HHS Public Access
Author manuscript
Int J Audiol. Author manuscript; available in PMC 2020 January 29.

Published in final edited form as:
Int J Audiol. 2018 February ; 57(2): 124–134. doi:10.1080/14992027.2017.1374568.

Efficacy of technology-based interventions to increase the use of hearing protections among adolescent farmworkers

Khalid M. Khan,
Department of Environmental Health, School of Public Health, Indiana University, Bloomington, IN, USA

Sydney S. Evans,
Department of Environmental Health, School of Public Health, Indiana University, Bloomington, IN, USA

Sylvanna L. Bielko,
Department of Environmental Health, School of Public Health, Indiana University, Bloomington, IN, USA

Diane S. Rohlman
Occupational and Environmental Health, College of Public Health, The University of Iowa, Iowa City, IA, USA

Abstract

Objective: Adolescent farmworkers are exposed to loud noise during farm activities. We present a prospective study that evaluated the efficacy of low-cost, technology-based intervention approaches in high schools to enhance the use of hearing protection among adolescent farmworkers.

Design: Six high schools in Iowa that agreed to participate in the study were divided into three equal groups through cluster-randomisation with each group receiving one of the three formats of hearing protection intervention: (a) classroom training, (b) classroom training coupled with smartphone app training and (c) computer training. Participants completed baseline (pre-training) and six-week post-intervention surveys for assessing hearing protection knowledge, attitudes and behaviour.

Study Sample: Seventy participants from six schools were initially enrolled but 50 completed both pre- and post-intervention surveys.

Results: In most cases, all three groups showed significant improvement in hearing protection knowledge, attitude and frequency of use from pre- to post-intervention. However, changes between groups were statistically non-significant.

Correspondence kmkhan@indiana.edu.

Declaration of interest
Dr. Diane Rohlman has a significant financial interest in Northwest Education Training and Assessment, LLC, a company that may have a commercial interest in the results of this research and technology. This potential conflict of interest was reviewed and a management plan approved by the University of Iowa Conflict of Interest in Research Committee was implemented. The authors alone are responsible for the content and writing of this article.

Conclusions: Although all three formats led to improvements on hearing protection knowledge, attitude and behaviour, the findings of the study, perhaps due to the small sample size, did not allow us to detect whether technology-based hearing protection interventions were more effective than the traditional face-to-face training for adolescent farmworkers.

Keywords

Noise-induced hearing loss; hearing protection; technology-based intervention; adolescent farmworkers

Introduction

Noise-induced hearing loss (NIHL) remains a major public health challenge in agricultural communities and is one of the top-ranked self-reported occupational health outcomes in the United States (Agrawal, et al., 2008; NIOSH 2009; Zhan et al. 2010). In addition to adult farmworkers, adolescents engaged in farm tasks may also be at risk of NIHL. Many routine farm tasks involve noise generating activities, such as running tractors, grain dryers and chain saws. Even though these agricultural tasks are exempt from Occupational Safety and Health Administration (OSHA) inspection, farmers are expected to follow safety rules regarding noise levels and exposure (Suter 2009; McCullagh 2011). Several studies have identified hearing loss as a significant risk factor for farm injuries (Hwang et al. 2001; Hager 2002; Sprince et al. 2003; Choi et al. 2005). Furthermore, NIHL may have detrimental effects on quality of life, communication and routine activities and may also be associated with impaired cognitive function and dementia, as well as reduced social integration (Dalton et al. 2003; Agrawal et al. 2008). NIHL is irreversible. Therefore, this specific disability, if initiated as early as adolescence, could result in a greater number of years of disability over an individual’s lifetime (Karlovich et al. 1988; Perry and May 2005; Ehlers and Graydon 2011). For this reason, early hearing protection intervention and mitigation for young adults working in agricultural settings are of utmost importance.

Hearing protection interventions typically use several information dissemination and training activities at individual and group levels, such as face-to-face lecture sessions, mailing printed information materials to the target groups, posters, flyers and leaflets, personalised multimedia education, on-site noise exposure monitoring, audiometric testing and providing free hearing protection devices (HPDs) (El Dib et al. 2007). In recent years, technology has begun to be utilized in hearing protection interventions. Information has been presented via computer and internet-based resources in order to reach a larger audience in a cost-effective manner, although the efficacy of such technological interventions compared to more traditional approaches remains unknown. For instance, an ongoing randomised controlled trial is comparing interactive and static web-based resources to promote the use of hearing protection among adult farmers (McCullagh and Ronis 2015). Hearing protection intervention researchers in the United States address some common gaps of knowledge among various age groups of farmers, as identified by the National Institute for Occupational Safety and Health (NIOSH). The training should include procedures for correct fitting and cleaning of hearing protection, the importance of hearing health in family and social life and measuring the risks associated with various ranges of noise exposures from farm equipment (NIOSH 2007a; NIOSH. 2007b; Rocha et al. 2011; Verbeek et al. 2014). Since technological and administrative noise control measures are difficult to implement in agricultural communities, most hearing protection intervention programmes, primarily developed for adult farmers, incorporate educational materials containing information on these learning areas (Murphy 1992; McCullagh and Ronis, 2015; McCullagh et al. 2016). A small number of intervention studies targeting rural adolescent farmworkers also follow similar educational approaches (Reed et al. 2003; Marlenga et al. 2011; Martin et al. 2013).

Traditionally, classroom-based training on noise exposure and hearing conservation, reminders by mail, and hearing screening have been used to promote the use of hearing protection devices among school-age farmers (Knobloch and Broste, 1998; Reed et al. 2001; Lee et al. 2004; Marlenga et al. 2011; Martin et al. 2013). Recent studies suggest that these traditional formats of training may not be effective in establishing sustainable positive changes several years after intervention, as the researchers did not find significant differences in audiometric test results between intervention and control groups composed of high school students (Berg et al. 2009; Marlenga et al. 2011). Although alternative technology-based formats of hearing protection training cannot guarantee higher efficacy to prevent hearing loss, they may offer greater degree of motivational power to younger farmers who are more inclined to use technology at the workplace.

Use of technology-centred training in changing health behaviour may be considered as a potential alternative to traditional training approaches. For instance, computer-based training has been effectively used in various occupational health interventions promoting exposure prevention in both younger and older workers (Anger et al. 2001; Lightfoot et al. 2007; Glass et al. 2010; Dennison et al. 2013; Martinez-Perez et al. 2013). A few adult studies have reported increased use of hearing conservation among firefighters and construction workers through computer training programmes (Kerr et al. 2007; Hong et al. 2013). Recent studies suggest that computer use among farmers is growing and adolescent farmers may be more receptive to this format (McCullagh et al. 2016). Providing exposure feedback to workers using simple-noise measuring devices is another application of technology that may be considered for agricultural intervention, even though efficacy of such approach remains questionable due to mixed findings in hearing protection intervention studies conducted in construction and manufacturing industries (Edelson et al. 2009; Seixas et al. 2011; McTague et al. 2013). However, recent success of smartphone applications (apps) in public health interventions for youth may present a potential alternative tool for self-measuring noise exposure by school-aged farmers, leading to greater degree of awareness to decide when to wear hearing protection (Dennison et al. 2013).

