Evaluation of a Point Source Intervention for Preventing Hearing Loss on Farmers' Attitudes and Beliefs:A Randomized Controlled Trial

Research

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HIGHLIGHTS

- About 30% of farmers had moderate or worse hearing in at least one ear for frequencies between 2000 and 6000 Hertz.
- Improvements in perceptions were observed by increased HBM concept scores for barriers related to comfort and communication, self-efficacy, and hearing protection benefits.
- Older farmers had higher HBM concept scores for barriers related to communication and the benefits of hearing protection compared to younger farmers.
- The point source intervention contributed to the effect of education in improving farmers' HBM concept scores for comfort and self-efficacy.

ABSTRACT.

Objectives: Hearing protection devices (HPDs) can effectively prevent hearing loss. However, they are not widely used by farmers. This study assessed factors influencing farmers' perceptions about hearing protection and evaluated if a point source hearing protection intervention changed these perceptions over time.

Methods: Intervention farmers (n=53) received education and the point source intervention (storing HPDs near major noise sources). Control farmers (n=36) received education only. Annually, for nearly four years, farmers from both groups were asked to complete a questionnaire about their perceptions of hearing protection.

Results: During the multi-year study, both intervention and control farmers' perceptions about hearing protection improved. Perceptions about barriers related to comfort were better for intervention farms (p=0.007) and for farmers that participated in the study longer (p<0.001). Perceptions about self-efficacy were also better for intervention farms (p=0.001) and for farmers that participated in the study longer (p<0.001). Age was associated with better perceptions about the benefits of hearing protection (p=0.011).

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Perceptions about communication barriers improved for all farmers as the study advanced (p=0.002) and for farmers that were older (p=0.006).

Conclusion: Intervention and control groups improved their perceptions of hearing protection over time. The point source intervention contributed to the effect of education on farmers' perceptions of comfort and self-efficacy but not to perceptions related to communication barriers or the benefits of hearing protection.

Keywords. *Agriculture, Farmer, Hearing; Noise, Personal protective equipment.*

Hazardous noise, defined as noise greater than 85 decibels (dB), is a common occupational hazard that can lead to noise-induced hearing loss (NIHL) (Masterson et al., 2016). Industries particularly affected by hazardous noise include mining, construction, and manufacturing (Masterson et al., 2016). Workers in agriculture are also affected by hearing loss (Tak and Calvert, 2008). Recent estimates indicated that about 11% of U.S. hired agricultural workers have hearing loss in at least one ear (Masterson et al., 2016). This estimate may not represent the true prevalence among all workers in agriculture, as other estimates have ranged widely from less than 20% to nearly 80% (Thelin et al., 1983; Broste et al., 1989; Carruth et al., 2007; Depczynski et al., 2011; McCullagh and Ronis, 2015; Masterson et al., 2016). The prevalence of hearing loss is higher in self-employed farmers compared to workers in most other occupations (Thelin et al., 1983); according to one study, this is the second highest prevalence of hearing loss in the entire American workforce (Tak and Calvert, 2008).

Farmers are exposed to hazardous noise from tractors (82-92 dBA) (Dewangan et al., 2005; Aybek et al., 2010), combines (90+ dBA) (Aybek et al., 2010), all-terrain vehicles (ATV) (83-85 dBA) (Axiom-Points, 2010), livestock (85-115 dBA), and other sources (Achutan and Tubbs, 2007). In addition to work-related exposures, farmers may have recreational exposures from firearms and other equipment (Broste et al., 1989; Carruth et al., 2007; Khan et al., 2018). Many farmers are aware of their exposure to hazardous noise (Broste et al., 1989; Stewart et al., 2003; Williams et al., 2004; Carruth et al., 2007; Depczynski et al., 2011). Yet, few take precautions to protect themselves (Carruth et al., 2007; Williams et al., 2004; Donham et al., 2013; McCullagh et al., 2016; Carpenter et al., 2002; Kearney et al., 2015). The Occupational Safety and Health Act (OSH Act), which includes audiometric testing and hearing conservation provisions, is not enforced on small family farming operations (Roka et al., 2009; Donham et al., 2013; Sherman and Chertok, 2014; McCullagh et al., 2016).

