kentucky and Indianapolis speedways prevented the authors from conducting a complete and thorough assessment of personal noise exposures at those race tracks. The most complete set of personal dosimetry measurements was conducted at the Bristol Motor Speedway since it represented the "worst-case

*Table 2—Area noise level measurements during races[2].*

| | Pit Area | | | Infield | | | Stands | | |
|---|---|---|---|---|---|---|---|---|---|
| | Leq | Lmax | Lpeak | Leq | Lmax | Lpeak | Leq | Lmax | Lpeak |
| Bristol Speedway | 96–114 | 119–124 | 136–143 | 97–119 | 111–123 | 130–142 | 96–104 | 106–114 | 120–150 |
| Indianapolis Speedway | 105 | 117 | 139 | 94 | 107 | 127 | 90–94 | 107–112 | 127–138 |
| Kentucky Speedway | 102–104 | 120–121 | 139–141 | 90–108 | 115–121 | 139–140 | 93–95 | 107–120 | 131–145 |

[2] Measurements conducted during each race, only single measurements were obtained at Indianapolis Pit and Infield areas.
Leq is equivalent-continuous (averaged) sound level in dBA based on a 3-dB exchange rate for the race period (typically 2–3 hours)
Lmax is the maximum noise levels in dBA based on a 3-dB exchange rate
Lpeak is the peak sound pressure level in dB, linear weighting.

*Table 3—Personal dosimetry measurements at the Bristol Motor Speedway[3].*

| | $L_{eq}$ (dBA) Allowed Exposure Duration | TWA (dBA) (Minutes) | Length of Exposure (Minutes) |
|---|---|---|---|
| Driver (Practice day) | 114.4 | 111.6 | 251 (4.18 hrs) |
| 0.54 | | | |
| Crew member (Practice day) | 107.2 | 107.7 | 545 (9.08 hrs) |
| 2.84 | | | |
| Crew member (Race day) | 107.7 | 106.0 | 322 (5.37 hrs) |
| 2.53 | | | |
| Infield observer #1 (Practice day) | 106.2 | 106.5 | 504 (8.40 hrs) |
| 3.58 | | | |
| Infield observer #1 (Race day) | 111.5 | 109.8 | 325 (5.41 hrs) |
| 1.05 | | | |
| Infield observer #2 (Practice day) | 104.5 | 105.2 | 556 (9.26 hrs) |
| 5.30 | | | |
| Infield observer #2 (Race day) | 110.2 | 109.7 | 430 (7.16 hrs) |
| 1.42 | | | |
| Spectator (Practice day) | 96.4 | 96.4 | 480 (8 hrs) |
| 34.5 | | | |
| Spectator (Race day) | 99.6 | 99.6 | 480 (8 hrs) |
| 16.45 | | | |

[3] Leq is the equivalent-continuous (averaged) sound level in dBA based on a 3-dB exchange rate.
TWA is the Time-Weighted Average sound level in dBA based on a projected 8-hour exposure.
Allowed exposure duration is the NIOSH maximum allowed exposure time based on the measured noise levels and as described in equation 1 in the results section.

scenario" for personal noise exposure and the authors had access to the racing team personnel without restrictions.

The NIOSH criteria document[6] states that occupational noise exposure shall be controlled so that a person is not exposed to hazardous noise levels ($L$) above a certain duration of time ($T$) given by the following equation:

$$T = \frac{480}{2^{(L-85)/3}} \tag{1}$$

where $3 =$ the exchange rate.

Table 3 shows personal dosimetry measurements from the Bristol Motor Speedway and the NIOSH recommended exposure durations based on the above equation. The table shows the $L_{eq}$ and TWA for the race car driver, crew members, observers in the infield and pit areas, as well as measurements from the spectator stands. The measurements were collected during two consecutive days—the first day included practice and qualifications while the second day was mostly devoted to the race and associated activities.

Some personal measurements for infield staff and spectators at the Kentucky and Indianapolis showed the measured $L_{eq}$ to be 4–10 dB lower on average than those found at the Bristol Motor Speedway. Overall, measurements showed that sound levels were 5–7 dB higher during the race than during practice and qualifications, mainly due to the total number of cars on the race track during the race compared to the fewer cars during practice and only one during qualifications.

