An Intervention to Reduce Occupational Health Risk from Antibiotic Resistant Pathogens Among Dairy Farm Workers

Research

Olivia Chao[1], John Shutske[1,*], Elsie Gonzalez[1], Danielle Veeser[1], Emily Diaz Vallejo[1], Ajay Sethi[1], Tony Goldberg[1], Ashley Kates[1], Mary Jo Knobloch[1], Juliana Leite de Campos[2], Pamela Ruegg[2], Nasia Safdar[1], Andrew Steinberger[1], Garret Suen[1], Amanda Young[1]

[1] University of Wisconsin, Madison, Wisconsin, USA.
[2] Michigan State University, East Lansing, Michigan, USA.
[*] Correspondence: shutske@wisc.edu

HIGHLIGHTS

- This intervention utilized the Health Belief Model and Theory of Planned Behavior to address the knowledge and social barriers that increase dairy farm workers' risk to antimicrobial-resistant infections.
- Dairy farm workers gained a significant increase in knowledge of the 8 desired outcomes, related to occupational health skills that reduce risks, from our intervention.
- Limited time was a major barrier as to why dairy farm workers felt like they could not make behavioral changes that would reduce their occupational health risk.
- Dairy farmworkers showed a strong likelihood of making workplace health-related behavioral changes, but their intention to change was weaker in areas of personal antibiotic stewardship.

ABSTRACT. *This study focused on developing and evaluating an educational intervention designed to mitigate occupational health risks associated with pathogens and antibiotic-resistant bacteria among dairy farm workers. Data collected from farms and workers as part of a larger umbrella project that focused on dairy farm antibiotic use for cows and calves were used to inform elements of the Health Belief Model and the Theory of Planned Behavior, leading to eight intervention outcomes. The intervention targeted increased knowledge and promoted behavioral changes related to worker and workplace hygiene best practices, PPE use, biosecurity, and personal antibiotic stewardship. Educational materials included instructional videos, fact sheets in English and Spanish, and*

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supplementary printed material, including illustrated take-home points, content summaries, and posters. The intervention was conducted with 32 workers from five dairy farms, using pre- and post-intervention assessments to measure knowledge gains and behavioral intentions. Results demonstrated statistically significant increases in knowledge across all targeted outcomes (p-value ≤ .001), with most participants showing a high willingness and likelihood to implement recommended behaviors related to their workplace exposures and best practices. However, participants indicated a greater reluctance to change around issues of personal antibiotic stewardship. Time constraints were the most significant and most consistent barrier to behavior change. The study highlights the importance of ongoing research and refinement of intervention strategies to address barriers and enhance protective practices among often underserved farmworkers in agriculture. These intervention strategies contribute to improved occupational health outcomes with benefits to public health by reducing the spread of antibiotic-resistant infections to the broader population.

Keywords. *Antibiotic resistance, Dairy farmworkers, Educational intervention, Infectious disease, Occupational health.*

In recent decades, there has been growing global concern in human medicine and public health about antimicrobial resistance as pathogens evolve as a natural consequence of antimicrobial use (Frieri et al., 2017). Note that for this article, the term antimicrobial includes antibiotic drugs and the potential for antibiotic resistance, a phenomenon where bacteria can become resistant to these products through mutations and ongoing genetic selection. Resistance can lead to adverse health outcomes for animals and people. Even though some types of antimicrobials are not considered antibiotics, the term “antimicrobial resistance,” or AMR, is often used in the literature, and antibiotic resistance as it relates to these products being administered on dairy farms will be described in this article as AMR. The agricultural sector has received considerable AMR attention as antibiotics are commonly used in food animal production to treat or prevent disease (Mann et al., 2021; Aslam et al., 2021). The role of the dairy industry in AMR has been previously studied (Virto et al., 2022). The use of antibiotics on dairy farms can lead to the development of resistant organisms that can directly infect workers (often through infected cows and calves) with bacterial pathogens that can be found in manure, animal body fluids, water, or on object surfaces (fences, gates, production equipment, concrete, etc.). The resistant organisms can enter the human body through ingestion or via droplets that come into contact with the eyes, ears, or nose. From a public health perspective, it is also possible that a resistant infection can move from an ill worker to family members, cohabitants in the same household, neighbors, or others who have not come in direct contact with the farm (Godijk et al., 2022; Martak et al., 2024). It is also possible that a farmworker can inadvertently move bacteria or resistance-conveying genes from resistant pathogens to locations and possible hosts off the farm through contaminated work clothing, boots, PPE, and other objects and by not following appropriate hygiene practices such as handwashing or laundering soiled clothing on the farm and wearing clean clothing home.

This study recognizes AMR as a significant and understudied agricultural occupational health concern (Karwowska, 2024; de Jon et al., 2022; Dignard and Leibler, 2019; de Jong et al., 2022). The protective occupational health intervention developed and evaluated for farmworkers in this project also has the potential to reduce public health risks. If we minimize worker illness risk from dairy pathogens, we can reduce the risk of person-to-person spread for those off the farm with whom workers come in contact. By promoting protective practices, we also reduce the risk that workers will carry infectious pathogens or resistance-conveying genes to those off the farm on clothing, footwear, skin, etc.

