Farm Family Total Noise Exposure Assessment
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List of Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
CFR	Code of Federal Regulations
dB	Decibels
dBA	Decibels on the A-weighted scale
FFHHSP	Farm Family Health and Hazard Surveillance Program
HCA	Hearing Conservation Amendment
kHz	kilohertz
L_{eq}	Equivalent continuous noise level
NIHL	Noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
NORA	National Occupational Research Agenda
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
REL	Recommended exposure level
TLV	Threshold limit value
8HR TWA	Eight-hour time-weighted average

Abstract

A pilot project was conducted to evaluate occupational and non-occupational noise exposures of three families living and working on farms in Northwest Ohio during planting season, growing season, and harvesting season. A total of nine family members (six adults and three children) participated in the pilot project. All nine participants completed three weeks of noise monitoring. Noise exposures were measured using both the OSHA and the NIOSH/ACGIH criteria. Adult noise exposures for on farm activities (occupational exposures) ranged from 81.2-89.3 dBA 8HR TWA during planting season, from 59.5-89.6 dBA 8HR TWA during growing season, and from 55.3-88.9 dBA 8HR TWA during harvesting season using the OSHA criteria and ranged from 84.3-89.9 dBA 8HR TWA during planting season, from 69.8-92.1 dBA 8HR TWA during growing season, and from 67.3-91.6 dBA 8HR TWA during harvesting season using the NIOSH/ACGIH criteria. Occupational exposures for the children ranged from 15.4-76.5 dBA 8HR TWA during planting season, from 50.9-67.1 dBA 8HR TWA during growing season, and from 79.9-81.2 dBA 8HR TWA during harvesting season using the OSHA criteria and ranged from 42.4-81.3 dBA 8HR TWA during planting season, from 64.5-77.6 dBA 8HR TWA during growing season, and from 83.7-85.5 dBA 8HR TWA during harvesting season using the NIOSH/ACGIH criteria. Non-occupational exposures were measured during many activities including off-farm activities, school, and an outdoor tractor pull. These L_{eq} exposures ranged from 62.6-104.0 dBA for the adults and from 68.6-88.4 dBA for the children. For the adults, none of the occupational exposures exceeded the OSHA standard, but 10 of 45 exposures exceeded the NIOSH/ACGIH guidelines. The tasks performed during the elevated exposures included tilling/plowing, operating front end loader, harvesting, planting, and repair/maintenance. Similarly, for the children, none of the occupational exposures exceeded the OSHA standard, but 1 of 11 exposures exceeded the NIOSH/ACGIH guidelines. The task performed during the elevated exposure for the child was tilling/plowing while operating a tractor with mulcher and disc. For the non-occupational exposures, the highest exposures were recorded during the outdoor tractor pull.

The results of this pilot project indicate that both occupational and non-occupational noise exposure could contribute to possible hearing loss in farm families living and working on farms in Northwest Ohio.

Highlights/Significant Findings

The first specific aim of this pilot project was to characterize both the occupational and the non-occupational noise exposures of three farm families in Northwest Ohio. Occupational noise exposures ranged from 55.3-89.3 dBA 8HR TWA using OSHA criteria and 67.3-92.1 dBA 8HR TWA using NIOSH/ACGIH criteria for the adults and from 15-4-81.2 dBA 8HR TWA using OSHA criteria and from 42.4-85.5 dBA 8HR TWA using NIOSH/ACGIH criteria for the children. None of these exposures exceeded the OSHA standard, but 11 exceeded the NIOSH/ACGIH guidelines. However, it should be noted that the OSHA noise standard does not apply to farm workers. Non-occupational noise L_{eq} exposures ranged from 62.6-104.0dBA for the adults and from 68.6-88.4 dBA for the children. Elevated exposures for both adults and children were recorded for the tasks of tilling/plowing, operating front end loader, harvesting, planting, other farm activities, and repair/maintenance. Elevated exposures were also recorded when using the equipment of tractor operation with disc, tractor operation with chisel plow, and tractor operation with mulcher and disc.

The second specific aim of the pilot project was to assess the feasibility of the monitoring strategy. The monitoring strategy required participants to wear a noise dosimeter during all waking hours for seven consecutive days, three times during a one-year period. In addition, the participants were required to complete a daily activity log to document both their occupational and non-occupational activities each monitoring day. The monitoring strategy was determined to be feasible since all nine participants who enrolled in the study completed at least some of the study requirements. No individual or family chose to discontinue participation.

The third specific aim of the pilot project was to assess the compliance of the participants with the monitoring strategy. Compliance was determined both as the percentage of time the dosimeter was worn and the percentage of completion of the daily activity log. These percentages could not be calculated due to improper use of the log books and frequent non-reporting of activities when field investigators were present, especially for Family 2 and Family 3. Additionally, the field investigator was not able to observe 100% of the farming activity of all 9 participants and therefore could not estimate the compliance percentage.

The final specific aim of the pilot project was to assess the quality of self-reported activities. Quality was determined by the agreement between self-reported activities and the activities recorded by investigators. Agreement for the first family was 64%. Agreement for the second and third families could not be calculated due to improper use of the log books and frequent non-reporting when observers were present.

Translation of Findings

Noise exposures during both occupational (farm-related) and non-occupational (all other) activities could be elevated and could potentially contribute to the possibility of hearing loss among household members who live and work on the farm. Elevated occupational noise exposures were measured for both adults and children according to NIOSH/ACGIH guidelines. Additionally, hearing protection devices (ear plugs) were only worn by 1 of the 9 participants during noise hazardous activities. The absence of hearing protection could increase the possibility of developing hearing loss.

Outcomes/Relevance/Impact

Noise exposures are elevated for both adults and children living and working on farms in Northwest Ohio.

Scientific Report

Background

Agricultural Demographics

According to the US Bureau of Census [US Department of Commerce. 1993], the US farm population consists of person living in households on farm residences. A farm residence is defined as housing units on a property ≥ 1 acre and producing ≥ $1,000 worth of agricultural products during the previous calendar year. The most recently available data estimated the farm population of 3,871,582 [US Department of Commerce, 1993] with almost half of this number residing in 12 states (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin). The vast majority (94%) of these farm residents are white and 27% of the white population (approximately 984,000) are less than 20 years of age. Additionally, 20% of white farm residents (more than 722,000) are less than 15 years of age [US Department of Commerce, 1993]. Therefore, youth constitute a significant portion of the US farm population. In the proposed project area, 4,335 farms make up the total study population [1997 Census of Agriculture].

Noise

The word *noise* is often used to mean unpleasant sound that the listener does not want to hear, although there are no physical characteristics distinguishing noise from wanted sound [Plog and Quinlan, 1997]. Exposure to intense noise has been shown to damage the human hearing process [McDonald, 2000] and noise has been labeled the most pervasive hazardous agent in the workplace [Berger et al, 2000]. Non-hazardous noise levels are generally agreed to be below 75 decibels on the A-weighted scale (dBA) [NIH Consensus Conference 1990]. Long-term noise exposure to levels below 80 dBA is not likely to injure hearing, exposure to levels of 85-90 dBA may injure hearing, and exposure to levels exceeding 90 dBA probably will injure hearing [McDonald, 2000]. Approximately 17% of the working population is employed in jobs where noise exposure occurs at hazardous levels, exceeding 85 dBA [Plog and Quinlan, 2002].

Occupational noise is the most common cause of noise-induced hearing loss (NIHL) [NIH Consensus Conference, 1990]. Accordingly, the National Institute for Occupational Safety and Health (NIOSH) considers NIHL as one of the 10 leading work-related diseases and injuries [NIOSH, 1988]. In the 1990s, NIOSH included hearing loss as one of the 8 most critical diseases and injuries requiring research and development activities within the framework of the National Occupational Research Agenda (NORA) [NIOSH, 1996]. Agricultural workers may experience excessive hearing loss [Dennis and May, 1995] and have one of the highest rates of hearing loss among all occupations [Baker, 1993]. Unprotected workers in high-noise environments, no matter the occupation, have more lost-time injuries, are less productive, and in general experience more problems than do those in lower noise environments [Berger et al, 2000].