We present a prospective pilot study measuring the efficacy of two different types of technology-based hearing protection interventions for adolescent farmers, one evaluating the use of noise-measuring smartphone apps coupled with typical classroom lecture, and the other evaluating a computer-based training programme compared to traditional classroom training with the following specific aims: (1) examine if each of the three types of interventions improved hearing protection knowledge, attitude and behaviour (i.e. use of hearing protection during noisy farms tasks) from pre- to six-week post-intervention and (2) assess if the two technology training groups demonstrated significantly higher changes of hearing protection knowledge, attitude and behaviour than the traditional classroom training alone from pre- to six-week post-intervention. Although this was a pilot study which utilised only a single session of training and a short intervention period (i.e. six weeks), efficacy of such short term hearing protection interventions has been already reported among studies examining adult farmers (Gates and Jones 2007).

Materials and methods

Study area and participants

The study was conducted among high school students aged 14–18 who were members of FFA chapters located in four counties in Iowa. Our community partner for this study, the Rural Health and Safety Clinic (RHSC) had contact information for 22 FFA chapters, located in 22 high schools, in these counties. Teachers in the schools who manage the FFA chapters were initially contacted by RHSC staff to discuss their interest and the feasibility of the study. Eighteen high school teachers agreed to participate in the study. A lottery was conducted by two RHSC staff who were not involved in the study to randomly select six schools. Each school was numbered following the sequence they were picked up in the lottery and then listed. Subsequently, the study arm (i.e. study group) allocation was determined through computer-generated randomisation with equal number of schools (i.e. two in each arm) allocated to one of the three intervention groups: (1) traditional classroom training, (2) traditional classroom training coupled with training on smartphone applications to measure noise at agricultural sources and (3) computer-based training. A biostatistician from the University of Iowa who was not a member of the research team used computer-generated allocation sequences (www.sealedenvelope.com) to randomly allocate schools to one of the three groups. No changes to allocation was made after this cluster randomisation. This cluster assignment aimed to minimise exchange of knowledge among the adolescent participants. Teachers at these schools indicated that approximately 60% or more high school students regularly use smartphones. The study team completed the first visit in these schools in February 2014 and identified 90 potential participants who met the inclusion criteria: (1) member of a family involved in farm production activities, (2) living and working on a farm and (3) having regular access to a smartphone and a computer. Seventy FFA students from six schools were enrolled in the study (response rate =78%). We obtained child assent and parental consent from 22 participants in classroom training, 26 participants from classroom and app training and 22 participants from computer training groups. The second visit was scheduled approximately two weeks after the first visit. A baseline survey assessing hearing protection and hearing health knowledge and attitudes and frequency of hearing protection use, that is, hearing protection behaviour, during various production activities was administered followed by the hearing protection training. All participants received a set of earplugs and earmuffs at the end of their respective training sessions. During the third and final visit, approximately six weeks after the baseline visit, we conducted a follow-up survey. The training was administered to all students in the class, irrespective of their participation in the study, although only data from the study participants who participated at both baseline and follow-up are presented here. Training and other study materials were approved by the Human Subjects Office (HSO). Supplementary Figure 1 depicts the recruitment of participants in the three intervention groups and study design.

Baseline questionnaire

The baseline survey included questions on sociodemographic characteristics, farm activities of the participants and questions to evaluate hearing protection knowledge, attitude and hearing protection use (behaviour) among the participants. The 20-item knowledge test (Supplementary Table 1) was broken up into four subscales of knowledge: hearing protection use (six items), ways to avoid noise exposure (four items), noise intensity (six items) and general hearing health (four items). Questions were adapted either from a study among children evaluating learning outcomes of participants after completing a hearing conservation programme or from key topics presented in two widely used printed materials published by NIOSH (NIOSH 2007a; NIOSH 2007b; Chen et al. 2008). Each knowledge question had three possible answers: “yes”, “no” and “don’t know.” A correct answer for each item was given one point, and an incorrect or “don’t know” response was worth zero points. Fourteen attitude-related questions (Supplementary Table 2) were adapted from six constructs of a hearing beliefs questionnaire for adults that used a Likert scale ranging from 1 = strongly disagree to 5 = strongly agree and demonstrated moderate-to-high reliability (Chronbach alpha >0.6) (Saunders et al. 2013). Validity of these constructs was also established and reported (Gates and Jones 2007). These attitude items were broken up into three subscales: hearing protection use (seven items), self-efficacy (four items) and impact of hearing loss (three items). Hearing protection use for 13 farm tasks were included in the questionnaire with two response options: (1) use hearing protection regularly or occasionally for a specific farms task and 0) did not use hearing protection for the same farm task.

Selection of noise apps

Six smartphone apps for noise measurement, three each for Apple iOS and Google Android platforms, were initially selected for the study. Apps which received at least a four-star user rating (out of five) through online review and were available free of charge were considered. All of these apps were evaluated in laboratory settings under the supervision of an Industrial Hygienist, who is also a faculty member of the College of Public Health at the University of Iowa. In the laboratory, we compared the performance of these apps with that of a Type-II sound-level monitor. Three apps (one using Apple iOS and two using Google Android platforms) were found to be the least accurate, showing a >±2 dBA difference in readings consistently, when compared with the sound level monitor and were not considered further for the study. The three remaining apps, Sound Meter Pro (version 2.4.4) for the Android system, Sound Meter (+) and Decibel 10th for iOS were included in the study. We developed a step-by-step training module to educate participants on the application of these apps for measuring noise at farms. Prior to the hearing protection training, each participant in the app group first downloaded an app compatible with their phone and then, simultaneously, measured a true sound level of 85 dBA (produced by the white noise app installed on a laptop in the classroom) using both a Type-II sound-level monitor and the smartphone app. Participants were also advised to use the app reading that corresponded to the 85 dBA reading of the sound level metre to determine when to use hearing protection during a farming activity. For instance, if an app read the white noise 86 dBA instead of 85 dBA (measured by Type-II sound-level metre), the participant was advised to use hearing protection when the app displayed a noise level above 86 dBA on the smartphone. Additionally, at least two types of farm equipment (chain saw, lawn mower etc.) were used to demonstrate how the noise app should be used on the farm.

Hearing protection training

The training curriculum for both classroom- and computer-based groups were developed using printed materials published by NIOSH. These include a pamphlet focussed on raising awareness among farmers about the relationship between farm noise and the early onset of tinnitus (i.e. hearing ringing or buzzing) and proper use of hearing protection devices (NIOSH 2007a). In addition, the Dangerous Decibels programme activity “How Loud is Too Loud?” was used (Martin 2008; Martin and Johnson 2010). Classroom training via face-to-face lecture session took place in the classroom used for agriculture classes in the high schools, whereas computer training was held in the computer laboratories of the schools. To demonstrate how commonly used hearing protection (e.g. formable and pre-moulded plugs, canal caps and ear muffs) should be inserted, a short six-minute training video and several PowerPoint slides with pictures were developed by the researchers involved in the study. The curriculum and audio-visual materials were reviewed by faculty from the University of Iowa Occupational and Environmental Health Department, NIOSH hearing protection experts, RHSC staff, rural community members and an external expert on hearing health (Martin and Johnson 2010). Computer-based training administered through the cTRAIN e-Learning software presented the same information as the classroom training (NwETA 2013). The e-Learning software has been utilised in a range of occupational groups, including adolescents, and has been demonstrated to effectively teach a wide range of participants (Eckerman et al. 2004; Anger et al. 2009; Austin et al. 2009; Olson et al. 2009; Glass et al. 2010; Laharnar et al. 2013; Hammer et al. 2015). Based on behavioural principles of learning, the software breaks information into smaller units, requires mastery of the material before moving on, is self-paced and includes pictures and videos (Anger et al. 2001). In addition to the content, the software programme included pre- and post-tests and quizzes throughout the training. After each 3–5 screens, quiz screens appeared with multiple choice questions. A correct response sent the participant forward in the course. An incorrect response showed the participant an error screen and returned the participant to the beginning of the information set to repeat that portion of the training.

