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International Dairy Health and Safety

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EDITORIAL

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INTRODUCTION AND BACKGROUND

Dairy has had a transformational impact on humans. Most mammals lose the ability to digest lactose after infancy. Between 5000 and 10,000 years ago, the LCT (lactase) gene underwent rapid evolution in human populations in northern Europe, eastern Africa, and the Middle East, allowing domesticated milk products to become an important dietary staple.[1–3] Adaptation of improved plows and changes in the way work was organized allowed the Nordic countries to develop a successful dairy export industry in the 13th century. This dairy industry (structure) was well positioned to meet the increased demand from smaller populations left in Europe following the Black Death (1347–1351). Development of mechanical milking technology and pasteurization in the 19th century was another milestone, greatly increasing efficiency and safety to meet the demand in growing cities.

The past two decades have again seen dramatic changes in the dairy industry that are playing out on a global scale. Advances in milking technology and dairy animal science have facilitated a rapid increase in the size of dairy herds. Operations with 400 to 5000 head of milking cows are not uncommon in the United States, European Union, China, Russia, South Africa, Australia, and New Zealand. Given the economies of scale, this trend is spreading worldwide as the demand for dairy protein grows. Expanding dairy production has required a larger workforce, most often consisting of immigrant labor, often with little experience in agriculture. Dairy farming is also among the most dangerous occupations, with high rates of injury, illness, and employee turnover. For dairy farmers trained to manage cows, the operation of a modern dairy employing a large immigrant workforce is a daunting challenge. The global market is highly competitive. To

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succeed, the dairy industry must sustain a healthy, productive workforce.

In 2009, the High Plains Intermountain Center for Agricultural Health and Safety (HICAHS) partnered with the Southwest Center for Agricultural Health, Injury Prevention, and Education (SWAG) to host the High Plains and Mountain Region Dairy Health and Safety Workshop, October 15–16, 2009, in Denver, Colorado. In addition to HICAHS and SWAG personnel, workshop attendees included faculty from the Swedish University of Agricultural Sciences, dairy extension specialists, dairy owners and managers, dairy equipment manufacturer, workers' compensation provider, and dairy producer organizations. Results of this workshop made it clear that we needed to go beyond our previous etiological and formative work to take the next steps in addressing the dairy industry's need for more comprehensive occupational health and safety programs, including risk assessment, surveillance, health care delivery, and effective interventions. It was also quite clear that this was a global need.

In response, we organized an International Dairy Research Consortium to collaborate with other international researchers involved in improving the health and safety of dairy workers. Our first meeting was in Colorado in July 2011. This consortium is intended to facilitate collaborations and to share successful injury and illness prevention strategies, tested dissemination channels, and novel approaches used to improve the health and safety of dairy workers globally. Such leveraging of resources will augment dairy research efforts and lead to greater impact regionally, nationally, and internationally. To date, members of the consortium represent the United States, Sweden, Finland, Denmark, Germany, Italy, Canada, The Netherlands, Australia, and New Zealand. Seven of the National Institute for Occupational Safety and Health (NIOSH) Agriculture Forestry and Fishing Centers are active in the consortium.

The goal of this special issue of the *Journal of Agromedicine* is to provide a comprehensive review of the status of the dairy industry, highlight current occupational health and safety research, and identify knowledge gaps and programmatic needs.

HIGHLIGHTS

The feature article describing the modern global dairy industry by Douphrate and colleagues provides the context for this issue. It addresses the growing demand for dairy protein and the unique ways that the industry has responded with changes in technology, work organization, producer cooperatives, trade regulations, and other economic strategies from a global standpoint and for selected key dairy producing countries. The commonalities and differences between markets and countries are explored. The article highlights the impact of worldwide shifts in water demand, land use patterns, food versus fuels, internationalization, and the major demographic shifts in immigrant workers.

Four articles on respiratory health, ergonomics, injury and fatality, and psychosocial and mental health summarize and evaluate current literature concerning the prevalence and risk factors for these health outcomes. Each of these papers also sought to address successful interventions.

Reynolds and 11 of his colleagues explored the impact of the dramatic changes in the dairy industry on respiratory health of workers. Workers in modern dairy operations exhibit obstructive respiratory conditions, including lower baseline pulmonary function, and cross-shift declines that are similar to, but not as prevalent as, those found among swine and poultry workers. Inhalation exposure to gram-positive bacteria and their chemical constituents (e.g., peptidoglycan) in dairies is much higher than previously thought, and there is strong in vitro evidence demonstrating their inflammatory effects. The exposure-response relationship between aerosols and respiratory effects in dairy workers is modulated by intrinsic factors such as genetic polymorphisms. There has been very little research on the application or effectiveness of intervention strategies to reduce worker inhalation exposures on dairies. Future research needs to include development of improved methods to measure inhalation exposure to aerosols and inflammatory lung changes among dairy workers; better understanding of the relationships between early immune changes and development of future lung disease; longitudinal studies of respiratory effects associated with dairy workers' personal measures of task-specific exposure to aerosols; evaluation of the role of intrinsic factors, especially gene-environment interactions, and underlying health status, particularly obesity; and development and testing of solutions to reduce dairy farm worker exposure to inflammatory aerosols.