Agricultural Noise Sources

The mechanization of agriculture, including the use of the internal combustion engine, greatly increased the noise exposure of the US farm population

[Matthews, 1968]. Unfortunately for farmers, equipment manufactured prior to the institution of noise reduction features is often still in use on US farms, as demonstrated by the New York Farm Family Health and Hazard Surveillance Program (FFHHSP) [Beckett et al, 2000].

Studies of agricultural noise sources date back many decades, but are limited in number. In 1958, tractor noise was determined to be intense enough to produce high frequency hearing loss among tractor operators [Lierle and Reger, 1958]. In Australia in 1963, noise levels of 12 tractors (8 diesel, 4 kerosene) ranged from 92 dB to 106 dB [Weston, 1963]. In Nebraska in 1968, noise levels of 58 new tractors ranged from 98 dB to 113 dB. Addtionally, the average sound pressure level for all 58 models, types, and operator positions was 103.5 dB [Jones and Oser, 1968]. In 1969 in Nebraska, noise levels of 55 tractors (21 gasoline, 30 diesel, 4 liquid petroleum) all exceeded 85 dB [Simpson and Deshays, 1969]. More recently, Plakke [1990] reported that noise levels of tractors without enclosed cabs can range from 100 dBA to 110 dBA and if the tractor has an implement attached, noise levels can exceed 110 dBA. In Wisconsin in 1993, the noise level of 75% of 110 tractors without cabs exceeded 90 dBA, whereas the noise level for only 18% of 45 tractors with cabs (windows closed, radio off) exceeded this level [Holt et al, 1993].

Noise-Induced Hearing Loss among Farmers

Noise-induced hearing loss (NIHL) describes the cumulative permanent loss of hearing, always of the sensorineural type, that develops over months or years of hazardous noise exposure [Plog and Quinlan, 2002]. NIHL is almost entirely preventable [NIH Consensus Conference, 1990]. NIHL has been recognized as an occupational disease since the 18th century and in 1996 the Occupational Safety and Health Administration (OSHA) estimated that 17% of production workers have at least a mild hearing loss [McCunney and Meyer, 1998]. NIHL rarely produces profound deafness, but the condition tends to be progressive [McCunney, 1992] and typically affects a person’s ability to communicate [Karlovich et al, 1988]. The risk of suffering NIHL tends to increase with advancing age and length of employment, but most of the damage that occurs to the hearing mechanism tends to occur within the first ten years. The major risk factor for developing NIHL is prolonged unprotected exposure to noise levels exceeding 85 dBA [McCunney and Meyer, 1998].

Sensorineural hearing loss has been a common complaint among farmers seen by rural otolaryngologists, at one time comprising about 6% of the patient load [Gregg, 1972]. Farmers have been reported to be among the most hearing impaired workers in the US and most can expect a significant hearing loss by age 50 [McMahon and Urbain, 1988]. As part of the Ohio FFHHSP, cash grain farmers received pure-tone air conduction audiometric testing of each ear at seven frequencies (0.5, 1, 2, 3, 4, 6, and 8 kilohertz (kHz)). Median hearing threshold levels of the cash grain farmers exceeded those of the reference group (database A, ISO 7029) from 2 dB to 24 dB, with the largest differences occurring at the higher frequencies among the older farmers [Wilkins, Mitchell, et al, 1998]. A high prevalence of significant hearing loss has also been reported among dairy farmers in upstate New York [May et al, 1990]. In this study the dairy farmers had poorer hearing sensitivity than non-farmers, especially at frequencies above 2 kHz. The hearing sensitivity was highly correlated with age and the number of years worked in farming [Marvel et al, 1991]. Polish farm tractor operators likewise had statistically worse hearing than a control group at high frequencies (3-6 kHz) especially among tractor operators over 30 years of age. Again, the tractor operator hearing loss was highly correlated with age and length of farming employment [Solecki, 1998].

Youth living on farms can also be exposed to hazardous noise levels. However, few studies have examined hearing loss among farm youth. One such study examined teenagers living in Wisconsin while still in school and actively participating in farm work. These teenagers had an increased prevalence of mild hearing loss and early NIHL [Broste et al, 1989]. Results from the Ohio FFHHSP also suggest that children and adolescents living on farms are at increased risk of high frequency hearing loss [Varchol et al, 1998].

Personal Noise Exposures on the Farm

Even though agricultural work can be noise hazardous and can contribute to NIHL among farm residents, few studies have examined personal noise exposures on the farm. In New York, 13 workers on 9 dairy farms were monitored beginning before the first task of the day and finishing after the last task of the day. The farmers worked on average 14 hours a day and their exposure was 86 dBA as an eight-hour time-weighted average (8HR TWA). Except for breakfast and lunch breaks, the farmers had nearly continuous noise exposure throughout the day to noise levels that exceeded the OSHA action level of 85 dBA. The majority of the noise exposure seemed to come from mechanical equipment [Dennis and May, 1995]. In Ohio, as part of the Ohio FFHHSP, self-reported noise exposure data were collected from more than 1700 cash grain farmers. The results of the mixed-mode survey indicated that agricultural sources accounted for 96% of the estimated cumulative lifetime hours, with operation of cabless tractors accounting for 52% of the exposures. The results also indicated that cash grain farmers engage in a wide variety of activities, both agricultural and non-agricultural, that are likely to cause exposure to hazardous noise levels [Wilkins, Engelhardt et al, 1998].

Noise Exposure Regulations

Under the Walsh-Healey Public Contracts Act, the Bureau of Labor Standards issued rules that required occupational noise exposure to be reasonably controlled to minimize fatigue and the probability of work-related injuries. Originally these rules applied only to contractors under the Walsh-Healey Public Contracts Act and the McNamara-O'Hara Service Contracts Act. However, with the passage of the Williams-Steiger Occupational Safety and Health Act of 1970, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) were established. Since then, OSHA has promulgated a noise standard and the Hearing Conservation Amendment (HCA) for general industry (29 CFR 1910.95). Unfortunately, the OSHA standard does not apply to agriculture and cannot be enforced [Plog and Quinlan, 2002].

Although not required in agriculture, the OSHA noise standard can still be applied to benefit farm residents. The noise standard established a permissible exposure limit

(PEL) of 90 dBA for eight hours and required the employer to reduce exposure to that level by the use of feasible engineering and administrative controls. With the addition of the HCA, employees whose noise exposures equal or exceed an 8HR TWA of 85 dBA must be included in a hearing conservation program. An effective hearing conservation program is designed to prevent hearing impairment as a result of noise exposures on the job. The five basic components included in the hearing conservation program are exposure monitoring, audiometric testing, hearing protection, employee training, and record keeping. Employees thought to be exposed at or above 85 dBA 8HR TWA must be monitored and the measurement must include all noise within an 80-130 dBA range. Audiometric testing and hearing protectors must be available to workers exposures at or above 85 dBA 8HR TWA. Additionally, those workers exposed at or above 85 dBA 8HR TWA must receive training annually on the following topics: the effects of noise; the purpose, advantages, disadvantages, and attenuation characteristics of various types of hearing protectors; the selection, fitting, and care of protectors; and the purposes and procedures of audiometric testing [Plog and Quinlan, 2002].

Other agencies have also established noise exposure guidelines. Both NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH) have established a recommended occupational exposure level (OEL) of 85 dBA 8HR TWA. However, these guidelines have a 3 dB exchange rate, whereas the OSHA PEL has a 5 dB exchange rate. Therefore, as the sound level increases, there are significant differences in allowable exposure times [Plog and Quinlan, 2002]. For example, at an 8HR TWA of 90 dBA, allowable exposure duration is 8 hours based on the OSHA regulations and 2.5 hours based on the NIOSH/ACGIH guidelines.

Study Significance

The National Occupational Research Agenda (NORA) was unveiled in 1996 with a consensus of the 21 top research priorities. Hearing loss was one of these priorities under the disease and injury category. Additionally, in a presentation by Merchant [1992] and a poster by Themann and Henderson [1992] at the Surgeon General's Conference on Agricultural Safety and Health April 30 – May 3, 1991 in Des Moines, IA, characterization of noise exposure on farms was given as a research priority. Healthy People 2010 also includes 3 goals related to noise exposures: Goal 20-10, reduce new cases of work-related NIHL; Goal 28-17, reduce NIHL in children and adolescents under age 17 years; and Goal 28-18, reduce adult hearing loss in the noise-exposed public [US Department of Health and Human Services, 2000]. Research performed as part of NORA for the hearing loss section includes "Cross-Sectional Survey: Characterization of Mine Noise Sources & Work Exposures" and "Hearing Loss Prevention Programs for Construction Workers." Both projects were funded within NIOSH (intramurally) and both attempted to establish noise exposure profiles for various jobs with the mining or construction industry. The completed pilot project attempted to establish both occupational and non-occupational noise exposure profiles for a sample of the farm population, including youth, living in Northwest Ohio throughout various farming seasons. Since NIHL is related to noise level, proximity to the harmful sound, time of exposure, and individual susceptibility [US Department of Health and Human Services, 2000], the completed project attempted to characterize the first three factors among farm residents.