Intervention follow-up

A follow-up survey took place approximately six weeks after the baseline visit. Out of the 70 participants who completed the training, 50 completed the follow-up survey (i.e. an overall 71% response rate) including 12 from the classroom training group (55% response rate), 20 from the classroom plus app training group (77% response rate) and 18 from the computer training group (82% response rate). This loss to follow-up was largely due to the follow-up visit falling during the last week of school, at which point many 12th-grade students were unavailable, having already completed their coursework. During this visit, participants were asked to complete a follow-up questionnaire asking about their participation in agricultural activities, their use of hearing protection devices over the past six weeks and to repeat the same attitude and knowledge tests administered at baseline.

Statistical analysis

All statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 22.0. (Bloomington, IN). Changes in the use of hearing protection and hearing health-related attitude and knowledge from baseline to follow-up were used as the primary outcome variables. The differences among the three training groups, in terms of sociodemographic and occupational characteristics and hearing protection intervention outcome variables, were calculated using a chi-squared test for categorical variables and ANOVA for continuous variables. There were a total of 20 total knowledge questions worth one point each for a maximum score of 20. Baseline and follow-up knowledge scores including both total and four subscale scores were reported as a percent. Change in knowledge scores were calculated as per cent correct at six-week follow-up minus per cent correct at baseline for each participant. Each of the 14 attitude items was scored from 1 to 5. The total attitude score was an average of all 14 responses, whereas the subscale scores are the averages of all items under each of the three subscales. Frequency of hearing protection use was defined as the percentage of noise-producing tasks in which HPD was used (occasionally or regularly) by a participant in a given agriculture production season. The change in hearing protection use was reported as the difference in the hearing protection use from baseline to follow-up. Noise-producing farm tasks that were used to estimate hearing protection use were divided into low noise (≤90 dBA; tasks such as working with a hay chopper, driving a tractor with a cab, operating a grain vacuum, working with a silage blower and dairy milking) and high noise (>90 dBA; tasks such as working in a feed mill, using electric shop tools, working in a hog confinement building, driving a tractor without a cab, using a lawn mower and/or weed whacker, hunting and target shooting, grain handling and using a chainsaw) activities.

A paired t-test was used to examine the difference between baseline and follow-up knowledge, attitude, and HPD use within each training group. ANOVA was used to examine the difference between groups at baseline and follow-up and for the change of knowledge, attitude and HPD use from baseline to follow-up. Linear models were used to examine changes across groups for knowledge, attitude and HPD use, controlling for potential confounding variables. Based on a literature review, the authors identified potential confounding variables that might differ between the groups. The authors then evaluated whether inclusion of potential confounding variables changed the estimated regression coefficient relating group (i.e. classroom training vs. classroom plus app training vs. computer training) to the outcome by more than 0.5 standard errors. Variables that met this criteria, such as maternal education (high school vs. below high school), maternal off-farm work (yes vs. no) and number of years working in agriculture (continuous), were included in the final regression models.

Results

Participant characteristics

More than half of the participants in each of the three training groups reported being engaged in some form of agricultural activities for approximately ten years, with 20 mean hours of work per week during the previous year (Table 1). The groups did not differ significantly in terms of most of the demographic and occupational characteristics except maternal occupation and education level. All participants of the computer training group had mothers working off the farm, which was significantly higher than the classroom training (83.3%) and classroom plus app training (65.0%) groups. Only 17% of the computer training group had mothers with high school education or less, which was lower than the other two training groups.

Knowledge

There were no significant baseline knowledge differences between the three groups. Total knowledge and knowledge scores on the noise intensity and general hearing health subscales improved significantly from baseline to post-intervention follow-up (six weeks after baseline) across all three groups (Table 2). The highest change in total knowledge score was observed among the recipients of computer training, who improved their mean score by 20.0 percentage points, as opposed to the two other groups who improved 14.2 and 16.3 percentage points (classroom training and classroom plus app training, respectively). However, the difference in improvement of knowledge scores across the three groups was non-significant. When the groups were examined individually, the computer training group demonstrated a significant increase of knowledge on three of the four subscales (hearing protection knowledge, noise intensity knowledge, and general hearing health knowledge). The classroom training and classroom plus app training groups showed significant improvement for only two subscales (noise intensity knowledge and general hearing health knowledge). The only subscale for which non-significant changes were observed in any of the three groups was the one estimating knowledge on the ways (other than HPD use) of avoiding noise exposure.

Attitude

Similar to the knowledge scores, there were no significant differences across the three groups on total and subscale attitudes measured at baseline. Total subscale attitude scores increased across all three groups, but the increases were significant only in the two technology-based groups (e.g. classroom plus app training and computer training). All subscale scores improved from baseline to follow-up across all three groups. However, only the computer training group showed significant improvement on all attitude subscales (Table 3). Among the participants in this group, all mean total and subscale attitude scores increased by at least 0.4 points (calculated on a Likert scale of 1–5). The computer training group had both the highest post-intervention follow-up mean scores and the highest improvement in mean scores for self-efficacy and consequences of hearing loss.

Participants in noise-producing activities

The baseline percentage of participation in 13 noise-producing activities did not differ significantly in the three groups with the exception of one task (Table 4). Participation in this task (working in a hog confinement building) differed in the classroom with app training group (12.5%) but not between the classroom training and computer training (43.8% and 43.8%, respectively).

Hearing protection device (HPD) use

We observed no significant differences across the three groups on self-reported use of hearing protection measured at baseline (Table 5). In all three groups, HPD use improved from baseline to follow-up, while significant improvements were observed in computer and classroom training groups, but not in the classroom plus app training group. The computer training group showed the highest improvement in HPD use with a mean per cent HPD use increase of 33.4 compared to an increase of 12.7 and 11.6 per cent scores for the participants of classroom and classroom plus noise app, respectively. The difference in HPD use from baseline to post-intervention follow-up is attributable to the high noise activities, that is, activities producing noise levels of 90 dBA or above as determined by the NIOSH (NIOSH 2007a NIOSH. 2007a. Have you heard? Hearing loss caused by farm noise is preventable., 2007b NIOSH. 2007b. They're your ears: Protect them: Hearing loss caused by farm noise is preventable. For low noise activities (activities producing <90 dBA noise), the changes from baseline to follow-up in all three groups were positive but not significant (Table 5).