The paper "Ergonomics in Modern Dairy Practice" (Douphrate et al.) describes the development of the industry and the challenges regarding increasing size of dairy operations and working conditions with high levels of exposure for ergonomic risk factors. It also points out the ergonomic research performed and the future needs involving new technologies for exposure studies in large-scale operations as well as automatic milking systems. It is also made clear that work-related mental stress and fatigue is a growing problem in new systems due to the need for farmers to conduct continuous monitoring to prevent mechanical breakdown. These new factors and their impact on worker health also need further study. In particular, risk factors contributing to upper extremity diseases (wrist and shoulder) need to be better understood, and controlled.

"Work-Related Injuries and Fatalities on Dairy Farm Operations" by Douphrate and coauthors highlights significant gaps in data available to make international comparisons. What data are available have important limitations and there is no harmonized system for injury recording. Research from Sweden, Australia, New Zealand, the United States, and China is summarized. Dairy farming is clearly among the most hazardous of occupations. Technological changes, including manure handling and storage systems, and the greatly increased use of all-terrain vehicles (ATVs)/quad bikes have been associated with high rates of fatalities on dairies along with tractors and other machinery. Even on modern dairies with increased artificial insemination, bulls remain a major source of injuries and fatalities. An important outcome of the use of immigrant workforce is that younger, less experienced workers are at greater risk. Future research should focus on better understanding and controlling risks associated with manure handling systems, ATVs, and other machinery. Evaluations of improved facility designs are also important to minimize slip, trips, falls, and injuries/fatalities from contact with livestock including bulls. Creation of a global database for injuries and fatalities among dairies would facilitate evaluation of the effectiveness of interventions.

Lunner Kolstrup et al. point out the commonality of stressors and physical and mental health outcomes shared across countries in their article on psychosocial working conditions, mental health, and stress. There are differences between owners and their workforce, and between smaller traditional dairies and large modern dairies, but globally, dairy farmers face a multitude of expectations and stressors, including high workload and time pressure, shift work, challenges involving immigrant and multigenerational workforces, financial debt, and other economic, regulatory, and social factors. Farm operators, workers, and their families manifest increased levels of poor mental health, depression, substance abuse, and suicide. An important point is that there is a need to find a balance with positive aspects, including the perception of meaningful work, independence, and level of control. There is a need to better understand factors contributing to stress in this rapidly changing industry. Research is also needed to develop and test interventions, including mental health care and programs, to help producers identify and manage stress and mental health.

Three papers address approaches to reduce occupational health and safety risk on dairies—including guidelines for animal handling, occupational health and safety (OHS) regulations, and leadership and management.

A disproportionate number of severe injuries and fatalities occur from contact with dairy cattle. Dairy bulls in particular are reputed to be most aggressive and dangerous. Lindahl et al. ("Occupational Health and Safety Aspects of Animal Handling in Dairy Production") provide a review of current research on livestock-related injuries on dairy farms, and share lessons learned from studies of human-animal interactions in relation to animal welfare and productivity. A key factor in animal response causing injury in humans is fear. Interestingly, the animal's perception of rank or status is also important, e.g., it is hypothesized that dairy bulls may see humans as competitors not handlers. Understanding an animal's "flight zone" or personal space, point of balance, range of vision, and need for consistent routines is important in reducing the risk of creating stress or fear that can lead to kicking, head butting, or flight. The concept of "low-stress livestock handling" has been associated with increased productivity, and can utilize the animal's behavior as a tool to improve safety. Other tools to maintain a safe distance or restrain animals are available, but there is a need for extensive appropriate training of handlers. The increasing numbers of dairy workers with minimal livestock handling skills requires development of effective safety management programs.

The paper on occupational health and safety (OHS) regulations by Reed and colleagues shows that the application of OHS legislation in the dairy industry varies throughout the world. A key issue is the size of the farm, as in the United States where the federal OHS legislation and enforcement does not apply to farms with less than 11 employees. In Italy, health surveillance of employed workers is mandatory, but this does not include self-employed and family workers who constitute the majority (90–95%) of the workforce. In these and other countries, there is a significant inequality in access to health care structures. The limited access to health surveillance, moreover, deeply affects also the quality of epidemiological data, which come from a minority of workers, and makes it impossible to assess the real burden of disease for specific risk factors. The paper concludes that there is little OHS legislation in the world that applies directly to the dairy industry. A final recommendation is that there needs to be an effective OHS training for all involved in dairy work.