Several studies have applied the health belief model (HBM) to investigate psychological factors influencing the decision to wear hearing protection (Lusk et al., 1997; McCullagh et al., 2002, 2010; Gates and Jones, 2007; Hong et al., 2013).The HBM uses behavioral concepts (individual's perceptions of severity, susceptibility, barriers, benefits, self-efficacy, and cues to action) and individual characteristics to predict the likelihood that a person will engage in a particular activity (Lusk et al., 1997; Cottrell and McKenzie, 2011). Perceptions about barriers with communication (Hass-Slavin et al., 2005; Gates and Jones, 2007; McCullagh et al., 2010) comfort (McCullagh et al., 2010), and accessibility (McCullagh and Robertson, 2009; McCullagh et al., 2010; Kearney et al., 2015) have been associated with hearing protective behaviors. Other perceptions related to hearing protection use include perceived susceptibility to hearing loss (Patel et al., 2001; Murray-Johnson et al., 2004; Gates and Jones, 2007; Smith et al., 2008; Hong et al., 2013), perceived severity of hearing loss (Patel et al., 2001; Murray-Johnson et al., 2004; Gates and Jones, 2007), and interpersonal influences (Lusk et al., 1999; Gates and Jones, 2007; McCullagh et al., 2016). Successful interventions to improve hearing protection use have included education about hearing conservation (Gates and Jones, 2007; Smith et al., 2008; McCullagh et al., 2016), the provision of multiple types of hearing protection (Gates and Jones, 2007; McCullagh et al., 2016), personalized noise exposure measurements (Gates and Jones, 2007), and the provision of routine audiometric tests (Knobloch and Broste, 1998; Lusk et al., 1999).

To overcome the inconveniences of hygiene, storage, and work efficiency, a hearing protection storage box containing earmuffs was placed at sources of hazardous noise on the farm. The novelty of this idea is that hearing protection is now associated with a piece of machinery and not a person. This study aimed to identify factors that influence farmers' perceptions about hearing protection and to evaluate if a point source hearing protection intervention (storing hearing protection near major noise sources) contributed to changes in farmers' perceptions about hearing protection.

METHODS

Study Population and Design

The study population was derived from the Farm Market ID's database of farm operations. Farm Market ID is a private company that provides a service for marketing and research organizations with the ability to draw samples of farm operations based on selected production, location, and operator characteristics (Farm Market ID, 2016). Principal farm operators managing farms located within a 100-mile radius of Omaha, Nebraska, were randomly selected for the study from the Farm Market ID database. Full-time principal farm operators aged 19 years and older who intended to continue to farm for the duration of the study were eligible to participate. Other farm operators or hired workers involved in agricultural work (up to five from the same farm) were also invited to join if they were at least 14 years old.

Principal farm operators (n=3,962) were contacted by mail about their potential eligibility and willingness to participate in the study. Farms of eligible responding principal operators were included in the study and randomly assigned to either control or intervention arms (1:1 allocation ratio) using a computer-based random number generator. This process was repeated during year 2 of the study to reach the recruitment target. Family members and workers who requested to join were added to the study. The study participation selection strategy is illustrated in figure 1. After randomization, one intervention farm withdrew from the study before any data were collected, and two farms (one control and one intervention) withdrew from the study after the first visit. The final study population consisted of 89 farmers and farm workers representing 51 farms randomly assigned into either control (n=26) or intervention arms (n=25) for up to four years, depending on the year in which they enrolled. All study participants are herein referred to as farmers for brevity.

Point Source Hearing Protection Intervention

Farmers in the intervention group received the point source intervention, consisting of up to four weatherproof boxes containing a pair of earmuffs and 30 sets of earplugs placed in areas of the farm identified as having loud noise. Details of this intervention are described elsewhere (Achutan, 2015). In addition, farmers in both the intervention and control

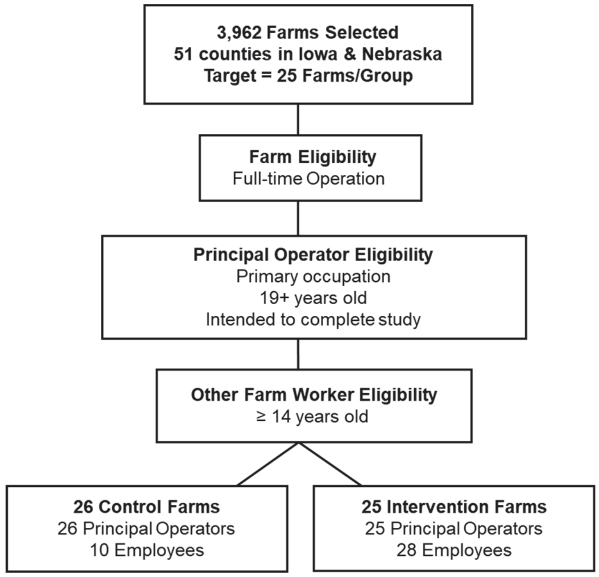

Figure 1. Flow chart of study participation selection strategy.