Specific Aims

The overall goal of this pilot project was to evaluate both occupational and non-occupational noise exposures of persons living and working on farms through the busiest farming seasons (planting, growing, and harvesting). The project's overall goal was accomplished by performing personal noise dosimetry on two to four residents of three farm households during all waking hours for seven consecutive days in each of the three busiest farming seasons. This pilot project was proposed in part due to the paucity of published data on this topic and in part as an initial investigation to fully evaluate exposure among farm families. Specific aims of the pilot project were:

(1) Systematically characterize the noise exposures of farm residents from occupational and non-occupational noise sources. The focus of this specific aim was to collect the noise exposure data for persons living and working on farms from the time each person arose in the morning until each person retired in the evening. Pilot project participants were asked to record daily time-activity data, which was evaluated along with the personal noise exposure data. The daily time-activity data was used in concert with the personal dosimetry data to relate elevated noise exposures to specific equipment and tasks. Three farm households were recruited to participate in this pilot project.

(2) Assess the feasibility of the monitoring strategy (i.e., continuous monitoring during waking hours for seven consecutive days, three times during a year). The focus of this specific aim was to evaluate the likelihood of all project participants completing the entire course of monitoring (a total of 21 days).

(3) Assess the compliance of participants with the monitoring strategy. The focus of this specific aim was to determine the likelihood of participants continuously wearing the noise dosimeter. During each monitoring cycle, a field investigator was on site and documented dosimeter use of the observed study participants.

(4) Assess the quality of self-reported activities. The focus of this specific aim was to determine the accuracy of the time-activity data reported by the project participants and to determine which of the three time-activity checklists provided the most accurate data. The field investigator also recorded time-activity data while observing the participants.

Research Design and Methods

Overview

Previous studies have measured hearing loss among farm residents or have determined the noise levels of farm equipment. However, very few studies have quantified noise exposures among farmers [Dennis and May, 1995; Wilkins, Engelhardt et al, 1998], and a search of the literature has revealed no published studies measuring noise exposures among farm residents.

The total noise exposure during a person's working lifetime must be known to arrive at a valid judgment of how noise will affect that person's hearing [Plog and

Quinlan, 2002]. The working lifetime of a farmer may begin early in life if children begin helping on the family farm. Additionally, farmers are likely to have more hours in their working lifetime not only due to an early age of starting work, but also due to farming often being a seven day a week operation that lasts more than eight hours per day. This early exposure to a noisy environment is critical since occupational hearing loss characteristically develops within the first few years of exposure and may continue to worsen over the next 8-10 years of continued exposure. Histologically, noise-induced hearing loss is never total and the damage does not continue to progress rapidly or substantially with exposure beyond 10 years [Sataloff and Sataloff, 1993].

Four factors are critical in the analysis of noise exposure [Plog and Quinlan, 2002]. These factors include the A-weighted sound level; the frequency composition, or spectrum, of the noise; the distribution and duration of the noise exposure during a typical workday; and the years of employment. Three of these four critical factors (excluding years of employment) were addressed in the completed pilot project.

Project Description

A pilot project was completed that determined the individual noise exposures, both occupational and non-occupational, of farm residents living and working on three cash grain farms in Northwest Ohio. Cash grain farms (principal products: corn, wheat, and oats for grain) were selected because they make more than 66% of the farms in the project area [1997 Census of Agriculture] and because of their variety of noise sources, such as tractors, grain dryers, chainsaws, other power tools, animals, etc. Two to four household residents on each of the three farms was enrolled in the study. Each participant was requested to wear a personal noise dosimeter from the time they arose in the morning until they went to bed at night. Project participants were also requested to complete daily time-activity checklists to document activities performed during each monitoring cycle. The participants in each household were monitored for seven consecutive days three times during the project period (once during planting season, once during growing season, and once during harvesting season). One household was monitored in each of the three years of the study. The field investigator (either the principal investigator or technician) was on site daily during each monitoring cycle when farm activities were occurring and documented activities and duration for any participant being observed.

Data Collection

Personal Dosimetry

The noise exposure measurements were collected with five Spark™ 705+ noise dosimeters (Larson Davis Inc., Provo, UT). The Spark™ 705+ can store minute-by-minute time-weighted average exposures using up to four multiple dose parameters. The dose parameters for this project were: 1) Occupational Safety and Health Administration (OSHA) compliance (80-130 dB range, 90 dBA criterion level, 5 dB exchange rate) and 2) American Conference of Governmental Industrial Hygienists (ACGIH) and National Institute for Occupational Safety and Health (NIOSH) recommended levels (80-130 dB range, 85 dBA criterion level, 3 dBA exchange rate).

Residents in the participating households determined when the monitoring was to occur each season. The season was determined by the tasks being performed on the farm (planting season, growing season, and harvesting season) and not by the dated on the calendar (spring, summer, or fall). On the day prior to the start of the monitoring event, a meeting was scheduled will all participating household residents. During the initial meeting, the project was described and written consent was obtained for each participant. For youth under 21 years of age, a parent signed a consent form to participate and the youth signed an assent form. The participants were then trained on the use of the Spark™ 705+ dosimeter. The participants were cautioned not to cover the microphone in any way and to place the microphone on the collar, under the ear, in the hearing zone. Each participant was assigned their own dosimeter for the entire monitoring event. The dosimeters were then left at the farm so that monitoring could begin the next morning. During this initial meeting, the head of the household was interviewed to collect basic information on the farm such as farm size (acreage), major crop, other crops, family size, number of family members working on the farm full-time, number of other employees, other employment of project participants, and hobbies of project participants. Prior to subsequent monitoring events (weeks 2 and 3), the participating household residents received refresher training on the use of the dosimeters and were again assigned a dosimeter for the entire monitoring event.

On the first day of monitoring, each participating household resident put on their individually assigned dosimeter after getting out of bed for the day. The dosimeters were pre-programmed to log 24 hours per day. Upon arrival each day, the field investigator checked the microphone location and made adjustments as necessary. Microphone placement was also spot checked throughout the day by the field investigator. The field investigator observed the participants performing farm work throughout the day.

The field investigator calibrated the dosimeters, changed the batteries, and downloaded the data every evening before leaving the farm for the day. The dosimeters were calibrated and the data was downloaded into a Spark™ 706RC dosimeter following the manufacturer's instructions. The data was then downloaded from the Spark™ 706RC into the principal investigator's laptop computer. The data were backed up by copying it onto a writable CD. At the conclusion of each week of monitoring, the principal investigator collected the dosimeters and returned them to the laboratory for inspection and any necessary maintenance.

Sound Levels and Frequency Distribution – Area Monitoring

The field investigator collected sound level measurements and frequency distributions for noise sources encountered on the farm by the household residents with a Quest™ Technologies (Oconomowoc, WI) type 2 integrating and logging sound level meter, model 2900, equipped with a Quest™ Technologies octave filter set, model OB-100 (Quest 2900/OB-100). The OB-100 filter created an octave band analyzer capable of measuring the frequency distribution from 31.5 Hertz to 16 kilohertz.

During each monitoring cycle the field investigator carried the Quest™ 2900/OB-100 around the farm. Whenever the project participants encountered a different noise source, a sound level measurement and frequency distribution were collected in the hearing zone of the participants. Sound level measurements were also collected under different operating conditions such as idle or under load. The sound levels were recorded onto field data sheets each monitoring day and entered into a spreadsheet on the same laptop computer with the personal noise exposure data. The sound level measurements were also be copied to a writable CD for back-up.