Discussion

Adolescent farmworkers are more vulnerable to NIHL than those living in agricultural and rural communities but not involved in agricultural activities (Humann et al. 2011). In spite of the public health importance of the problem, especially for youths who can be targeted for early-stage prevention, only a few published studies have examined the efficacy of school-based educational interventions for promoting the use of hearing protection and these studies provided inconsistent evidence of success. Two randomised control trials and one quasi-experimental crossover study were conducted among high school students, using various educational approaches. (Knobloch and Broste 1998; Reed et al. 2001; Lee, Westaby, and Berg 2004). In a Wisconsin study, a four-year, in-depth, multifaceted hearing conservation programme consisting of educational items such as access to hearing protection devices, annual hearing tests and mailed reminders, improved the use of hearing protection in the intervention group more than the control group (Knobloch and Broste 1998). In another study conducted with farm youth from Kentucky, Iowa, and Mississippi enrolled in agriculture class and who also participated in the Agricultural Disability Awareness and Risk Education (AgDARE) Project in their schools, researchers demonstrated that adolescents in the intervention group had significant improvement in their attitudes and readiness to adopt positive hearing protection behaviour compared to the controls (Reed et al. 2006). However, a study that solely evaluated the FFA-based rural health and safety initiative promoting the use of hearing protection across the United States, found that the education initiative failed to increase the use of HPDs among adolescent farmworkers (Reed et al. 2006). These inconsistent results emphasise the need to develop new, innovative and low-cost intervention programmes to reach out to widely dispersed youth populations across the United States. A recent report recommends that such low-cost intervention programmes may be more effective in rural and agricultural settings, if offered to the participants via computer (McCullagh and Ronis 2015).

Technology-based interventions that rely on computer, the Internet and smartphone technologies have been applied successfully in promoting positive health behaviours among adolescents in various fields of public health including mental and sexual health, and preventing factors for cancer, obesity and asthma (Lightfoot, Comulada, and Stover 2007; Bannink et al. 2012; Lana, Faya-Ornia, and Lopez 2014; Burbank et al. 2015; Gold et al. 2016; Peskin et al. 2015; Pretlow et al. 2015). Adolescents are also very receptive to both mobile apps and educational computer modules (Hamel, Robbins, and Wilbur, 2011; Hamel and Robbins 2013). Technology-based interventions also offer an advantage over didactic training methods because they are increasingly interactive and require active learning and participation on the part of the student. Furthermore, computer modules can also be individually tailored to the student to a certain degree (Hamel, Robbins, and Wilbur 2011; Hamel and Robbins 2013). To the best of our knowledge, no study has evaluated the efficacy of technology-based approaches to promote the use of hearing protection in adolescent farmworkers, although similar approaches have successfully maximised other health behaviour change in farm adolescents (Renick, Crawford, and Wilkins 2009).

Measures of knowledge, attitude and hearing protection use indicated that all three formats of training resulted in positive impacts on the three measures of efficacy, even after a relatively short period (six weeks long) of follow-up. The greatest, and most consistent, improvement for these outcome variables was observed in the computer training group. Unlike the two other training groups, participants in this group showed a significant change of knowledge from baseline to follow-up for three subscale measures out of four (Table 2) and a significant change of attitude for all three subscale measures (Table 3). Furthermore, the highest improvement in hearing protection use was observed in the computer training participants, for all activities, with significant improvement of hearing protection use for production activities that produce noise above 90 dBA (Table 3). Even after accounting for some potentially confounding variables, such as maternal education and number of years of farming experience, the improvement of knowledge, attitude and hearing protection use remained the highest among the computer training participants (data not shown). The same group of students might have been able to distinguish between low and high noise sources, as they demonstrated 35.7% increase of HPD use post-intervention for the very loud production activities (>90 dBA) compared to 21.8% increase for low noise activities (≤90 dBA).

The efficacy of the computer training was likely due to the individualised pace and built-in knowledge cheques. The individuals could not advance further in the training until they were able to correctly answer a few questions on the material they had just learned. Our study results are consistent with the results obtained by Martin et al through a study with elementary school children who made more significant improvements in hearing related knowledge via an Internet-based exhibit than children who received education through traditional lecture approaches (Martin et al. 2013). In our study, we applied a computer software cTRAIN that had been successfully used to design occupational health and safety training for adults in farmworker populations (Anger et al. 2009; Austin et al. 2009). This specific software has already produced superior learning in several occupational health studies (“large” effect sizes of d=0.9–3.15, greater than typical training results of d=0.6) (Anger et al. 2009; Olson et al. 2009;; Glass et al. 2010; Laharnar et al. 2013). The computer training group of our study also demonstrated similar “large” effect sizes for all three outcome variables, that is, in hearing protection knowledge, attitude and use (behaviour) values of d were computed as 1.16, 0.94 and 0.96, respectively. The cTRAIN software allowed us to include text, pictures, recordings and movies from NIOSH-published and other sources. This specific training may be delivered via the Internet, resulting in large audience access at relatively low cost.

Possible confounding variables for these results include: type of farm tasks, number of hours spent on the farm, number of bedrooms in the home (a possible indirect indicator of socioeconomic status), whether the parents work on or off of the farm, mother's education level and amount of time the participant spends working on the farm (data not shown). The baseline total knowledge and attitude scores were significantly higher for those who spent nine or more months working on a farm when compared to those who spent less time. It is possible that the increased experience and exposure to both the environment and other farmers had an impact in these areas. The groups performed approximately the same for follow-up knowledge due to the fact that the less experienced group made a significant increase in average knowledge score (and average attitude score for those who spent more than 20h per week on the farm in the fall) from baseline to follow-up. It may be that this educational intervention is more successful in increasing hearing health knowledge for those who have less farming experience because they have less opportunity to pick up this information on the job. Also, comparison of the outcomes of the three interventions, after adjusting for potential confounders, yielded the same findings, that is, improvements in knowledge, attitude and behaviour were non-significantly highest among the computer training participants when compared with the two other groups of trainees.

The outcome variable used for assessing hearing protection behaviour was essentially the self-reported frequency of the use of HPD, which was shown to be highly correlated with the observed use of hearing protection (Griffin et al. 2009; McCullagh et al. 2016). Frequency of HPD use has been derived in multiple ways in the previous studies. Studies with larger sample sizes reported percentage of participants who used HPD before and after intervention, mean percentage of time (within a week or a month) for wearing hearing protection, or mean score derived from a three point Likert-type scale (Knobloch and Broste 1998; Lusk et al. 2004; Berg et al. 2009). Due to the short intervention period of our study, our participants only had the opportunity to engage in a limited number of noisy farm tasks during this period. This has resulted in a few missing values for most of the participants for two categorical variables, that is, a specific noise-producing activity performed during a production season and use of hearing protection while performing that specific task. We did not conduct imputation to handle the missing values, which may be considered a limitation of the study. However, we created a composite and continuous outcome variable by dividing the number of tasks with hearing protection by the total number of tasks performed. We acknowledge that this outcome variable was not used in any previous study, and therefore, future studies need to validate such outcome measure.

There were a few other limitations to this study. Due to this low statistical power, with only 20 or fewer students participating through completion within each training group, our ability to detect the differences in outcomes between groups and within a group was substantially limited. Moreover, inclusion of only two schools in each of the hearing protection intervention groups did not allow us to take clustering into account while comparing the outcomes between the schools during statistical analysis. However, this limitation had minimal impact on the findings since we did not observe any significant differences between groups for any of the outcome variables. This study may also not generalise beyond rural Iowa. However, the results may apply to many similar rural communities in the Midwest, since the farming activities are fairly similar and the socioeconomic conditions are not expected to be substantially different.

Although personal supervision of the insertion of ear plugs during high noise activities is ideal for the adolescent participants to ensure maximum reduction to noise exposure, our study did not offer any such activity. It remains unknown whether participants were able to fit the hearing protection correctly during the intervention period (six weeks following training). However, participants had the opportunity to practice proper insertion of these devices following the instructional audio-visual materials presented during the training.