groups were taught how to insert earplugs properly and educated one-on-one on the importance of wearing hearing protection devices and the ramifications of hearing loss.

Collection of Demographic, Audiometric, and Hearing Protection Perception Data

Each farmer was asked to complete a standardized baseline demographic and medical history form, which provided information regarding their gender, age, self-reported hearing health, and perceived hearing loss. We also gathered information describing their farming operation and farm activities. In each year of the study, all farmers were asked to participate in an audiometric test and complete the Beliefs about Hearing Protection and Hearing Loss (BHPHL) Questionnaire.

The BHPHL questionnaire (Svensson et al., 2004) was used to gauge farmers' perceptions about hearing loss and hearing protection. Farmers reviewed 15 different statements corresponding to four concepts within the health belief model (HBM): (1) barriers of comfort; (2) barriers of communication; (3) self-efficacy; and (4) benefits. Respondents indicated whether they strongly agreed, agreed, disagreed, or strongly disagreed with each statement. For analysis, responses were scored on a four-point scale (1=Strongly Agree; 2=Agree; 3=Disagree; 4=Strongly Disagree). When the statement was inversely worded, the scores were reversed. Within each year, each farmer's responses to the statements within each HBM concept were summed to provide a score for each HBM concept. Favorable perceptions corresponded to higher HBM concept scores; unfavorable perceptions corresponded to lower HBM concept scores. Farmers that did not respond to all statements within each HBM concept were excluded from the analysis of that HBM concept for the year that was missed. All data were manually entered into a Microsoft Excel database and then imported into SAS® (Version 9.4; SAS Institute Inc.; Cary, NC) for data management and analysis. Random checks of the data were performed to identify and correct any errors.

Statistical Analysis

Simple descriptive statistics were used to describe the study population and the HBM concept scores for farmers' perceptions of hearing protection. Cronbach's alpha coefficient was calculated to measure the internal consistency of the statements used within each HBM concept. Alpha coefficient values greater than 0.70 demonstrated high internal consistency between the statements.

Generalized linear mixed models (GLMM) were built to model the main effects of group assignment, duration of participation in the study, age, and hearing loss on each HBM concept score. These covariates were added to understand the study's impact and the farmer's unique impact on their perceptions of hearing protection. A random subject effect was included to account for the within-person correlation among farmers from the same farm and the data collected from the same farmer. The significance level was set at two-sided alpha=0.05. The study protocol was approved by the University of Nebraska Medical Center's Institutional Review Board (263-12-EP).

Results

The baseline statistics of both study groups are displayed in table 1. Eighty-nine, mostly male, farmers from Nebraska and Western Iowa participated in the study for an average of 2.2 years. Thirty-two participated for four years, 48 for three years, four for two years, and five for one year. Many were lifelong farmers, reporting an average of 35 years in farming. Nearly all said they cultivated crops, predominantly corn and soybeans; about half also reported raising livestock. Over three-quarters reported previous exposure to loud noise. Sixty-seven percent said they had previously used hearing protection, and just under 40% reported using it during their current operations. Farmers in the control group were an average of about 12 years older than farmers in the intervention group. A larger proportion of farmers in the control group had hearing loss than those in the intervention group.

Most farmers were healthy adults reporting few health issues related to impaired auditory function, such as chronic ear infections, measles, or mumps. Roughly 25% reported that they experienced tinnitus. Most reported occasional problems with their hearing, and 19% reported some hearing loss. Hearing tests showed approximately 32% had moderate or worse hearing loss in at least one ear for frequencies between 2000 and 6000 Hertz.

Table 2 describes the partitioning of the BHPHL questionnaire into the HBM concepts. In general, the raw unstandardized Cronbach's alpha coefficients indicated that responses were consistent within each HBM concept across all years of the study.