Time-Activity Documentation

In an attempt to determine which equipment and/or tasks contributed to elevated noise exposures, daily time-activity checklists were completed by project participants and by the field investigator for each monitoring cycle. The checklists were developed and validated previously for a study on adolescent farm injuries by Wilkins et al [Wilkins, Engelhardt et al, 1998]. The checklists were updated to include any additional tasks that could have been performed by the adult household residents and to account for off-farm activities. Each checklist contained information for one day. The checklist was pocket sized for easy portability, had a laminated cover for durability, and had a plastic binding for ease of use. To aid the household residents in documenting the correct times, each participant was given a watch during the initial training session. All watches for a household were set to the same time prior to issuance. The checklists did not contain any personal information about the participants and were distinguished only by the unique identifier for the person completing the checklist.

During the initial training session (or the refresher training session for later monitoring cycles) each participant was given one daily time-activity checklist for the following day. Each evening, the project participants received from the field investigator another daily time-activity checklist for the following day. The completed checklists from the previous day were collected by the field investigators on the day following completion by the participants. At the conclusion of each monitoring cycle, the principal investigator collected the final daily-time activity checklist along with the dosimeters on the day following the end of each monitoring cycle.

Three different time-activity checklists were used during the project to determine which format provided the most accurate data with the least amount of missing information. One checklist was used throughout each monitoring cycle. Therefore, each household used all three checklists, a different one during each week of monitoring.

The field investigator used the same time-activity checklists as the participants for Family 1, but for Family 2 and Family 3, the field investigator recorded farm activity in a notebook of field notes. The field investigator attempted to spend a minimum of 10 hours each day at the farm focusing attention on the participant with the highest noise exposure during farming tasks. For the three participating households, one person performed the majority of the work on the farm and therefore was observed almost exclusively.

Data Analysis

Data Management

The collected exposure data (personal dosimetry) was downloaded daily into the principal investigator's laptop computer, which had the Blaze™ software (Larson Davis Inc., Provo, UT) installed. Each participant was given a unique identifying code for each monitoring cycle. The exposure data for each participant was stored in the database developed with the Blaze™ software using this unique identifying code. Each participant had two exposure profiles for each day of the monitoring cycle – one for each of the pre-programmed dose parameters. The collected exposure data included the date and time based on the pre-programmed start time.

The Blaze™ software displays the collected data as minute-by-minute averages. Over the course of each monitoring cycle up to 10,080 (7 days x 24 hours/day x 60 minutes/hour) values of exposure data were collected for each participant and were stored in the database under the unique identifying code. Using the times provided by the participants for when they awoke in the morning and when they went to bed each day, when available, the non-waking hours were partitioned off from the waking hours using the Blaze™ software.

The sound level measurements and frequency distributions collected by the field investigator were entered daily into a spreadsheet on the principal investigator's laptop computer. The sound sources, operating conditions, and other pertinent information were manually entered into the spreadsheet by research technicians. The research technician also manually entered the information from the daily time-activity checklists into a spreadsheet stored on the principal investigator's laptop computer. The activity database used the same unique identifying code as was used in the personal dosimetry database.

Data Analysis

The Blaze™ software is capable of partitioning data. Initial partitioning involved separating the exposure profiles into occupational and non-occupational components based on the information provided in the time-activity checklists. For this project, occupational referred to exposures relating to work on the farm. Any exposures from jobs away from the farm were considered non-occupational. The initial partitioning and all subsequent analysis was conducted identically for both exposure profiles of each participants.

The occupational portion of each exposure profile was used to calculate daily eight-hour time-weighted averages (8HR TWAs) whenever farm work was performed. An 8HR TWA was calculated separately for each set of dose parameters (OSHA and NIOSH/ACGIH). The 8HR TWAs were then compared to either the OSHA compliance limits or the NIOSH/ACGIH recommended levels to determine if any of the 8HR TWAs exceeded the standards/guidelines.

Using the partitioning capabilities of the Blaze™ software, each exposure profile was separated into tasks based on the information provided in the time-activity checklists and from the field investigator. The partitioning was used to determine the proportion of the total exposure time spent on each task and which tasks had the largest contribution to the total exposure.

To assess the feasibility of the monitoring strategy, the field investigator was to question any participants who withdrew from the study for their reasons for withdrawal. No analysis could be performed for this specific aim as none of the participants officially withdrew from the study.

To assess the compliance of the participants with the monitoring strategy, the total number of minutes per day during waking hours that the participant wore the dosimeter was calculated when possible. Family 2 and Family 3 participants generally did not complete the daily activity logs and therefore the minutes per day the dosimeter was worn could not be calculated.

To assess the quality of the self-reported activity data, a percent agreement was calculated between the activities reported by the participants and the activities reported by the field investigators for the same time periods. This percent agreement could only be calculated for Family 1. Family 2 and Family 3 participants generally did not complete the daily activity logs.

Results

Participant Description

Three families participated in the study, one during each year. Family 1 consisted of two adults and four children. Three family members participated in the study. Subject 1 was the farm operator and worked on the farm full time. Subject 2 was a full-time teacher and assisted on the farm part time. Subject 3 was a high school student who assisted on the farm part time.

Family 2 consisted of two adults and four children. Four family members participated in the study. Subject 4 was the farm operator and worked on the farm full time. Subject 5 was a homemaker, home schooled the children, and assisted on the farm part time. Subjects 6 and 7 were home schooled and assisted on the farm part time.

Family 3 consisted of two adults. Both family members participated in the study. Subject 8 was the farm operator and full-time teacher who worked on the farm part time. Subject 9 was a part-time hospital worker who assisted on the farm part time.

Compliance with the Monitoring Strategy

Although all 9 participants wore the dosimeter during the study, most did not wear the dosimeter every monitoring day. For Family 1, the participants wore the dosimeter 17-21 of 22 monitoring days for 5.95 – 10.0 hours/day. For Family 2, the participants wore the dosimeter 1-20 of 21 monitoring days for 2.08 – 16.5 hours/day. For Family 3, the participants wore the dosimeter 14-21 of 21 monitoring days.

Quality of Self-Reported Activities

In order to determine the quality of self-reported activities, a comparison of participant codes and researcher codes was made for those times when codes were available from both sources. The percentage of codes that were the same for the researcher and the participant was calculated. For Family 1, the overall percent agreement ranged from 43% to 100%. Family 2 and Family 3 generally did not complete the daily activity logs, especially when field investigators were observing, and therefore a percent agreement could not be calculated.

Characterization of Noise Exposures During Farming

Comparison to OSHA Criteria

To evaluate the participants' exposure to noise for comparison to the OSHA criteria, all data were normalized to an 8HR TWA using a 5 dB exchange rate and a 90 dBA criterion level. After the data were normalized, the results were compared to the OSHA action level of 85 dBA and the OSHA permissible exposure limit (PEL) of 90 dBA, both as 8HR TWAs. None of the days of monitoring, for any of the subjects, exceeded the PEL.

The results of exposure monitoring during planting season are presented in Table 1 for all 9 subjects. For Family 1, Subject 1 worked on the farm 4 of 7 days and had one exposure exceed the OSHA action level. Subjects 2 and 3 did not work on the farm during planting season. For Family 2, Subject 4 worked on the farm 6 of 7 days and had no exposures exceed the OSHA action level. Subject 5 did not work on the farm during planting season. Subjects 6 and 7 each worked on the farm 3 of 7 days and had no exposures exceed the OSHA action level. For Family 3, Subject 8 worked on the farm during planting season. However, all data were lost due to technical difficulties.

The results of exposure monitoring during growing season are presented in Table 2 for all 9 subjects. For Family 1, Subject 1 worked on the farm 6 of 7 days, but had no exposures exceed the OSHA action level. Subject 2 did not work on the farm during growing season. Subject 3 worked 1 day on the farm and the exposure did not exceed the OSHA action level. For Family 2, Subject 4 worked on the farm all 7 days and had no exposures exceed the OSHA action level. Subject 5 did not work on the farm during growing season. Subject 6 worked on the farm 1 of 7 days and the exposure did not exceed the OSHA action level. Subject 7 did not work on the farm during growing season. For Family 3, Subject 8 worked on the farm 4 of 7 days and had 1 exposure exceed the OSHA action level. Subject 9 did not work on the farm during growing season.

