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SAFETY AUDITING (3): Development of Self-Audit Systems.

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Abstract

The paper describes and discusses the development of self-audit systems, and the warm acceptance of quality auditing worldwide by industries in the USA, Europe and Australia. Special attention is paid to Australian, and particularly Western Australian experience, where mining and mineral processing industries derived numerous benefits in occupational safety and health from systematic applications of safety auditing using self-audit systems.

Key Words Development of self-audit systems. Mining and mineral processing operations. International safety and quality standards. Occupational safety and health.

Introduction

The first article in this series (Nedved, 2014a) discussed the significance of safety auditing in the prevention of accidents and ill-health at work. Major objectives, main elements and organisational aspects of safety auditing were discussed. Recent Western Australian (WA) experience in the development of the safety auditing system was described and the development of an international level programme, not only of sound safety auditing practices but also a training programme for safety auditors developed by the WA team and tested extensively throughout South East Asia was outlined. The significance of well-prepared audit documents, including audit protocols and checklists, was explained. The second article in this series (Nedved, 2014b) dealt in more detail with the development of audit protocols, rating systems and checklists for pre—audit surveys and for the actual safety audits.

Such audit protocols guide and direct the safety auditors as to the observations that should be made and the questions to ask in order to effectively verify all the organisational aspects relevant to the occupational safety and health programme element under review by the safety audit.

This paper will deal in more detail with the development of safety audits for the purpose of company's self-assessment, i.e., the development of a self-audit system.

Development

The previous two articles in this series have illustrated the advantages of the system safety approach to accident prevention over the classical industrial safety approach. The use of the classical industrial safety techniques, including the preventive strategies formulated on the basis of accident investigation or of various accident sequence models, routine safety inspections, etc., have reached the limit of their effectiveness. A variety of measures used in classical industrial safety to evaluate and measure the safety performance are reactive and calculated on the basis of consequences, i.e., the accidents we have not been able to prevent. Examples quoted previously included lost time injuries, first aid injuries or medical treatment injuries, as well as restricted duty injuries. The system safety approach focuses on the preventive measures, without waiting for occupational accidents to happen and for occupational diseases to develop. This is connected with the effort to develop predictive measures of the occupational safety and health performance. One of these predictive measures, and a very powerful one, is auditing of the critical range of the accident prevention processes.

The development of system safety techniques started during the early 1970s, and frequent subsequent improvements during the further 30 years have provided our profession with the wide range of systematic methods of evaluating a system designed to ensure that it operates as intended and that system failures do not occur, or that they are properly mitigated. These techniques include HAZOP - hazard and operability studies, "what if' analysis, PHA — preliminary hazard analysis, FTA - fault tree analysis, FMEA - failure modes and effect analysis, ETA ~ event tree analysis, DOW Index technique, MORT – management oversight risk tree analysis and some other techniques. MORT has been frequently referred to as the most powerful and effective tool in the hands of safety management practitioners. The discussion of these techniques is beyond the scope of this paper, and readers are referred to a number of specialised manuals and textbooks. (Collins and Nedved, 1999, Tweeddale 2003, Toohey, Borthwick and Archer 2005, Clifton and Ericson, 2011).

Simultaneously with the development of the above system safety techniques, the International Organisation for Standardisation (ISO) has been working on the developments of quality system standards. This specific standard development culminated in 1987, when ISO published the first 9000 Series of Quality System Management Standards. Then between 1987 and 1995 approximately 25,000 industrial companies in America and Europe have received ISO 9000 registration. The international recognition of ISO 9000 is illustrated by the fact that close to one hundred countries representing 95% of the world's industrial capacity have adopted the ISO 9000 series standards. These countries include the entire European community, the United States of America, Canada, Australia, most of Asia and part of South America. The ISO quality system standards encourage companies to develop and implement quality management and quality assurance systems, which ultimately are intended to improve products and services through the improvement of the production systems. The most important feature of the ISO 9000 series standards is their flexibility. They can be used as a tool to evaluate the system performance of practically any and every activity in any and every industry. The quality systems required according to the standard are applicable at all levels of technical sophistication including small companies or those who do not possess high level sophisticated technology.

There are five standards in the ISO 9000 series (International Organisation for Standardisation, 1991, updated 2008), all complementary to each other. ISO 9000 and ISO 9004 are guidance documents. ISO 9000 introduces potential users to the entire 9000 series and explains the distinction between the selection and use of the five different 9000 series standards. Standard 9004 (updated in 2009), provides guidelines for quality management and quality system elements, providing company management with assistance in the development of a quality system. ISO 9001, 9002 and 9003 represent varying degrees of achievement in quality system performance. Out of these three standards, ISO 9001 is the most extensive standard encompassing quality systems assurance in design and development, production, servicing and related activities.

The most significant step in obtaining an ISO 9000 registration by a company is the ISO 9001 field audit, carried out by a full complement of ISO auditors. The auditors review company documents and evaluate site operations during a comprehensive site audit. Such an audit is expected to verify that the quality system the company reported to be in place is actually in existence and is being effectively implemented throughout all levels of the organisation. The scope of an ISO 9001 field audit is listed below:

Scope of ISO 9001 Field Audit
1. Management Responsibility.
2. Contract Review.
3. Document Control.
4. Purchaser Supplied Product.
5. Process Control.
6. Inspection, Measuring and Test Equipment.
7. Control of Nonconforming Product.
8. Handling, Storage, Packaging and Delivery.
9. Internal Quality Audits.
10. Servicing.
11. Quality System.
12. Design Control.
13. Purchasing.
14. Production Identification and Traceability.
15. Inspection and Testing.
I6. Inspection and Test Status.
17. Corrective Action.
18. Quality Records.
19. Training.
20. Statistical Techniques.

The use of quality management principles started being seen as an obvious basis for a systems approach. In Queensland, a “best practice” model health and safety management system based on AS/NZS ISO 9001:2008 has been designed by the Queensland Department of Mines and Energy. This model system, called *SafeGuard*, also includes audit criteria, since the original idea was that quality style audits of mine occupational safety and health systems will be carried out by the Queensland Mining Inspectorate. These quality audits were aimed at testing whether the safety and health management systems were in place, and whether they have been successfully implemented, i.e., whether they were really efficiently functioning throughout the entire organisation at all levels, from managers to supervisors and to all miners and operators. The elements audited have closely followed the list of ISO 9001 Field Audit scope.

Since the Queensland Department of Mines and Energy believed that occupational safety and health should be integrated with production operations, their auditing closely followed quality management procedures and documentation. The *SafeGuard* system has been designed to be useful for both external auditors such as the mining inspectorate and for the mining companies carrying out their own internal occupational safety and health audits, i.e., for self-auditing.

SafeGuard has been developed to allow managers, supervisors and workers to:

- Self-assess their health and safety management systems.
- Use as a guide in setting up and improving health and safety management systems
- Encourage mines to carry out detailed self-audits of their health and safety management systems using quality auditing principles.
- Encourage audit team members to gain training and understanding in formal quality auditing principles.

The significance of systematically applying this quality auditing technique has been reflected in improved corrective actions, i.e., that future accident prevention strategies have been aimed at preventing or correcting fundamental root causes of the safety and health problems.

The *SafeGuard* quality audit system has been very successful in Queensland. Its usage has helped the managers of mining companies to successfully control and eliminate occupational safety and health problems by setting up a system for corrective and preventive actions and continuous improvement, in line With the original intent of the ISO 9000 series standards. The *SafeGuard* system has also increased the efficiency of inspections carried out by the mining inspectorate. It is expected that the inspectors in parallel with their own, i.e., external audits, will audit the self-audits undertaken by the mining companies.

The Chamber of Mines and Energy of Western Australia developed the Health, Safety and Environment self-audit system during the nineties. The manual has been produced to assist the management at various levels to implement a health, safety and environment self-audit system in their companies. The system comprises three key elements:

- Self-audit of the essential elements of a comprehensive health, safety and environment programme.
- Identification of areas where performance is below that which the user believes is appropriate and determination of priorities for remedial action.
- Development of a follow—up plan and identification of future targets.

This system advises the users to employ either the ratings on the scale from excellent to poor (as described in Nedved, 2014a) or the point scoring system (where excellent means 5 points, good 4 points, etc.). The self-audit system audits 21 elements of the ideal health, safety and environment management system in a mining company.

Under the Management Systems heading, occupational safety and health policy is examined, together with the line management responsibility for accident prevention and with the advisory role in the safety and health area. Health and Safety manuals are examined, together with the provision of GHS (Globally Harmonized System of chemical hazard classification) information for both managers and employees.

In the companies with potential major hazard installations, the relevant documentation is scrutinised with emphasis on written control measures and emergency procedures. All relevant regulatory requirements should be fully identified and listed in the company documentation, and the audit has to verify that the company can demonstrate full compliance with these regulatory requirements. Purchasing policies need to include health, safety and environment considerations and the audit aims at verifying this fact, as well as whether the provisions for health, safety and environment factors are being considered in the design, construction and installation of plant and equipment.

Hazard evaluation and control plays a particularly important role. The self—audit aims at checking a written hazard control programme, as well as whether or not the line managers and all employees have been trained in the implementation of such a programme. The audit also verifies whether such programme is periodically and systematically updated.

Emergency procedures should be clearly available in the form of an emergency procedure manual. This needs to be verified by the audit, together with the provisions for regular training of all employees for emergencies, and for the training of special emergency crews. A written job safety analysis programme, with the provisions for its systematic update, attracts the audit0r’s attention, together with the areas of housekeeping and transport and mobile equipment. The personal protective equipment system deserves particularly good attention during the self—audit. The development of audit protocols for the personal protective equipment system was described in detail in the previous article in this series (Nedved, 2014b).

Standards and design criteria for machinery guarding are audited, and particular emphasis is being paid to the areas of training of new employees (induction training), periodic training of all employees and safety and health training of managers and supervisors. The audit includes the provisions of communication with employees, and the provisions for recording and analysis of injuries, incidents and physical damage to plant, equipment and property. Inventory of chemical substances, including the material safety data sheet system is audited together with the programme for minimising the use of hazardous chemicals and the programme for substituting toxic chemicals with the chemicals of lower toxicity.

A written work environmental monitoring programme and the environmental monitoring programme are audited, with particular emphasis on conformity with statutory and company requirements. First-aid facilities and written procedures for the treatment of major injuries and illnesses are reviewed together with the provision of a functioning rehabilitation programme for injured or ill employees.

Every self-audit needs to verify whether, as a result of the previous audit report, a written improvement plan was formulated and implemented in accordance with scheduled deadlines. This self-audit system has been used by a number of WA mining companies, and is seen as particularly useful for medium sized organisations. The large organisations, and particular the multinationals, have been placing more emphasis on visible organisational commitment to safety and health. This includes not only strong management leadership at the corporate and local levels, but also effective safety and health programmes enabling employee participation at all levels in health and safety training, development of safe work practices and instructions, workplace inspections, accident investigation, job safety analysis, etc. Employees actively participate as members of self-audit teams and in various safety and health reviews. Self-audit systems in the large organisation frequently establish that employees at all levels are aware that their demonstrated commitment to occupational safety and health will be taken into consideration during the assessment of their performance, and will affect their promotion prospects and their performance pay. In well managed large organisations, a strong sense of employee ownership of the safety and health management system has been developed through a number of strategies, including self-auditing activities.

In such organisations, self-auditing also centres on the functions of occupational safety and health professional staff, which would include occupational physicians, occupational health nurses, safety engineers and occupational hygienists. Off-the-job (non-occupational) safety, with the activities frequently having strong family involvement, include health promotion, safe (defensive) driving, first-aid programmes, bicycle safety. Self-audits in large, well—managed organisations include the above, and verify whether the company has established off-the-job injury reduction goals.

Particular attention is being paid in self-audits to the areas known for very high frequency of occupational injuries. The fall protection programmes must ensure that the control measures have been developed and are documented, communicated, implemented and verified, and that a comprehensive fall hazard survey takes place at regular intervals. Such programmes would include large vehicles being provided with adequate ladders and platforms to permit safe access. The self-audit also intends to verify if ergonomic processes are in existence and are being implemented to effectively identify, evaluate and control the hazards associated with the interfaces between job design, methodology and human limitations. Formal housekeeping programme and storage practices supplement a concerted effort at all levels to reduce manual handling injuries. An occupational safety and health management system in the above large organisations includes provisions for contractors' safety and health. These provisions include having safety and health requirements included in the job description, mandatory pre-job safety briefing, detailed documented and communicated safety and health rules for the contractors, and the compliance requirements with the company and statutory safety and health requirements.

Conclusions

The self—audits have been developed to enable the management in industrial organisations to regularly conduct consistent high quality self-assessments of occupational safety and health management systems and internal controls. Such self—assessment facilitates and verifies compliance with company and statutory requirements and objectives, and recognised best practices.

The next paper in this series will deal in more detail with the development of various positive occupational safety and health performance indicators as tools in the proactive approach to the prevention of accidents ill health at work. The paper will also briefly describe the latest relevant developments in Australia and worldwide.

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Creating a Safe Workplace in a High Risk Tree Lopping Industry

By Reece Hall

Abstract

The article describes and analyses the most frequently occurring serious hazards in a tree lopping work, and suggests a range of effective cost efficient accident prevention strategies.

Key words

High risk tree lopping industry. Occupational hazards in tree lopping. Accident prevention. Cost efficient preventive strategies.

Introduction

In this article, tree loppers can find useful suggestions on how to reduce the risks and improve safety in their high risk occupation.

Having a workforce operating in a safe manner is essential for tree lopping businesses and this article will demonstrate practical, cost effective solutions that can be implemented with ease. The practical solutions will also aid in complying with legislative requirements so the organisation you operate or work for is not vulnerable to legal penalties as an unsafe workplace. The potential benefits to an organisation with effective safe work practises will also be reviewed.

Health hazards in tree lopping work

Hazards include noise, working at heights, operating chainsaws and manual handling; also slips, trips and falls, stump grinding, wood chipping and falling branches.