Hagevoort, Douphrate, and Reynolds ("A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms") found very few publications addressing the effectiveness or return on investment of occupational health and safety risk management in any industrial sector, including dairy. There is recognition in the industry that "good dairy farming practice ensures that milk is produced by healthy animals in a manner that is sustainable and responsible from the animal welfare, social, economic and environmental perspectives,"[4] but the sustainability of a healthy productive workforce is seldom specifically included. Managers on expanding dairies worldwide often have little training or experience in managing *people*. The transition to human resource management, especially with a largely immigrant workforce, is challenging and stressful. Lessons from other industries and the few studies of OHS management approaches on dairies suggest that there can be a competitive edge, but there is pressing need for studies evaluating OHS program effectiveness and the connection to productivity and profitability. Systematic approaches to risk management, including transformational (positive) leadership and integration of OHS with animal welfare, food safety, and productivity, need to be developed and evaluated.

GAPS AND RESEARCH NEEDS

Risk Factors and Health Care

There are major gaps in dairy research and data related to a variety of health outcomes such as zoonoses, dermatoses, and cardiovascular disease. As noted in "Systematic Review of Respiratory Health Among Dairy Workers" (Reynolds et al.), it is important to understand the multiple extrinsic and intrinsic factors that affect the health of dairy workers. Along with health outcomes there is a need to evaluate exposures to agents such as sanitizers (e.g., iodine), pesticides, hydrogen sulfide, ammonia, and other chemicals where there is again a paucity of peer-reviewed publications. Although Lunner Kolstrup et al.'s article on psychosocial and mental health touches on health care for the dairy industry, there is again a major gap in the literature on health programs and their effectiveness. A recent change in the US Migrant Clinic system to specifically include dairy workers is an important step that needs to be evaluated and optimized.

Immigrant Workforce

Although a few articles focusing on particular health outcomes indicate that immigrant workers are at higher risk for respiratory disease and injuries, there is little work in the peer-reviewed literature specifically addressing the core issues for immigrant workers on dairies. “A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms” calls out the need for culturally and linguistically appropriate risk management systems, but found little published evidence of successful examples in the dairy industry. “Occupational Health and Safety Regulations in the Dairy Industry” points out that even in countries with well-developed workplace health surveillance systems, dairy workers are often excluded for a number of reasons. The psychosocial article by Lunner Kolstrup et al. noted that these workers face different psychosocial work environments than domestic workers, including long work hours in a foreign country away from their family and friends, and social isolation caused by linguistic and cultural barriers. These conditions are often found to be associated with ill mental health, anxiety, depression, alcohol and drug abuse, and even suicide. One possible way forward is to explore engaging the “highly educated fraction” often present among these workers. Those who have high education in their countries usually have their education (in some cases degrees) not recognized in the country of migration for legal reasons. Akin to the *promotoras* approach in the United States, they are a potential resource for training and other programs. The Guest Editorial, “Occupational Health in the Dairy Industry Needs to Focus on Immigrant Workers, the New Normal” (Schenker and Gunderson), shines a spotlight on this critical issue, discussing the magnitude of the workforce transformation and factors such as “precarious employment” and cultural and legal aspects that contribute to the increased risks afflicting this workforce.

Effective Interventions

All of the papers in this issue note the paucity of peer-reviewed publications regarding effective interventions. There has been very little published regarding effective engineering, organizational, medical, education, or managerial strategies specifically for the dairy industry. An integrated approach to OHS risk management would provide a systematic framework to address many of the gaps identified.

CONCLUSIONS AND RECOMMENDATIONS

Dairy in the 21st century is a dynamic industry, depending largely on immigrant employees working long hours at a high pace, under difficult environmental and social conditions. This collection of articles addresses broad aspects of OHS in dairy, especially highlighting important gaps in knowledge. Research is needed to develop and evaluate cost-effective solutions that address the business model of the dairy industry and the challenges of the largely immigrant workforce. Given the common issues around the globe, future research requires international collaboration to provide economies of scale, ensure robust methodology, and produce products and interventions with optimal impact. We believe this special issue of the journal will be a resource to help guide future research to enhance the health and sustainability of the dairy workforce.