There is a risk of bias in the results as the baseline questionnaires addressed two full-farming seasons, whereas the follow-up questionnaire only took into account part of a spring season (six weeks). Future studies may consider reaching a large population over a broader area for a longer time frame at follow-up. Additionally, a control group that does not receive any form of education may be included to observe if training groups differ for pre- to post-training changes when compared with a “no-training” group. Also, similar research projects with greater sample sizes should continue to explore computer training and mobile apps as a part of hearing protection interventions for student farmers, due to their popularity and potential efficacy to change adolescent behaviour in this high risk group.

Conclusions

In spite of small sample size and short-term intervention of six weeks, the pilot yielded marked improvement in the knowledge, attitude and use of hearing protection while performing noisy farm tasks across all three intervention groups. However, the positive changes in the three outcome variables from pre- to post-intervention were not significantly different across the groups. Health promotion studies have recommended the use of periodic messaging and prompts using mobile apps and text messages to sustain these positive changes (Neff and Fry 2009; De Leon, Fuentes, and Cohen 2014). More work needs to be done on the use of these technology-based prompts to maximise the benefits of hearing protection training among youth. Findings from the pilot study therefore, do not provide enough information to evaluate if computer training or noise detecting apps are more or equally effective than the traditional classroom training for farm youths in the United States. The larger, but non-significantly higher magnitude of change in hearing protection behaviour in the computer training group may be considered as an encouraging sign, as computer-driven hearing protection interventions are easier to implement for thousands of adolescent farmers at a relatively low cost and with minimal logistic support. Considering the popularity of technology among youths, the final conclusions regarding the efficacy of computer training, smartphone noise apps and other technology-based tools for increasing the use of hearing protection can only be made through a larger study that would have adequate statistical power to detect the differences between hearing protection intervention groups.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

We thank Andy Winborn, the Program Manager of the Rural Health and Safety Clinic of Greater Johnson County, Iowa City, Iowa, for his collaboration to schedule training and data collection activities in the high schools. We also thank Dr. T. Reneé Anthony, an Associate Professor of Occupational and Environmental Health and an Industrial Hygienist at the University of Iowa, who advised us on designing the protocol for testing the noise-measuring smartphone applications in the laboratory. Additionally, we thank Stephanie Dickinson, Manager of the Study Design and Data Analysis Consulting Center in the Department of Epidemiology and Biostatistics at Indiana University-Bloomington, for her help in data analysis.

This work was supported by the Pilot Funding from the CDC-NIOSH Great Plains Center for Agricultural Health at the University of Iowa College of Public Health (grant number 5 U54 OH007548-11).

Abbreviations

FFA	Future Farmers of America
HPDs	hearing protection devices
HSO	Human Safety Office
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
RHSC	Rural Health and Safety Clinic

References

Agrawal Y, Platz EA, and Niparko JK. 2008 "Prevalence of Hearing Loss and Differences by Demographic Characteristics Among US Adults: Data From the National Health and Nutrition Examination Survey, 1999–2004." Archives of Internal Medicine 168: 1522–1530. [PubMed: 18663164]

Anger WK, Patterson L, Fuchs M, Will LL, and Rohlman DS. 2009 "Learning and Recall of Worker Protection Standard (WPS) Training in Vineyard Workers." Journal of Agromedicine 14: 336–344. [PubMed: 19657883]

Anger WK, Rohlman DS, Kirkpatrick J, Reed RR, Lundeen CA, and Eckerman DA. 2001 "cTRAIN: A Computer-Aided Training System Developed in SuperCard for Teaching Skills Using Behavioral Education Principles." Behavior Research Methods, Instruments, and Computers: A Journal of the Psychonomic Society, Inc 33: 277–281.

Austin J, Alvero AM, Fuchs MM, Patterson L, and Anger WK. 2009 "Pre-Training to Improve Workshop Performance in Supervisor Skills: An Exploratory Study of Latino Agricultural Workers." Journal of Agricultural Safety and Health 15: 273–281. [PubMed: 19728549]

Bannink R, Joosten-van Zwanenburg E, van de Looij-Jansen P, van As E, and Raat H. 2012 "Evaluation of Computer-Tailored Health Education ('E-health4Uth') Combined with Personal Counselling ('E-health4Uth+counselling') On Adolescents' Behaviours and Mental Health Status: Design of a Three-Armed Cluster Randomised Controlled Trial." BMC Public Health Journal 12: 1083.

Berg RL, Pickett W, Fitz-Randolph M, Broste SK, Knobloch MJ, Wood DJ, and Kirkhorn SR. 2009 "Hearing Conservation Program For Agricultural Students: Short-term Outcomes from a Cluster-

Randomized Trial with Planned Long-Term Follow-Up." Preventive Medicine 49: 546–552. [PubMed: 19800914]

Burbank AJ, Lewis SD, Hewes M, Schellhase DE, Rettiganti M, Hall-Barrow J, and Bylander LA. 2015 "Mobile-Based Asthma Action Plans for Adolescents." The Journal of Asthma: Official Journal of the Association for the Care of Asthma 52: 583–586. [PubMed: 25494553]

Chen H, Huang M, and Wei J. 2008 "Elementary School Children's Knowledge and Intended Behavior Towards Hearing Conservation." Noise and Health 10: 105. [PubMed: 19075457]

Choi SW, Peek-Asa C, Sprince NL, Rautiainen RH, Donham KJ, Flamme GA, Whitten PS, et al. 2005 "Hearing Loss as a Risk Factor For Agricultural Injuries." American Journal of Industrial Medicine 48: 293–301. [PubMed: 16142735]

Dalton DS, Cruickshanks KJ, Klein BEK, Klein R, Wiley TL, and Nondahl DM. 2003 "The Impact of Hearing Loss on Quality of Life in Older Adults." The Gerontologist 43: 661–668. [PubMed: 14570962]

De Leon E, Fuentes LW, and Cohen JE. 2014 "Characterizing Periodic Messaging Interventions Across Health Behaviors and Media: Systematic Review." Journal of Medical Internet Research 16: e93.

Dennison L, Morrison L, Conway G, and Yardley L. 2013 "Opportunities and Challenges for Smartphone Applications in Supporting Health Behavior Change: Qualitative Study." Journal of Medical Internet Research 15: e86.

Eckerman DA, Abrahamson K, Ammerman T, Fercho H, Rohlman DS, and Anger WK. 2004 "Computer-Based Training for Food Services Workers at a Hospital." Journal of Safety Research 35: 317–327. [PubMed: 15288565]

Edelson J, Neitzel R, Meischke H, Daniell W, Sheppard L, Stover B, Seixas N, et al. 2009 "Predictors of Hearing Protection Use in Construction Workers." The Annals of Occupational Hygiene 53: 605–615. [PubMed: 19531807]

Ehlers JJ, and Graydon PS. 2011 "Noise-Induced Hearing Loss in Agriculture: Creating Partnerships to Overcome Barriers and Educate the Community on Prevention." Noise and Health 13: 142–146. [PubMed: 21368439]

El Dib RP, Atallah ÁN, Andriolo RB, Soares BGdO, and Verbeek J. 2007 "A Systematic Review of the Interventions to Promote the Wearing of Hearing Protection." São Paulo M J 125: 359–361. [PubMed: 18317610]

Gates DM, and Jones MS. 2007 "A Pilot Study to Prevent Hearing Loss in Farmers." Public Health Nursing (Boston, Mass.) 24: 547–553.