The multi-disciplinary team responsible for this study has previously examined the overarching issue of AMR on dairy farms using a systems approach that examined total annual on-farm antibiotic use for cows and calves on 40 large Wisconsin dairy farms (250 or more cows) with workers (de Campos et al., 2021). Subsequent work occurred with a subset of eight of these farms, with four considered "high intensity" users of antibiotics in cows and calves (based on annual per-animal doses for cows and calves) and four considered "low intensity" use. As a part of the preparation for the work described in this article, focus groups and other mixed methods were used to examine baseline knowledge, work practices, and worksite resources available to farmworkers (Kates et al., 2021).

This article reports on an educational intervention embedded in the larger umbrella research project. The intervention was designed with farmworker occupational health in mind, knowing the bonus potential to reduce public health risks. It focuses on specific outcomes intended to positively influence practices and behavioral intentions for occupational health and boost AMR protection and general dairy farmworker health knowledge, topics that are novel for many farmworkers on the front lines of production agriculture. The purpose of this study was to evaluate the effectiveness of the education intervention.

Materials and Methods

Recruiting Workers to Participate in Intervention

The original 40 farms were selected from a pre-existing list of farms that had participated in previous dairy studies led by the authors of this article. To be eligible, the farm needed to have ≥250 lactating dairy cows and needed to have used antimicrobials to treat or prevent at least one event in the past year. Additionally, participating farms needed to be using computerized herd management software that tracked all veterinary treatments. From the original 40 farms, the eight that participated in other aspects of the study represented the four "low intensity" of antimicrobials among the original 40 farms and the four "high intensity" farms. The farms that participated in the final intervention were from those eight high- and low-use farms, with representative farms from each. The overall study protocol is explained in Leite de Campos (2021). To provide perspective, the 2022 Census of Agriculture (USDA NASS, 2022) found that there were 6216 dairy farms (with milk cows). Of these 23.3% of farms had 200 or more cows, but those farms (1449 in total) had 77.3% of all of the milking cows in the state. Additionally, larger farms (above 200 cows) are highly likely to have hired non-family workers.

Farm managers from the eight farms that participated in the earlier-cited focus group study and worker health interviews were contacted by telephone to invite their workers to participate in the intervention pilot, which included delivering all intervention educational content in person and having participants complete the evaluation instrument with needed assistance and clarification from the instructor. Six farms responded, all willing to participate. Based on the timing and availability of training staff (a bilingual dairy production educator/consultant also involved in the intervention's development) and farm availability, the intervention was offered on five farms. Employees were provided written invitation materials in English and Spanish posted at the farms. A $25 gift card was provided to workers as an incentive for workers to participate. Thirty-two workers on five farms participated in the entire program and evaluation. All were Spanish-speaking. The workers' countries of origin were Mexico, Guatemala, Nicaragua, and Honduras. Research by Valenzuela (2020) reveals that the majority of large dairy farms in Wisconsin employ non-family hired farmworkers, predominantly from Mexico (89%), with smaller percentages from Central America (10%) and a few from the USA (1%). The study also found that Spanish is the preferred language among dairy farmers.

Recruitment, incentive, and consent protocols, both at the farm employer and worker (employee) levels, were reviewed and approved by the University of Wisconsin-Madison's IRB. The IRB approval included a thorough review of all educational content and evaluation instruments, including the translated Spanish content.

Development of Intervention and Assessment Tools

Preliminary Research Used to Create the Intervention

Mixed methods were used to gather information from 60 farmworkers through focus groups and worksite observations of facilities, and approximately 80 workers participated in one-on-one health and knowledge-related interviews (Kates et al., 2021). There was an overlap in these two groups of 60 and 80 workers from the eight study farms. However, the degree of overlap is not fully known as the team did not track workers' names or other personal identifiers due to issues of privacy and requirements by IRB. These information-gathering efforts focused on workers' understanding of general health knowledge, work practices, management support, workplace resources, and practices connected to both animal and personal use of antibiotics. Information about workplace resources included the availability of PPE, on-farm laundering facilities, handwashing resources, dedicated lunchrooms, safe food storage refrigerators, antibiotic storage cabinets/dedicated refrigerators, and overall workplace layout. This initial assessment led to the development of a dairy-specific conceptual model based on the SEIPS (Systems Engineering in Patient Safety), a model previously created for use in human healthcare settings (Holden and Carayon, 2021). The dairy-based SEIPS adaptation is as shown in figure 1.