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Occupational Health in the Dairy Industry Needs to Focus on Immigrant Workers, the New Normal

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Occupational Health in the Dairy Industry Needs to Focus on Immigrant Workers, the New Normal

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This journal issue focuses on the many health and safety outcomes associated with dairy work, including changes resulting from new technologies associated with modern, larger dairies. However, there is another more dramatic change that has occurred in the dairy industry and that has an even more profound impact on the ultimate goal of improving the health and safety of dairy workers. That change is the transition to an immigrant workforce, a transformation that has occurred over the past 10 to 15 years. In the United States, this has largely been a transition to immigrant Latino workers, whereas elsewhere in the world other immigrant ethnic groups represent this transition. For example, growth in the large New Zealand dairy industry has been largely sustained by increasing the migrant workforce, half of whom come from the Phillipines.[1] Immigrant labor is becoming an increasingly important part of agriculture and animal husbandry in the European Union, particularly since the 2005 EU enlargement. Over 40% of agricultural workers in Italy are from outside the European Union, with the remainder coming from EU countries. In some regions of Italy, the majority of cow milkers come from India. Similarly across the EU countries, unique immigration patterns exist for each country, but all the countries have the similar reality that an increasing percentage of agricultural workers, including dairy workers, are immigrant.

The magnitude of this transition to an immigrant workforce in the global dairy industry is documented in the paper in this volume, "A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms." But even this paper by Hagevoort, Douphrate, and Reynolds, though recognizing that immigrant workers face challenges of low education levels, illiteracy, and culture and language barriers, does not address some of the core issues nor provide serious discussion of tools to improve their health and safety. It is critical that efforts to improve health and safety in dairies address the unique health needs, and social, cultural, and legal realities of immigrant workers.

Sadly, there is a centuries-old history of immigrant workers suffering a greater burden of fatal and nonfatal occupational injuries and illnesses than do nonimmigrant workers.[2,3] This history is reflected in higher fatal and nonfatal occupational injury rates. In the United States, this can be seen in the major industries with large immigrant workforces—agriculture, construction, transportation, and domestic service. These industries have higher occupational injury and more severe disability than do other major industrial sectors. Even within industry sectors,

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immigrant workers have higher fatality rates than do nonimmigrant workers in the same job categories. Unfortunately, there has been little research on the occupational health of immigrant workers, and most of the limited research has been done in the United States.

Why do immigrant workers have worse health and safety outcomes at work? One major finding of recent research is that "precarious employment" is a contributing factor.[4] Precariousness refers to the lack of employment security, a typical condition of immigrant workers that is most extreme for those who are undocumented. Such workers, particularly those fearful of immigration law enforcement, may take greater risks at work, not complain about unsafe conditions, and work without appropriate safety equipment and procedures. Even mental health and other chronic conditions may be worse among workers with precarious employment. Other factors contributing to worse health outcomes include low salary and working two or more jobs, limited or absent health care, language barriers, and lack of transportation.[5]

The largest immigrant population in the United States is of Latino origin, which now represents over 50 million people, or 16% of the population.[6] This is a dramatic increase over the past decade, during which time over half the growth of the US population was due to Latinos. Although three fourths of Latinos live in the West and the South, other parts of the country such as the Midwest and Northeast have experienced dramatically increased growth rates of Latinos.

Agriculture has always been a first occupation for immigrants, and that continues to be the case in the United States as immigrants make up an increasing percentage of farm labor. Thus, the farm labor workforce is now 40% immigrant for the country as a whole, but in some areas such as California immigrants make up over 85% of the agricultural workforce. This transition is dramatically reflected in the dairy industry. Over the past decade, immigrant workers have increased to 70% of the milk production workforce.[7,8] Increases in this largely Latino population are expected to account for all growth in the industry in coming decades.[9]

Why is it important to understand the changing nature of the workforce to improve health and safety among dairy workers? Quite simply, different approaches are needed to address health and safety among immigrant, often non–English-speaking workers. The traditional focus of health education programs on "Anglo farm families" is a model that won't work with this new workforce. However, the demographic transition among dairy workers has been so rapid that health and safety personnel experienced in working with immigrant workers are limited or nonexistent in some areas with large dairy industries such as the Midwest and the Northeast. The obvious first requirement is for health and safety personnel to be fluent in Spanish or other immigrant languages, but that is not sufficient. Establishing trust is a critical requirement that requires listening to workers and working with them to address their needs. The use of *promotoras* or lay health workers from the community is an effective tool to achieve many of these goals. Health care providers should also be knowledgeable about immigrant beliefs about health and disease, traditional medicine, and cultural beliefs.