Glass N, Bloom T, Perrin N, and Anger WK. 2010 "A Computer-Based Training Intervention for Work Supervisors to Respond to Intimate Partner Violence." Safety and Health at Work 1: 167–174. [PubMed: 22953177]

Gold MA, Tzilos GK, Stein LAR, Anderson BJ, Stein MD, Ryan CM, Zuckoff A, et al. 2016 "A Randomized Controlled Trial to Compare Computer-assisted Motivational Intervention with Didactic Educational Counseling to Reduce Unprotected Sex in Female Adolescents." Journal of Pediatric and Adolescent Gynecology 29: 26–32. [PubMed: 26514957]

Griffin SC, Neitzel R, Daniell WE, and Seixas NS. 2009 "Indicators of Hearing Protection Use: Self-report and Researcher Observation." Journal of Occupational and Environmental Hygiene 6: 639–647. [PubMed: 19626532]

Hager LD 2002 "Hearing Protection. Didn't Hear It Coming. Noise and Hearing in Industrial Accidents." Occupational Health & Amp; Safety (Waco, Tex.) 71: 196–200.

Hamel LM, and Robbins LB. 2013 "Computer- and Web-Based Interventions to Promote Healthy Eating Among Children And Adolescents: A Systematic Review." Journal of Advanced Nursing 69: 16–30. [PubMed: 22757605]

Hamel LM, Robbins LB, and Wilbur J. 2011 "Computer- and Web-Based Interventions To Increase Preadolescent and Adolescent Physical Activity: A Systematic Review." Journal of Advanced Nursing 67: 251–268. [PubMed: 21198800]

Hammer LB, Truxillo DM, Bodner T, Rineer J, Pytlovany AC, and Richman A. 2015 "Effects of a Workplace Intervention Targeting Psychosocial Risk Factors on Safety and Health Outcomes." BioMed Research International 83:6967.

Hong O, Eakin BL, Chin DL, Feld J, and Vogel S. 2013 "An Internet-Based Tailored Hearing Protection Intervention for Firefighters: Development Process and Users' Feedback." Health Promotion Practice 14: 572–579. [PubMed: 23149759]

Humann M, Sanderson W, Flamme G, Kelly KM, Moore G, Stromquist A, Merchant JA, et al. 2011 "Noise Exposures of Rural Adolescents." The Journal of Rural Health: Official Journal of the American Rural Health Association and the National Rural Health Care Association 27: 72–80.

Hwang SA, Gomez MI, Stark AD, St John TL, May JJ, and Hallman EM. 2001 "Severe Farm Injuries Among New York Farmers." American Journal of Industrial Medicine 40: 32–41. [PubMed: 11439395]

Karlovich RS, Wiley TL, Tweed T, and Jensen DV. 1988 "Hearing Sensitivity in Farmers." Public Health Reports (Washington, D.C.: 1974) 103: 61–71. [PubMed: 3124200]

Kerr MJ, Savik K, Monsen KA, and Lusk SL. 2007 "Effectiveness of Computer-Based Tailoring Versus Targeting to Promote Use of Hearing Protection." The Canadian Journal of Nursing Research=Revue Canadienne De Recherche En Sciences Infirmieres 39: 80–97. [PubMed: 17450706]

Knobloch MJ, and Broste SK. 1998 "A Hearing Conservation Program for Wisconsin Youth Working in Agriculture." Journal of School Health 68: 313–318. [PubMed: 9800180]

Laharnar N, Glass N, Perrin N, Hanson G, and Kent Anger W. 2013 "A Training Intervention for Supervisors to Support a Work-Life Policy Implementation." Safety and Health at Work 4: 166–176. [PubMed: 24106648]

Lana A, Faya-Ornia G, and Lopez ML. 2014 "Impact of a Web-Based Intervention Supplemented with Text Messages to Improve Cancer Prevention Behaviors among Adolescents: Results from a Randomized Controlled Trial." Preventive Medicine 59: 54–59. [PubMed: 24287124]

Lee BC, Westaby JD, and Berg RL. 2004 "Impact of a National Rural Youth Health and Safety Initiative: Results from a Randomized Controlled Trial." American Journal of Public Health 94: 1743–1749. [PubMed: 15451744]

Lightfoot M, Comulada WS, and Stover G. 2007 "Computerized HIV Preventive Intervention for Adolescents: Indications of Efficacy." American Journal of Public Health 97: 1027–1030. [PubMed: 16670219]

Lusk SL, Eakin BL, Kazanis AS, and McCullagh MC.2004 "Effects of Booster Interventions on Factory Workers' Use of Hearing Protection." Nursing Research 53: 53–58. [PubMed: 14726777]

Marlenga B, Linneman JG, Pickett W, Wood DJ, Kirkhorn SR, Broste SK, Knobloch MJ, et al. 2011 "Randomized Trial of a Hearing Conservation Intervention for Rural Students: Long-Term Outcomes." Pediatrics 128: e1139–e1146. [PubMed: 21987700]

Martin WH 2008 "Dangerous Decibels: Partnership for Preventing Noise-induced Hearing Loss and Tinnitus in Children." Seminars in Hearing 29: 102–110.

Martin WH, Griest SE, Sobel JL, and Howarth LC. 2013 "Randomized Trial of Four Noise-Induced Hearing Loss and Tinnitus Prevention Interventions for Children." International Journal of Audiology 52: S41–S49. [PubMed: 23373742]

Martin WH, and Johnson M. e.. 2010 Dangerous Decibels® Educator Resource Guide, Oregon Health & Science University (OHSU), Portland, Oregon. [Accessed 03 October 2015]: http://dangerousdecibels.org/education/resources/educator-resource-guide/.

Martinez-Perez B, de la Torre-Diez I, and Lopez-Coronado M. 2013 Mobile Health Applications for the Most Prevalent Conditions by the World Health Organization: Review and Analysis. Journal of Medical Internet Research, 15: e120.

McCullagh MC 2011 "Effects of a Low Intensity Intervention to Increase Hearing Protector Use Among Noise-Exposed Workers." American Journal of Industrial Medicine 54: 210–215. [PubMed: 20721900]

McCullagh MC, Banerjee T, Cohen MA, and Yang JJ. 2016 "Effects of Interventions on Use of Hearing Protectors Among Farm Operators: A Randomized Controlled Trial." International Journal of Audiology 55: S3–S12.

McCullagh MC, and Ronis DL. 2015 "Protocol of a Randomized Controlled Trial of Hearing Protection Interventions for Farm Operators." BMC Public Health 15: 399. [PubMed: 25927191]

McTague MF, Galusha D, Dixon-Ernst C, Kirsche SR, Slade MD, Cullen MR, Rabinowitz PM, et al. 2013 "Impact of Daily Noise Exposure Monitoring on Occupational Noise Exposures In Manufacturing Workers." International Journal of Audiology 52: S3–S8. [PubMed: 23373740]

Murphy DJ 1992 Safety and health for production agriculture: American Society of Agricultural Engineers.

Neff R, and Fry J. 2009 "Periodic Prompts and Reminders in Health Promotion and Health Behavior Interventions: Systematic Review." Journal of Medical Internet Research 11: e16.

NIOSH. 2007a Have you heard? Hearing loss caused by farm noise is preventable.