The results of exposure monitoring during harvesting season are presented in Table 3. For Family 1, Subject 1 worked on the farm all 7 days and had 3 exposures exceed the OSHA action level. Subject 2 worked 1 day on the farm and Subject 3 worked 3 days on the farm. None of the exposures for Subjects 2 or 3 exceeded the OSHA action level. For Family 2, Subject 4 worked on the farm 4 of 7 days and had no exposures exceed the OSHA action level. Subjects 5, 6, and 7 did not work on the farm during harvesting season. For Family 3, Subject 8 worked on the farm for 7 of 9 days and no exposures exceed the OSHA action levels. Days 8 and 9 were added due to rain interrupting the harvesting. Subject 9 did not work on the farm during harvesting season.

Comparison to ACGIH/NIOSH Criteria

To evaluate participants’ exposure to noise for comparison to the NIOSH/ACGIH criteria, all data were normalized to an 8HR TWA using a 3 dB exchange rate and an 85 dBA criterion level. After the data were normalized, the results were compared to the ACGIH-TLV and the NIOSH-REL of 85 dBA as an 8HR TWA.

The results of exposure monitoring during planting season are presented in Table 1 for all 9 subjects. For Family 1, Subject 1 worked on the farm 4 of 7 days and had 2 exposures exceed the NIOSH/ACGIH guidelines. Subjects 2 and 3 did not work on the farm during planting season. For Family 2, Subject 4 worked on the farm 6 of 7 days and had 1 exposure exceed the NIOSH/ACGIH guidelines. Subject 5 did not work on the farm during planting season. Subjects 6 and 7 each worked on the farm 3 of 7 days and had no exposures exceed the NIOSH/ACGIH guidelines. For Family 3, Subject

8 worked on the farm during planting season. However, all data were lost due to technical difficulties.

The results of exposure monitoring during growing season are presented in Table 2 for all 9 subjects. For Family 1, Subject 1 worked on the farm 6 of 7 days, but had no exposures exceed the NIOSH/ACGIH guidelines. Subject 2 did not work on the farm during growing season. Subject 3 worked 1 day on the farm and the exposure did not exceed the NIOSH/ACGIH guidelines. For Family 2, Subject 4 worked on the farm all 7 days and had no exposures exceed the NIOSH/ACGIH guidelines. Subject 5 did not work on the farm during growing season. Subject 6 worked on the farm 1 of 7 days and the exposure did not exceed the NIOSH/ACGIH guidelines. Subject 7 did not work on the farm during growing season. For Family 3, Subject 8 worked on the farm 4 of 7 days and had 1 exposure exceed the NIOSH/ACGIH guidelines. Subject 9 did not work on the farm during the growing season.

The results of exposure monitoring during harvesting season are presented in Table 3. For Family 1, Subject 1 worked on the farm all 7 days and had 4 exposures exceed the NIOSH/ACGIH guidelines. Subject 2 worked 1 day on the farm and Subject 3 worked 3 days on the farm. None of the exposures for Subject 2 exceeded the NIOSH/ACGIH guidelines, but 1 exposure for Subject 3 exceeded the NIOSH/ACGIH guidelines. For Family 2, Subject 4 worked on the farm 4 of 7 days and had no exposures exceed the NIOSH/ACGIH guidelines. Subjects 5, 6, and 7 did not work on the farm during harvesting season. For Family 3, Subject 8 worked on the farm 7 of 9 days and had 1 exposure exceed the NIOSH/ACGIH guidelines. Subject 9 did not work on the farm during harvesting season.

Characterization of Non-Occupational Noise Exposures

Table 4 displays the results of exposure monitoring during non-occupational activities, other than school, and Table 5 displays the results of exposure monitoring during school activities. Since these exposures are non-occupational for this study, the best measure is the equivalent continuous noise level (L_{eq}). For other than school exposures, the L_{eq} was 62.6-104.0 dBA. For the school exposures, the L_{eq} was 70.0-82.3 dBA.

Characterization of Noise Exposure by Farming Task

Tables 6 and 7 display 8HR TWA exposures by task, based on coding by the field investigator and by the participant, respectively, for Family 1. Since Family 2 and Family 3 did not complete the daily activity logs, exposures by task could not be calculated. For field investigator coding, tasks that exceeded the OSHA action level included tilling/plowing and tasks that exceeded the NIOSH/ACGIH guidelines included other farm activities, planting, and tilling/plowing. For participant coding, tasks that exceeded the OSHA action level included harvesting and tilling/plowing and tasks that exceeded the NIOSH/ACGIH guidelines included other vehicle operation, harvesting, and tilling/plowing.

Characterization of Noise Exposure by Farm Equipment

Table 8 displays the 8HR TWA exposures by equipment used based on field investigator coding for Family 1. Since Family 2 and Family 3 did not complete the daily activity logs, exposures by equipment used could not be calculated. Equipment used that exceeded the OSHA action level included tractor with disc and equipment used that exceeded the NIOSH/ACGIH guidelines included tractor with disc.

Discussion

Overview

In general, the findings of this project confirm that noise exposure levels did not exceed the OSHA-PEL for any of the participants on any given day during any given task. However, during certain farming activities and days of monitoring, the ACGIH-TLV and the NIOSH-REL were exceeded.

Summary of Results

The fact that none of the participants officially withdrew from the program indicates that the monitoring methodology is feasible. Even though participation was not 100% for any of the subjects, extending the monitoring period over 3 weeks allowed for a large volume of data to be collected. The length of monitoring also eliminated the potential for a complete loss of data due to weather conditions.

Due to the intrusive nature of the constant observation, monitoring periods were fewer than originally planned. Although the observation periods were reduced to primarily farm activities, sufficient data were collected to meet the goals of the study. Coding of non-farming tasks required less detail than farming tasks, therefore it is likely that the reported activities of the subjects during school and non-farm work accurately reflected those activities.

The analysis of time activity data suggests that farmer surveys and time activity logs may not be indicative of the true exposure times or activities. Indeed, data logged by the farmer yielded different 8HR TWAs for activities and identified different activities as producing higher exposure levels. While the differences between field investigator and participant codes were not so great as to result in OSHA-PEL exceedances, the OSHA hearing protection program action level of 85 dBA 8HR TWA, the ACGIH-TLV, and the NIOSH-REL exceedances were different.

Anecdotal information obtained during the study revealed that completion of the log book was often done at the end of the day or during break periods. This would explain the variation between the participant and the field investigator start and stop times. It is also probable that short term activities, especially those less than 15 minutes in duration, would be excluded from the farmers' reports. The observer, unobstructed by other work requirements, could maintain a more complete diary of activities.

While no one log book was preferred by all of the participants, the inconvenience of constantly logging activities was noted, especially since participants from Family 2 and Family 3 did not complete the daily activity logs. A more convenient means of recording activities may improve field investigator and participant agreement. Likewise, elimination of recording by participants who are being observed may make the monitoring methodology more appealing to the participants.

It is notable that only one participant (Subject 8) wore hearing protection during this study. This information is similar to other findings from studies that have evaluated hearing protection use (Carpenter et al., 2002; Karlovich et al., 1998; Nieuwenhuijsen et al., 1996).

Even though noise exposure levels of the participants did not exceed the 90 dBA 8HR TWA OSHA PEL, farming activities frequently exceeded the ACGIH-TLV and the NIOSH-REL. It is notable that these exceedances occurred during some relatively short exposure durations. The exposure durations of activities with ACGIH-TLV and NIOSH-REL exceedances ranged from 2.18 to 12.77 hours. Only 3 of 10 events over 85 dBA 8HR TWA occurred on workdays lasting greater than 8 hours. All 3 events occurred during the planting season.

In contrast with Weston's (1963) findings, machinery operation never exceeded 8 hours during any work day. However, there were notable differences among the seasons. For Family 1, planting and harvesting overlapped as monitoring occurred during winter wheat planting and harvesting of corn. During growing season, when no tractor operation was conducted, none of the daily 8HR TWAs exceeded the ACGIH-TLV and NIOSH-REL, nor did any of the task specific 8HR TWAs. For Family 2 and Family 3, a similar comparison could not be conducted due to the limited data available from the daily activity logs.