Health care delivery and public health programs must also be tailored to the needs and realities of immigrant workers. This includes monitoring and studying the health of migrant workers, migrant sensitive health systems, creating policy and legal frameworks that enable, instead of blocking, health care for migrants, and even exploring multinational approaches to health care for this population.[10]

The dairy workforce *and* the workplace have both dramatically changed in the United States and other developed countries in the past two decades. Efforts to improve health and safety need to adapt to that changing reality. Most importantly, an understanding of occupational risk factors causing specific health problems (musculoskeletal injury, asthma, skin rash, infection, etc.) is not sufficient. A critical piece is the dairy worker. With immigrants representing the majority of dairy workers, understanding the causes of illness and injury need to take into account the different perceptions, understanding, and behaviors that may be associated with being an immigrant. Equally as important, efforts to prevent injury and illness, or to treat those outcomes when they do occur, need to be sensitive to the realities of the immigrant worker. It is perhaps worth recalling the Haddon matrix for injury prevention and intervention.[11] This model addresses the pre-event, event, and post-event factors associated with injuries. The intersecting factors influencing these phases of an injury are host, agent/vehicle, physical environment, and social environment. Clearly the host and social environment influences would be very different for the immigrant worker, and need to be addressed differently for the prevention and intervention efforts to improve health and safety of dairy workers.

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The Dairy Industry: A Brief Description of Production Practices, Trends, and Farm Characteristics Around the World

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SPECIAL FEATURE

The Dairy Industry: A Brief Description of Production Practices, Trends, and Farm Characteristics Around the World

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ABSTRACT. The global dairy industry is composed of a multitude of countries with unique production practices and consumer markets. The global average number of cows per farm is about 1–2 cows; however, as a farm business model transitions from sustenance to market production, the average herd size, and subsequent labor force increases. Dairy production is unique as an agricultural commodity because milk is produced daily, for 365 days per year. With the introduction of new technology such as the milking parlor, the global industry trend is one of increasing farm sizes. The farm sizes are the largest in the United States; however, the European Union produces the most milk compared with other global producers. Dairy production is essential for economic development and sustainable communities in rural areas. However, the required capital investment and availability of local markets

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and labor are continued challenges. Due to farm expansion, international producers are faced with new challenges related to assuring food safety and a safe working environment for their workforce. These challenges exist in addition to the cultural and language barriers related to an increasing dependence on immigrant labor in many regions of the world. Continued success of the global dairy industry is vital. Therefore, research should continue to address the identification of occupational risk factors associated with injuries and illnesses, as well as develop cost-effective interventions and practices that lead to the minimization or elimination of these injuries and illnesses on a global scale, among our valuable population of dairy producers and workers.

KEYWORDS. Dairy, international, worker health and safety

INTRODUCTION

In many respects dairy production may be viewed as being in a unique position compared with other sectors of agriculture. Milk is harvested every day, and this continuous production provides a regular source of revenue to producers around the world. Milk production is labor-intensive and provides employment opportunities for agricultural workers globally. Dairy producers are challenged with meeting a growing demand for dairy protein and products among an increasing global human population. The number of dairy producers is decreasing while dairy herd sizes continue to increase. The risk for occupational injury and illness in the dairy sector is high among producers and hired laborers. In order to appreciate the health and safety risks associated with dairy production, a description of the current global dairy industry is needed. The objectives of this paper are to provide a brief description of the unique features of dairy production, as well as provide profiles of dairy industries in major dairy producing countries around the world. Subsequent papers in this special edition will address specific issues and challenges related to worker health and safety in dairy production around the world.

UNIQUE FEATURES OF DAIRY PRODUCTION

The dairy industry has a number of features that distinguish it from the other sectors of agriculture. For example, milk is a liquid consisting of 87% water, which equates to a commodity with substantial mass that is produced daily, 365 days a year. Therefore, milk requires high-cost transportation unless or until it is condensed or transformed into cheese or powder. Dairy production is labor-intensive because the production and harvest of milk involves the husbandry of animals. Furthermore, milk is a perishable product with a limited shelf life, which requires it to be shipped and processed daily, limiting the opportunity for delayed marketing to obtain better pricing. Additionally, milk is potentially subject to adulteration, whereas the composition and quality of fresh milk is highly dependent on farm management practices. Strict and comprehensive quality regulations and enforcement are therefore customary, which is often more far-reaching and comprehensive than in other agricultural sectors.[1,2]

Another unique feature of the dairy industry involves the socioeconomic position of dairy producers. The vast majority of global farmers are small-scale producers, with a weak and vulnerable position on the dairy market. The nature of the business (involving a high percentage of fixed costs) means that they are only able to adjust to market changes in a limited, slow, and gradual way. Milk is harvested every day and provides a daily source of income despite limited control of the production and marketing process by the producer. At the same time, milk production is labor-intensive and provides many employment opportunities, not only on the farm, but also in the transport and processing of milk and the agricultural supplies and services sectors. For that reason, in many countries the dairy industry is considered to be vital for the sustainability of rural areas. Due to this factor and its economically vulnerable position (dairy producers are price takers not price setters), the dairy industry in several countries often enjoys the highest degree of economic protection. Additionally, dairy farming in several countries has come to be regarded as increasingly valuable in terms of nature and countryside conservation,[1,2] and a valuable source for agritourism.