Simple cost effective accident prevention strategies

Noise problems

Purchasing less noisy machinery would be an effective control strategy but many companies do not have the available funds and replacing such equipment is expensive. A practical strategy is isolating the loud machine away from the public and only having one person near the machine at any one given time. Ear muffs or plugs should also be used.

Working in heights

The way tree loppers minimise the hazard of working at heights is to use a correctly fitted harness, having two anchor points whenever possible and also completing the relevant climbing courses and tickets. Close on-site training must be given to a tree climber in their learning stage until they have adequate experience. Tree loppers can also substitute this hazard with a less hazardous alternative, the cherry picker. Thus not needing to climb with the use of a cherry picker, which has similar risks involved but is safer due to the person not fatiguing as much.

A practical control strategy to be suggested would be to provide safety advice at the beginning of each climb. The supervisor/employer could also ensure the climber not to rush and should set an environment where the climber is not pressured into working faster or taking shortcuts to finish the job quicker. Being thorough and careful whilst climbing is paramount to doing the job without damage to property or harm to personnel.

Chainsaw safety

Control strategies for minimising the hazard of chainsaw operation include utilising the chain brake mechanism when a person is moving position or handing the saw to another person. Chainsaw pants/chaps should be available to employees who operate a chainsaw, these pants have special fibres inside which stall the chainsaw before damage can be done. Many chainsaw accidents occur with blunt chains, keeping chains sharpened as part of a maintenance schedule minimises this risk. Lastly, each employee can be put through a chainsaw operating and maintaining course to gain relevant knowledge of safe chainsaw operation.

Prevention of manual handling injuries

Practical control strategies for manual handling include onsite training for all employees on how to lift logs and branches safely and prevent back problems. A very effective mechanical substitute to minimise the hazard of manual handling is purchasing a small front end loader which is able to lift and transport heavy logs, meaning that manual handling is minimised. Another substitute that tree loppers use instead of manual handling is operating the wood chippers winch, which is attached to the back of the chipper to drag large branches to the chipper which eliminates the lifting task. Employees should be encouraged to assess the manual handling task before they lift a heavy object. Things to consider include weight, size, lifting aids available (winch or loader), how far must the object be moved and how many people are needed to complete the lift safely. That way the person(s) can lift objects as safely as possible and minimise the risk.

Preventing slips, trips and falls

Practical control strategies for slips, trips and falls include placing rubber anti-slip mats inside the bucket of the cherry picker, groundsmen to be constantly clearing branches, debris and trees from walkways and footpaths, blowing down walkways to prevent slipping, steel cap boots with appropriate rubber grip and having handrails and footsteps for when climbing into the bucket of the cherry picker. Another practical strategy to be implemented is when training employees, teach them the importance of keeping the work site as clean as possible and have footpaths and walkways clear at all times, that way the site is kept tidy and the employees don't have anything to trip on. This can also be reiterated to the team on a weekly basis.

Safety in stump grinding and wood chipping

Control strategies for stump grinding include training on how to safely control and operate machine so that no harm is done to the operator, equipment, property or others. PPE such as gloves, safety glasses, ear muffs and hard hat should be worn. Another strategy is setting up screens around the tree stump to prevent debris from flying into property such as windows or doors.

Wood chipping is an accepted risk in the industry since this is how large quantities of trees can be removed from a job site without doing numerous trips to and from site. Control strategies to prevent damage or harm include emergency stop buttons, long feed tray, emergency pull ropes, PPE such as hard hats, gloves, glasses and hearing protection, keeping machine regularly serviced, greased daily, weekly inspection checklist and training to employees on how to correctly feed, service and operate chipper safely. A practical suggestion for employers to adopt would be to reiterate the chippers safe work practises during times such as toolbox meetings.

Reducing risks from falling branches

Practical control strategies put in place for falling branches and trees include communication to groundsmen when the climber drops branches, awareness of where groundsmen are before dropping branches, signage and cones to prevent public access, roping off and lowering larger branches safely and training on how to efficiently and safely clean-up site without putting themselves in danger. A suggestion to be easily implemented is to reiterate the dangers of falling branches and trees during a toolbox meeting or before work commences each morning.

Benefits from improving safety and health at work

There are huge advantages a safe workplace offers to any tree lopping company. Some of these benefits are minimising risks decreases the chances that a negative outcome will occur from a given situation or event (both financially and no harm suffered). Performance can be maintained at a high level since there are minimal disturbances to the production line, both machinery and employees. Insurance premiums can be maintained at low rates since minimal claims will be put through, thus keeping business operation costs down.

The existence of safe working practises gives a company culture of a high awareness of risks and the impact if the risk causes an incident. If a company has this understanding, then employees are likely to acknowledge and support the controls in place. Contingency plans can then be formed for when a surprise or incident happens at the workplace, procedures are already put into place to minimise down time and get production back on track. From this benefit, there are less shocks and unwelcome surprises.

Safe working practises would also aid in facilitating an organisational culture that is improving team work. For example, lifting heavy objects with two people, brainstorming risks, and looking out for one another's safety builds a culture rich in teamwork and comradery and leads to high productivity in teams.

Lastly, the organisation must have a persistent leader facilitating the change. This person must have strong working relationships with employees who are willing to make the relevant changes to adopt safe work practises. If this is the case, then the company will reap the benefits stated above.

Implementing safe work practises also demonstrates that the company is complying with their legislative requirements if they are ever inspected by the associated government body.

FUNDAMENTAL SAFETY REQUIREMENTS FOR

WARE HOUSE

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ABSTRACT

Warehouse is a building with large spaces used for bulk storage of manufactured goods or raw materials for distribution and for mercantile purposes and an essential operational part in Supply ChainSystem. This building plays an important role both for the profitability of the company and for the business operations.The annual turnover of these warehouse operations in private sector crosses more than 400 billion dollars globally. While in the warehouse finished goods and raw materials may contain both hazardous and non-hazardous materials. Loss of these stored goods, either because of a fire accident or flooding etc. can result to the company going out of business for a considerable time until it recovers from the tragic loss. Such unexpected events can be avoided by proper planning and implementing best safety practices beginning at the planning stage of a warehouse. This paper describes the intrinsic safety requirements for such storage places

Warehouse Safety Requirements, Ware house Safety, Warehouse Safety Standards, Warehouse safety parameters, Ware housing; Ware house Risk control measures, Storage requirements for Food grains.

1. **Preface**

A warehouse in a factory or manufacturing organization plays a critical role for keeping the raw materials and finished goods in a safe custody till the distribution startup. Since a warehouse holds materials in large quantities, loss of such materials either by fire accidents or natural hazards hampers day to day production and stalls the progress of the company. A warehouse is not totally different from the present day business ventures like huge Shopping Malls with multiple stories wherein large number of people floating personnel of more than 50 persons at time either for purchasing the goods or for window shopping the goods. Presence of such large number of people at a time calls for ensuring that the building is safe in all aspects and ensure their safe exit in times emergency. Most of the guidelines mentioned in this article are equally applicable to such premises.

A warehouse with built-in safety arrangements and proper planning ensures uninterrupted business operations and adds to the profitability of company in the long run. Approval for factory warehouse and its structure is within the scope of the local Regulatory authority along with other factory layouts. If it is private owned and located in open areas other than factory, the plan and construction should comply with local civil authorities. In view of the hazards existing in the warehouse during storage and handling operations, which can lead to serious accidents, one should be thoroughly conversant with basic safety precautions described in this paper. However this article does not touch upon stacking and storage patterns within the warehouse, which itself is wide subject area to cover.

2. Hazards in the Warehouse

Warehouses generally store huge quantities of materials with different physical and chemical properties and sometimes woolen and textile materials which are required according to seasonal demands. The biggest threat to these buildings is a fire accident caused by unsafe work practices, poor housekeeping or defective electrical installation. A fire can result in destruction of goods, loss of lives and release of large quantities of toxic gasses due to combustion of materials.

Table-1 LIST OF MAJOR WAREHOUSE FIRES IN RECENT TIMES

YEAR	COUNTRY	DESCRIPTION
01/22/2013	USA	BRIDGEFORT WAREHOUSE
30/05/2013	GUJARAT,INDIA	TOBACCO GODOWN
02/08/2014	USA	SAVANNAH,GEORGIA WARE HOUSE
07/07/2014	GUNTUR,INDIA	TOBACCO GODOWN
08/11/2014	GUNTUR,INDIA	TOBACCO GODOWN
25/06/2014	NEPAL	SURYA TOBACCO GODOWN
07/22/2015	USA	NJ WAREHOUSE NORTH BRUNSWICK,NJ
05/08/2015	UK	SAINSBURY DISTRIBUTION DEPOT
18/02/2016	INDIA	PLASTIC GODOWNAT HYDERABAD
30/01/2016	INDIA	PLASTIC GODOWN AT VIJAYWADA
08/05/2015	INDIA	COTTON GODOWN AT PRAKASAM DIST
21/01/2016	INDIA	CRACKERS GODOWN AT KERALA
03/06/2015	INDIA	GOWOWN FIRE AT DELHI

SOURCE: Information collected from Google search on different occasions.

Figure 1: MASSIVE BLAZE ENGULFS WAREHOUSE

Figure 2:

Source Acknowledged :http://www.wbaltv.com/news/crews-battle-2alarm-fire-in-east-baltimore/37215160

3. Warehouse Hazard Classification

Considering presence of bulk storage of goods for which the ware house is meant for which can readily support combustion, pose physical hazards and depending upon the quantity of materials exceeding the permitted threshold quantities of materials at a time, a ware house comes under ***HIGH HAZARD GROUP H-3*** as per **Chapter** 3 of **International Building Code 2006** classification for which appropriate occupational health, safety and fire safety measures as called for should be taken for that occupancy category.

4. Risk Control Measures

In order to ensure risk free operations in a warehouse the following important requirements should be adhered.

5. Location

While selecting a location for ware house in a factory, it should be ideally located near to a plant where the final product is made, to reduce the downtime and packed and transported to the ware house either by conveyors, trolleys or forklifts. Approach roadways to WH should be consolidated and neatly done up either with concrete or asphalt to withstand a lorry load of 9 to 12 Metric tons. The ware house should be located on a raised ground, not accessible for flooding and not to be affected by any seepage water. At the loading bay, the lorry should be positioned such that the lorry platform is in line with ware house loading bay platform for speedy and safe loading operations. Other than the industrial warehouses, the construction of a warehouse in the private sector in and around the residential areas should be avoided. In selecting the location of a warehouse particularly meant for storage of ***food grains***, maximum attention should be paid to the hygienic and sanitary conditions of the area and the following minimum distances as per Table1 should always be maintained from the identified facilities:

Table1: Suggested Distances[1].

	Facilities	Distance from Ware House
1	Kilns, bone-crushing mills, garbage-dumping grounds, slaughter-houses, tanneries and hide-curing centers or such other places, the vicinity of which is deleterious to the safe storage of grain quality	500 Mts
2	Dairies and poultry farms	500 Mts
3	Factories and other sources of fire such as workshops, hay stacks, timber stores and petrol pumps, Processing Operations generating wood dust	200 Mts

Source: **Storage Structures issued by Warehousing Development and Regulatory Authority, India**

6. **Design features of a ware house.**

On an average the size of Conventional Godown for storing Cotton, and tobacco bales for 5000 MTonnes will be as follow.
Length & Width: 126 x 28 meters.
Height: 6.35 meters provided with doors and ventilators as under.
.Top Ventilators size 1.54m x 0.62 m (5' x 2')
Bottom Ventilators size 0.62m x 0.62 m (2' x 2')
Doors of size1.830 X 2.45Mts are provided with Rolling Shutters.

7. **Limitation[3].**

In case of packed Jute bales the storage should not exceed 400 metric tonnes and loose bales should not exceed 100 metric tonnes. For detailed guidance please go through Indian Standard IS 3836:2000(Fire Safety of Industrial Buildings-Jute Mills)

For warehouses other than located in industrial complexes, they should preferably be situated near a transport head or a main road. If the godown is located in the interior, an approach road suitable for the movement of trucks, trollies, open space for free maneuverability of Fire tenders and should be provided. At the site of the godown, there should be sufficient parking and maneuvering space for emergency vehicles like Fire Tenders etc. Ventilators on top and bottom should be provided with two layers of copper or non-corrodible wire gauge mesh of size of 11meshes per centimeter to allow maximum cross ventilation in the godown and to prevent fire entry into the godown.
Ridge Roof Ventilators on slanted roof should be provided for satisfactory cross ventilation as per statutes stipulated in many countries across the ware house. Additionally turbo ventilators on the roof can be added gadgets for bringing fresh air inside the ware house.

Figure 3. Turbo Ventilator model

Retrieved from Google images

8. Safe Design Features

8.1. Structure

The warehouse should be so designed to ensure that the entire building should be wind and water- tight and maintained to a reasonable standard of construction to prevent destruction and damages due to cyclonic effects. HUDHUD, the cyclone which changed the landscape of a port city in India can be an example .Shape of Doors, windows, ventilators and roof should be in good condition and intact should allow good cross ventilation Roofs should be watertight and galleys kept clear of debris and leaves, which might clog the rain water drainage pipes. Wind load should be calculated as per standard calculations. ASTM E1300 Wind Load Calculator and other standards like IS 875 part 3 can be useful in determining the wind speed.

8.2. Direction

In designing the ware house, if the identified location of the ware house is less than 150 metres to that of public street, or roadways used primarily for ware house purposes, the ware house facing should be designed in a such way that the ware house doors should be positioned perpendicular to the street view and not in full view to street view. This is basically to prevent consequential effects to the public through the doors in case of any emergencies.
As far as possible, provide the doors facing opposite to the wind direction to avoid dust accumulation and rain water entry into the Ware house.

8.3. Foundation

The foundation should be firm. Foundations depending upon the site conditions and the subsoil should be provided according to relevant Standard Codes. In no case, the depth of the foundation should be less than 1.2 meter below the cement concrete column. Plinth protection of 900 mm should be provided around the structure excluding the platform with an outward slope of 1in 48 for rain water drainage purposes.