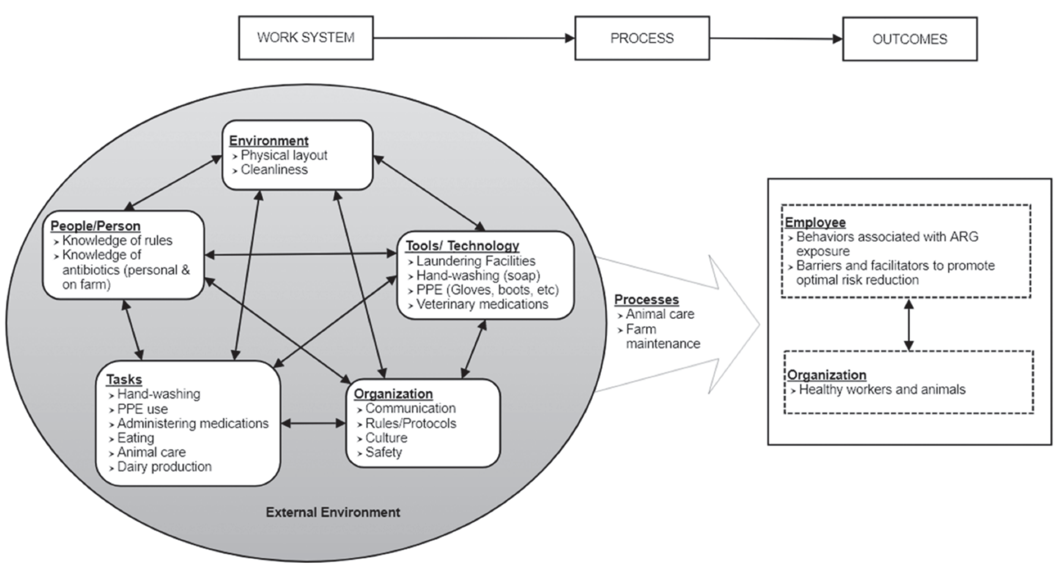

Figure 1. Dairy-focused SEIPS Model from Worker and Worksite Assessment (adapted from Kates et al., 2021).

As a result of this initial work, the team focused on rural/agricultural health and assessed the available data to develop an educational intervention targeted toward areas where gaps in knowledge or best practices existed and where the most significant gains could be made to protect workers from infectious disease. This included reducing worker risks connected to AMR through personal infection and their possible role and risk to others, contributing to public health AMR risk (for example, NOT wearing home manure-soiled work clothing). There was also recognition that while we were trying to reduce exposure to AMR pathogens and resistance-conveying genes in the production environment, we also needed to actively promote the stewardship of "personal-use" antibiotics, another significant public health issue that is tangled together with the role of farm-related AMR stemming from farm occupational health and animal health practices.

Grounding the Intervention in Theory

The educational intervention was based on the Health Belief Model and the Theory of Planned Behavior. The Health Belief Model (HBM) shown in figure 2 is a commonly used grounding public health, behavioral change construct often used to ground agricultural safety and health interventions in areas that have included general safety and health literacy and pesticide safety and exposure reduction (Afshari et al., 2021).

As the development team considered the Health Belief Model (HBM), information gathered from workers in the first stages of the project was mapped against key elements of the HBM, helping to create desired intervention outcomes and the content to be included in materials. This mapping of worker-based information included these questions developed by the research team:

- Perceived susceptibility: Could I get sick as a worker from pathogens? If so, could AMR impact my illness in terms of severity or duration? What about the risk for my family or other loved ones?
- Perceived severity: Will I lose income if I get sick or am affected by AMR pathogens? What will my medical bills be? Will loved ones be harmed? If I get sick, will I lose leisure time? How might I be harmed if I spread the infection into the

Concept	Definition	Potential Change Strategies
Perceived susceptibility	Beliefs about the chances of getting a condition	• Define what population(s) are at risk and their levels of risk • Tailor risk information based on an individual's characteristics or behaviors • Help the individual develop an accurate perception of their own risk
Perceived severity	Beliefs about the seriousness of a condition and its consequences	• Specific the consequences of a condition and recommended action
Perceived benefits	Beliefs about the effectiveness of taking action to reduce risk or seriousness	• Explain how, where, and when to take action and what the potential positive results will be
Perceived barriers	Beliefs about the material and psychological costs of taking action	• Offer reassurance, incentives, and assistance; correct misinformation
Cues to action	Factors that activate "readiness for change"	• Provide "how to" information, promote awareness, and employ reminder systems
Self-efficacy	Confidence in one's ability to take action	• Provide training and guidance in performing action • Use progressive goal setting • Give verbal reinforcement • Demonstrate desired behaviors

Graphic adapted from US-HHS. (2005). *Theory at a Glance: A Guide for Health Promotion Practice.*

Figure 2. Health Belief Model for Occupational Safety and Health and Public Health Promotion.

community? How about my children, family, or neighbors? How would my employer and co-workers be affected?

- Perceived benefits: If I act desirably to protect my health or public health, will there be any benefit or incentive? Recognition? Job security? Lowered risk of personal illness?
- Perceived barriers to action: Do I know how to reduce risk? Are there workplace cultural factors or norms that might hinder my ability to act in a desired way? Can I access the facilities needed (handwashing, clean eating location, protective gloves, onsite work clothing laundry)? Are there time pressures that will impede healthy actions? Do I have moral support and encouragement from my employer and co-workers?
- Cues to action: Is health-related information easily available and applicable (including language)? Does my employer support health-related actions and provide reminders and ongoing training?
- Self-efficacy: If I act in ways that are supposed to reduce risk, will my actions realistically protect my health or that of others?

The Theory of Planned Behavior (TPB), also a common agricultural safety and health construct, shown in figure 3, was used to ground several of the questions from the above list related to norms, beliefs, motivation, and perceptions.

But the main reason for incorporating the TPB was that behavioral intentions are an essential precursor to actual behavior change and successful intervention outcomes (Colémont and Van den Broucke, 2008; Petrea, 2001; Pirmoghni et al., 2024). In our evaluation, there was a focus on motivating positive behavioral intention leading toward the planned outcomes (per the TPB) and also understanding the specific barriers and obstacles in areas where there was less success in altering behavior (per elements in the HBM).

Intervention Outcomes

The intervention development team formulated eight outcomes based on gathered information and known AMR risk factors from previously cited work.