Average HBM concept scores for control and intervention farmers for each year of the study are summarized in tables 3 and 4. Table 5 summarizes the results from the GLM model for each HBM concept.

Barriers: Comfort

Barriers related to comfort HBM concept scores increased for both groups over the study, indicating improved perceptions of barriers related to comfort (tables 3 and 4). Farmers with higher HBM concept scores for barriers related to comfort tended to provide responses that did not indicate that they felt comfort was a barrier to using hearing protection. For instance, their responses disagreed with statements about earmuffs being uncomfortable or annoying. In the generalized linear mixed model, intervention farmers had higher HBM concept scores for barriers related to comfort than control farmers after adjusting for

Table 1. Baseline demographic and exposure characteristics of study farmers (n=89).

Characteristics	Control		Intervention	
	n	(%)	n	(%)
Farms	26	(51.0)	25	(49.0)
Farmers	36	(40.5)	53	(59.5)
Employment Status				
Principal Operator	26	(72.2)	25	(47.2)
Employee	10	(27.8)	28	(52.8)
Gender				
Male	33	(91.7)	46	(86.8)
Female	3	(8.3)	7	(13.2)
Duration of Participation				
Mean (±SD; Years)	2.3	(0.7)	2.2	(0.9)
Range	1 day–3.6 years		1 day–3.4 years	
Age (Years)				
Mean (±SD)	56.9	(15.3)	45.0	(15.8)
Range	22–90		17–73	
Years Farming				
Mean (±SD)	42.4	(14.1)	29.8	(19.1)
Range	10–70		0.2–68.4	
Crop Producer	35	(97.2)	50	(96.2)
Corn	33	(94.3)	44	(88.0)
Soybeans	33	(94.3)	44	(88.0)
Other[a]	15	(42.9)	18	(36.0)
Livestock Producer	19	(52.8)	21	(39.6)
Cattle	14	(73.7)	9	(42.9)
Other[b]	5	(26.3)	12	(57.2)
Perceived Hearing Loss[c]				
Perfect to Mild	25	(69.4)	46	(88.5)
Moderate to Profound	11	(30.6)	6	(11.5)
Measured Hearing Loss[d]				
Normal – Mild in Both Ears	20	(55.6)	40	(76.9)
Moderate – Profound ≥ 1 Ear	16	(44.4)	12	(23.1)

[a] Other subcategories includes hay, alfalfa, rye, wheat, oats, and yeast.
[b] Other reported livestock exposures included hogs, chickens, horses, sheep, and transporting livestock.
[c] One intervention farmer did not provide information about their self-perceived hearing ability.
[d] Audiometric testing was not included for one intervention farmer and one control farmer; these farmers already had profound hearing loss and used hearing aids.

farmers' participation time in the study, age, and hearing loss (p=0.007). Also, participation time in the study was positively associated with higher HBM concept scores for barriers related to comfort for all farmers after adjusting for all other covariates (p<0.001), with HBM concept scores for barriers related to comfort being higher over time for all farmers.

Self-Efficacy

Self-efficacy HBM concept scores increased for both groups over the study, which indicated improved perceptions of self-efficacy (tables 3 and 4). As the study progressed, farmers in both groups appeared to become increasingly confident in using hearing protection properly. Their responses shifted from being less confident about how to fit and wear earplugs to being more self-assured with using and caring for earplugs. In the generalized linear mixed model, intervention farmers generally had higher HBM concept scores for self-efficacy than control farmers after adjusting for farmers' participation time in the

Table 2. HBM concept summary, including BHPHL statements, response scores, and Cronbach's alpha coefficient.

HBM Concept	Statements[a]	Mean Response Scores at Baseline[b] Mean (Range)	All Years Cronbach's α[c]
Barriers: Comfort (4 items)	- I think earmuffs put too much pressure on my ears. - I think earmuffs make my head sweat too much. - Hearing protectors are uncomfortable to wear. - Wearing hearing protection is annoying.	10.41 (5-16)	0.77
Self-Efficacy (5 items)	- *I believe I know how to fit and wear earplugs.* - I'm not sure how to tell when earplugs need to be replaced. - *I know when I should use hearing protectors.* - *I know how to tell when an earmuff needs to be replaced.* - *If co-workers asked me, I would be able to help them wear hearing protectors correctly.*	13.41 (5-20)	0.76
Benefits (3 items)	- *I think wearing hearing protectors every time I am working in loud noise is important.* - *I am convinced I can prevent hearing loss by wearing hearing protectors whenever I work in loud noise.* - *If I wear hearing protection, I can protect my hearing.*	9.84 (5-12)	0.65
Barriers: Muffling (3 items)	- I think it will be hard to hear warning signals (like backup beeps) if I am wearing hearing protectors. - Hearing protectors limit my ability to hear problems on the job site. - I can't hear problems with my tools and machinery if I wear hearing protectors.	7.55 (3-12)	0.78