8.4. Flooring

This is one area requiring attention while laying the floor. The floor should be damp proof, rigid and should be free of cracks and holes. The floor should never be smooth or slippery to prevent slips and falls Cement concrete of 50mm should be laid either in panels of 3.5Sq meters. In areas where water logging is a problem, 700mm gauze polythene sheet is provided in between the sand layers below the concrete to prevent water seepage. Alternately bitumen asphalt of 80/100 can be provided uniformly in between the layers of concrete. This protection not only arrests water leakage but also protect the ware house against the termites and other insects that can damage the goods. In the heavy Rainfall areas, external surface of walls should be finished with water proof cement paint.

8.5. Aisles

In order to have safe manual handling operations, proper aisles must be demarked and the minimum width of aisle space should be 2 metres. Where mechanical operations are envisaged by fork lifts the aisle width should be 2.5 meters. As far as possible aisles and passage ways are to be planned opposite to doors and windows and should always be clear of material not blocking the free access.

8.6. Perfect Party Wall / Separation Wall

This wall is basically a separation wall with no openings at all. It is a 1 foot thickness wall constructed with brick, cement and mortar or 9 inch RCC wall extended 6 inches above the roof to eliminate spreading of fire. The specifications of PPW are given in table 2. Separating walls are generally provided between two different storages:

I. A storage godown and a packing godown,
II. A storage godown and a process building,
III. A storage godown and boiler house, where naked flames are used,
IV. A non-hazardous storage godown and a hazardous or extra-hazardous storage godown,
V. Hazardous storage godown and an extra hazardous storage godown.

Note. A Cavity wall is not accepted as a separating wall. Minimum separation distance between storage areas (aisle width) = 3.5 m. Maximum Stack storage height: h = 7 meters. • Maximum length of the Stack: 2h = 14 meters.

• Maximum surface area of the Stack: =100 square meters. External walls should be at least 30cm thick brick.

TABLE 2: SPECIFICATIONS OF PERFECT PARTY WALL [2].

DESCRIPTION	WALL THICKNESS
Burnt bricks, Stone, concrete blocks set in cement and/or lime mortar	300 mm
Reinforced Concrete	200mm
Plain walls	400mm

Source: Section1/III Page No.10 Building Regulations published by *Indian Tariff Advisory Committee , General Insurance ,Govt of India*

9. Electrical Installation

This is one critical area which will ensure fire accident free operations if correctly installed. As far as possible natural light is the best option for ware houses by having adequate skylights depending on the surface area. In case electrical supply is a must, the following precautions should be taken.

9.1. Electrical Best Practices

1. All wiring shall be enclosed in a heavy gauge screwed steel conduits or shall be of mineral insulated copper or aluminum sheathed cables with or without PVC sleeving. Use of temporary wiring should be completely avoided in ware house.
2. No jointing of cable inside the godown shall be permitted.
3. In case any electrical fittings & sprinklers are provided at roof level, a safe clearance of 1Meter should exist between the fittings and sprinklers and the goods upper surface.
4. Only bulkhead lighting fittings shall be installed inside the godown. The glass cover of the fitting shall be protected by steel wire guards All lights provided at roof level should have covers firmly fixed to the electrical fittings to avoid the fall of heated bulb on the goods accelerating a fire accident.
5. Wherever switch boxes necessary, they should be of metal. Wood should be avoided.
6. Main isolation switch for the lighting system and all fuses or cut-out should be provided outside adjacent to the main door in a convenient place closed box with lock and key available in the glass box protected from weather.

   The purpose of this arrangement is that in cases of internal fire accidents, power can be isolated from outside without entering inside.
7. If forklifts are used in the ware house, Forklift Battery charging should be done in well-ventilated area but not within ware house.
8. If ware house is out of lightening protection zone, a separate lightening arrestor should be provided with separate earthing.
9. Smoking by all means should be prohibited in ware house.
10. Ware house should maintain Material Safety Data Sheets (MSDS) of every chemical stored in the ware house and must be thoroughly read and understood by all persons in ware house.

10. Fire Protection

Good housekeeping is a basic step in preventing accidents and is a must in ware house. Scattered materials unsatisfactory piled up materials are sources of accidents and injuries. Materials are to be stored as per their classification whether hazardous or nonhazardous. Required portable fire extinguishers suitable to the risk and calculated as per floor area should be provided throughout the ware house conspicuously visible near the entrances and exits. Ensure that the extinguishers are appropriately mounted on the wall as per **National Fire Protection Association, (NFPA) USA Standard** for Portable Fire Extinguishers which is appended below.

``NFPA 10Rule No:1.5.10 Fire extinguishers having a gross weigh t not exceeding 40 lb. (18.14 kg) shall be installed so that the top of t.he fire extinguisher is not more than 5 ft. (1.53 m) above the floor. Fire extinguishers having a gross weight greater than 40 Ib. (18.14 kg) (except wheeled types) shall be so installed that the top of the fire extinguisher is not more than 3V2 ft (1.07 m above the floor. In no case shall the clearance between the bottom of the fire extinguisher and the floor be less than 4 in. (10.2 em)''

Ensure that the bottom of the extinguisher is not more than 4 inches thus enabling the user to pull the extinguisher without any bodily strain. Clear space in front of Extinguishers should always be maintained and not to be blocked. This can be ensured by marking ground space 1Square meter below the extinguisher with yellow and zebra marks indicating free space. Fire /Emergency Exits should be conspicuously visible from a distance. While portable fire extinguishers are primarily meant for control of minor fires, full pledged hydrant system or sprinkler system is a must to fight major fires Automatic Heat and Smoke Detection System, though luxury protection, but will certainly safeguard the property. Ensure that water is available for 4 hours of fire pump capacity.

10.1. Fire Exits

At least two exit routes must be available to permit prompt evacuation of employees and other building occupants during an emergency. The exit routes must be located as far away as practical from each other so that if one exit route is blocked by fire or smoke, employees can evacuate using the second exit route. Fire Exits should be provided with double doors openable outside from inside s*winging in direction of exit*. *Collapsible gates should not be provided at all*.

Exit route doors must be free of any device or alarm that could restrict emergency use of the exit route if the device or alarm fails. Exit access must be at least 36 inches wide at all points. Exit routes must support the maximum permitted occupant load. The exit pathway should be clear always. Each exit discharge must lead directly outside or to a street, walkway, public way, or open space with access to the outside. In case the warehouse or Mall has multiple stories, invariably, personnel should use external staircases in the event of emergency. The width of the staircase is governed by the following rule as constricted width will result stampede causing deaths and serious injuries. All floors should have Fire Escape Staircase connected each other wide enough to accommodate the occupants to safely exit. All Staircases should have guard rails to prevent the fall of person.

10.2. Fire Escape Staircase Width Calculation for multistory Building:

Assuming that work area is 14000 SFT in all floors applying single person's required area @7 Sft/person Number of Occupants in the builing :14000/7=2000 occupants.

10.3. Using Life Safety Code principles:

If the occupants are traveling straight out of the building on the same level (in other words, walking out doors, or walking on ramps and not negotiating stairs to get out) then the Code prescribes taking the occupant load and multiplying it by 0.2. This would mean 2000 x 0.2 = 400 inches which is to be provided for the building to safely exit the 2000 occupants. If the facility, for example, could provide10 doors that are each 36 inches in clear width for a total of 10x 36 = 360 inches of exiting width to comply with the requirement.

If the occupants need to travel up or down stairs to exit, then the Code-prescribed factor of 0.3 must be used to calculate the exit width. Again, for the above example this would mean 2000 x 0.3 = 600 inches of stairway width. Note that the total required egress width of stairs is larger than the total egress width resulting from calculating level paths of egress such as doors (600 inches compared to 360 inches) because the Code recognizes that the biomechanics of walking down stairs causes side-to-side swaying which prevents people from walking shoulder to shoulder as they would on a level plane and therefore more exiting width is needed when stairs are in the egress path so the width of the staircase should be 600 inches.

11. Important safety measures for a ware house in a nutshell

1. Good Housekeeping is of utmost importance.
2. Clear unwanted material periodically from time to time.
3. Demark the aisles and the stacking lines with yellow lines.
4. Demark 1 meter clearance from internal walls to stacking and between the stackings with yellow lines for free access in case of any emergencies and ensuring that this rule is complied with.
5. Stacking and storage of bales and cartons should be as per approved practices.
6. Portable Fire extinguishers according to the identified fire risks should be provided.

7. As a guide rule for every 11250 square feet one suitable fire extinguisher of capacity 9 liters should be provided to covers a floor area of 75square feet.
8. Ring Main Hydrant system should be provided in the absence of any sprinkler system.
9. Heat & Smoke Detection System is a recommended protection measure.
10. MSDS (Material Safety Data Sheets) for chemicals must be made available in the ware house and all personnel must be made fully aware of where to find and how to use these sheets.

12. DO'S AND DON'TS

12.1. DO'S

1. Locate a go down on a well raised drained site.
2. Locate it near transport head.
3. Locate it away from pollution sources such as dairy, poultry, slaughter houses etc.
4. Maintain a safe distance from processing operations to avoid dust accumulation on bales and cartons, electrical cables which can source of fire hazard.
5. Locate it away from sources of fire such as kilns, factories etc.
6. Provide suitable access, approach, internal roads and maneuvering and parking spaces for vehicles. .
7. Provide sufficient height of plinth to avoid flooding of stocks in times of heavy rains.
8. Provide good ventilation.
9. Provide damp proof floor.
10. Provide leak proof roofs and sufficient projection of roof all round.
11. Provide suitable projection at plinth level and use steps to enter godowns
12. Provide the minimum firefighting equipment and adequate source of Fire water Reserve for minimum period of 4 hours of Fire Fighting.
13. Fumigate the stacks if called for, at the required intervals.
14. Maintain the buildings, roads and all equipment properly.
15. Maintain cleanliness. Godown must be thoroughly clean
16. Provide Onsite Emergency training including First Aid training to all the ware house employees.
17. Provide a full pledged First Aid Box.
18. Maintain the Stack height less than 8 meters.

12.2. *DON'TS*

1. Do not Provide Asbestos Roofing.
2. Do not allow poor specifications for construction.
3. Do not extend stacking beyond the stacking lines.
4. Do not exceed stacking of bags beyond the specified limit.
5. Do not exceed the dosages prescribed for fumigation.
6. Do not keep the infested/damaged goods along with good stock.
7. Never stack bales against walls.
8. Do not obstruct fire Extinguishers.
9. Do not provide charging area for Forklift batteries within the Ware house Instead provide it in well-ventilated area outside the ware house
10. Never store agrochemicals within the ware house

13. ACKNOWLEDGEMENTS & CONCLUSION

An attempt has been made to touch upon the fundamental safety provisions required for day to day operations in a ware house based on my varied industrial experience. Further this article could not have been completed without the availability of important resourceful information acknowledged in the References Section. However this information is not complete without having covered all the operations in a ware house and could not be abridged within these few pages. Ware house custodians may further go through the suggested reading material as given at the end of this paper.

References

[1].Warehouse Manual for Operationalising Warehousing (Development & Regulation) Act, 2007
[2].Extract from Indian Tariff Advisory Committee (General Insurance) s Building
WebLink: http://www.firenetindia.com/docs/building_regulations.doc
[3].IS 3836:2000 Jute Mills — Fire Safety of Industrial Buildings -Code of practice

Suggested Additional Reading material

Safe Stacking And Storage Published by the Occupational Safety and Health Service. Department of Labour ,Wellington, New Zealand.
Racking & Warehouse Storage Guide published by Link51 (Storage Products). Link House, Halesfield 6,Telford, Shropshire
Safety-guide-warehouses
Link:https://www.mapfrere.com/reaseguro/es/images/safety-guide-warehouses_tcm636-80929.pdf

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Perceptions of the pre employment medical: Are we all reading from the same page?

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Abstract

Background

The pre employment medical assessment (PEM) is a relatively standard practice that is suggested to driven more by perceived benefits than empirical evidence. This pilot investigation reports the perceptions of the key user groups involved in the PEM process.

Methods

A descriptive cross sectional study design was used to investigate the opinions of assessors, employers and employees involved in PEM. An anonymous survey was distributed to 40 individuals from each group. Areas covered included the objectives and benefits of assessment; consent; and duty of care.

Results

Sixty seven questionnaires were returned (56% response rate), with 21 from assessors, 18 from employees and 28 from employers. All groups considered the main aim of PEM was to reduce the risk of injury (88% of all respondents); and that it benefits employers (99%) and employees (87%). A lower proportion of employees considered safety to be an objective of the PEM, compared to assessor and employer groups ($p<0.01$). A greater proportion of assessors considered there to be choice to participate in PEM, compared to employer and employee groups ($p<0.05$). The duty of care of assessors was considered to be to the employer by 49% of all respondents and to the employee by 48% of respondents, with no differences between user groups.

Conclusions

The PEM is perceived as useful in risk assessment, and beneficial to employers and employees. There is a lack of agreement regarding consent, duty of care, and its role in safety. Greater understanding of user views of the PEM is essential in promoting a focused and acceptable process.

Keywords:

Pre employment medical assessment. Perception. Objectives. Consent. Duty of care

Introduction

There is little empirical evidence to support the use of pre employment medical (PEM) assessments in preventing occupational injuries and reducing sickness absence (Mahmud et al., 2010; Pachman, 2009, Roelen et al., 2006; Bigos et al., 1992). The ongoing use of PEM assessments has been considered as culturally driven, based more on tradition than evidence (Pachman, 2009; Houghton, Edmonson-Jones and Harris, 1989). The perceptions of PEM assessments have not been explored, despite perceptions being a driving force for their ongoing use. This pilot study investigates the perceptions of PEM assessments of key user groups in the process, including the potential employee, the employer and professional performing the assessment.