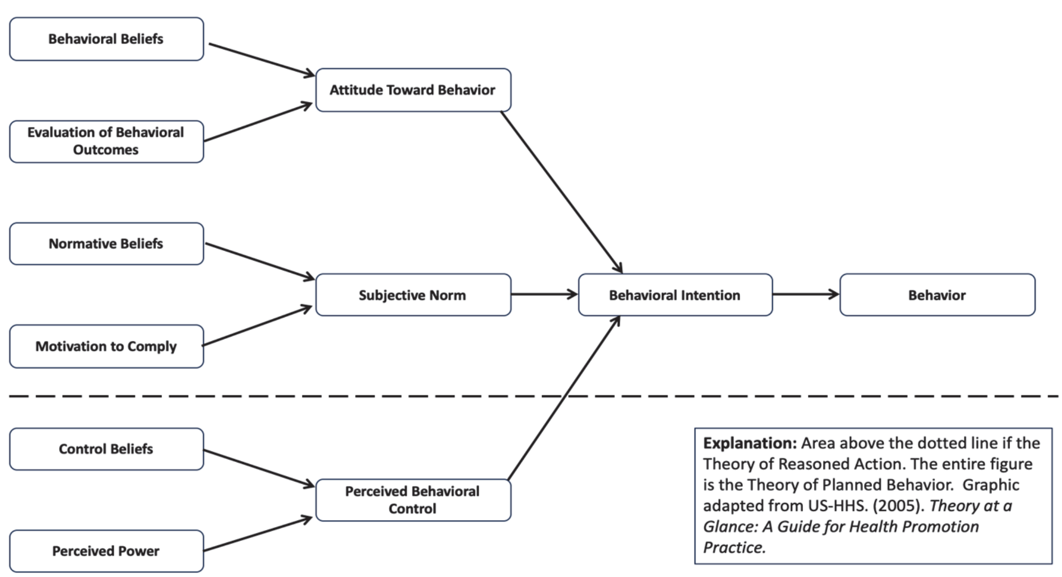

Figure 3. Theory of Planned Behavior.

Following their participation in the educational intervention, dairy farmworkers on participating farms were expected to:

1. Increase the frequency of washing hands with soap and water before consuming food and after using the bathroom throughout the workday.
2. Increase the use of a designated area for consuming food at work.
3. Store food in a lunchroom or other safe, dedicated storage space.
4. Increase the frequency of protective glove use when performing all dairy work tasks involving contact with animals, their body fluids, or manure.
5. Wear only designated work clothes and shoes that will stay at the farm and launder all work clothing in employer-provided facilities.
6. Leave the workplace every day with clean, non-work clothing and clean shoes.
7. Handle animal health medicines (for those employees doing so) in full accordance with a veterinarian's recommendations.
8. Only use personal health antibiotics per healthcare provider prescription and instructions (including not sharing antibiotics and completing the entire course of prescribed drugs).

Educational Content

The educational program consisted of six instructional videos, each with an average length of five minutes, available in English and Spanish (12 videos total). These videos covered the importance of pathogens and infection from work exposures, differences between bacteria and viruses, preventing antibiotic resistance, proper personal hygiene and sanitation techniques (focused on meals and bathroom use), correct use of personal protective equipment (PPE) with a focus on gloves, basic animal biosecurity protocols, the importance of laundering work clothes at the worksite, and the importance of veterinarian oversight with any animal drug used on the farm. The videos also included content offered that covered personal antibiotic stewardship for prescribed human antibiotics to be taken only for bacterial infections. A 12-page review guide was created with information that paralleled the video content and provided support material that could be posted in key areas (such as handwashing facilities and lunchrooms). The poster-style materials in the guide were intended to address the need for the HBM's call for accessible "cues for action." The guide included prompts for conversation, discussion, and questions that paralleled and reinforced video content. The viewing, discussing, and reviewing of the videos was designed with a 60–90 minute delivery time in mind. For this pilot intervention evaluation study, an additional 30 minutes were allocated for the program evaluation and debriefing.

Program Evaluation

To gauge the intervention's efficacy, all 32 workers participated in two hours of program delivery and evaluation. The evaluations were given on paper and consisted of a pre- and post-knowledge assessment (available in both English and Spanish) taken after the intervention (retrospective) with questions aligned with the eight planned outcomes. Both the pre- and post-knowledge assessments occurred after a break that immediately followed the intervention. Work by Bhanji (2012) informed the retrospective pre/post approach. To address potential reading comprehension barriers, a facilitator read the evaluations aloud to the participants, was available to privately address any individual questions, and the language used in the evaluations was simplified.

The assessment had seven questions aligned with program outcomes. Participants indicated their degree of knowledge before and after the complete program on a simple threepoint scale of knowledge, with "none" getting a score of 0, “low” a score of 1, “some” a score of 2, and "expert" a score of 3.