Similar to McBride et al.'s (2003) findings, the farm operator typically performed more than one task per day and often performed three or more tasks per day. For Family 1, only one task, tilling/plowing, exceeded the ACGIH-TLV and NIOSH-RLE more than half of the time (60%) as coded by the field investigator. Only two other tasks, other farm work (20% of events) and planting (33% of events) exceeded the ACGIH-TLV and NIOSH-REL. The calculated 8HR TWAs demonstrate the lack of agreement between the field investigator and participant coding, since participant coding resulted in two tilling/plowing events and one harvesting event exceeding the ACGIH-TLV and the NIOSH-REL. None of the activities or equipment monitored generated maximum levels in excess of 115 dBA. For Family 2 and Family 3, a similar comparison could not be conducted due to the limited data available from the daily activity logs.

Limitations

This project was limited by the small sample size. However, as a pilot project, the ability and efficiency of data collection were as important as the data collected.

One of the difficulties of the project was the balancing the observation times and need for collection of data with the privacy needs of the participants. A balance was struck by limiting most monitoring to actual farm work events and locating the observer in a general work area, out of the way of the worker. Sound level measurements were collected only during times that were convenient for the farm worker. For Family 1, although the monitoring was expected to span over much of one year, all data were collected in a relatively short period (3 months). The planting and harvesting observation were consecutive, which may have affected the level of participation. Anecdotal reports suggested that initial use of the dosimeter was not problematic, however, as the monitoring period extended to the second week, it become more inconvenient. For Family 2, the monitoring spanned the period from May through October with planting followed by growing followed by harvesting. The farm operator fully participated in the study, but other family members lost interest and only participated sporadically as time progressed. For Family 3, the monitoring spanned the period of June through October with harvesting followed by growing followed by planting. Family 3 did no farm full time and therefore observation was limited due to their off farm activities.

Recruitment of study participants was exceedingly difficult and resulted in the study being extended to a third year to complete data collection. This inability to recruit study participants limits the generalizability of the study findings since these results may not be representative of similar farms in Northwest Ohio. Future studies will require a person dedicated to recruiting farm households for participation.

Recommendations for Future Studies

Although the monitoring strategy did produce results, better results may be gained through alteration of the activity logging protocol. These findings do support the findings of previous studies, in that farm workers, including children, are exposed to noise levels in excess of the ACGIH-TLV and NIOSH-REL. Therefore, it is recommended that future studies include children working and residing on farms. Future studies would benefit from improved activity logging, improved or altered recruiting methods, and a larger study group.

Conclusions

Noise exposure on farms does contribute to the total noise exposure of residents. Although the family members residing on the farm for Family 1 performed limited farm work, the adolescent included in the study was exposed to noise levels in excess of the ACGIH-TLV and NIOSH-REL. The farm operator also performed tasks and had daily 8HR TWAs in excess of the ACGIH-TLV and NIOSH-REL. For Family 2 and Family 3, only the farm operator had exposures that exceeded any standards or guidelines. However, all household members were exposed to noise from farm operations. These findings confirm that if farmers were regulated as other occupations, farm workers would have to be included in a hearing protection program. Considering the reportedly limited use of hearing protection devices, farm worker exposure should be conducted on a larger scale to better evaluate noise exposure.

Publications

Milz SA, Witherspoon MK, Ames AL, Wilkins JR. Noise exposure assessment of three adolescents living on farms in Northwest Ohio. *Seminars in Hearing* (in press)

Presentations

Milz SA, Witherspon MK, Ames AL, Wilkins JR. “Total Noise Exposure Assessment of Three Farm Families in Northwest Ohio.” American Industrial Hygiene Conference & Exposition, Philadelphia, PA, June 2007.

Milz SA, Wilkins JR, Witherspoon MK, Ames AL. “Noise Exposure Assessment of Three Adolescents Living on Farms in Northwest Ohio.” Noise-induced Hearing Loss in Children at Work & Play, Cincinnati, OH, October 2006.

Witherspoon MK, Milz SA. “Total Noise Exposure Assessment of a Farm Family.” American Industrial Hygiene Conference & Exposition, Chicago, IL, May 2006.

Witherspoon MK, Milz SA. Poster Session. “Total Noise Exposure Assessment of a Farm Family.” American Industrial Hygiene Conference & Exposition, Anaheim, CA, May 2005.

Citations

Baker DE: [1993] Noise the Invisible Hazard. University Extension, University of Missouri-Columbia. Columbia, MO. http://www.cdc.gov/niosh/nasd/docs2/as24800.html

Beckett WS, Chamberlain D, Hallman E, May J, Hwang SA, Gomez M, Eberly S, Cox C, Stark A: [2000] Hearing Conservation for Farmers: Source Apportionment of Occupational and Environmental Factors Contributing to Hearing Loss. Journal of Occupational and Environmental Medicine 42(8):806-813.

Berger EH, Royster LH, Royster JD, Driscoll DP, Layne M (Editors): [2000] The Noise Manual, Fifth Edition. Fairfax, VA: AIHA Press.

Broste SK, Hansen DA, Strand RL, Stueland DT: [1989] Hearing Loss among High School Farm Students. American Journal of Public Health 79(5):619-622.

Carpenter WS, Lee BC, Gunderson PH, Stueland DT: [2002] Assessment of Personal Protective Equipment Use among Midwestern Farmers. American Journal of Industrial Medicine 42(3):236-247.

Dennis JS, May JJ: [1995] Occupational Noise Exposure in Dairy Farming. In: Agricultural Health and Safety Workplace, Environment, Sustainability (eds. HH McDuffie, JA Dosman, KM Semchuk, SA Olenchok, A Senthilselvan), Lewis Publishers, pp 363-367.

Gregg JB: [1972] Noise injuries to Farmers. Agricultural Engineering March:12-15.

Holt JJ, Broste SK, Hansen DA: [1993] Noise Exposure in the Rural Setting. Laryngoscope 103(3):258-262.

Jones HH, Oser JL: [1968] Farm Equipment Noise Exposure Levels. American Industrial Hygiene Association Journal 29:146-151.

Karlovich RS, Wiley TL, Tweed T, Jensen DV: [1988] Hearing Sensitivity in Farmers. Public Health Reports 103(1):61-71.

Lierle DM, Reger SN: [1958] The Effect of Tractor Noise on the Auditory Sensitivity of Tractor Operators. Annals of Otology, Rhinology, & Laryngology 67:372-388.

Marvel ME, Pratt DS, Marvel LH, Regan M, May JJ: [1991] Occupational Hearing Loss in New York Dairy Farmers. American Journal of Industrial Medicine 20(4):517-531.

Matthews J: [1968] Measurements of environmental noise in agriculture. Journal of Agricultural Engineering Research 13(2):157-167.

May JJ, Marvel M, Regan M, Marvel LH, Pratt DS: [1990] Noise-Induced Hearing Loss in Randomly Selected New York Dairy Farmers. American Journal of Industrial Medicine 18(3):333-337.

McBride DI, Firth HM, Herbison GP: [2003] Noise Exposure and Hearing Loss in Agriculture: A Survey of Farmers and Farm Workers in the Southland Region of New Zealand. Journal of Occupational and Environmental Medicine 45(12):1281-1288.

McCunney RJ, Meyer JD: [1998] Occupational Exposure to Noise. In Environmental and Occupational Medicine (eds. WM Rom), Little, Brown, and Company, pp. 1345-1357.

McCunney RJ, Meyer JD: [1992] Occupational Exposure to Noise. In Environmental and Occupational Medicine (eds. WM Rom), Little, Brown, and Company, pp. 1121-1132.

McDonald C (Editor): [2000] Epidemiology of Work Related Diseases, Second Edition. London: BMJ Books.

McMahon KB, Urbain CD: [1988] Farming in Silence. Farm Journal November:13-15.

Merchant JA: [1992] Research for Agricultural Safety and Health. Proc of the Surgeon General's Conference on Agricultural Safety and Health.

Nieuwenhuijsen MS, Schenker MB, Samuels SJ, Farrar JA, Green SS: [1996] Exposure to Dust, Noise, and Pesticides, Their Determinants and the Use of Protective Equipment among California Farm Operators. Applied Occupational and Environmental Hygiene 11(10):1217-1225.

NIH Consensus Conference – Noise and Hearing Loss [1990]. JAMA 263(23):3185-3190.

NIOSH: [1988] A Proposed National Strategy for the Prevention of Noise-Induced Hearing Loss. In Proposed National Strategies for the Prevention of Leading Work-Related Diseases, Part 2. Association of Schools of Public Health, pages 51-63.