In the Netherlands, legislation has been developed that forbids the use of pre employment examinations unless the job poses special requirements for medical suitability (Sorgdrager, Hulshof and van Dijk, 2004; de Kort and van Dijk, 1997). The legitimacy of the need for the assessment is reviewed by a panel before assessment can occur. In other countries, including Australia, the purpose of the PEM assessment is often not as clearly defined (Whitaker and Aw, 1995). There is a shared lack of understanding of the goal of assessment by employers, employees and assessors.

The objective of PEM is considered in terms of determining capacity to work safely (AFOM, 1998; Cox, Edwards and Palmer, 2000; Kelman, 1985) preventing occupational injuries and disease (Sorgdrager, Hulshof and van Dijk, 2004; ILO, 1998) reducing the risk of injury to the worker and others (Sorgdrager, Hulshof and van Dijk, 2004; ILO, 1998); collecting baseline data (AFOM, 1998; Kelman, 1985; Poole, 1999); adhering to legislative requirements (Serra et al., 2007); and identifying personal risks and increased susceptibility to occupational hazards (Poole, 1999). There is a lack of evidence that supports any of these at the prime objective of the PEM.

PEM assessments must be performed in an appropriate ethical framework (Poole, 1999). Employees should be protected from unnecessary examination and investigation (Serra et al., 2007). Consent participate in these must be informed and freely given (NHMRC, 2007). The participation in a PEM assessment is often a mandatory requirement of the employment selection process. Participants are required to complete a consent form; however the validity of this is uncertain. The concept of consent in the PEM assessment is an area that requires further investigation.

There is a mixed duty of care given the multiple stakeholders (Serra et al., 2007). Assessors have a duty of care to the employer, with whom a contractual agreement exists, but also the potential employee in identifying potential health concerns, maintaining confidentiality and to not discriminate (Kelman, 1985; Sholz, 1998). The duty of care of the assessor is not determined by the party that pays for the assessment (Kelman, 1985) but is considered to be to all parties involved. The degree to which this is understood by key user groups is not clear. The perceived purpose of other occupational health services and the duty of care associated with these not shared between user groups (Bradshaw et al., 2001).

Williams et al. (1994) demonstrated a lack of agreement the between user groups of the perceived purpose of occupational health services between employers, employee representatives and providers of the service. Understanding the nature of these differences is critical in the provision of quality services (Bradshaw et al., 2001). Similarly, the provision of quality PEM assessments requires a shared understanding of the potential purpose of these assessments, and exploration of the employees desire to have PEM performed (Harris, Dworking and Park, 1990; Conway, Simmons, and Talbert, 1993).

The extent and purpose of the PEM should be properly understood by the employer and the assessor and clearly expressed to the person being assessed (AFOM, 1998). Understanding the purpose of the PEM is an integral component to performing the assessment, few studies have addressed the perceptions of the purpose of the assessment by each of these groups. It is the aim of this pilot study to assess the perceptions of the PEM assessment and determine whether there was agreement amongst user groups.

Materials and Methods

A cross sectional design was employed. Questionnaires were developed to include information regarding the objectives of the pre employment medical, perceived effectiveness, aspects of privacy, consent, control of information and duty of care. Responses were collected using a Likert scale for each item. Questionnaires were completed anonymously by three groups of respondents, potential employees, assessors and employers. This project was approved by independent ethics committee, Bellberry Limited.

Questionnaire

Questionnaires involved 9 main questions, with a further 24 components. The objectives of assessment were assessed by level of importance for each item. Respondents then identified the most important objective from the list provided.

Consent was considered in three different aspects. Respondents were asked to indicate if they agree that potential employees were had no choice to participate, withdraw consent or decline participating in the PEM.

The duty of care of assessors was considered in terms of towards the employer or to the employee. Participants were asked to rank the level of duty of care, where 1 indicated the primary duty of care, 2 the secondary.

Participants

A total of 120 questionnaires were distributed amongst potential employees, employers and assessors. Due to the variable availability of each of these groups, different recruitment strategies were utilised for each group. Potential employees were recruited by opportunistic sampling. Forty questionnaires were placed in two clinics where pre employment medical assessments were conducted. Demographics of employees were collected. Emails were sent to forty employers who utilised the services of above mentioned clinics. The email provided an external link to anonymous web based questionnaire. Characteristics of each company were collected as part of the questionnaire. Emails were sent to forty individuals involved in assessment of pre employment medicals. This included doctors, nurses and occupational health technicians. The email provided an external link to anonymous web based questionnaire. Information regarding the degree of experience of each assessor was collected. Responses were collected over a four week period.

Data analysis
The data was analysed using the statistical package SPSS (version 18). Characteristics of each group were tabulated. Responses to all Likert scale items were analysed using the Kruskall-Wallis test. Items with less than 5 responses from any of the participant groups were not included in the analysis.

Results

The characteristics and response rate of each group of respondents is summarised in Table 1. A total of 67 questionnaires were returned, the overall response rate was 56%.

Table 1. Characteristics of each response group.

Potential Employees	
Response rate	18 / 40 (45%)
Age (mean +/- SD)	37.3 (13.50)
Highest education level	
TAFE/College/Secondary	13 (72.2%)
Employers	
Response Rate	28 / 40 (70.0%)
Industry	
Mining	11 (39.3%)
Background of respondent	
Health and Safety Officer	11 (39.3%)
Size of organisation	
> 500 employees	13 (46.4%)
Assessors	
Response rate	21 / 40 (52.5%)
Role	
Medical practitioners	8 (38.1%)
Nurse or Technician	13 (62.01%)
Years of experience	
> 5 years	11 (52.4%)

There was an overall low response rate, with poor response from potential employees and assessors.

The mean age of potential employees was 37.3 +/- 13.5 years; the highest education level of the majority of respondents were not university qualified (72% of respondents).

Employers had the highest response rate of 70%. The majority were from the mining sector (39%), and tended to be health and safety officers (39%).

The largest single group of assessors to respond were medical practitioners, including General Practitioners, doctors working in occupational medicine and Occupational Physicians (38%).

Due to the small sample size, differences within each respondent group were unable to be analysed.

Objectives of assessment

The PEM has many potential objectives (Kelman, 1985). Respondents were asked to rate ten different objectives, including the areas safety, legal requirements, risk assessment and collection of baseline data. The two most important objectives are seen in Table 2.

Table 2. The most important objective of the pre employment medical assessment.

	Employee		Assessor		Employers		Total		Kruskal Wallis test statistic	
	N = 18		N = 21		N = 28		N = 67			
	N	%	N	%	N	%	N	%	χ^2	p
The most important objective of assessment is										
Risk assessment	10	55.6	9	42.9	13	46.4	32	47.8	0.122	0.941
Safety	5	27.8	11	52.4	9	32.1	23	34.3	11.864	0.003

A greater number of respondents (48%) considered risk assessment as the most important objective of the PEM. There was no statistically significant difference between groups. The second most important objective was to assess the potential employee's ability to work safely in the role (34%). A significantly greater percentage of assessors considered safety as the most important objective (53%) compared to employees (28%) and employers (32%; χ^2 = 11.864, $p<0.05$).

Duty of care

The perception of duty of care was assessed by asking respondents to indicate who they perceived the main duty of care to be towards, to the employer or the potential employee. The perceived duty of care of assessors is shown in Table 3.

Table 3. The perceived duty of care of assessors

	Employee		Assessor		Employers		Total		Kruskal Wallis test statistic	
	N = 18		N = 21		N = 28		N = 67			
	N	%	N	%	N	%	N	%	χ^2	p
The duty of care of the assessor is to the										
Employer	8	44.4	10	47.6	15	53.6	33	49.3	0.439	0.803
Employee	9	50.0	11	52.4	12	42.9	32	47.8	1.221	0.543

Approximately 49% of all respondents considered the duty of care of assessors to be the employer, with no statistically significant difference between groups. Approximately 48% considered duty of care to be to the employee, with no statistically significant difference between groups. These results support the mixed duty of care model suggested by Serra et al.(2007).

Consent

Three aspects of consent were considered, however sufficient data for analysis was only obtained for one element. The results for the perceived ability to choose are shown in Table 4.

Table 4. The perceived ability to choose to participate in the PEM.

	Employee		Assessor		Employers		Total		Kruskal Wallis test statistic	
	N = 18		N = 21		N = 28		N = 67			
	N	%	N	%	N	%	N	%	χ^2	p

Employees have no choice in PEM	13	72.2	9	42.9	22	78.6	44	65.7	6.607	0.048

The majority of respondents agreed that employees have no choice in participating in the PEM (65.7%). The number of assessors who agreed (43%) was less than the number of employees (72%) and employers (79%). There was a statistically significant difference between groups ($\chi^2 = 6.607$; p =0.048). Assessors perceive a greater level of freedom in consenting to PEM than employees and employers.

Discussion

A pilot study to assess the perceptions of the PEM assessment and determine whether there was agreement amongst user groups was performed. The results indicate that the main perceived objectives of the PEM assessment are risk assessment and determination of a potential employee to safely perform their proposed role. Safety was considered to be more important by assessors than employees and employers. The difference in opinion regarding these two aspects could be as a result of an increasing awareness amongst employers and employees about the risk assessment approach to occupational health and safety. This shift in approach may not yet be shared by those performing PEM assessments. Assessors not only need to maintain their own continuing medical education, but need to actively remain up to date with occupational health and safety standards, approaches and systems. Occupational health focused clinics provide an opportunity to maintain these standards.

The mixed duty of care of professionals performing PEM assessments was demonstrated in this study. Almost 50% of all respondents considered the duty of care to be to the employer and the remaining 50% considered it to be to the employee, with no differences between user groups. This difficulty in determining where the duty of care lies is an ongoing issue with PEM assessments. Kelman[11] highlighted that any professional requested to perform an examination owes that person a reasonable duty of care. A duty of care also exists with the employer who has contracted the service. The differences here most likely stem from the understanding of duty of care, and that duty of care, in itself, is a multifaceted concept. Clear definitions and boundaries regarding the PEM need to be established.

Involvement in any assessment requires informed consent from the candidate. In a treatment situation, consent is implied by attendance at a health clinic, or by means of a signed written consent form. The PEM process often forms part of the determination of the most suitable applicant for a proposed role. As such, there is often no choice for a candidate to participate; they are unable to decline participating, and unable to withdraw consent. In these circumstances, the question of informed consent is paramount. Informed consent suggests that an individual is aware of the purpose of the assessment, and freely decides to be involved. Given that there is no conclusive evidence for the use of PEM; and that decision not to participate will often result in not being considered for a role, it can be said that informed consent does not occur in PEM. This ethics of the PEM need to be further explored. As the assessment is not for the purpose of treatment, the NHMRC statement on ethical conduct in human research (2007) could be used a framework for developing PEM assessments.

In utilising a research based framework, approval of the PEM assessment should be obtained from an appropriate committee. In the Netherlands, PEM are performed only with the permission of the Occupational Health Service (de Kort and van Dijk, 1997). A similar approach should be considered in Australia. Although the overall perceptions of the PEM are similar among user groups, a committee of representatives from each group should be formed to review the validity of employers' requests for PEM assessments and ensure that these are ethically conducted.

Limitations

This study was limited by small sample size. Much of the data collected could not be reliably used in the analysis. A larger sample will allow further analysis of the differences between different user groups, and within each user group. The questionnaire used requires further development, including the capture of qualitative data. Though more difficult to collect and analyse, this would provide better data on perception. Self selection bias is present in this study. Anonymous questionnaires would have been completed by those with an interest in the PEM process. A wider group of respondents needs to be engaged in future studies.

Conclusion

The effectiveness of pre employment medical assessments requires further analysis and review. The development and implementation of these screening devices requires involvement of all key user groups to ensure mutual understanding of its purpose and use.

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NOISE EXPOSURE ASSESSMENT FOR RACING CAR DRIVERS

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ABSTRACT

Noise Induced Hearing Loss through excessive noise pollution has become an epidemic, being the third most common illness worldwide. Racing car drivers and flag marshals exposed to noise in the motor sport environment are potentially susceptible to excessive noise exposure above the recommended National Standard for Occupational Noise [NOHSC:1007(2000)]. This study measured the exposure to noise of flag marshals and selected racing car drivers, specifically within the cockpits of cars, during motor racing events at the Wanneroo Raceway in Western Australia. The effectiveness of currently used hearing protection devices were evaluated to determine the level of attenuation offered by the protectors and the protected exposure of the drivers and flag marshals. Analytical statistics were used to examine the dose-response relationship between identified factors that can be linked to hearing loss. Results were analyzed to identify the degree of noise exposure and whether the noise exposure was above the recommended Australian Standard of 85 dB(A). Results overall suggest that the motor sport environment is one with excessive noise levels and that drivers and flag marshals are exposed to levels that require the correct selection and use of hearing protection to reduce the protected exposure to below 85dB(A) and preferably to 75-80dB(A) if practicable. These results provide an advance in knowledge concerning noise exposure levels of racing car drivers and flag marshals during car racing events and provides a base line for further research. Recommendations are made for appropriate hearing protection for flag marshals and for racing car drivers in a variety of classes.

Key words

Noise induced hearing loss. Motor sport racing. Hearing protection.

1. Introduction

Three hundred and sixty million people worldwide have disabling hearing loss; 328 million adults and 32 million children (World Health Organization, 2013). Disabling hearing loss refers to hearing loss greater than 40 dB(A) in the better hearing ear in adults and a hearing loss greater than 30 dB(A) in the better hearing ear in children (World Health Organization, 2013). Worldwide 16 % of the disabling hearing loss in adults (over 4 million disability adjusted life years [DALYs]) is attributed to occupational noise (Nelson, et al., 2005). In 2005 the financial cost for hearing loss in Australian residents was $11.75 billion (Access Economics, 2006). Hearing loss workers compensation claims in Australia were 25% of workers compensation claims for occupational diseases in 2010-2011 (Safe Work Australia, 2013). In the past ten year period the largest increase in the number of serious occupational disease claims occurred because of work related deafness with these claims increasing by 50%, from 3,755 compensation claims in 2000-2001 to 5,640 compensation claims in 2009-2010 (Safe Work Australia, 2013). Although at times organized car racing may have adequate noise limits, most race organisers appear to do little to no work in reducing sound exposure to participants and spectators to noise in motor sports (Dickinson, 2003).