Another unique feature of the dairy industry is the strong position held by cooperatives. Cooperatives often have different and varied functions. Some cooperatives receive, process, and market dairy products for producers. Many cooperatives provide very specific services such as distribution and retailing, whereas others only provide wholesale marketing of raw milk to other major processors. Producer-owned dairy cooperatives engage in a variety of activities to provide members an assured market for their milk. Cooperatives may negotiate prices for their processed products and assemble, haul, manufacture, and market dairy products to wholesalers, retailers, or in their own stores. For example, in the United States, milk marketing cooperatives have succeeded in building a strong position with a share of 80% of milk supply to the dairy processing industry, which consists mainly of private enterprises. Cooperatives, in addition to processing the milk, also have become increasingly alert to world market challenges and opportunities. Partnerships with large dairy product wholesalers and distributors are on the rise, mutually benefiting the producer and retailer. Producers and retailers benefit from the other's strengths in procurement or marketing. This is especially important with the short shelf life of fresh milk and the limited opportunities to defer sales. However, when milk is processed into various dairy products (butter, cheese, powder, etc.), deferred marketing to some degree becomes an option. As long ago as the 19th century, this market position led dairy producers to want a direct influence on the processing industry, on which their livelihood was, and still is, so crucially dependent. Any dairy operation, large or small, with such a vulnerable and difficult product as milk to deliver to market, still needs an assured outlet and guarantee of a known price.[1,2] Some countries such as Canada and EU nations have developed supply management programs to minimize farm price fluctuations and guarantee access to domestic markets. According to the International Farm Comparison Network (IFCN), the top five milk processing countries in terms of volume of milked processed globally are the United States, Germany, China, France, and India.[3]

Lastly, and most certainly not of lesser importance, dairy production is unique in that dairy cattle are efficient converters of crops such as grasses and fodder that are not suitable for human consumption into a high-quality, nutritious food product for human consumption. Too often ruminant animals such as dairy cows are disparaged worldwide as inefficient as compared with other livestock species (poultry, swine, etc.). The unique aspect about a dairy cow is the ability of the animal, in a symbiotic relationship with rumen bacteria, to convert plant resources largely indigestible by humans into milk, which is a high-quality source of nutrients for human consumption. Many of the protein and energy supplements fed to dairy cattle are by-products of human food processing such as distillers grains, soybean meal, and other food processing waste. Plant nutrients, which otherwise would have remained inaccessible and unavailable, would eventually have been returned to the land without utilization. The dairy animal's digestive system accelerates the first step of the decomposition process of remaining nutrients into organic material, providing a high-quality fertilizer with soil-enhancing capacities back to the farming operation. All that remains for producers is to balance the nutrient cycle in an efficient and sustainable fashion. A particular challenge to modern dairy farms is managing farm waste (manure management) in a sustainable and environmentally sound manner. Owners of farms with 200 or more cattle are often required to create and follow farm nutrient management plans (Concentrated Animal Feeding Operation Plans), which may restrict further herd expansion.

Over the years, the aforementioned factors have helped to form the very special position the dairy industry today occupies among all other sectors of agriculture. However, the great changes that are affecting the world as a whole are likewise leaving their mark on the dairy industry. The forces generated by these changes, such as increased world population, shifts in land use patterns, increased demands and competition for water use and water rights, increased demand for feedstuffs for ethanol production, a fast pace of technological progress, economic liberalization, increased regulatory pressure, privatization, horizontal integration and economy of scale, internationalization and globalization, and demographic shifts in immigrant workers, are also exercising a growing influence on the dairy industry.

MODERN DAIRY PRODUCTION AND PROCESSES

Traditionally, dairy operations were located close to urban areas so that milk could be sold fresh daily into cities and excess milk could be converted to cheese and butter. With the development of refrigeration tankers capable of hauling milk long distances to be processed, the need for daily market access was diminished, and dairy operations could relocate to more remote areas with a more preferable climate, more affordable land, and ample water availability. This has allowed dairies to grow and develop without the constraints that typify operating an agricultural operation in close proximity to large urban populations. A significant problem with farms near urban (even suburban) areas is conflict with nonfarm neighbors. Issues include noise, odors, and farm traffic on local roads.

Modern dairy operations seek to maximize the efficiency of the conversion of resources to product where inputs such as water and energy (in the form of feed) are converted to animal protein in the form of dairy products and eventually meat, depending on the local circumstances (such as climate) and availability and accessibility of these resources. These operations, because of economies of scale, tend to be large to very large. Farms may range in size from those with hundreds of cows in areas where additional labor is expensive or unavailable, to those with 2000–3000 cows in areas with ample access to land and water in close proximity.