## 4 DISCUSSION

In addition to the competition, it is apparent that the noise generated by the powerful car engines is part of the allure of stock car racing. Racing associations briefly experimented with the use of mufflers in the 1970s but quickly abandoned the idea because quiet cars proved unpopular by racing teams and spectators alike[7]. According to the Orlando Sentinel articles, drivers, crew members, and spectators agree that auto racing is inherently noisy; however, they don't seem to realize that exposure to excessive noise levels can lead to several negative health outcomes including NIHL. Furthermore, team and crew members do not often consider hearing damage to be an occupational hazard but rather a form of sports injury[3]. This disparity in qualifying terms and hazard awareness may explain why motor sports hearing damage has received almost no attention from regulators and noise conservation researchers. The results of the NIOSH noise survey confirm that noise levels often exceeded those found in some the harshest of industrial settings[6].

## 4.1 Area Noise Level Measurements

All of the area noise level measurements exceeded the NIOSH REL of 85 dBA. The results also confirmed that the Bristol Motor Speedway represented the worst-case scenario for noise emissions, presumably because of its small track size and bowl-shaped, metal-constructed stands that reverberate and amplify the noise generated by the stock cars. The other racetracks fared slightly better because of their larger tracks and open spectator stands; however, noise levels were still considered hazardous to hearing.

The results showed the highest area noise levels were found in the pit area at the three racetracks because of the proximity of these areas to the race track and cars. Area noise levels in the infield area varied among the different tracks and they were highest at the Bristol Speedway because of the small size and close proximity of the infield area to the pit area. Area noise levels at the Kentucky and Indianapolis speedways were comparably lower due to the fact they have much more expansive infield areas. Area noise levels in the spectator stands were on average 3 – 10 dB higher at Bristol than those found at Kentucky and Indianapolis speedways, again likely due to the small size and shape of the racetrack.

Peak sound pressure levels in the pit area at all three race tracks reached and exceeded 130 dB-often recognized as the human hearing threshold for pain. Peak sound pressure levels reached or exceeded the NIOSH and OSHA "140 dB" maximum allowable exposure limit at the Kentucky and Bristol Motor Speedways. While team and crew members are required to wear communication headsets that provide some form of protection to their hearing, the majority of event staff and workers as well as spectators are exposed to harmful noise levels without having the benefit of hearing protection.

## 4.2 Personal Noise Exposure

Personal dosimetry conducted on team and crew members, infield staff, and spectators showed levels that exceeded the NIOSH REL within the first ten minutes from the start of the race. Personal noise measurements on a driver during a practice session (with fewer cars on the track than the actual race) exceeded the NIOSH REL in less than one minute. The measured noise dose was 50 to 900 times higher than the allowable occupational daily noise dose.

Races alone, however, are the not the sole contributor to the cumulative noise dose. There are approximately 200 racing teams in the stock car racing circuit. The size of each team varies with the level of competition and the organization to which they belong; most teams have around 20-30 members while some of the most recognized operations have much larger teams. Teams participate in 22–36 races a year. They typically arrive two to three days before each race and continually work in the garages and on the racetrack, making final mechanical and engine adjustments for maximum performance. The team members and mechanics spend approximately 12 – 18 hours before each race on these activities. Annually, they receive up to 15 – 21 hours of intensive noise exposure every week up to 40 consecutive weeks. Even on non-race days and after the racing season is over, many crew members continue to work at the team's home garage, building and improving cars and engines for the following year's races. The problem of quantifying the overall cumulative effect of noise exposure is compounded by the fact that some crew members and drivers work on several teams and are involved in more than a single race each week.

Although the emphasis of this exploratory survey was placed on evaluating occupational exposures, it is important to note that the problem of racing noise extends beyond the occupational environment. There are 8 million spectators who attend racing events every year. Most are very dedicated and travel from track to track to attend the various activities leading to the race; the lower league races, the practice sessions, and the race. These spectators can be exposed to more than 10 cumulative hours of hazardous noise levels in a single weekend. Based on the measured noise levels in the stands reported in Table 2 and 10 hours of exposure per week, these spectators are thus exposed to a noise dose that is two to ten times higher than a person working a 40-hour week at the maximum allowable limit of 85 dBA. The other issue of recreational noise exposure is that very little attention is devoted to hearing protection. Several sports-related and cultural aspects play significant roles in why hearing protection is not used. Fans reported to NIOSH investigators their reluctance to wear hearing protection is based on their need to hear and feel the roar of the engines. Recently, with the advancement of communication and radio systems, fans can listen to their favorite team's communications and some have opted to wear communication headsets while watching the race. Although these headsets have some protective features, their efficacy as hearing protection devices has not been documented.