Damage from noise pollution is a serious issue for those involved in motor sports as they are exposed to an environment with excessive noise over long periods of time on a daily basis (Rose, Ebert, Prazma & Pillsbury, 2008; Lindemann & Brusis, 1985). It is important for race personnel to know the consequences of excessive noise exposure and recommendation for using hearing protection devices (Scheinder, 2010). Based on information from studies conducted on noise exposure in motor sports racing, (Dickinson, 2003; Lindemann & Brusis, 1985; Van Campen et al., 2005; Rose, Ebert, Prazma & Pillsbury, 2008; Tratner, 2003), this is a significant issue that needs to be addressed due to the many health implications of noise exposure. Although studies have been conducted to identify the relationship between car racing and noise exposure most published studies have been conducted in America with Formula one racing and NASCAR. In Australia little research has been published for the motor racing industry.

The aim of this pilot study was to determine the noise level exposure of selected racing car drivers and flag marshals during racing events at a V8 Supercars event held at the Barbagallo Raceway in Wanneroo, Western Australia. The objectives of the research were to:

1. Determine drivers' exposure to noise during a car racing event, specifically the noise levels within the cockpit of various types of cars as well as flag marshal exposure.
2. Evaluate the level of attenuation provided by hearing protection devices used and available to drivers and flag marshals and calculate the protected exposure.
3. Provide recommendations for racing car driver and flag marshals regarding appropriate hearing protection management based on data from noise assessment, questionnaires and hearing protectors evaluated.

2. Review of related literature

It is known that race car drivers and personnel are susceptible to excessive noise exposure in the motor sport environment, mostly emitted by car engines that produce noise above the standards recommended by occupational organizations across the globe. Reports of motor sport racing have recorded the sound pressure levels emitted by car engines to be around 125 dB(A) to 140 dB(A), exceeding permissible standards required by occupational organizations and governments (Van Campen et al., 2005). Various race sport professional drivers, track officials, spectators and other personnel are exposed to noise levels ranging from 90 dB(A) to 140 dB(A) on a daily basis (Lindemann & Brusis, 1985; Rose, Ebert, Prazma & Pillsbury, 2008). Hearing protection worn by drivers and personnel who are present on the race track during the race is used to attenuate excessive noise that can cause hearing loss/damage to hearing (Van Campen et al., 2005).

2.1. Physiology of noise and noise effects

Noise, its emission and its effects on humans in the workplace have been well described (World Health Organization, 2013; Safe Work Australia, 2012), however far less is known about the risks and effects of noise from recreational sources, one of which includes motor sports (Rose, Ebert, Prazma & Pillsbury, 2005). Noise Induced Hearing Loss through excessive noise pollution has become an epidemic, being the leading cause of hearing loss which although is irreversible, is easily preventable if risk control measures are used (Cannington, 2009; Mohammadi, Mazhari, Mehrparvan, & Attarchi, 2009; Traynor, 2013).

Excessive noise exposure may damage hearing and cause other health effects such as stress, hypersensitivity to noise, reduced concentration, physiological changes, fatigue, irritability, decreased reaction time, increased blood pressure (hypertension), increased heart rate and may increase the likeliness of accidents occurring (Azizi, 2010; Safe Work Australia, 2011. Prolonged exposure to excessive noise, at work and in the community, can also cause permanent medical conditions, such as ischemic heart disease (Azizi, 2010). Louder noise can have a negative effect on performance in reading, attentiveness, problem solving, concentration and memory increasing the probability of accidents and injury occurring (WHO, 2001; Cantrell, 1974; CCOHS, 2008; Occupational Safety And Health Administration, 2012). Tinnitus (ringing in the ear) is a common hearing condition shown to increase as damage to hearing increases with accompanying hearing loss. Although hearing loss may not always be the cause of tinnitus it is a common risk factor (Dias, Cordeiro, Corrente and Gonçalves, 2006; König, Schaette, Kempter, Gross, 2006; Soalheiro, Rocha, & Teixeira, 2012).

A study conducted by Janghorbani, Sheikhi & Pouradbian (2009) that measured noise and hearing levels in long distance lorry drivers found there to be a higher prevalence of noise induced hearing loss affecting the ear closest to the window of drivers, specifically the left ear in a scenario of left side drivers.

2.2 Australian Standards on noise exposure

The AS/NZS 1269.0:2005 states that exposure to noise is determined by the person's ear position without taking into account any protection which may be afforded by personal hearing protectors (Standards Australia, 2005b). The exposure standard for noise exposure is anLAeq,8h of 85 dB(A) which indicates the eight-hour equivalent continuous A-weighted sound pressure level that one can be exposed to and C-weighted peak sound pressure level LC,peak of 140 dB(C) (National Occupational Health and Safety Commission, 2000). These values are used to determine the exposure to noise of all likely people that have been exposed to excessive noise.

2.3 Race car driver noise exposure and effects

In various race sport scenarios professional drivers, track officials, spectators and other personnel are exposed to noise levels ranging from 90 dB(A) to 140 dB(A) on a daily basis (Lindemann & Brusis, 1985; Van Campen et al., 2005; Rose, Ebert, Prazma & Pillsbury, 2008). The researchers Lindemann and Brusis, (1985) found that there was a difference in terms of overall exposure time and hearing protection use, with drivers having less of the former and more of the latter. Scientific investigations in other motor sport activities, including snowmobile and motorcycle associated sports, have confirmed that noise levels in these sports can have harmful effects on the auditory system (McCombe, 2003). The significant noise issues and combined effects of noise including chemicals, heat, and vibration, represent potential hearing health, miscommunication risks and harmful effects to adequate occupational performance (Lindemann & Brusis; 1985). Non-auditory noise effects include physiologic changes, fatigue, increased reaction time, reduced concentration, and irritability (Safe Work Australia, 2011). Due to these consequences having a psychological effect on individuals, improved noise reduction could result in improved performance and safer racing conditions.).

Specific to excessive noise scenarios, such as motor sports, miscommunication risks may affect effective occupational performance (Van Campen et al., 2005; Australian Hearing, 2010; Workplace Health & Safety Queensland, 2011a). Although hearing protection is provided and worn in most cases of motor sport racing and its related activities, a variety of noise-related complaints may arise during a race including questioning the suitability of hearing protection devices through inability to hear important sounds due to attenuation, difficulty in team communication and muffled hearing and/or tinnitus for hours after a race (Van Campen et al., 2005; Lindemann & Brusis, 1985).

2.4. Noise from motor raceways and risk control of noise sources

There are a variety of sources of noise from a motor sport raceway. These mainly include exhaust noise emitted from car engines of each vehicle, other vehicle noise such as tyre/track interaction, mechanical noises, aerodynamic noises, induction noises, transmission noises (changing the gearbox), noise from engine ancillary components, body work components, wind turbulent noise emitted by the speed of the car which affects mainly drivers of open car vehicles, collateral noise from unofficial revving and racing in the vicinity, public address systems and noise from increased traffic to and from the venue during the time of an event (Waites & Grant, 2009; Dickinson, 2012). Controlling noise at its source is the most effective way of reducing noise emissions from the track (Waites & Grant, 2009; Dickinson, 2012; Williams & Burgess, 2007).

2.5. Hearing protection measures

Due to excessively loud noise in the motor sports environment, choice of hearing protection requires a background knowledge of hearing attenuation that the device will give when worn in any given environment where noise is a possible hazard. Organized racing may sometimes have adequate noise limits, however most appear to do little to no work in reducing sound exposure of participants and spectators to noise in motor sports due to the absence of hearing protection (Dickinson, 2003; Verbeek et al., 2012; Hear-it, 2010). Hearing protection efficacy in shielding the inner ear from noise through laboratory testing has been proven. Hearing loss prevention effectiveness from excessive noise exposure depends mainly on the regular use of hearing protection in the situation of excessive noise exposure. Intervention strategies to promote hearing protection use are therefore important preventative measures (El Dib, Mathew & Martins, 2012; Dickinson, 2003; Verbeek et al., 2012).

Preventative measures implemented in hearing conservation programs include identifying hazardous areas through a noise questionnaire or survey, elimination or reduction of the source of excessive noise, posting warning signs and posters, provision of appropriate hearing protection devices (HPDs), providing periodic hearing tests for both the public and those exposed to excessive noise on a continuous basis, educating workers and those exposed to excessive noise about the effects of noise exposure and the need for consistent use of hearing protection devices for all excessive noise exposure activities (Harrison, 1974; Verbeek et al., 2012; Centers for Disease Control and Prevention, 2011). It is stated by the Centers for Disease Control and Prevention, (2011) that for successful implementation of a hearing loss prevention program, the program must contain noise exposure monitoring, engineering and administrative controls, audiometric evaluation, use of hearing protection devices, education, motivation, record keeping, program evaluation and an audit of the program's effectiveness.

3. Method

3. 1 Research setting, participants and scope

This research was conducted at the Wanneroo Race Track – Barbagallo Raceway, in Western Australia. The research participants were ten racing car drivers across five categories that included Saloon Cars, Touring Car Masters, V8 Utes, V8 Supercars and Formula Fords. The racing car drivers were monitored for noise exposure in the races that they participated in over the 3 days. Four Flag Marshals were monitored with two each day monitored for 8 hours each. The scope of the research was limited to 1 to 4 races for each driver. Monitoring concentrated only on race noise exposure for drivers converted to an 8 hour equivalent. Noise exposure for flag marshals was the overall daily noise exposure. Prior to each race, participants were checked by the researcher to ensure their comfort and that the noise dosimeter did not harm or affect their ability to race in any way. This was particularly important for the Formula Ford cars which are a relatively small car. Ethics approval from the Curtin University Ethics Committee was obtained prior to the research being conducted.

3.2 Methods of data collection

3.2.1 Racetrack noise exposure assessment

The Barbagallo Raceway is approximately 1.760km in length for the short circuit and 2.411km in length for the long circuit. Over 50,000 people attend each event. Personal noise monitoring was conducted on 3 different race car drivers in 3 different vehicles classes per day for the 1st 2 days and 4 race car drivers on the 3rd day on the 3rd, 4th and 5th of May. A noise dosimeter was strapped to the cage in each driver's car and located within 300 mm of the driver's ear whist the driver was competing in a race, or practicing for a race. Vehicles in which the drivers were monitored were as follows.

Day 1. V8 Utes, Formula Fords, Touring Car Masters.

Day 2. Saloon Cars, Touring Car Masters, Formula Fords.

Day 3. Saloon Cars, Touring Car Masters, V8 Utes, V8 Super Cars, Formula Fords.

Noise level measurements were used to determine the level of noise attenuation needed for each car category via the class method. A detailed noise assessment was carried out on drivers in five car categories at the V8 supercars championship for V8 Supercars, V8 Utes, Saloon Cars, Touring Car Masters and Formula Fords. Each participant had a noise dosimeter placed in the car 30-45 minutes before a race either on the back roll cage inside the car, on the passenger seat next to the driver seat or to the side of the driver depending on the type of car, with the microphone being as close as possible to the ear of the driver without disturbing them during the race. Personal noise dosimeter measurements were conducted with NoisePro DLX Series dosimeters (3M Quest – Technologies) and B & K 4463 dosimeters (Bruel & Kjaer Denmark). The dosimeters were set to "fast" response, "A" frequency-weighting response, an exchange rate of 3 dB, a threshold of 85 dB(A) and a range of 70-140dB. All dosimetry data was recorded manually after the race and data from the NoisePro DLX dosimeter was downloaded to a computer for analysis via QuestSuite Professional II software. All dosimetry data from the 4463 calibrators were recorded manually. Noise dosimeters were then set up for the next race depending on the race timetable. Each driver was unable to be monitored for the full three days of the event due to the limited number of noise dosimeters available.

On the 2nd and 3rd day, two Flag Marshals on each day had a noise dosimeter placed in their back pocket for 8 hours from approximately 9am until 5pm. All noise monitoring equipment used in the field was calibrated before and after use to ensure the reliability of the monitoring information obtained. The maximum deviation in calibration permitted was ± 0.5 dB.

3.2.2. Physical examination of drivers, flag marshals and races

Before each race, each driver that was being monitored for noise exposure had recorded what he was wearing (Balaclava, helmet, etc.) besides hearing protection that would affect hearing protection, what the weather conditions were at the time of the race (as this may have influenced the driver keeping their windows open or closed), the number of cars on the race track during noise monitoring and the distance between each car as driving close together, or far apart, may influence noise levels. For Flag Marshals it was also noted the type of hearing protection worn by each Marshal, the weather conditions but, instead of car characteristics, for Flag Marshals their station placements and the noise characteristics they experience at the flag stations were observed and recorded.

3.2.3. Hearing protection questionnaires

Hearing Protection questionnaires were provided to each category manager to be filled out by the drivers. Forty questionnaires were distributed to Saloon Cars, 20 questionnaires to Formula Fords and 30 questionnaires to each of the other categories of racing car drivers. A total of 125 questionnaires were completed by car drivers and flag marshals. The questionnaires asked questions about the types of hearing protection used, respondent's age and if the respondent had ever had a hearing test/hearing loss. The completed questionnaires were collected at the end of the last race of each category, except for the drivers who participated in noise monitoring where the questionnaire was provided to the drivers with their consent form. These drivers completed their questionnaire before their first monitored race and gave their completed questionnaire to the researcher before this race.

3.2.4. Hearing protection attenuation evaluation

A variety of hearing protection, both covered (ear muffs) and not covered (ear plugs), were included in the questionnaire for evaluation, rather than the makes and models of each type of hearing protection device. Based on each type of hearing protection presented in the questionnaire, at least one of each type was evaluated, and a variety of others used in and out of the workplace were evaluated to identify the suitability of hearing protection that can be used by flag marshals and drivers, depending on car category. Those listed in the questionnaire that were evaluated included custom fitted molded silicone/gel ear type inserts, quality Universal fit silicone/gel type ear moulds and simple foam, plastic or wax industrial type ear plugs.