The next portion of the evaluation examined the worker’s willingness and likelihood to embrace specific changes post-intervention. Responses were categorized as "less willing" (-1), "same" (0), or "more willing" (1) for willingness to make specific changes in practices, and "less likely" (-1), "same" (0), or "more likely" (1) for the likelihood of making the same set of changes. This portion of the evaluation contained behavioral intention questions per the TPB to discern participants' willingness to adopt specific practices as well as their likelihood of acting on these same practices connected to the outcomes. The reason for assessing willingness and likelihood in separate sets of questions was to recognize that a worker might be open and willing to make changes but, for whatever reason, might be less likely to make those same changes. Recognizing that the degree of likelihood might be less than willingness, we also added questions in the evaluation about potential barriers to change that might allow us to understand differences in their willingness/likelihood responses. These possible barriers included:

- Negative pressures or perceived feelings from the supervisor
- Negative pressures or perceived feelings from co-workers
- Lack of needed supplies (such as soap and paper towels)
- Lack of facilities (lunchroom, laundering facilities)
- General workplace and workflow time pressures

Results and Discussion

Results

The workers who participated in the program expressed excitement about participating and learning about human/personal health. In some prior visits connected to other aspects of the overarching research project farm visits, workers occasionally mentioned being pleased that researchers cared about their personal health, not just cow and calf health. The research team had also previously noted a heightened interest in occupational health, PPE, infectious disease, and other workplace health hazards due to heightened sensitivity because of COVID-19 as the pandemic began about two years into the overall project. Note that the intervention development, delivery, and evaluation occurred in 2023, and farm visits for data collection and environmental sampling occurred from 2019–2022 with significant pauses due to the pandemic.

Comparing pre- and post-knowledge assessments, workers exhibited a statistically significant increase in knowledge across all seven questions, indicating notable progress in boosting knowledge around targeted outcomes (p-value $\leq .001$) using a paired t-test that considered all 32 participants. Figure 4 shows the overall average self-reported knowledge scores pre- and post-training. Table 1 shows the actual mean calculated differences in the same seven areas of knowledge along with the actual calculated level of significance (2-tailed as calculated by SPSS). Before the training, workers averaged a score close to 1, indicating low knowledge about the seven questions. After the program, participants averaged a score above 2, indicating a slightly higher than moderate level of knowledge for all questions.

In figure 5, black bars correspond to the workers’ willingness to change after the educational training. In most categories, both willingness and likeliness to change were greater than 0.8, indicating that almost all the workers were more willing and likely to make

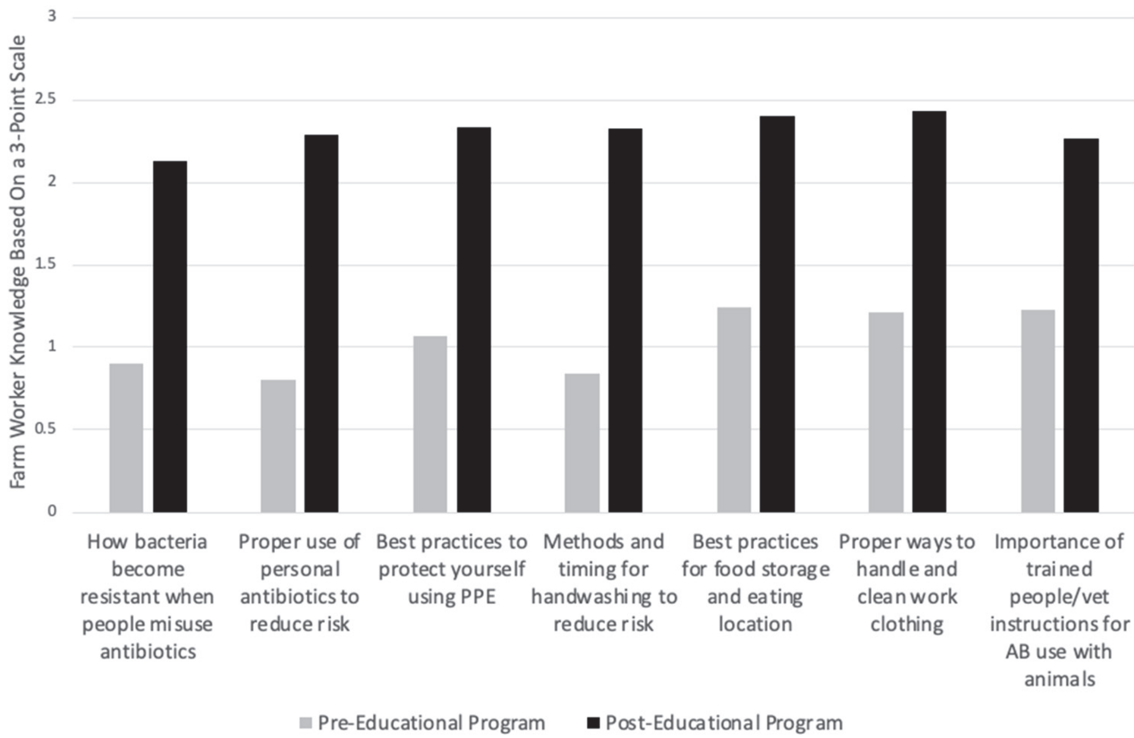

Figure 4. Farm Worker's Self-Assessed Knowledge for the Intervention Outcomes.

Table 1. Pre- and Post-Intervention Self-Assessed Knowledge Means and Differences.