[a] 4-point Scale: 1=Strongly Agree; 2=Agree; 3=Disagree; 4=Strongly Disagree; *italicized s*tatements indicate reversal of scale.

[b] Favorable perceptions correspond to high response scores; poor perceptions correspond to low response scores.

[c] Cronbach's alpha coefficient based on current study, all years, all participants combined, n=285, missing responses excluded.

Table 3. Summary of control farmers' HBM concept score by year.

	Control Group (n=36)											
	Year 1			Year 2			Year 3			Year 4		
	n	mean	(±SD)	n	mean	(±SD)	n	mean	(±SD)	n	mean	(±SD)
Barriers: Comfort[a]	35	9.83	(2.20)	35	10.43	(1.72)	35	11.34	(1.78)	10	12.00	(2.36)
Self-Efficacy[b]	31	12.61	(2.19)	29	13.38	(1.84)	30	13.77	(2.18)	9	14.56	(2.30)
Benefits	36	9.78	(1.24)	35	10.03	(1.40)	35	10.2	(1.32)	12	10.00	(1.35)
Barriers: Communication	36	7.39	(1.55)	35	7.91	(1.46)	35	7.91	(1.70)	12	9.17	(1.19)

[a] At year one, one farmer had incomplete responses; at year four, two had incomplete responses.

[b] At year one, five farmers had incomplete responses; at year two, six had incomplete responses; at year three, five had incomplete responses; and at year four, three had incomplete responses.

study, age, and hearing loss (p=0.001). Participation time in the study was also positively associated with higher HBM concept scores for self-efficacy for all farmers after adjusting for all other covariates (p<0.001), with HBM concept scores for self-efficacy being higher over time for both groups.

Table 4. Summary of intervention farmers' HBM concept score by year.

	Intervention Group (n=53)											
	Year 1			Year 2			Year 3			Year 4		
	n	mean	(±SD)	n	mean	(±SD)	n	mean	(±SD)	n	mean	(±SD)
Barriers: Comfort[a]	52	10.81	(2.39)	48	11.88	(2.52)	46	11.91	(2.26)	20	11.6	(2.50)
Self-Efficacy[b]	50	13.90	(2.63)	45	14.67	(2.24)	46	14.85	(2.12)	20	15.9	(2.45)
Benefits[c]	52	9.88	(1.48)	48	10.29	(1.32)	46	10.35	(1.37)	20	10.4	(1.64)
Barriers: Communication[d]	52	7.65	(2.15)	48	7.73	(1.89)	46	8.22	(2.04)	20	8.45	(2.04)

[a] At year one, one farmer had incomplete responses.
[b] At year one, three farmers had incomplete responses; at year two, three had incomplete responses.
[c] At year one, one farmer had incomplete responses.
[d] At year one, one farmer had incomplete responses.

Table 5. Summary of generalized linear mixed models (GLMM) of the differences in farmers' perceptions of each HBM concept.[a],[b],[c]

	Barriers: Comfort		Self-Efficacy		Benefits		Barriers: Communication	
Covariates	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*
Intercept	**8.17 (0.85)**	**<0.001**	**11.91 (0.85)**	**<0.001**	**8.62 (0.48)**	**<0.001**	**5.45 (0.70)**	**<0.001**
Group								
Control	Ref.	--	Ref.	--	Ref.	--	Ref.	--
Intervention	**1.19 (0.43)**	**0.007**	**1.45 (0.43)**	**0.001**	0.42 (0.24)	0.082	0.44 (0.36)	0.226
Time (Years)	**0.48 (0.12)**	**<0.001**	**0.59 (0.13)**	**<0.001**	0.14 (0.08)	0.081	**0.28 (0.09)**	**0.002**
Age (Years)	0.02 (0.01)	0.150	0.01 (0.01)	0.720	**0.02 (0.01)**	**0.011**	**0.03 (0.01)**	**0.006**
Measured Hearing Loss								
Normal: Mild in Both Ears	Ref.	--	Ref.	--	Ref.	--	Ref.	--
Moderate: Profound ≥ 1 Ear	0.38 (0.38)	0.336	-0.69 (0.41)	0.137	-0.35 (0.23)	0.160	-0.38 (0.30)	0.233