3.3. Data analysis

3.3.1. Noise level data analysis

Results of noise monitoring were compared to recommended levels in the Australian Code of Practice Managing Noise and Preventing Hearing Loss at Work (Safe Work Australia, 2011) and to the Commonwealth Australian Government Work Health and Safety Regulations 2011, part 4.1 r.56 (1) + (2). Originally the Equivalent Sound Level (LEq)/Lavg (Time Weighted Average [TWA] when the Exchange Rates and Threshold Levels are the same and the measurement period was 8 hours) noise levels readings corresponded to a time including before the race, during the race and after the race (partial noise exposure of drivers). Data was collected using the noise dosimeter and split into only the time of the race to obtain a realistic reading of the noise exposure from the cars and what the driver was exposed to. This reading was then converted to an LAeqT (time in minutes) specific to the time of the race, as well as an LAeqT including 10 minutes before and after the race to show the difference in Sound Level Exposure (SEL). The race had a higher noise exposure level than the 10 minutes before and after. The LAeqT race data over each of the 3 days was then converted to a LAeq,8h value for each racer each day that they had been monitored for noise exposure. Peak levels across the three days were also reported and commented on. Each of these levels ignore protected exposure (presence of hearing protection devices worn) of drivers. After LAeq,8h values were determined, class of hearing protector required was selected using the classification method for those values where LAeq,8h is less than 110 dB(A) while those that are 110db(A) or more required a higher class to be sufficient and also required SLC80 calculation or an Octave Band Method calculation listed in the AS/NZS 1269.3:2005 and AS/NZS 1270:2002.

3.3.2. Hearing protection questionnaire data analysis

Questionnaires were grouped by car category and overall. Answers were tallied for each question and analyzed as percentages. Chi-square tests were used to calculate the presence of hearing loss amongst participants by looking at the factors documented in the questionnaire that may contribute to hearing loss. Analysis included Category to Hearing Test; Age to Hearing Test; Transducers to Hearing Test; Hearing Protection to Hearing Test; Category to Hearing Protection; Age to Hearing Protection; Transducers to Hearing Protection; using the overall item results for all 125 completed questionnaires. Results were also analysed to determine if the presence of hearing loss was found when drivers had a hearing test.

3.3.3. Hearing protection attenuation evaluation

Thirty Seven different hearing protection devices were evaluated. Each hearing protection device had either an SLC80 rating (Australian Standard for attenuation as stated in the AS/NZS 1269.3:2005 and AS/NZS 1270:2002 Standards) and an American Standard Noise Reduction Rating (NRR) for attenuation listed by the National Institute for Occupational Safety and Health, or had just an NRR. Those devices that had an SLC80 were converted to a class method and, based on LAeq,8h level data, the protection was calculated. Hearing protection was recommended for car categories depending on the degree of noise exposure for the category and ranged from Class 1-5 hearing protection. Any devices that only had an NRR were converted to an SLC80 rating and class equivalent; then recommendations were made for the car categories drivers' hearing protection.

4.0 Results

4.1. Physical examination of drivers, flag marshals and races

All drivers monitored for noise exposure were found to wear a helmet and a balaclava (a form of cloth headgear that covers the whole head, exposing only part of the face) under their helmet. In observing other drivers at the race track, all had worn helmets and balaclavas, thus it is safe to assume that every driver participating over the weekend had worn both items. During the practice races, the majority of the cars were not close to one another in proximity however, during qualifying and actual races, cars were very close to each other both behind and beside one another in proximity. The helmet and racing car driver's uniform are both made of fire proof material in case a fire arose.

In the morning of each day before 11am, the weather was cloudy and cold. As the day progressed weather ranged from sunny to both windy and sunny until 5pm. For the drivers monitored for noise levels, V8 Ute drivers and the Saloon car driver had only the driver window open with an open cloth cage on the driver window to reduce wind disturbance to some degree. Touring Car Masters drivers had both front seat windows open with no open cloth cage during practice races, and an open cloth cage on the driver seat window during actual races. Formula Ford cars have no windows so the cars were always open without any covering so all drivers were subjected to wind turbulence noise. All V8 supercar and Dunlop Series drivers had all windows closed during races.

Saloon car driver races ranged from 36-40 racers. V8 Utes ranged from 31-32 racers. Formula Fords ranged from 15-25 racers. Touring Car Masters ranged from 26-31 racers. Dunlop Series races ranged from 25-28 racers and V8 Supercars ranged from 26-28 racers. Practice races had most, to all, racing car drivers in the category racing. Actual races had fewer racers due to some drivers not making it through the qualifying races. Flag Marshals monitored were situated at flag points where they were exposed to noise levels of the race cars. All Flag Marshals wore ear muffs and other forms of hearing protection. Flag Marshals were all placed at stations where their noise exposure was similar to that of the drivers in each race.

4.2. Hearing protection questionnaires

Of the 125 completed questionnaires collected 38 were from Saloon Car drivers, 26 from V8 supercar drivers, 21 from Dunlop Series drivers, 3 from Formula Ford car drivers, 30 from V8 Ute drivers, 3 from Touring Car Masters drivers and 4 were from Flag Marshalls. The following table documents the total use of hearing protection for all categories of racing car drivers and for the flag marshals.

Table 1. Total use of hearing protection by category

Category	Transducers/Speakers in Ear moulds (Yes/No/Other)	Had a hearing test? (Yes/No)	If yes, hearing loss? (Yes/No/Don't know)	Type of Hearing Protection Custom, Universal, Ear Plugs, Other, None
V8 Supercars	26 Yes	15 Yes 11 No	4 Yes 11 No	17 Custom, 8 Universal, 1 Ear Plugs
Dunlop Series	20 Yes 1 No	7 Yes 14 No	6 No 1 Don't know	14 Custom, 4 Universal, 5 Ear Plugs
V8 Utes	27 Yes 3 No	18 Yes 12 No	2 Yes 16 No	12 Custom, 5 Universal, 11 Ear Plugs, 1 Other, 1 None
Saloon Cars	2 Yes 36 No	12 Yes 26 No	2 Yes 10 No	2 Ear Plugs, 36 None
Touring Car Masters	1 Yes 1 No 1 Other	1 Yes 2 No	1 No	1 Universal, 1 Other, 1 None
Formula Fords	1 Yes 2 No	2 Yes 1 No	1 Yes 1 No	2 Custom, 1 None
Flag Marshals	4 Yes	4 No	-	1 Ear Plugs, 3 Others (Ear Muffs, Radio Communications Headset/Ear Muffs)
Total	81 Yes (64.8%) 43 No (34.4%) 1 Other (0.008%) = 125	55 (44%) Yes 70 (56%) No = 125	9(16%) Yes 45 (82%) No 1 Don't know (2%) = 55	45 (35%) Custom, 18 (14%) Universal, 20 (16%) Ear Plugs, 5 (4%) Other, 39 (31%) None = 127 (2 people had chosen 2 options)

Table 1 shows the results for all car categories and flag marshals. The most common type of hearing protection used by drivers and flag marshals overall were custom molded ear plugs. These were used by 36% (45/127 – 2 people had chosen 2 options) of participants. Out of the 125 participants, 65% had worn transducers/speakers in ear molds. 55 participants out of 125 (44%) had taken a hearing test. Nine of those 55 (16%) participants who had taken a hearing test had reported they had some form of hearing loss.

4.3. Chi-Square data analysis results

A Chi-square test was performed for a variety of category comparisons. Results were significant if the p value was 0.05 or less.

Table 2. Chi-Squared data

	Pearson Chi-square value	df (degrees of freedom)	Asymp. Sig. (2 sided) – p value	Significance
Age to hearing protection	19.992	6	0.003	p = 0.003 = < 0.05 (level of significance). Association exists for both age of the drivers/flag marshals and use of hearing protection.
Category to hearing protection	104.216	4	0.000	p = 0.000 = < 0.05. Association between category and use of hearing protection.
Transducers/Speakers to hearing protection	76.939	1	0.000	p = 0.000 < 0.05. Association between use of transducers/speakers and hearing protection for drivers/flag marshals.
Age to hearing test	4.684	5	0.433	p = 0.433 = > 0.05. Age of drivers/flag marshals and taking a hearing test are not associated amongst the sample population.
Category to hearing test	9.240	4	0.055	p = 0.055 > 0.05. Both category and taking a hearing test are not associated.
Hearing Protection to hearing test	8.060	4	0.089	p = 0.089> 0.05. Both hearing protection and taking a hearing test are not associated.
Transducers/Speakers in ear moulds to hearing test	2.211	1	0.137	p = 0.137> 0.05. Both transducers and taking a hearing test are not associated in the sample population

4.4. Noise level exposure assessment – Barbagallo Raceway Wanneroo

The main sources of noises were car engine emissions and tyre noises as heard on the track. Every driver reached a peak level of above 140 dB(C) in at least one race on one of the days according to the data obtained, even though on some days a peak above 140 dB(C) was not reached, such as for Touring Car Masters Driver 1 where a peak level of 127.2 dB(C) was reached on Day 1-Practice Race 1, but on Day 3- Race 3, a peak level for the same driver reached 145 dB(C).

A LaeqT for each race was calculated and a LAeq,T for all races occurring during that day. LAeq,T of races for all drivers on all days except for Saloon Cars Driver 1-Day 3 showed significant exposure levels exceeding an LAeq,8hr of 85dB(A). An example of this was V8 Ute Driver 1 and 2 monitored for 1 race on Day 3 (Race 3), the race being 20 minutes long, giving LAeq, 20min values of 105 dB(A) and 102 dB(A) respectively. This converted to a LAeq,8hr gave values of 91dB(A) and 88dB(A), above the 85dB(A) standard for a LAeq,8hr. Although the Saloon Car Driver 1 had not exceeded 85 dB(A) on Day 3, on Day 2 he had as he participated in 2 races equating to 35 minutes total, instead of just a 20 minute race which occurred on Day 3. Most drivers monitored had worn custom fitted molded ear silicone/gel type inserts and overall all drivers had worn hearing protection except for Saloon Car Driver 1. All Flag Marshals had exceeded peak levels of 140 dB(C) and a LAeq,8hr of 85dB(A); all reaching noise levels of 100dB(A) and above.

Raw data included Sound Exposure Level/Short-term exposure limit (SEL) in decibels used to calculate the approximate time the dosimeters were running for. The LAvg data for partial noise exposure presented in the following table is the LAvg for the total duration time the noise dosimeter was running, as well as the Dose % and Pa^2H. The P Dose % is a dose at an 8 hour equivalent. The maximum and minimum levels are the highest and lowest average levels reached during the duration the dosimeter was running. As the peak levels are the highest levels of noise reached at any given point in time, this is unaffected by time duration and was reported as presented. An LAvg was also collected from the dosimeter of each minute that it was running. Both the LAvg of each minute collected from the dosimeter and the raw data presented in this tables were used to calculate the LAeq,8h and LAeq,T via Australian Standard methods stated in AS/NZS 1269.1:2005 (Standards Australia, 2005b). Following is a table representing the hearing protection class required for each category monitored based on LAeq,8h levels collected.

Table 3. Hearing protection class requirement

Driver/Flag Marshal	Day 1 LAeq,8h	Day 2 LAeq,8h	Day 3 LAeq,8h	Recommended Class of Hearing Protector Required
V8 Ute Driver 1	88 dB(A)	-	91 dB(A)	Class 1 to Class 2
V8 Ute Driver 2	94 dB(A)	-	88 dB(A)	Class 1 to Class 2
Saloon Cars Driver 1	-	88 dB(A)	83 dB(A)	Class 1
Touring Car Masters Driver 1	97 dB(A)	93 dB(A)	97 dB(A)	Class 2 to Class 3
Touring Car Masters Driver 2	-	91 dB(A)	96 dB(A)	Class 2 to Class 3
Formula Fords Driver 1	103 dB(A)	-	-	Class 4
Formula Fords Driver 2	-	104 dB(A)	-	Class 4
Formula Fords Driver 3	-	-	101 dB(A)	Class 4
V8 Supercar Driver 1	-	-	112 dB(A)	Class 5 and above. Requires SLC80 or Octave Band Method calculation
V8 Supercar Driver 2	-	-	112 dB(A)	Above Class 5. Requires SLC80 or Octave Band Method calculation
Flag Marshal 1 +2	-	102 dB(A)	-	Class 4
Flag Marshal 3 +4	-	-	110 dB(A)	Class 5 and above. Requires SLC80 or Octave Band Method calculation

All of the hearing protection devices recommended in table 3 are suitable in the racing scenario in having attenuation levels able to reduce noise received at inner ear from majority of races depending on the category. For each race that was monitored across the 3 day race weekend, the LAeq,8h including the race and 10 minutes before and after was found to be lower than the LAeq,8h by 1-5 dB(A), most commonly by 3 dB(A). In relation to peak levels, the categories that reached the highest were V8 Supercars while Touring Car Masters had the lowest peak levels. Despite some races not reaching peak levels, every driver participating had reached peak level in at least one of their races. Peak noise levels for all flag Marshals had reached over 140dB.

4.5. Hearing protection attenuation evaluation

Thirty-seven brands and types of hearing protection were evaluated. All of the hearing protection devices attained were earplugs, mainly polyurethane foam earplugs. From the SLC80 rating, or SLC80 rating equivalent attained from an NRR, a class of hearing protection was found for each device, ranging from class 2-5 depending on the rating. Most of the devices listed ranged from class 3-5 and were suitable for drivers and flag marshals being exposed to noise levels above 95dB(A). This included drivers of V8 Supercars, Touring Car Masters and Formula Fords. Class 2 hearing protection types are suited for drivers exposed to 90 to 95 dB(A) or just less than 90 dB(A), such as for drivers racing V8 Utes or Saloon Cars. Each driver can wear a range of classes within acceptable attenuation [to reduce noise levels to 70-75 dB(A) or 80-85dB(A)] to good attenuation [between 75 to 80dB(A)]. Good attenuation is recommended over acceptable attenuation. Any further attenuation from hearing protection devices results in over and under attenuation.