NIOSH. 2007b They're your ears: Protect them: Hearing loss caused by farm noise is preventable.

NIOSH. 2009 National agriculture, forestry, and fishing agenda.

NwETA. 2013 Northwest Education and Training Assessment cTRAIN eLearning Software.

Olson R, Anger WK, Elliot DL, Wipfli B, and Gray M. 2009 "A New Health Promotion Model for Lone Workers: Results of the Safety and Health Involvement for Truckers (SHIFT) Pilot Study." Journal of Occupational and Environmental Medicine 51: 1233–1246. [PubMed: 19858740]

Olson R, Grosshuesch A, Schmidt S, Gray M, and Wipfli B. 2009 "Observational Learning and Workplace Safety: The Effects of Viewing the Collective Behavior of Multiple Social Models on the Use of Personal Protective Equipment." Journal Safety Research 40: 383–387.

Perry MJ, and May JJ. 2005 "Noise and Chemical Induced Hearing Loss: Special Considerations for Farm Youth." Journal of Agromedicine 10: 49–55.

Peskin MF, Shegog R, Markham CM, Thiel M, Baumler ER, Addy RC, Gabay EK, et al. 2015 "Efficacy of It's Your Game-Tech: A Computer-Based Sexual Health Education Program for Middle School Youth." The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine 56: 515–521. [PubMed: 25739520]

Pretlow RA, Stock CM, Allison S, and Roeger L. 2015 "Treatment of Child/Adolescent Obesity Using the Addiction Model: A Smartphone App Pilot Study." Childhood Obesity (Print) 11: 248–259. [PubMed: 25760813]

Reed DB, Browning SR, Westneat SC, and Kidd PS. 2006 "Personal Protective Equipment Use and Safety Behaviors Among Farm Adolescents: Gender Differences and Predictors of Work Practices." The Journal of Rural Health: Official Journal of the American Rural Health Association and the National Rural Health Care Association 22: 314–320.

Reed DB, Kidd P, Westneat S, and Rayens M. 2001 "Agricultural Disability Awareness and Risk Education (AgDARE) for High School Students." Injury Prevention 7: i59–i63. [PubMed: 11565974]

Reed DB, Westneat SC, and Kidd P. 2003 "Observation Study of Students Who Completed a High School Agricultural Safety Education Program." Journal of Agricultural Safety and Health 9: 275–283. [PubMed: 14679876]

Renick KM, Crawford JM, and Wilkins JR. 2009 "Hearing Loss Among Ohio Farm Youth: A Comparison to a National Sample." American Journal of Industrial Medicine 52: 233–239. [PubMed: 19089836]

Rocha CH, Santos LHD, Moreira RR, Neves-Lobo IF, and Samelli AG. 2011 "Effectiveness Verification of an Educational Program About Hearing Protection for Noise-Exposed Workers." Jornal da Sociedade Brasileira de Fonoaudiologia 23: 38–43. [PubMed: 21552731]

Saunders GH, Frederick MT, Silverman S, and Papesh M. 2013 "Application of the Health Belief Model: Development of the Hearing Beliefs Questionnaire (HBQ) and its Associations with Hearing Health Behaviors." International Journal of Audiology 52: 558–567. [PubMed: 23682849]

Seixas NS, Neitzel R, Stover B, Sheppard L, Daniell B, Edelson J, and Meischke H. 2011 "A Multi-component Intervention to Promote Hearing Protector Use Among Construction Workers." International Journal of Audiology 50: S46–S56. [PubMed: 21091403]

Sprince NL, Zwerling C, Lynch CF, Whitten PS, Thu K, Logsden-Sackett N, Burmeister LF, Sandler DP, and Alavanja MCR. 2003 "Risk Factors for Agricultural Injury: A Case-Control Analysis of Iowa Farmers in the Agricultural Health Study." Journal of Agricultural Safety and Health 9: 5–18. [PubMed: 12673912]

Suter AH 2009 "The Hearing Conservation Amendment: 25 Years Later." Noise and Health 42: 2–7.

Verbeek JH, Kateman E, Morata TC, Dreschler WA, and Mischke C. 2014 “Interventions to Prevent Occupational Noise-Induced Hearing Loss: A Cochrane Systematic Review.” International Journal of Audiology sup253: S84–S96. [PubMed: 24564697]

Zhan W, Cruickshanks KJ, Klein BEK, Klein R, Huang GH, Pankow JS, Gangnon RE, and Tweed TS. 2010 “Generational Differences in the Prevalence of Hearing Impairment in Older Adults.” American Journal of Epidemiology 171: 260–266. [PubMed: 20008889]

Table 1.

Sociodemographic characteristics of the participants who completed both baseline and follow-up activities.

	Classroom training (n=12)	Classroom+App training (n=20)	Computer training (n=18)	
Variables	**Mean (SD) or % (N)**	**Mean (SD) or % (N)**	**Mean (SD) or % (N)**	**p value**
Age	17.1 (0.6)	17.7 (0.8)	17.0 (1.0)	0.08
Gender (male)	75.0 (9)	70.0 (14)	72.2 (13)	0.95
Ethnicity (white)	100.0% (12)	100.0% (20)	100.0% (18)	NA
Race (Caucasian)	100.0% (12)	100.0% (20)	88.9% (16)	0.45
Individuals in home (>4)	41.7% (5)	25.0% (5)	27.8% (5)	0.59
Farmers in home (>2)	41.7% (5)	35.0% (7)	50.0% (9)	0.80
Beds in home (>3)	41.7% (5)	60.0% (12)	66.7% (12)	0.51
Father works on the farm	83.3% (10)	60.0% (12)	77.8% (14)	0.29
Father works off the farm	58.3% (7)	75.0% (15)	50.0% (9)	0.50
Mother works on the farm	50.0% (6)	30.0% (6)	50.0% (9)	0.54
Mother works off the farm	83.3% (10)	65.0% (13)	100% (18)	0.02 *
Father's education (high school or below)	58.3% (7)	60.0% (12)	50.0% (9)	0.73
Mother's education (high school or below)	33.3% (4)	55.0% (11)	16.7% (3)	0.05 *
Non-family members employed on farm	41.7% (5)	30.0% (6)	33.3% (6)	0.79
Years working in agriculture (≥10)	58.3% (7)	55.0% (11)	66.7% (12)	0.76
Months in the last year working in agriculture (≥9)	91.7% (11)	65.0% (13)	61.1% (11)	0.46
Hours per week working in spring 2013 (≥20)	50.0% (6)	50.0% (10)	50.0% (9)	>1.00
Hours per week working in fall	50.0% (6)	50.0% (10)	55.6% (10)	0.93
2013 (≥20)				

* *p* values from chi-square test after comparing characteristics between groups.

Table 2.

Baseline and follow-up knowledge scores for the three training groups.