Knowledge Area	Mean Score Pre	Mean Score Post	Difference in Pre/Post	Paired t-test sig. (2-tailed)
How bacteria become resistant	0.90	2.13	1.23	<.001
Proper use of personal antibiotics	0.81	2.29	1.48	<.001
Best practices to protect yourself using PPE	1.07	2.33	1.27	<.001
Methods and timing for handwashing to reduce risk	0.84	2.32	1.48	<.001
Best practices for food storage and eating location	1.24	2.40	1.16	<.001
Proper ways to handle contaminated work clothing	1.21	2.43	1.22	<.001
Importance of trained people/vet instructions for animal AB use	1.23	2.27	1.04	<.001

behavioral changes after the educational program. In "Only take antibiotics when you have had them prescribed by a health professional" and "Wash your hands before eating any meal or snack," every worker was more willing to make behavioral changes, resulting in an average score of 1.0 and a standard deviation of 0.

The one category where workers' average score was less than 0.8 was the willingness and likeliness to "Never share antibiotics with another friend, family member, or co-workers." For this question, 25 workers were more willing to change after the educational training; however, six were less willing to change. For the likelihood responses related to antibiotic sharing, 21 of the workers were more likely to change, nine workers expressed the same likelihood, and two workers expressed that they were less likely to change after the educational program. Note that the y-axis of figure 5 goes negative because of the possibility that mean values for change could have reflected mean negative change (but did not).

The final portion of the survey asked workers about potential barriers that impacted their likelihood of change. This was an important issue to ask about, and it had been predicted

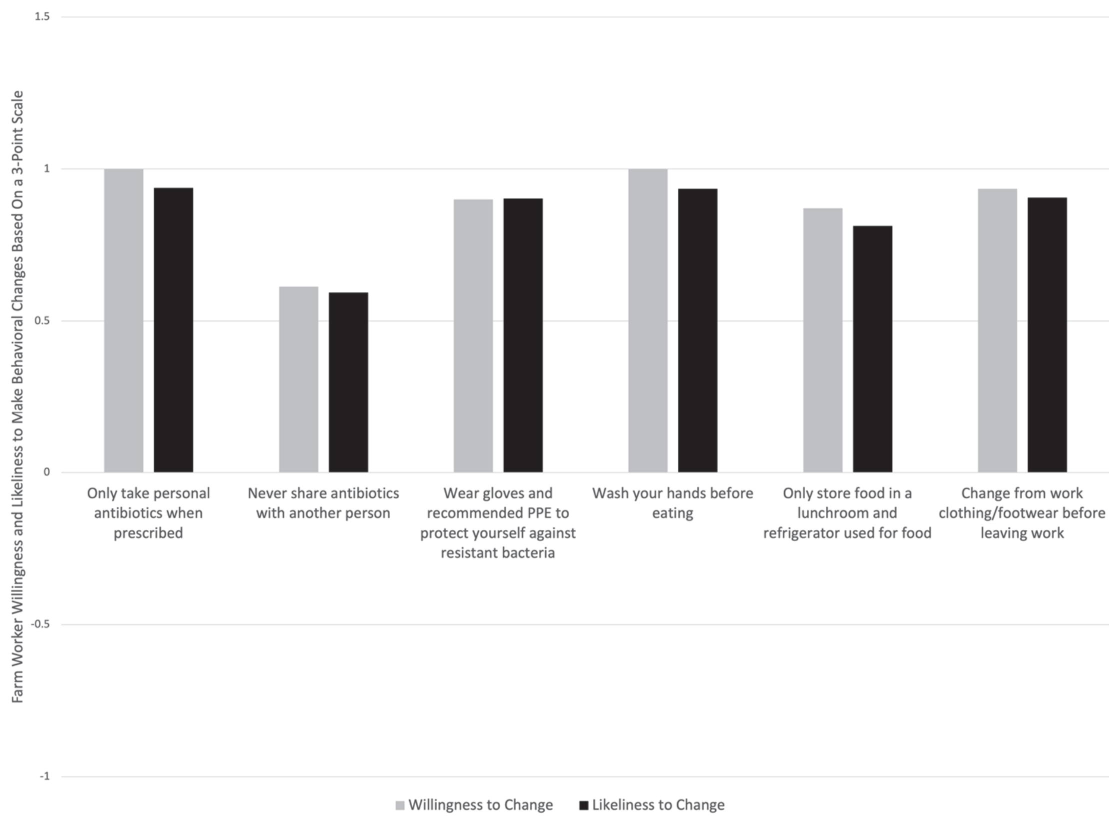

Figure 5. Willingness and Likelihood of Farm Workers to Make Behavioral Changes.

that there would be gaps between "willingness and likelihood" of change. The question was, "Why?" Examining the possible barriers was also important, given the role of barriers in the Health Belief Model. The gray bars in figure 6 correspond to the percentage of workers who responded that the barrier or factor "never" impacted their likelihood of making changes. The black bars correspond to the percentage of workers that felt the factors "sometimes/yes" had affected their change likelihood. In every category, more than half of the workers expressed that sometimes/yes those factors were barriers to behavioral change. Time pressures were the most critical and often cited. This is not a surprise given the "busyness" of any dairy farm activity (milking, maternity tasks, caring for calves, moving animals, feeding, etc.) and the fact that many dairy operations are understaffed due to economic conditions and difficulties finding workers. Based on previous focus groups, the issues of "pressure" from others, including supervisors and co-workers, are often rooted in perceived time pressure, and it should be noted that workers frequently cited "perceived" pressure rather than overt statements, actions, policies, etc.