*Fig. 4—Crews at work during a refueling stop.*

### 4.3 Communication and Hearing Protection Use

Race car drivers, team and crew members, and race officials rely on customizable racing communication systems to communicate during race and practice sessions. Skull fracture injuries sustained by crew members in recent years have prompted stock car racing associations and teams to advocate helmet use for head protection. Drivers and crew members usually wear custom-molded earphones under their helmets, while the rest of the team members use generic communication headsets with their radios. Race officials now use headsets that are integrated into their helmets. Figure 4 shows a typical race crew during a fueling and tire-change stop and their proximity to the car. The figure shows working conditions before the current mandatory requirement that all crew members who service the race car wear helmets. The engines are never shut off and there are usually multiple cars in adjacent pit areas during normally scheduled pit stops.

Anecdotal accounts cited by several drivers and crew chiefs show that emphasis is always placed on optimal communication with little attention paid to hearing protection. They describe accidents caused by drivers' inability to hear speech communication from their crew chiefs and position spotters[14]. Because personal safety depends partly on clear and precise communication among crew members and between drivers and crew, radio-communication volume is usually adjusted to its loudest setting. Interestingly, these volume adjustments in order to overcome background noise seem to defeat any hearing protection the headsets or communication earphones might otherwise provide[15].

A study of earplug attenuation for motorcyclists showed degradation in their performance at low to mid frequencies when worn under a crash helmet[16]. This degradation has been attributed to the phenomenon of helmet resonance at 500 Hz by wind at racing speeds[17]. The finding is significant because sports car drivers and crew members are also exposed to low-frequency noise. In fact, stock cars have no side windows and drivers are exposed not only to low-frequency noise but also to wind noise when racing at speeds that sometimes approach 200 miles per hour. Three types of earplugs studied, used with and without a helmet, provided approximately 15 dB of sound attenuation, which is hardly adequate when noise exposures to drivers and crew average 110 dBA, with peak levels reaching 140 dB. A separate study showed marked improvement in noise attenuation when earmuffs were incorporated into a helmet shell[18].

However, the efficacy of these communication systems as hearing protection devices in such a high-noise and physically demanding environment such as stock car racing has never been documented. Most racing associations do not require drivers and crew to wear hearing protection devices during practice or race activities, nor do they provide any guidelines about the selection of appropriate communication headsets that can provide adequate protection[19].

NIOSH recommends that noise exposures reaching workers' ears not exceed a TWA of 85 dBA during an 8-hour working shift[4]. Since available noise control solutions (e.g. mufflers) are not likely to be applied to reduce the noise emissions from race cars to a TWA below 85 dBA, hearing protection must be used. In certain working environments with excessive noise levels, double hearing protection (earplugs and earmuffs) may be warranted. Newer technologies employing noise cancellation and level-dependent circuitry that provide better attenuation of ambient noise and improve speech intelligibility are now available commercially[20]. Crewmembers should be afforded the same hearing protection currently provided to drivers—that of custom-molded earplugs with built-in speakers. Spectators should also be made aware of the noise problem through education and informational campaigns. Most spectators assume that few hours of recreational noise exposures are harmless, but the data in this study show otherwise. When appropriately selected, hearing protection can become a competitive performance advantage, both as a means to improve communication accuracy as well as a means to prevent long-term noise-induced hearing loss.

## 5 CONCLUSION

Stock car racing is vastly expanding in popularity throughout North America, yet there is little recognition of the associated noise exposure as an occupational hazard. This NIOSH study found that noise levels on three race tracks exceeded those measured in many hazardous industrial environments. Innovative technologies, as well as educational approaches, should be employed to limit hazardous noise exposures to stock car drivers, team and crew members, and spectators. Hearing protection should be incorporated into the communication needs of professional auto racing.

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