[a] Bolded p-values considered statistically significant.
[b] Model adjusted for group assignment, duration of participation, age, perceived hearing loss, and measured hearing loss.
[c] β Estimates indicate the direction of the effect of each covariate in each GLMM.

Benefits

Overall, farmers in both groups appeared to have positive perceptions about the benefits of hearing protection. Most seemed to agree that hearing protection would prevent hearing loss. HBM concept scores for the benefits of hearing protection improved slightly for both groups (tables 3 and 4). In the generalized linear mixed model, farmers' age was positively associated with HBM concept scores for the benefits of hearing protection after adjusting for all other covariates (p=0.011), with older farmers having higher HBM concept scores about the benefits of hearing protection compared to younger farmers.

Barriers: Communication

Barriers related to communication HBM concept scores increased for both groups over the study, indicating improved perceptions of barriers related to comfort (tables 3 and 4). Farmers with higher HBM concept scores for barriers related to communication tended to provide responses that did not indicate that they felt communication was a barrier to using hearing protection. Many responded that they did not think hearing protectors would limit their ability to hear important sounds, like warning signals or equipment problems. In the generalized linear mixed model, participation time in the study was positively associated with higher HBM concept scores for barriers related to communication for all farmers after adjusting for all other covariates ($p<0.002$), with HBM concept scores for barriers related to communication being higher over time for all farmers. Also, farmers' age was positively associated with HBM concept scores for barriers related to communication for all farmers after adjusting for all other covariates ($p=0.006$), with older farmers having higher HBM concept scores for barriers related to communication compared to younger farmers.

Discussion

Low perceptions of barriers, high self-efficacy, and positive views of hearing protection benefits have previously been linked to greater hearing protection use (Lusk et al., 1997; McCullagh et al., 2002, 2010; Hong et al., 2013). We assessed the effect of age and hearing loss and the study intervention effects contributing to farmers' perceptions about hearing protection. In general, farmers experienced improvements in all their perceptions related to hearing protection. Higher HBM concept scores for barriers related to comfort were associated with intervention farms ($p=0.007$) and longer durations of participation ($p<0.001$). Similarly, higher HBM concept scores for self-efficacy were associated with intervention farms ($p=0.001$) and longer durations of participation ($p<0.001$). Older age was associated with higher HBM concept scores for the benefits of using hearing protection ($p=0.011$). In addition, higher HBM concept scores for barriers related to communication were associated with a longer duration of participation ($p=0.002$) and older age ($p=0.006$).

Barriers to hearing protection have consistently been identified as significant factors for their use (Lusk et al., 1997; Murray-Johnson et al., 2004; Hass-Slavin et al., 2005; Ronis et al., 2006; Edelson et al., 2009; McCullagh et al., 2010). Many have felt that comfort was a barrier to using hearing protection (Murray-Johnson et al., 2004; Ronis et al., 2006; Edelson et al., 2009; Hong et al., 2013), as was the potential for muffling important sounds (Lusk et al., 1997; Murray-Johnson et al., 2004; Hass-Slavin et al., 2005; Ronis et al., 2006; Gates and Jones, 2007; Edelson et al., 2009). At the beginning of the study, farmers had generally lower scores and thus poorer perceptions of barriers related to comfort and communication for hearing protection. Although the changes were subtle, many had improved their perceptions of barriers by the end of the study. Specifically, many changed their perception that lack of comfort was a barrier to using hearing protection, and many changed their perception that hearing protection would disrupt their ability to communicate with others effectively. These changes were observed across both groups.