Additional statistical analysis was used to examine the relationships between willingness and likelihood of behavioral change more closely as they related to the barrier information provided. Linear regression found that those who were both willing and likely to make all recommended changes were influenced if they stated that they NEVER faced barriers due to a "lack of supplies" ($R^2 = 0.44$, $\beta = 0.61$, $p < 0.001$). Similarly, there were connections for those willing and likely to make changes related to perceived pressures from co-workers at all levels (Yes, Sometimes, Never) – ($R^2 = 0.43$, $\beta = 0.71$, $p < 0.001$), meaning that less perceived co-worker pressure was related to positive changes. Similarly,

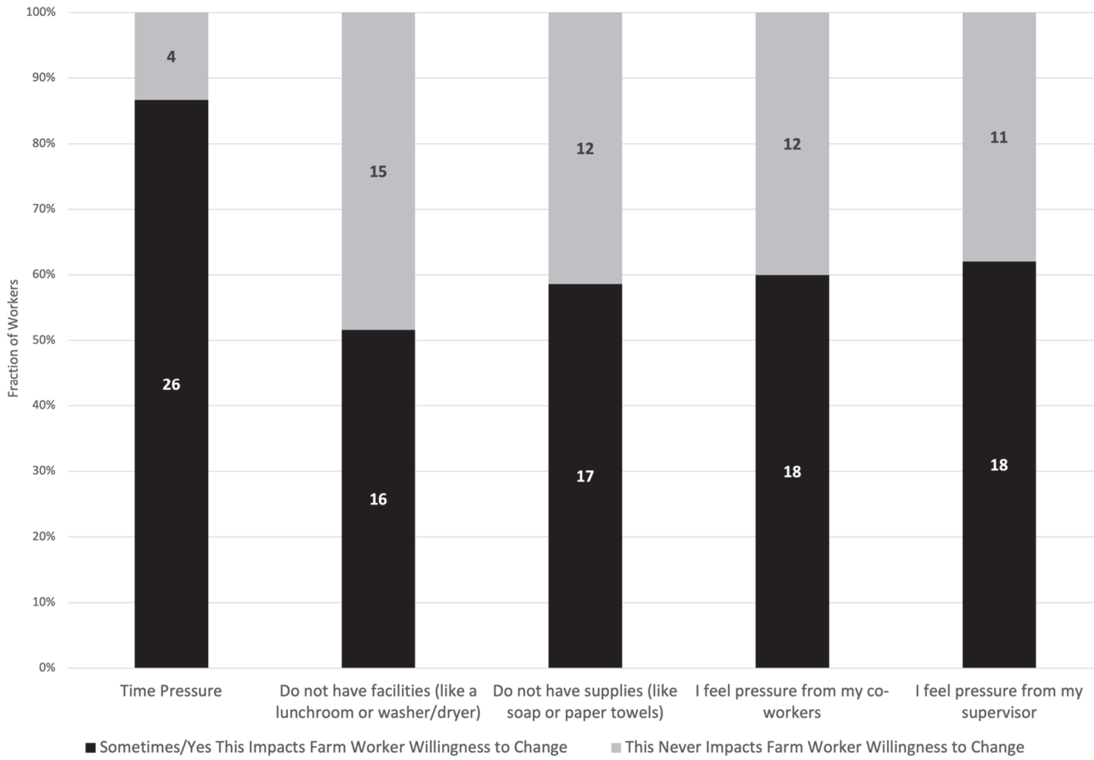

Figure 6. Barriers That Impact Workers and Their Ability to Engage in Risk-Reducing Behaviors and Actions.

there were connections at all levels of willingness and likeliness when perceived supervisor pressure was indicated to be NEVER ($R^2 = 0.52$, $\beta = 0.65$, $p < 0.001$).

Discussion

The study presents an intervention that addresses the occupational health risks associated with infection and AMR and the actions that have the potential to reduce public health risks. The intervention and its evaluation were part of a more extensive, multi-year study that included an assessment of antibiotic use on 40 large dairy farms and then following back with high and low-antibiotic-use farms to assess the risk of exposure to AMR by doing manure and environmental sampling and working on occupational health issues with a total of more than 80 farm workers, 32 of whom participated in this intervention project.

The intervention aimed to give farmworkers the knowledge and skills to protect personal health and reduce exposure to and spread of antibiotic-resistant bacteria. Parts of the intervention also helped workers understand the importance of making judicious use of resources and practices that already exist on many large dairy farms. Examples of pre-existing resources included dedicated lunchrooms, laundering facilities, handwashing facilities and supplies, and the requirement imposed on many farms for protective plastic glove use. Many of these standard practices and facilities are in place to reduce animal infection, but by reinforcing their use, there is also a solid potential to reduce human risk.

The multi-disciplinary research team, including investigators from engineering, dairy science, human medicine, veterinary medicine, microbiology, infection control, and epidemiology, worked together to ground the educational efforts using several sets of data and the common desire to reduce individual worker and public health risk. The uniting frameworks to aggregate data and develop outcomes and methods were the Health Belief Model and the Theory of Planned Behavior. The team was surprised to see the positive level of farmworker engagement and interest. As stated, the COVID-19 pandemic seemed to have created a highly teachable moment that persisted over two years.