NIOSH: [1996] National Occupational Research Agenda. National Institute for Occupational Safety and Health, DHHS (NIOSH) Pub No. 96-115, Cincinnati, OH.

Plakke BL: [1990] Noise in Agriculture and its Effect on Hearing. Hearing Instruments 41(10):22-24.

Plog BA, Quinlan PJ (Editors): [2002] Fundamental of Industrial Hygiene, 5th Edition. New York: National Safety Council.

Sataloff RT, Sataloff J: [1993] Occupational Hearing Loss, Second Edition. New York: Marcel Dekker, Inc.

Simpson EW, Deshayes EL: [1969] Tractors Produce Ear Damaging Noise. Journal of Environmental Health 31(4):347-350.

Solecki L: [1998] Occupational Hearing Loss among Selected Farm Tractor Operators Employed on Large Multiproduction Farms in Poland. Internal Journal of Occupational Medicine and Environmental Health 11(1):69-80.

Themann CL, Henderson D: [1992] Noise and Hearing Loss in the Agricultural Setting. Proc of the Surgeon General's Conference on Agricultural Safety and Health.

US Department of Commerce. Economics and Statistics Administration, Bureau of Census: [1993] 1990 CP-2-1 1990 Census of Population, Social and Economic Characteristics, United States. Washington, DC: Government Printing Office.

US Department of Health and Human Services: [2000] Healthy People 2010 (Conference Edition – Volume II). Washington, DC.

Varchol K, Wilkins III JR, Mitchell GL, Engelhardt H, Bean TA: [1998] Farm Residence Increases Risk of Hearing Loss among Youth (abstract). American Journal of Epidemiology 147:S16.

Weston HR: [1963] A Survey of Tractor Noise and the Effects on Hearing. The Journal of the Australian Institute of Agricultural Science 29(1): 15-22.

Wilkins III JR, Engelhardt HL, Crawford JM, Mitchell GL, Eicher LC, Bean TA, Jones LA: Self-Reported Noise Exposures among Ohio Cash Grain Farmers. Journal of Agricultural Safety and Health Special Edition (1):79-88.

Wilkins III JR, Mitchell GL, Alatsis E, Engelhardt H, Bean TA: [1998] Hearing Loss Among Cash Grain Farmers in Ohio (abstract). American Journal of Epidemiology 147:S85.

1997 Census of Agriculture, http://www.usdalgov/nass/census

Inclusion of Gender and Minority Study Subjects

Inclusion of Children

Children were included in this pilot project. The aim of the project was to evaluate noise exposures of household residents living and working on farms in Northwest Ohio. Farm residents include children. Three adolescents were participants in the study. The study design allowed children as young as six to participate as long as they could read, write, and tell time. However, none of the households volunteered the younger children to participate. In addition to the three adolescents who participated in the study, five other children also lived in the participating households. The participating adolescents performed their normal activities during the study.

Materials Available for Other Investigators

The data collected in this study has been or will be presented at national conferences. Additionally, a publication in a peer-reviewed journal will be forthcoming. These published and presented results will then be available for any researcher to access.

Table 1 – Planting Season Farming Activity Noise Exposure Per Participant*

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
1	1	5.98	80.5	29.5	81.2	95.2	84.8
1	2	10.48	81.0	40.0	83.4	*125.5*	*86.0*
1	6	4.73	79.8	29.6	81.2	85.7	84.3
1	7	9.93	84.9	*90.5*	*89.3*	*298.6*	*89.8*
4	1	11.37	82.4	22.2	79.1	74.9	83.7
4	2	12.77	83.7	48.7	84.8	*113.6*	*85.6*
4	3	6.78	83.2	22.2	79.1	53.1	82.3
4	3	5.97	81.6	8.8	72.4	31.7	80.0
4	4	2.82	71.4	0.3	49.2	0.7	63.7
4	5	6.37	85.3	15.1	76.4	81.5	84.1
4	5	2.73	81.3	3.2	65.2	13.2	76.2
4	6	12.45	79.0	8.4	72.1	33.5	80.2
6	1	1.25	81.5	2.3	62.6	6.4	73.1
6	2	0.63	88.8	0.8	73.4	19.0	77.8
6	7	0.65	70.6	0	50.9	0.1	54.7
7	1	1.15	81.4	2.0	61.9	5.8	72.7
7	2	3.52	85.0	15.4	76.5	42.9	81.3
7	4	0.20	66.9	0	15.4	0	42.4

*The data for Subject 8 during the planting season was unavailable for analysis.

Table 2 – Growing Season Farming Activity Noise Exposure Per Participant

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
1	1	4.00	69.1	2.7	64.0	6.9	73.4
1	2	3.22	70.1	16.3	66.6	7.9	74.0
1	3	4.98	73.3	4.5	65.1	12.7	76.0
1	4	2.48	76.6	4.7	59.5	3.0	69.8
1	5	3.47	69.4	3.4	65.6	8.7	74.4
1	6	4.48	71.6	5.0	68.4	12.8	76.1
3	6	1.00	72.8	4.2	67.1	18.1	77.6
4	1	13.58	80.1	20.1	78.4	91.8	81.2
4	2	0.23	78.4	0.2	46.1	0.6	62.6
4	3	12.33	73.0	2.4	63.2	5.4	72.3
4	4	9.77	82.9	17.6	77.5	70.8	83.5
4	4	2.45	84.3	4.1	66.9	4.1	66.9
4	5	10.00	81.7	11.1	74.1	54.2	82.3
4	5	3.62	86.5	11.0	74.1	62.6	83.0
4	6	6.55	83.1	8.3	72.0	49.6	82.0
4	7	11.50	77.7	5.6	69.3	14.3	76.6
6	3	4.23	72.1	0.4	50.9	0.9	64.5
8	2	10.10	84.2	20.4	78.5	98.7	84.9
8	4	2.00	86.8	8.9	72.5	37.3	80.7
8	5	4.92	94.2	*95.2*	*89.6*	*510.9*	*92.1*
8	6	1.00	80.3	1.3	58.9	3.6	70.5

Table 3 – Harvesting Season Farming Activity Noise Exposure Per Participant

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
1	1	5.72	86.8	*51.1*	*85.2*	*156.4*	*86.9*
1	2	5.38	86.6	*61.5*	*85.7*	*359.7*	*90.6*
1	3	1.48	67.5	1.4	59.3	4.1	71.5
1	4	5.47	87.0	*85.4*	*88.9*	*461.4*	*91.6*
1	5	4.47	79.0	21.3	78.8	74.4	83.7
1	6	4.33	81.2	22.0	79.1	*123.8*	*85.9*
1	7	5.97	68.5	0.8	55.3	1.7	67.3
2	2	2.27	76.9	7.0	70.8	44.8	81.5
3	4	2.32	79.1	24.6	79.9	74.0	83.7
3	5	2.18	80.7	29.7	81.2	*111.1*	*85.5*
3	6	2.75	79.2	24.7	79.9	81.9	84.1
4	1	7.40	83.6	27.7	80.7	64.7	83.1
4	2	1.90	77.2	1.3	58.6	3.3	70.1
4	3	3.23	80.2	4.1	67.0	10.7	75.3
4	5	2.40	75.7	1.1	57.2	2.6	69.2
8	1	0.33	82.9	1.1	57.2	2.5	68.9
8	4	1.90	85.9	7.5	71.3	28.1	79.5
8	5	1.75	90.2	19.5	78.2	71.7	83.6
8	6	1.50	83.0	2.5	63.3	11.2	75.5
8	7	10.47	83.7	28.0	80.8	90.9	84.6
8	8	7.23	88.9	73.3	87.8	*222.7*	*88.5*
8	9	0.87	88.3	8.3	72.1	22.9	78.6