Outcome variables		Classroom training (n=12) Mean percent score (SD)	Classroom plus app training (n=20) Mean percent score (SD)	Computer training (n=18) Mean percent score (SD)	p values between groups
Total Knowledge Score	*Baseline*	64.58 (19.12)	54.00 (25.99)	60.83 (21.57)	0.42
	Follow-up	78.75 (11.10)	70.25 (20.23)	80.83 (11.01)	0.10
	Change from Baseline to Follow-up	14.16 (20.76)	16.25 (29.77)	20.00 (19.55)	0.80
	***p* values within group**	**0.04** *	**0.03** *	**<0.001** *	
Hearing Protection-Related Knowledge Score	*Baseline*	69.44 (28.28)	55.83 (27.19)	55.56 (24.25)	0.30
	Follow-up	83.33 (14.21)	68.33 (26.98)	81.48 (12.64)	0.06
	Change from baseline to follow-up	13.89 (31.65)	12.50 (34.99)	25.93 (19.99)	0.34
	***p* values within group**	0.16	0.13	**<0.001** *	
Ways to Avoid Noise Exposure Knowledge Score	*Baseline*	70.83 (23.44)	56.25 (36.16)	66.67 (28.44)	0.38
	Follow-up	64.58 (19.82)	62.50 (20.68)	65.28 (17.44)	0.09
	Change from baseline to follow-up	−6.25 (28.45)	6.25 (38.79)	−1.39 (31.47)	0.58
	***p* values within group**	0.46	0.48	0.85	
Noise Intensity-Related Knowledge Score	*Baseline*	56.94 (21.86)	53.33 (28.92)	62.04 (23.44)	0.58
	Follow-up	87.50 (14.43)	78.33 (22.36)	87.04 (14.64)	0.25
	Change from baseline to follow-up	30.56 (25.46)	25.00 (31.76)	25.00 (24.42)	0.84
	***p* values within group**	**0.002** *	**0.002** *	**<0.001** *	
General Hearing Health-Related Knowledge Score	*Baseline*	62.50 (19.94)	50.00 (26.90)	61.11 (26.04)	0.28
	Follow-up	75.92 (16.71)	68.75 (25.49)	86.11 (15.39)	0.03 *
	Change from baseline to follow-up	10.42 (16.71)	18.75 (36.16)	25.00 (25.72)	0.41
	***p* values within group**	**0.05** *	**0.03** *	**<0.001** *	

* and bold text: significant *p*-values (<0.05) for the difference between baseline and follow-up scores within an intervention group.

* only: significant difference between intervention groups.

Table 3.

Baseline and follow-up attitude scores for the three training groups.

Outcomes		Classroom training (n=12) Mean percent score (SD)	Classroom plus app training (n=20) Mean percent score (SD)	Computer training (n=18) Mean percent score (SD)	p values between groups
Total Attitude Score	*Baseline*	3.83 (0.76)	3.71 (0.42)	3.79 (0.70)	0.85
	Follow-up	4.18 (0.47)	4.08 (0.51)	4.33 (0.41)	0.26
	Change from Baseline to Follow-up	0.35 (0.62)	0.36 (0.55)	0.53 (0.65)	0.62
	***p* values within group**	0.08	**0.01** *	**0.003** *	
Hearing Protection-Related Attitude Score	*Baseline*	3.68 (0.75)	3.46 (0.53)	3.75 (0.76)	0.40
	Follow-up	4.10 (0.55)	3.96 (0.58)	4.17 (0.49)	0.49
	Change from baseline to follow-up	0.42 (0.72)	0.49 (0.59)	0.41 (0.87)	0.93
	***p* values within group**	0.07	**0.001** *	**0.05** *	
Self-Efficacy-Related Attitude Score	*Baseline*	3.98 (0.70)	4.09 (0.55)	3.94 (0.80)	0.80
	Follow-up	4.25 (0.49)	4.23 (0.54)	4.57 (0.51)	0.10
	Change from baseline to follow-up	0.27 (0.60)	0.14 (0.74)	0.53 (0.80)	0.12
	***p* values within group**	0.15	0.41	**0.004** *	
Consequences of Hearing Loss-Related Attitude Score	*Baseline*	4.00 (0.79)	3.82 (0.58)	3.70 (0.86)	0.57
	Follow-up	4.28 (0.40)	4.15 (0.75)	4.37 (0.53)	0.53
	Change from baseline to follow-up	0.28 (0.83)	0.33 (0.70)	0.67 (0.66)	0.25
	***p* values within group**	0.27	**0.05** *	**<0.001** *	

*and bold text: significant *p*-values (<0.05) for the difference between baseline and follow-up scores within an intervention group.

Table 4.

Baseline percentage of participation in noise-producing activities for the three training groups.

Outcome variable	Classroom training (n=12) % involved (n)	Classroom with app training (n=20) % involved (n)	Computer training (n=18) % involved (n)	p value
Low noise tasks (<90 dBA)				
Hay chopper	29.2% (7)	37.5% (9)	33.3% (8)	0.71
Driving a tractor with a cab	22.2% (8)	41.7% (15)	36.1% (13)	0.88
Operating a grain vacuum	50.0% (6)	25.0% (3)	25.0% (3)	0.05 *
Working with a silage blower	44.4% (4)	33.3% (3)	22.2% (2)	0.27
Dairy-milking	0.0% (0)	25.0% (1)	75.0% (3)	0.21
High noise tasks (<90dBA)				
Working in a feed mill	22.2% (2)	33.3% (3)	44.4% (4)	0.84
Using electric shop tools	23.3% (10)	41.9% (18)	34.9% (15)	0.80
Working in a hog confinement building	43.8% (7)	12.5% (2)	43.8% (7)	0.01 *
Driving a tractor without a cab	25% (10)	37.5% (15)	37.5% (15)	0.77
Using a lawn mower and/or weed whacker	25% (12)	41.7% (20)	33.3% (16)	0.16
Hunting and target shooting	24.3% (9)	37.8% (14)	37.8% (14)	0.86
Grain handling	21.6% (8)	37.8% (14)	40.4% (15)	0.52
Using a chain saw	21.9% (7)	40.6% (13)	37.5% (12)	0.89

* Significant difference between intervention groups.

Table 5.

Baseline and follow-up percentage of farm tasks conducted with hearing protection by the three training groups.

	Classroom training		Classroom plus app training		Computer training			
Outcome variables	**N**	**Mean percent score (SD)**	**N**	**Mean percent score (SD)**	**N**	**Mean percent score (SD)**	**p values between groups**	
All farm tasks (all three noise levels)								
Baseline	12	19.54 (26.56)	20	30.73 (34.84)	18	33.70 (37.5)	0.52	
Follow-up		32.25 (35.60)		42.29 (41.34)		67.11 (31.72)	0.03 *	
Change from baseline to follow-up		12.70 (17.70)		11.55 (53.46)		33.42 (40.69)	0.24	
***p* values within group**		**0.03** *		0.35		**0.003** *		
Low noise tasks (≤90 dBA)								
Baseline	7	10.11 (17.32)	10	22.14 (37.56)	13	23.08 (34.55)	0.67	
Follow-up		27.38 (34.93)		45.00 (49.72)		44.88 (47.81)	0.68	
Change from baseline to follow-up		17.26 (25.95)		22.85 (58.30)		21.79 (44.42)	0.97	
***p* values within group**		0.13		0.25		0.12		
High noise tasks (above 90dBA)								
Baseline	11	23.71 (28.21)	20	36.51 (37.61)	18	41.14 (43.17)	0.46	
Follow-up		36.80 (42.47)		45.55 (41.66)		76.78 (35.00)	0.01 *	
Change from baseline to follow-up		14.28 (20.88)		9.04 (57.84)		35.65 (46.24)	0.22	
***p* values within group**		**0.05** *		0.49		**0.001** *		

* and bold text: significant *p*-values (<0.05) for the difference between baseline and follow-up scores within an intervention group.