Increasingly, certain tasks on the dairy are being automated. New technologies range from automatic feeding systems to cow separation systems and robotic milking, all utilizing the premise of individual electronic identification of the cow. Electronic cow identification can decide which pen a cow should be housed, if she needs to be separated for treatment or reproductive reasons, or simply how much feed she needs to receive based on her level of milk production and consumed feed. Additionally, temperature, location, and movement sensors can provide management with information predictive of cow health status, for example, if she is eating or drinking, or if her activity level coincides with the probability of her reproductive status.

The cost associated with providing feed to many animals is a major planning consideration. Dairy owners and managers plan to grow the majority of their feed requirements in close proximity to the farm to minimize transportation costs, and consequentially must plan to accommodate the application of nutrients produced by such a large number of animals. However, many farms in the United States and other countries (Japan, Middle Eastern counties, and increasingly so in China) must purchase a significant portion of their animal feed. In different parts of the United States, feed costs can exceed 50% of total operating costs. A well-developed nutrient management plan is essential for the long-term sustainability of dairy operations. Since the costs of housing facilities for a dairy operation are the second largest investment (behind the costs of the milking parlor), many large operations are constructed in areas with climates that allow cows to be comfortably housed outside, with low humidity, and preferably with moderate temperatures and favorable temperature differentials between day and night. These environmental conditions allow cows to more effectively dissipate heat at night. Elevated desert climates are ideal for these kinds of operations. Key to the success of these operations is ample water availability to support the growth of crops to feed cows. Less than 2% of the total water needs for a dairy operation is used for drinking water and cleaning purposes, and the remaining 98% is needed to provide growth of forage crops.[4] In some of the large-herd operations, adequate amounts of potable water can become a challenge. Another necessity on large operations is the availability of labor. As stated previously, about one employee is needed for every 80–100 cows on large US dairy farms.[5] Typically in the design of these operations, the number of animals is determined by the capacity of the milking parlor. Because of the high costs of a milking parlor, and in order to maximize return to investment, it is essential to maximize the throughput in a parlor in terms of cows per hour, accommodating time between pens twice a day for cleanup. Temperature-controlled bards to house cows can be built in areas where the climate is not conducive to large outdoor open-lot housing. Temperature is typically controlled by evaporative cooling of incoming air, systems that therefore are much more efficient in areas with low humidity versus areas with a high humidity. The investment costs per cow for these systems are much higher than open-lot housing systems, but can be offset by advantages in the operation such as lower feed costs due to water availability, land prices, or higher milk prices due to marketing advantages.

Milking Systems and Processes (Inside the Milking Barn)

Two types of milking systems are used in modern dairy production in industrialized countries: tie stall/stanchion and milking parlor systems. In stanchion systems, milking units are brought to a tethered dairy cow for milking, and milk is collected in a pipeline system. A worker stands between tethered cows where they kneel or squat to attach specialized milking equipment to the cow's udder. Tie stall/stanchion systems are common among farms with smaller herd sizes. In contrast, parlor systems involve cows being housed in dry-lot or loose housing facilities and moved into a milking parlor with stationary stalls where they are milked simultaneously with specialized milking equipment. Workers are located in a pit below the level of the milking platform. The number of cows milked at one time varies by parlor design. Parlor systems can accommodate large numbers of dairy cattle and therefore are used almost exclusively in large-herd dairy operations.[6] Three configurations are commonly used in parlors: parallel, herringbone, and rotary. These configurations present different workstation designs and may create different worker demands. As dairy farms increase their milking herd sizes, questions arise regarding the occupational health and safety issues among parlor workers. Acceptable worker comfort and safety in different milking systems becomes an issue when considering higher cow throughput rates combined with larger herd sizes. Work demands may increase in large-herd dairy operations due to more cows being milked per unit time compared with small-herd operations.[7] Large-herd farms (>500 cows) often operate milking parlors 24 hours a day to maximize parlor efficiency. This may entail milking three or more times per day, thus requiring additional hired labor. Modern large-herd milking systems may increase the physical workload, thus having an effect on the development of musculoskeletal disorders. Changes in work organization and pace also contribute to increased stress among managers and workers, and technology may modify (increase or decrease) other health outcomes such as respiratory and zoonotic diseases. Robotic milking is gaining in popularity as a practical alternative not only in smaller herds with several robotic milking stations available at every hour to the cows' discretion, but also in rotary parlor designs where cows are still moved to the parlor for milking, but the actual task of attaching and detaching milking machines is automated and computer-controlled. This would maximize the return on investment by spreading the costs across as many animals as possible, while reducing labor costs and limiting direct exposure to animals by milkers. An additional motivation to employ robotic milking technologies is the uncertainty of the availability of skilled milkers in many regions of the world.