Self-efficacy has been widely associated with the use of hearing protection (Lusk et al., 1997, 1999; Kerr et al., 2002). Self-efficacy can relate to one's ability to insert hearing protection properly, understand when to use hearing protection, and can relate to one's confidence in teaching others about hearing protection. One's self-efficacy has been implicated as a key predictor for hearing protection use; individuals who feel more confident in their ability to use hearing protection are more likely to use it (Lusk et al., 1999; Kerr et al., 2002; Ronis et al., 2006; Gates and Jones, 2007). We found that farmers felt more confident in their ability to use hearing protection properly over time. The increase in the number of farmers that experienced improvements in their perceptions of barriers and self-efficacy may be attributed to the point source intervention, as well as the educational component of the intervention, as education has consistently been shown to improve hearing protection use (Lusk et al., 1999; Jenkins et al., 2007; Gates and Jones, 2007; Smith et al., 2008; McCullagh et al., 2016).

Farmers generally agree that hearing protection is essential to prevent hearing loss. This perception was mostly the same over the course of the study. The perceived value of hearing protection has been associated with hearing protection; people who trust hearing protection will protect their hearing will be more inclined to use it (Lusk et al., 1997, 1999). Despite the minor change in farmers' perception of the value of hearing protection, reported current use of hearing protection increased for all farmers from just under 40% at the beginning to nearly 65% by the end of the study.

In our study, age was not associated with self-efficacy. Ronis et al. (2006) and Murray-Johnson et al. (2004) demonstrated the effect of age as a critical predictor of self-efficacy by suggesting that older working adults have lower self-efficacy than their younger counterparts; they propose that age works as a moderating variable on hearing protection use. For instance, the effect of years of employment (used instead of age) negatively affects workers' self-efficacy (by increasing workers' perceptions of barriers related to hearing protection use), ultimately resulting in poor hearing protection practices (Murray-Johnson et al., 2004; Ronis et al., 2006). Lusk et al. (1997, 1999) proposed the idea that the effect of age is closely tied to experience and linked to greater use of hearing protection.

Age was associated with the HBM concept scores for barriers related to comfort and for the benefits of hearing protection. We observed that older farmers had higher HBM concept scores for barriers to communication and the benefits of hearing protection than younger farmers. More specifically, older farmers tended not to see communication as a barrier to using hearing protection; they also tended to agree that hearing protection would prevent hearing loss. It is likely that older farmers may already have hearing loss and be more likely to use hearing protection to preserve their remaining hearing; moreover, their experience may also allow them to recognize hazardous noise, anticipate the risk with noise, and defend their hearing better (Lusk et al., 1997, 1999).

Several researchers (Broste et al., 1989; Kerr et al., 2002; Smith et al., 2008) have found that self-reported hearing loss is a good indicator for measured hearing loss. This was inconsistent with our findings. Almost 46% of farmers had measured moderate or worse hearing in at least one ear, but only 20% acknowledged having hearing loss. The effect of hearing loss was not associated with any of the HBM concept scores. Murray-Johnson et al. (2004) and Smith et al. (2008) have speculated that farmers with hearing impairments may not believe hearing protection will protect their already damaged hearing. In any case, it is important to note that most farmers with hearing loss don't use hearing protection, and efforts to curb this behavior should continue (Carpenter et al., 2002; Williams et al., 2004; Donham et al., 2013; Kearney et al., 2015; McCullagh et al., 2016).

Farmers from both study groups were trained about the effects of hazardous noise and the long-term consequences of hearing loss. Both groups also received training on how and when to use hearing protection and how hearing protection works. They were also given a chance to observe and test hearing protection in a setting outside of their work environment. Over time, farmers had more opportunities to interact with the research team, use hearing protection, and have the critical points of the educational component reinforced. All three factors likely contributed to the changes in farmers' perceptions.

Strengths and Limitations

This study had several strengths. First, it linked each farmer's characteristics to their beliefs about hearing protection. Using the data collected during this study, we could link the intervention, audiometric data, questionnaires, and health data across the same group of farmers. Though there were missing data, we had a robust dataset for each year of the study, which enabled us to evaluate the same group of farmers over time and draw conclusions about the effectiveness of our intervention in changing farmers' perceptions about hearing protection.

One limitation was related to the formation of the study populations. Farms, not farmers, were allocated into each of the study arms. We allowed other farm workers (n=38) from the same farm to join during the study. An oversight of this approach was that many of these unsolicited participants were from intervention farms (n=28); they also happened to be younger than the principal operators. Including other farm workers as the study progressed ultimately skewed the age and sample size distributions between the groups. On average, the control group of farmers was 12 years older than the intervention group; they also had more evidence of hearing loss. In addition, there were also 17 more farmers in the intervention group than in the control group.