After the two-hour pilot intervention, workers expressed interest in additional workplace health (and safety) topics. Despite the busy activity level, pressures, and stress seen in any modern agricultural production operation, farm owners and operators cooperated and supported their workers' participation. This level of positive engagement was observed throughout the project, including the initial inventorying of on-farm antibiotic use, worker focus groups and interviews, and ongoing manure and environmental sampling for pathogens and resistance genes. Part of the positive engagement was due to the research team having ongoing face-to-face contact with each farm over an extended period and the pre-existing relationships with nearly all of the original 40 farms who were part of the umbrella study.

The knowledge increase measured by self-reported, subjective content knowledge was not surprising. The team used retrospective pre-post methods to recognize that people often “don’t know what they don’t know” when administering a “pre-intervention” pre-test. That is, give a pre-intervention knowledge assessment; they may intuitively feel that they have a high degree of knowledge but later learn that they do not. Given the enthusiasm of participants and eagerness to participate, increasing knowledge was not difficult, and the knowledge gains were likely boosted because the topics covered (bacteria vs. viruses; how resistance develops; why PPE is used; handwashing; clothing/footwear cleaning; etc.) are not topics that are typically part of training that occurs on dairy farms. This meant that baseline knowledge was relatively low to start with. In fact, several workers indicated never having had exposure to these topics. Workers told the intervention team that they were grateful that videos were directly narrated in Spanish and that there was a native Spanish-speaking facilitator who also appeared frequently in the videos.

The research team relied heavily on self-assessed behavioral intentions to assess the potential for actual intervention-based behavior change. Initially, pre-COVID, the project intended to measure intervention impact over several months by collecting participant stool samples pre- and post-intervention. This would have allowed us to directly measure the effectiveness of the educational intervention without relying on a self-assessment. However, these protocols needed to be abandoned during the pandemic, which compressed the timing and caused changes in the initial plans. Given this limitation and the previous data that had been collected through focus groups and health interviews, examining the possible differences between behavioral change intention willingness and likelihood was necessary and strongly supported by the TPB. Examining barriers at least partially explained some of the gaps between the willingness and likelihood indicators. In the future, if access permits, a full-scale evaluation could include directly measuring pathogen exposure (through stool samples or other measures) and measuring changes in the use of hygiene supplies (soap, paper towels, laundering facility use, etc.).

Learning that time was a significant factor in acting in healthy/safe ways is likely not viewed as a surprise, but we were able to quantify it as a barrier for almost 90% of workers. The perceived (or actual) pressures from supervisors and co-workers are most likely connected to time pressure. Time constraints certainly appear to influence many agricultural safety and health practices, whether related to wearing PPE or following injury-prevention measures, such as turning off power when working with machinery. More conversation and research are needed to overcome this barrier, including considering safe designs that incentivize taking extra time to perform tasks safely. In this case of dairy worker time pressures, the barrier could be partially addressed through frequent communication between workers and managers, acknowledging that some health-related actions will require time but that time spent to reduce risk is valued as an investment in the farm's overall well-being and success. Other options could include adding facilities and resources to make healthy actions easier and result in less time requirement. Examples could include adding handwashing stations or designated lunch areas, improving quick and convenient access to gloves and supplies, or providing other essential resources on large farms, where geographic spread can make some best practices more time-consuming.

In terms of the original intent of this overall project—reducing risk connected to AMR, it is critical to note that despite information contained in the videos, study guide, and conversations, in the end, workers exhibited relatively less willingness and likelihood to refrain from sharing personal antibiotics used for human health as compared to their desire on other categories and desirable occupationally-focused practices connected to the farm and dairy animals. This observation warrants further exploration in subsequent research or education. This finding may not seem relevant in a project focused on AMR connected to farm work practices and exposure to pathogens and resistant genes in the workplace. However, it suggests that even if these workers achieve 100% "compliance" on workplace practices but fail to change behaviors on personal antibiotic stewardship, the "individual use" of medicine gaps could wash out any progress made on the farm side. Understanding why workers persist in sharing personal antibiotics despite awareness of their detrimental consequences could inform the development of more targeted interventions to address this specific behavior. Additional information on addressing this issue can be found in Dobson et al. (2017) and Wu et al. (2022).

A limitation of this study is the potential influence of the Hawthorne effect, wherein participants may alter their behavior due to awareness of being observed. Consequently, farm workers might have provided favorable responses or exaggerated their willingness to implement behavioral changes, influenced by the in-person delivery of the evaluation and direct interactions with instructors. Additionally, participant bias could have affected the results, as individuals may have tailored their responses to align with perceived researcher expectations, potentially inflating short-term outcomes without guaranteeing sustained behavioral changes. Lastly, while the participants' countries of origin mirrored those of the broader Wisconsin workforce, they may not fully represent all farm workers in the state.

Conclusion

The intervention, grounded in the Health Belief Model and the Theory of Planned Behavior, addressed individual knowledge, perceptions, and workplace norms. The intervention significantly increased the farm worker's knowledge on how to prevent the development and spread of antibiotic-resistant infections. After the intervention, farm workers expressed a strong willingness and likeliness to apply the knowledge they had gained from the educational program into practice. The one area where farm workers were less willing and likely to change was sharing antibiotics with others, despite being aware of the associated risks. Additionally, farm workers identified time constraints as the main barrier to translating the knowledge they had gained in the educational intervention into action. By improving farmworker knowledge and encouraging best practices related to antibiotic resistance on dairy farms, this intervention will promote safer practices that benefit both the workers and their surrounding communities.

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