Table 4 – Non-Occupational Noise Exposures per Participant, Other Than School

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
2	P1	6.98	79.0	16.2	76.9	61.6	82.9
2	P2	5.48	73.5	6.1	69.8	17.5	77.4
2	P7	6.97	72.7	4.7	68.0	14.5	76.6
2	G2	6.98	74.7	7.8	71.6	22.6	78.5
2	G3	6.98	62.6	0	22.8	0	46.9
2	G4	6.98	70.8	2.9	64.6	7.0	73.5
2	H2	7.98	75.6	10.2	73.5	29.5	79.7
2	H3	7.23	71.1	3.2	65.2	7.9	74.0
2	H6	8.98	75.7	10.6	73.8	30.8	79.9
2	H7	6.98	79.0	16.2	76.9	80.8	84.1
6	P1	6.23	84.4	7.6	71.4	65.8	84.3
6	P2	12.68	76.3	4.2	67.1	15.2	76.8
6	P3	2.90	76.7	1.5	59.6	4.0	71.1
6	P5	2.08	81.4	3.5	65.8	10.3	75.1
6	P6	2.80	72.5	0.4	50.4	1.1	65.6
6	P7	4.72	72.7	0.8	55.1	1.9	67.8
6	G2	3.38	68.6	0	30.4	0.1	52.1
6	G3	4.70	72.0	0.5	51.7	1.4	66.6
6	G3	9.10	70.6	0.5	52.0	1.5	66.7
7	P1	2.45	88.4	10.8	73.9	66.0	83.2
7	P2	7.15	78.9	5.5	69.1	17.2	77.4
7	P3	6.45	74.3	1.9	61.3	4.6	71.7
7	P4	7.78	75.1	3.2	65.2	8.1	74.1
7	P5	5.65	76.1	2.0	61.6	8.2	74.1
8	G5	4.00	104.0	*154.9*	*93.2*	*4008.7*	*101.0*
8	G5	6.97	101.6	*157.8*	*93.3*	*4015.1*	*101.0*
8	G6	4.50	88.3	15.8	76.7	*119.2*	*85.8*
8	G6	9.87	90.7	77.4	88.2	*450.9*	*91.5*

P – planting season; G – growing season; H – harvesting season

Table 4 – Non-Occupational Noise Exposures per Participant, Other Than School

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
9	G2	9.25	72.4	1.7	60.4	3.8	70.8
9	G3	8.75	77.0	5.5	69.1	13.9	76.4
9	G4	9.00	73.0	2.1	62.0	4.4	71.4
9	G5	3.32	75.8	1.4	59.3	4.3	71.3
9	G6	13.75	82.1	74.8	87.9	*388.5*	*90.9*
9	G7	11.53	77.8	8.6	72.3	22.0	78.4

P – planting season; G – growing season; H – harvesting season

Table 5– School Noise Exposures per Participant

Subject	Day	Exposure Duration (hours)	Leq (dBA)	$Dose_{OSHA}$ (%)	8HR TWA_{OSHA} (dBA)	$Dose_{ACGIH}$ (%)	8HR TWA_{ACGIH} (dBA)
3	P1	7.92	74.3	5.7	69.3	19.9	78.0
3	P2	6.00	73.5	4.3	67.3	20.0	78.0
3	P7	8.00	75.7	8.6	72.3	32.1	80.1
3	G1	8.00	74.7	7.5	71.3	21.6	78.3
3	G2	7.83	73.8	5.8	69.5	17.8	77.5
3	G3	7.67	74.2	6.5	70.2	19.8	78.0
3	G4	8.17	74.6	7.5	71.3	22.8	78.6
3	G5	7.75	74.2	7.2	71.1	22.8	78.6
3	H2	7.48	76.7	6.2	69.9	35.2	80.5
3	H3	7.48	76.6	7.4	71.3	42.7	81.3
3	H7	7.75	74.2	6.2	69.9	19.9	78.0
3	H8	7.50	70.8	2.6	63.8	7.5	73.8
6	P1	4.97	70.0	0.2	46.0	0.5	61.9
7	P1	4.75	70.6	0.3	47.1	1.7	67.3
7	P2	3.02	82.3	3.7	66.3	18.8	77.7
7	P5	5.57	81.6	4.6	67.8	30.7	79.9

P – planting season; G – growing season; H – harvesting season

Table 6 – 8HR TWAs by Task Based on Field Investigator Coding – Family 1

Subject	Number of Events	Exposure Duration All Events (hours)	Task	8HR TWA_{OSHA} (dBA)	8HR TWA_{ACGIH} (dBA)	L_{max} (dBA)
1	5	4.87	Other farm	61.5-82.9	72.3-88.9	100.6-111.2
1	5	2.34	Machinery operation – other vehicle	52.5-58.5	65.9-70.1	97.9-100.6
1	4	1.60	Machinery operation – tractor on road	57.0-70.6	68.5-80.8	88.6-108.7
1	3	7.57	Machinery operation – harvesting	72.0-80.4	77.9-83.8	104.2-105.2
1	3	2.82	Machinery operation – planting	63.4-78.1	73.8-85.1	97.7-108.2
1	5	14.80	Machinery operation – till/plow	71.2-88.9	77.7-91.7	101.2-113.4
1	1	2.13	Repair/maintenance of other equipment	70.7	78.5	107.6
1	1	0.27	Dumping water	55.4	68.0	101.0

8HR TWA_{OSHA} – normalized 8HR TWA using 5 dB exchange rate and 90 dBA criterion level
8HR TWA_{ACGIH} – normalized 8HR TWA using 3 dB exchange rate and 85 dBA criterion level

Table 7 – 8HR TWAs by Task Based on Participant Coding – Family 1

Subject	Number of Events	Exposure Duration All Events (hours)	Task	8HR TWA_{OSHA} (dBA)	8HR TWA_{ACGIH} (dBA)	L_{max} (dBA)
1	3	11.21	Other farm	65.6-73.8	74.4-79.8	97.5-103.1
1	1	0.98	Machinery operation – power tools	70.1	78.0	104.0
1	9	24.77	Machinery operation – other vehicle	54.0-81.1	65.8-84.7	51.8-111.5
1	2	0.71	Machinery operation – tractor on road	65.8-68.4	75.8-78.3	98.7-104.7
1	2	10.48	Machinery operation – harvesting	80.6-86.2	83.7-85.1	104.7-107.6
1	2	2.75	Machinery operation – planting	73.1-74.8	80.0-80.7	99.7-105.4
1	4	13.73	Machinery operation – till/plow	70.4-87.8	77.4-91.3	101.9-113.4
1	1	0.48	Handling – small grain/pellets	53.8	65.6	91.6
1	1	0.48	Handling – bags/sacks	55.3	67.9	94.8
1	5	11.93	Repair/maintenance of other equipment	49.8-64.0	63.9-73.4	99.4-103.8
1	1	0.48	Animal work – load/unload	42.8	61.7	100.6

8HR TWA_{OSHA} – normalized 8HR TWA using 5 dB exchange rate and 90 dBA criterion level
8HR TWA_{ACGIH} – normalized 8HR TWA using 3 dB exchange rate and 85 dBA criterion level

Table 8 – 8HR TWAs by Farm Equipment Based on Field Investigator Coding – Family 1

Subject	Number of Events	Exposure Duration All Events (hours)	Equipment	8HR TWA_{OSHA} (dBA)	8HR TWA_{ACGIH} (dBA)	L_{max} (dBA)
1	3	1.57	Semi-truck	44.5-53.2	61.2-66.2	67.8-91.2
1	1	1.00	White tractor with mulcher and disc	75.6	82.3	106.3
1	1	4.07	White tractor with disc	86.2	88.4	102.5
1	2	2.53	White tractor with chisel plow	54.7-83.7	67.7-88.9	100.6-111.2
1	1	0.65	Massey Ferguson tractor with disc	75.9	85.0	113.4
1	1	0.07	Massey Ferguson tractor	49.5	64.6	94.5
1	2	6.40	Combine	80.4-80.7	83.7-83.8	104.2-104.7
1	2	0.12	Pick-up truck with wagon	18.0-46.0	43.7-61.9	84.4-95.8
1	1	0.22	Pick-up truck	65.7	77.3	97.9
1	1	1.42	Mulcher and disc (tractor not identified)	71.5	77.8	103.4
1	1	0.48	Water tank (tractor of vehicle not identified)	69.5	80.5	108.7
1	1	4.98	Semi-truck on road	81.0	84.7	107.9
1	1	2.48	White tractor	78.6	82.1	99.5
1	1	0.07	Wagon (tractor not identified)	56.4	70.2	95.4

8HR TWA_{OSHA} – normalized 8HR TWA using 5 dB exchange rate and 90 dBA criterion level
8HR TWA_{ACGIH} – normalized 8HR TWA using 3 dB exchange rate and 85 dBA criterion level