5. Discussion

5.1. Health protection questionnaire

Based on the findings from the questionnaires, a total of 82 drivers plus 4 flag marshals surveyed out of 125 (68.8%) had worn hearing protection. Custom fitted molded silicone/gel type inserts were found to be the most used type of hearing protection overall, being used by 45 out of 121 (37.2%) drivers who completed the questionnaire and 45 out of 82 drivers who had worn hearing protection (54.9%). Ear plugs were found to be the second most used hearing protection amongst participants and were used by 20 out of the 86 drivers and flag marshals who had worn hearing protection, followed by quality universal fit silicone/gel type ear moulds used by 18 drivers. There were 5 other forms of hearing protection used. Due to excessive levels of noise known amongst some categories such as V8 Supercars being equivalent to NASCARs in America, hearing protection is a must. However for those that have a lack of knowledge of noise levels, hearing protection may not be as common such as with Saloon Car drivers (Hear-it, 2010; Centers for Disease Control and Prevention, 2010; Schneider, 2010). Ear plugs, both foam and custom molded, are suitable hearing protection types for drivers due to easily being able to be worn with other equipment such as balaclavas and helmets. They are cheap, good in hot, humid environments, most are re-usable and washable and are easy to carry. Custom molded earplugs were the most used type of hearing protection amongst drivers surveyed due to the wider availability in size, suiting the ear of any driver (CCOHS, 2007; Bowling Green State University, 2012).

The other forms of hearing protection used included Ear Muffs or Radio Communications Headset with Ear Muffs worn by 3 out of the 4 flag marshals monitored. Vinyl sticky tape with headphones was worn by one of the touring car masters drivers and a stilo type helmet was worn by one of the V8 Utes drivers. Drivers find it difficult to wear ear muffs due to less portability, heavier weight, inconvenience with other personal protective equipment such as helmets and confined areas, uncomfortable in hot humid areas (which a car does become during racing) (CCOHS, 2007). However for Flag Marshals, as they do not wear helmets and are not subjected to confined areas when at the track, ear muffs are a suitable choice of hearing protection as ear muffs are designed to fit most head sizes, there is less attenuation variability amongst users, they are easily monitored for use and do not irritate the ear canal. Ear muffs can also be worn with ear plugs for further attenuation (CCOHS, 2007; Abel & Odell, 2006; Advanced Communication Solutions, 2008).

Fifty five drivers (44%) out of the total 125 participants had taken a hearing test. Of the 55 drivers who had taken a hearing test, 9 drivers (16.3%) had stated that they were advised they had some hearing loss. One person had not known the results of their test. The rest of the drivers (45) were advised that they did not have hearing loss. The two drivers who had stated that they had some form hearing loss identified by hearing tests and did not wear hearing protection were both from Saloon cars. One was aged 20-24 while the other was aged over 60. For the driver who was over 60 years presbycusis (age-related hearing loss or AHL) could be a contributing factor as with increasing age presbycusis contributes to hearing loss resulting in a decline of auditory function due to increased hearing thresholds and poor frequency resolution (Hear-it, 2013a; Yamasoba et al., 2013.

Noise levels are extremely loud in the motor sport environment, so the majority of drivers, excluding saloon cars, had worn hearing protection devices. Despite the use of hearing protection devices 7 of the 9 drivers found to have hearing loss wore hearing protection. Five of these nine drivers who had hearing loss and wore hearing protection were between the ages of 20-30. Their hearing loss may be due to the attenuation of hearing protection not being sufficient, incorrect wearing or removal of hearing protection devices due to miscommunication during crucial periods of excessive noise levels (Standards Australia, 2005c; 2005d; CCOHS, 2007; Van Campen et al., 2005; Australian Hearing, 2010; Workplace Health & Safety Queensland, 2011a). Other driver who had worn hearing protection and had some form of hearing loss were between the ages of 36-40. For all drivers further information including medical history, cigarette smoking status and leisure activities would be required to identify if there were other factors which could contribute to the presence and severity of hearing loss (Hear-it, 2013b; Cruickshanks et al., 1998; Nondahl, et al., 2004).

As 70 participants had not taken a hearing test, many of the racing car drivers could have hearing loss without their knowledge. Audiometric testing determines a subject's hearing level with the use of an audiometer. Monitoring audiometry testing is performed to detect temporary or permanent threshold shift. If temporary threshold shift is present, it gives an early indication of the likelihood of permanent threshold shift being present. Once testing is conducted, results obtained are recorded concerning the noise exposure of the test subject in the 16 hour prior to the test as well as information regarding any hearing protection devices used. Monitoring audiometry testing is recommended to be carried out 12 months after the initial reference audiometry test (Standards Australia 2002; Standard Australia, 2005e; Brown, et al., 1981; Bilski, 2003).

Eighty one (64%) of the questionnaire respondents had worn transducers/speakers in ear moulds. Thirty six drivers from the Saloon Cars Category had not worn any form of hearing protection or transducers/speakers either. Due to the excessive noise levels exhibited in motor sports, drivers that communicate with pit crews often while wearing hearing protection are in need of transducers/speakers to prevent removal of hearing protection resulting in damaging of the inner ear (Dickinson, 2003; WHO, 2001; Traynor, 2013).

5.2. Noise level data

5.2.1. LAeq,8h

The LAeq,8h of drivers monitored for noise exposure amongst all monitored car categories included in this research experienced an LAeq,8h above the recommended exposure level of 85 dB(A) over 8 hours. The majority of research participants were exposed between 88 dB(A) to 112 dB(A); however as not every race was monitored this could indicate greater noise level exposures for some drivers. The LAeq,8h values obtained are similar to other studies in which professional drivers and track officials were found to be exposed to noise levels that ranged from 90 dB(A) to 140 dB(A) on a daily basis (Lindemann & Brusis, 1985;Van Campen et al., 2005; Rose, Ebert, Prazma & Pillsbury, 2008). The levels of noise exposure in racing car drives and flag marshals exceeded the Australian Standard. The Australian exposure standard for noise is stated as LAeq,8h of 85 dB(A) which indicates the eight-hour equivalent continuous A-weighted sound pressure level that one can be exposed to (Standards Australia, 2005a).

All races were above a peak level of 125dB(C), with all the drivers reaching over 140dB(C) in at least one race monitored, or 16 (80%) out of 20 race scenarios (driver monitored on that day), the highest being 146dB(C), above the peak noise level permissible standards required by occupational organizations and governments reaching levels of C-weighted peak sound pressure level LC,peak standard of 140 dB(C) (Standard Australia, 2005a; Van Campen et al., 2005). Examples of these levels that exceed the 140 dB(C) standard include Practice Race 1 for V8 Ute Driver 1, Driver 2 and Formula Fords Driver 1, reaching values of 143.1 dB(C), 140.8 dB(C) and 143.3dB(C) respectively, above the 140 dB(C) standard.

Although in some cases practice races were found to be less excessive in sound than actual races for some categories (such as V8 Utes), it was still shown that practice races are relatively harmful to noise exposure and still have an impact that leads to the standard of 85 dB(A) for an LAeq,8h and 140 dB(C) peak level being exceeded where leading to pre-event control is stated to be fairly impossible to implement (Standards Australia 2005a; Dickinson, 2012; Williams & Burgess, 2007). This is because that even though qualifying races and actual races will always have drivers driving at their maximum at race tracks, where even if this may not be the case in practice races, drivers still alter their vehicles to increase the power before using the track, leading to excessive noise during practice races (Dickinson, 2012; Williams & Burgess, 2007).

Each of these exceeded levels are significant as it is known that race car drivers and personnel are susceptible to excessive noise exposure in the motor sport environment, mostly emitted by car engines that produce noise above the standards recommended by occupational organizations across the globe (Waites & Grant, 2009; Dickinson, 2012). This is important as the actual degree, prevalence and type of hearing loss associated with motor sport racing are unknown (Lindemann & Brusis, 1985). The noise levels stated in the results of this study are excessive due to the influence of a variety of main noise sources from a motor sport raceway that include exhaust noise emitted from car engines in each vehicle, but could have also been due to other vehicle noise such as tyre/track interaction and mechanical noise, aerodynamic noise, induction noise, transmission noise (changing the gearbox), engine ancillary components, body work components, wind turbulent noise emitted by the speed of the car affecting mainly drivers of open car vehicles and collateral noise from unofficial revving (Waites & Grant, 2009; Dickinson, 2012).

Although some limitations are sometimes put on motor sport vehicles, specialized high performance vehicles currently have no output noise limits. In Australia these limits for motor sport cars are 95 dB at 30m, such as from the edge of the spectator areas. Although some spectators are possibly exposed to higher levels of noise, it is assumed that a spectator at a range of motor sports activities could be exposed to a LAeq of around 90 dB over the duration of the event (Williams & Burgess, 2007; Waites & Grant, 2009).

Noise level exposure for professional drivers, spectators, pit crew and track officials ranged from 90 dB(A) to 122 dB(A). Further supporting this evidence is a study (Schneider, 2010) conducted at the Bristol Motor Speedway, showing noise levels exceeding the standard ranging from 96dB(A) (two to 10 times higher than a person working a 40-hour week at the maximum allowable limit of 85 decibels in the stands) to 114 dB(A) for a driver inside a car during practice and greater during actual races in the pit area. Schneider, (2010) reported that the racing car noise was found to have exceeded a peak noise level of over 130dB which is a level of human hearing threshold often recognized for pain (Centers for Disease Control and Prevention, 2010; Hear-it, 2010).

Amongst the categories, V8 Supercars had the highest LAeq,8h values, in both drivers having an LAeq,8h of 112db(A) on Day 3 in which they were monitored. Noise levels emitted from Formula cars are described to be similar to that produced by a jet plane taking off, (Tranter & Lowes, 2005; Neitzel, Seixas, Goldman & Daniell, 2004), which may also explain the excessively loud noise in having an LAeq,8h for each Formula Ford driver above 100dB. The lowest LAeq,8h value was 83 dB for the Saloon Car driver on Day 3, the only value below the acceptable noise limit, however this was due to an exposure of 15 minutes and if further excessive noise exposure had occurred, the exposure level would be above the recommended limit. Saloon Car Driver 1 and Formula Ford Driver 3 both had not worn any form hearing protection despite the high levels of LAeq,8h obtained and are recommended to wear hearing protection during their races.

5.2.2. LAeqT and LAeqT +/- 10 minutes

The LAeqT and LAeqT +/10 minutes showed a difference of usually a change in 3 dB(A) over the 10 minute before and after the race. This period was relatively significant as there was a change from 85dB(A) to 96dB(A) over 8 hours which ranged from two to ten times higher than allowable noise exposure. A 3 dB different in 20 minutes for partial exposure could be around the same range as that over 8 hours (Hear-it, 2010).

5.2.3. Peak levels

Peak levels emitted by car engines were around 125 to 140 dB(C) in a single race. These levels showed that drivers and flag marshals were exposed to noise exceeding a C-weighted peak sound pressure level above the recommended standard of 140dB(C) (Standards Australia, 2005b; Van Campen et al., 2005).

5.3. Driver and flag marshal examination

Formula Fords may have higher noise level exposure compared to other categories (excluding V8 Supercars) due to wind turbulence being an additional factor to car engine noise emission due to the driver and being an open car, compared to other drivers who either had windows closed or a cloth cage while keeping the window open. Amongst studies, the significance and impact of wind noise has been shown to be contributing to hearing impairment amongst drivers involved in motor sports, such as with motorcyclists being subjected to a significant amount of wind noise which was enough to cause some degree of hearing impairment/hearing loss (Traynor, 2011; McCombe, 2003; Harrison, 1974; Ross, 1989). This hearing loss may be due to the use of modern helmets used by motorcyclists and drivers participating in races as these helmets offer very poor low-frequency sound attenuation, specifically between 250 Hz to 500 Hz, have a form of resonance at 250Hz and are not useful in blocking out excessive levels of noise present at high frequencies (McCombe, 2003). For motor cyclist McCombe, (2003), Traynor, (2011); Aldman, Gustafsson, Nygren & Wersall, (1983), Bess, Dale, Aarni & Redfield, (1974) found the source of helmet attenuation proved to be a turbulent boundary layer, with wind vibrating against the outside of the helmet shell, with its maximum sound energy focused between 250 and 500 Hz. This may then impact formula ford drivers as it does motorcyclists. Further investigation may be needed for drivers who had kept windows open during races between V8 Utes, Saloon Cars and Touring Car Masters, to see if wind turbulence effects them greatly and the degree to which the cloth cage or a closed window reduce noise.

V8 Supercars had the loudest engine noise according to the noise exposure assessment. This finding is similar to the findings of Fernbach, (2012) who monitored a 2010 event in which V8 supercars were reported to produce sound in excess of an average of 100 dB(A) at the Boundary Street. It is then vital that V8 Super car racing drivers keep both windows closed as well as wear the recommended class of hearing protection. The Dunlop race series had taken a similar approach in keeping all windows closed. For both categories this may be specific due to the design of the engine and the car itself. All Flag Marshals being stationed close to the cars in stations 1 and 11 had excessive noise exposure over an 8 hour period which was above the recommended Australian standard of 85dB(A) due to being in close proximity to the cars and thus experience similar noise levels to that of car drivers, ranging from 90-140dB(A) (Standards Australia, 2005a; Lindemann & Brusis, 1985; Van Campen et al., 2005; Rose, Ebert, Prazma &

Pillsbury, 2008).