Post hoc sensitivity analyses of the GLMM were run only to include the principal operators to understand the impact of these potential biases. There were 25 farmers in the intervention group and 26 farmers in the control group in Year 1. In Years 2 and 3, there were 24 farmers in the intervention group and 25 farmers in the control group. In Year 4, there were 11 farmers in the intervention group and nine farmers in the control group. So, the sample size for the post hoc sensitivity analysis was 165, reduced from 285 when employees were included. These results are provided in table 6. The exclusion of other farm workers from the analyses changed the impact of group assignment on the 'Barriers:

Table 6. Summary of generalized linear mixed models (GLMM) of the differences in primary farm operators' perceptions of each HBM concept.[a],[b],[c]

	Barriers: Comfort		Self-Efficacy		Benefits		Barriers: Communication	
Covariates	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*	β Estimate (±SE)	*p*
Intercept	**9.46 (2.08)**	**<0.001**	**12.35 (1.97)**	**<0.001**	**9.60 (1.09)**	**<0.001**	**6.70 (1.76)**	**0.004**
Group								
Control	Ref.	--	Ref.	--	Ref.	--	Ref.	--
Intervention	1.04 (0.61)	0.095	0.77 (0.57)	0.185	0.56 (0.32)	0.076	0.55 (0.52)	0.300
Time (Years)	**0.65 (0.17)**	**0.001**	**0.99 (0.16)**	**<0.001**	0.11 (0.10)	0.278	**0.30 (0.13)**	**0.017**
Age (Years)	-0.01 (0.04)	0.721	-0.01 (0.03)	0.732	<0.00 (0.02)	0.807	0.01 (0.03)	0.732
Measured Hearing Loss								
Normal: Mild in Both Ears	Ref.	--	Ref.	--	Ref.	--	Ref.	--
Moderate: Profound ≥ 1 Ear	0.72 (0.47)	0.173	-0.72 (0.48)	0.194	-0.19 (0.27)	0.496	-0.28 (0.38)	0.475

[a] Bolded p-values considered statistically significant.

[b] Model adjusted for group assignment, duration of participation, age, perceived hearing loss, and measured hearing loss.

[c] β Estimates indicate the direction of the effect of each covariate in each GLMM.

Comfort' and 'Self-Efficacy' HBM concept scores in the GLMM. More specifically, the effect of the intervention was no longer associated with the HBM concept score in these models. In addition, excluding other farm workers from the analyses changed the impact of age in the 'Benefits' and 'Barriers: Communication' HBM concept scores in the GLMM. In these models, age was no longer associated with the benefits or barriers of communication HBM concept scores. Although the effect of group assignment and age changed in the post hoc sensitivity analyses, the conclusions from the models remained the same for the effect of the duration of participation. In the 'Barriers: Comfort,' 'Self-Efficacy,' and 'Barriers: Communication' GLMM, farmers that participated in the study for a longer duration had higher HBM concept scores than farmers that did not participate as long.

While post hoc sensitivity analyses of the GLMM may have identified some potential bias in the way the study groups were formed, the inclusion of other farm workers in the study demonstrated that the point source intervention was generating an interest in hearing conservation on intervention farms. The reduction in sample size could have also led to an underpowered analysis. The new participants likely volunteered to join because they were interested in the point source intervention and wanted to use the hearing protection. In addition, these participants also had the added benefit of social influence compared to others on more isolated sole-proprietor farms. Future interventions should include a social influence component, mainly since other studies have found the effect of social norms to contribute greatly to the decision to wear hearing protection (McCullagh et al., 2010, 2016). Finally, it should be noted that farmers' answers to the questionnaires could be misrepresented due to their participation in an observational study. This phenomenon is known as the Hawthorne effect and is common with self-reported data (Wickstrom and Bendix, 2000; Delgado-Rodriguez and Llorca, 2004).

Conclusion

The study findings show that intervention and control groups improved their perceptions about hearing protection over time. The point source intervention contributed to the effect of education on farmers' perceptions of comfort and self-efficacy but not to perceptions related to communication barriers or the benefits of hearing protection. Education about hearing loss and hearing protection should continue to be an integral component of interventions designed to improve the use of hearing protection.

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