<u>5.4. Hearing protection attenuation evaluation</u>
Each Hearing Protection device has an 'In-ear/Real-Ear' attenuation, which is defined as "the difference in decibels between the occluded-ear threshold of hearing and the open-ear threshold of hearing" by the AS/NZS 1270:2002 (Standards Australia, 2002, p.5). In selecting appropriate hearing protection, noise level exposure for participation in a loud activity, specifically for drivers in motor sports, must be known and the compatibility of the hearing protection device in the race environment and other protective or necessary equipment known and used. Attenuation must be set to block out the excessive noise exposure but must not over protect to avoid feelings of isolation and cause communication problems that may lead to inconsistent wearing of the hearing protection. Reduction to an "in-ear" level of 70 dB(A) and below should be regarded as over-protection. Although the area between 80 and 85 dB(A) is of acceptable attenuation, because of uncertainties introduced by the "real world" ear protection, it could be regarded as potentially under-protecting. If there is under attenuation of the device this results in the device not being able to reduce noise level exposure to a sufficient level resulting in hearing loss (El Dib, Mathew & Martins, 2011; Dickinson, 2003; Verbeek et al., 2012; Centers for Disease Control and Prevention, 2011; 2012). For good attenuation the "in-ear" noise level should generally be required to fall between 75 and 80 dB(A), while acceptable attenuation lies between 70 to 75 db(A) and 80 to 85 db(A) (Workplace Health and Safety Queensland, 2011b).

Drivers may remove hearing protection devices due to miscommunication if there is over attenuation of the hearing protection device, or the driver already has some form of hearing loss possibly due to removal of hearing protection at crucial time (Lindemann & Brusis, 1985). If the hearing protection is only worn 90% of the time around excessive noise, effectiveness of hearing protection is decreased to less than one-third (Verbeek et al., 2012). Where although hearing protection was provided and worn in most cases of motor sport racing and its related activities removal of hearing protection was shown by Van Campen et al., (2005), to be due to a variety of noise-related complaints including questioning the suitability of hearing protection devices through inability to hear important sounds due to attenuation, difficulty in team communication and muffled hearing and/or tinnitus. Drivers and team members may have a greater concern for communication and performance over using hearing protection which can result in race car drivers and other personnel removing hearing protection devices for periods of time that may significantly affect hearing in a negative way in shorter amounts of time due to continuous exposure (Kardous & Morata, 2010). It is through the use of hearing protection that drivers and personnel who are present on the race track during the race that attenuates excessive noise from causing hearing loss/damage to hearing (Van Campen et al., 2005; Lindemann & Brusis, 1985).

The flag marshals had worn ear muffs, while no drivers had worn earmuffs, only ear plugs and if no earplugs, every driver had worn helmets and balaclavas. Although ear muffs are not suitable for racing car drivers due to the helmets small size and recoil of the race, the ear plugs requires skill and attention during application and some people may need a different size plug for each ear, hence why custom molded earplugs are made to compensate for this. People having different sized ears compared to universal sizes mean that custom earplugs will be more comfortable and are needed. This may reflect the results of the questionnaire in custom molded ear plugs being the most used hearing protection device. Sufficient low-frequency attenuation may be achieved when combining earmuffs and earplugs to prevent hearing loss from excessive noise. Attenuation however may be maximized by choosing a smaller earplug to achieve a better fit. Possible downsides of using both in conjunction are the reduced detection of warning sounds and speech intelligibility (Bowling Green State University, 2012; CCOHS, 2007).

Different hearing conservation/protection programs and regulations for occupational noise exposure have been designed and implemented in a variety of workplaces, however are not implemented well, or are absent, in places of recreation such as motor sports where there exists virtually little to no standards in place for recreational noise (Michael, Opie & Smith, 2010). This is an emerging contributor to noise-induced hearing loss to those continuously exposed to loud noise (Traynor, 2013). Hearing Protection is then vital in the motor sport environment where no there is no implementation of standards or legislation (Williams & Burgess, 2007; Waites & Grant, 2009).

6. Conclusions and recommendations
Noise exposure levels of drivers participating in motor sports in Western Australia were not known as minimal previous research on this topic had been published. This research has provided an increase in information on noise level exposure for racing car drivers and flag marshals in Australia. Studies on the types of hearing protection

racing car drivers and flag marshals in Australia wear and the frequency that hearing tests are undertaken by Australian racing car drivers and flag marshals is new knowledge that has been generated through this research. This new knowledge has been used to determine the suitability and types of hearing protection to be worn by racing car drivers and flag marshals. Suggestions for improvement in the use of hearing protection and frequency of hearing tests have been provided.

Excessive noise exposure is a significant problem within motor sports and needs to be dealt with by the implementation of rules and legislation in motor sports as the LAeq,8h exceeded the recommended standard of 85 dB(A) across all categories of racing cars monitored in at least one out of the three days of the V8 supercars event and peak levels exceed 140dB(C) in at least one race that a driver participates in. Drivers and flag marshals that are exposed to noise levels that exceed the Australian noise standards should be required to have their noise exposure reduced by implementing cost effective hearing protection conservation program following the criteria stated in the AS/NZS 1269:2005 standard, specifically those criteria stated by the AS/NZS 1269.3:2005 standard for occupational noise to reduce and manage noise levels at the race track (Standards Australia, 2005a; Standards Australia 2005d). This is important as both drivers and flag marshals have been proven to be exposed to excessive noise levels during car racing. This means that spectators, pit crews and others attending these events may also be exposed to similar excessive levels of sound. Spectators are recommended to wear hearing protection devices, and where possible management of noise levels improved by decreasing noise sources including car engine emission, tyres, induction noise and other forms of excessive noise.

As noise induced hearing loss is preventable protection against hazardous noise exposure should be included into overall hazard prevention and risk control programs implemented in workplaces and recreational areas (WHO, 2001; NOHSC, 2004; Traynor, 2013; Cannington, 2009). Knowledge of the dangers of noise in work activities should be recognized, education provided to workers before work and risk control measures implemented to minimise the occurrence of hearing difficulties (WHO, 2001; Traynor, 2013). Motor sports are one of four activities with the highest associated noise exposures worldwide (Neitzel, Seixas, Goldman & Daniell, 2004). It is important for race personnel to know the consequences of excessive noise exposure and to wear hearing protection devices as once hearing is damaged from any situation, it usually cannot be restored (Scheinder, 2010).

The racing car and flag marshals hearing protection program should include, as stated by the AS/NZS 1269.3 (Standards Australia, 2005d), the following:

- Management responsibility which would be managed by the raceways and separate categories.
- If possible there should be a reduction of noise at the source, specifically the car engine and tyres.
- Knowing the noisiest areas in the raceway which are identified as hearing protection areas.
- Proper usage of hearing protection including hearing protection usage and selection based on noise exposure, compatible with job requirements, personal characteristics and workplace.
- There should be documented, know and used instructions on when hearing protection devices should be used and the correct fitting of hearing protection that considers comfort and meeting communication requirements for drivers, flag marshals and spectators. Regardless of class required for each category, all are recommended to wear some form of hearing protection of the required hearing protection class.
- A correct training program in the use of hearing protection devices for all personnel.
- In wearing hearing protection devices, attenuation requirements should be met, reaching at least between 70dB(A) Laeq,8h to 85dB(A) Laeq,8h if not practicable to reach a good attenuation range of 75dB(A) Laeq,8h to 80dB(A) Laeq,8h. Anything below 70dB(A) Laeq,8h or above 85dB(A) Laeq,8h is hazardous due to over and under attenuation respectively.
- Inspection for defects of hearing protection devices.
- Correct cleaning, storage and maintenance of hearing protection devices.
- A correct training program in the use of hearing protection devices for all personnel.
- There should be the use of hearing protection conservation programs which have been shown to be effective in most workplaces.
- Evaluating the effectiveness of the hearing protector program through monitoring noise levels, program auditing, maintenance and evaluation of user awareness and making improvements where opportunities are identified.

As published studies have proven that when hearing protection is worn correctly with the correct attenuation, excessive noise exposure and hearing loss is prevented all the above aspects should be implemented to protect driver and flag marshal hearing and ability to adapt to excessive noise level exposure in the motor sports environment. Annual audiometric testing should be performed for the purpose of identifying and documenting existing hearing loss, early detection of deterioration of hearing in users of hearing protectors, prompt direction of an appropriate rehabilitation program for individuals identified with hearing loss and the supply of a warning system that me be needed in the workplace for an individual with hearing loss (Standards Australia, 2005d).

This pilot study has generated new knowledge by providing evidence that racing car drivers and flag marshals in Western Australia are exposed to excessive work related noise levels. For future studies a larger sample group should be monitored for noise levels in the motor sport environment to provide additional insight into the potential hazards that personnel participating in and attending motor sports are exposed to.

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World Safety Organization

Code of Ethics

Members of the WSO,
by virtue of their acceptance of membership
into the WSO,
are bound to the following Code of Ethics
regarding their activities
associated with the WSO:

Members must be responsible for
ethical and professional conduct in relationships
with clients, employers, associates, and the public.

Members must be responsible for professional competence
in performance of all their professional activities.

Members must be responsible
for the protection of professional interest,
reputation, and good name of any deserving WSO member
or member of other professional organization
involved in safety or associate disciplines.

Members must be dedicated to professional development
of new members in the safety profession
and associated disciplines.

Members must be responsible
for their complete sincerity in professional service
to the world.

Members must be responsible for continuing improvement
and development of professional competencies
in safety and associated disciplines.

Members must be responsible
for their professional efforts to support the WSO motto:

"Making Safety a Way of Life…Worldwide."

World Safety Organization

Statement of Purpose and Objective

WSO's purpose is to internationalize all safety fields, including occupational and environmental safety and health, accident prevention movement, etc., and to disseminate throughout the world the practices skills, arts, and technologies of safety and accident prevention.

WSO's objective is to protect people, property, resources, and the environment on local, regional, national, and international levels. WSO membership is open to all individuals and entities involved in the safety and accident prevention field, regardless of race, color, creed, ideology, religion, social status, sex, or political beliefs.

WSO is in Consultative Category II Status (Non-Governmental Organization-NGO) to the Economic and Social Council of the United Nations.

The WSO is a Not-for-Profit Corporation (Missouri, USA), non-sectarian, non-political movement dedicated to *"Making Safety a Way of Life…Worldwide."*

World Safety Organization (WSO)

World Safety Organization Profile

The WSO was founded in 1975 in Manila, The Republic of the Philippines, as a result of a gather of over 1,000 representatives of safety professionals from all continents at the First World Safety and Accident Prevention Congress. The WSO World Management Center was established in the United States of America in 1987 to be responsible for all WSO activities, the liaison with the United Nations, the co-operation with numerous Safety Councils, professional safety/environmental (and allied areas) organizations, WSO International Chapters/Offices, Member Corporations, companies, groups, societies, etc. The WSO is a not-for-profit corporation, non-sectarian, non-political movement to **"Make Safety a Way of Life…Worldwide."**

World Safety Organization Activities

The WSO publishes WSO Newsletters, World Safety Journal-ESP, and WSO Conference Proceedings.
The WSO provides a network program linking various areas of professional expertise needed in today's international community.
The WSO develops and accredits educational programs essential to national and international safety and establishes centers to support these programs.
The WSO presents annual awards: the James K. Williams Award, Glenn E. Hudson International Award, J. Peter Cunliffe Transportation Award, WSO Concerned Citizen, WSO Concerned Professional, WSO Concerned Company/Corporation, WSO Concerned Organization, Educational Award, WSO Chapter/National Office of the Year, and Award for Achievement in Scientific Research and Development.
The WSO provides recognition for safety publications, films, videos, and other training and media materials that meet the WSO required educational standards.
The WSO receives proposals from professional safety groups/societies for review and, if applicable, submits them to the United Nations for adoption.
The WSO establishes and supports divisions and committees to assist members in maintaining and updating their professional qualifications and expertise.
The WSO has Chapters and National/International Offices located throughout the world, providing contact with local communities, educational institutions, and industrial entities.
The WSO organizes and provides professional support for international and national groups of experts on all continents who are available to provide expertise and immediate help in times of emergencies.

Benefits of Membership

The WSO publishes the "WSO Consultants Directory" as a service to its Members and to the Professional Community. Only Certified Members may be listed.
The WSO collects data on the professional skills, expertise, and experience of its Members in the WSO Expertise Bank for a reference when a request is received for professional expertise, skill, or experience.
The WSO provides a network system to its Members whereby professional assistance may be requested by an individual, organization, state, or country or a personal basis. Members needing assistance may write to the WSO with a specific request, and the WSO, through its Membership and other professional resources, will try to link the requester with a person, organization, or other resource which may be of assistance.
The WSO provides all Members with a Membership Certificate for display on their office wall and with a WSO Membership Identification Card.
The WSO awards a Certificate of Honorary Membership to the corporations, companies, and other entities paying the WSO Membership and/or WSO Certification fees for their employees.
Members have access to WSO Newsletters and other membership publications of the WSO on the WSO website, and may request hard copies by contacting the WSO World Management Center. Subscription fees apply to certain publications.
Members are entitled to reduced fees at seminars, conferences, and classes given by the WSO. This includes local, regional, and international programs. When Continuing Education Units (CEUs) are applicable, an appropriate certificate is issued.
Members who attend conferences, seminars, and classes receive a Certificate of Attendance from the WSO. For individuals attending courses sponsored by the WSO, a Certificate of Completion is issued upon completion of each course.
Members receive special hotel rates when attending safety programs, conferences, etc., sponsored by the WSO.

Membership

The World Safety Organization has members who are full time professionals, executives, directors, etc., working in the safety and accident prevention fields, including university professors, private consultants, expert witnesses, researchers, safety managers, directors of training, etc. They are employees of multi-national corporations, local industries, private enterprises, governments, and educational institutions. Membership in the World Safety Organization is open to all individuals and entities involved in the safety and accident prevention field, regardless of race, color, creed, ideology, religion, social status, sex, or political beliefs.

Membership Categories

Associate Membership: Individuals connected with safety and accident prevention in their work or individuals interested in the safety field, including students, interested citizens, etc. **Affiliate Membership**: Safety, hazard, risk, loss, and accident prevention practitioners working as full time practitioners in the safety field. Only Affiliate Members are eligible for the WSO Certification and Registration Programs. **Institutional Membership**: Organizations, corporations, agencies, and other entities directly or indirectly involved in safety activities and other related fields.

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