GLOBAL MILK PRODUCTION IN SELECTED COUNTRIES

Farm Characteristics

Dairy farms and dairy production systems around the world are vastly different due to many of the external factors listed above, but one way to categorize and evaluate dairy production systems would be based on size either in terms of number of cows or volume of milk produced and sold. One approach to understand and appreciate the characteristics of modern dairy farms is to analyze farm sizes in different countries around the world. The International Farm Comparison Network (IFCN) Dairy Report of 2011 includes data and profiles for 90 countries, representing 98% of milk production worldwide. The top five milk-producing countries are India, United States, Pakistan, China, and Brazil; however, in countries such as India and Pakistan only a small fraction of that milk makes it to a processing facility. These 90 countries have an average herd size of only 3 cows per farm. This observation may be due to the fact that in developing and transition countries many small-scale dairy farms with 1–2 cows exist. Only 7 of the 90 countries have an average farm size of more than 100 cows. According to the IFCN Report, 78% of all farms and 56% of cows are represented by farm sizes of 1–2 cows. A large portion of milk produced on these farms is consumed by the family, with the remaining milk sold locally and often to an informal market. This selling of milk provides daily cash for family subsistence. Farm sizes of 11–100 cows represents 22% of all farms and 28% of cows. Most of these farms can be described as "family farms," as most of the work is performed by family members. The economic aim of these farms is to generate a sufficient income for family members. Farms with more than 100 cows represent only 0.3% of dairy farms and 16% of cows. Although still family owned, these farms can be described as "business farms," as most of the work is performed by hired labor coming from off the farm.[8] As farms continue to grow in size, the dependence on immigrant labor is a commonality globally, which presents new human resource management challenges related to cultural and language barriers.

Cow numbers in many parts of the world have decreased between 2007 and 2011 including the EU-27, the former Soviet Union, and Asia (China and Japan), which is more than likely a reflection of low milk prices worldwide in 2009 and first part of 2010. Cow numbers in North, Central, and South America remained fairly constant, whereas New Zealand and India saw a 16% and 18% increase in cow numbers, respectively.[9]

Dairy Production in the United States

The United States ranks second (behind EU-27) among major dairy (cow) producing countries in the world. The US dairy industry produces 14.6% of the world's milk supply, with an estimated 9.2 million cows.[10] The US dairy farm profile is unique as it relates to most other dairy regions of the world. Dairy production in the United States has steadily moved toward a large-herd, high-efficiency model due to associated economies of scale.[11] Milk production in the United States has essentially quadrupled since 1944, producing 59% more milk with only 36% of the cows.[12] Dairy operations have shifted from small dairy farms with minimal to no hired employees to large operations with many hired workers. Yet, despite the increasing size of the dairies, almost all (94%) of the dairies in the United States are family owned (79.1%) or in a partnership (14.8%), whereas only 6.1% is structured as a corporation and the remaining 0.5% is either in the form of a trust or an estate. Larger dairies in the United States will typically employ one person for every 80–100 cows, not including farm labor needed to grow forage crops. According to the 2007 US Census of Agriculture, the average herd size in the United States was 246 cows and ranged from 122 cows per herd in Pennsylvania to 1906 cows per herd in New Mexico.[13] Between 2005 and 2009, farms with fewer than 500 cows declined, whereas farms with 500–999 cows held steady. In contrast, farms with 1000 or more cows increased 20%, driven by significantly lower costs of production. In 2005, dairy farms with 1000 cows or more had average operating costs of production of $13.59 per hundredweight of milk, 15% below the average for farms with 400–999 head, and 35% below costs for farms with 100–199 head. Average operating costs were much higher for even smaller operations.[14] In 1998, nearly 70% of milk produced in the United States came from small-herd operations (<500 head). By 2011, over 63% of milk produced in the United States came from large-herd operations (>500 head), and 34.6% came from operations of 2000 head or more.[15] Combined, only 2.7% of dairies in the United States, representing large herds of more than 1000 head, produce 50.3% of US milk.[15] The largest milk producing states include California, Wisconsin, New York, Idaho, and Pennsylvania. The 10 largest dairy producing states accounted for nearly 74% of total milk production in the United States in 2009.[16]

Dairy housing systems in the United States largely depend on regional climate conditions and can range from traditional flat-barn housing in the winter and pasture grazing during the summer, to free-stall housing, to open dry-lot housing systems with or without a grazing component, to full acclimatized cross-ventilated barns in areas with relative low humidity.

Dairy Production in Europe

The composite European Union (EU)-27 is the largest dairy producer in the world, accounting for 25.2% of the world's milk production. Nearly 24 million dairy cows constitute the EU-27 dairy herd. Germany is the largest dairy producing country in the EU-27, accounting for 4.9% of global milk production with over 4 million milk cows. France is second in EU-27 production, accounting for 4.0% of global milk production with an estimated 3.7 million herd size. The United Kingdom ranks third in EU-27 production, accounting for 2.3% of global production with an estimated 1.8 million milk cows. These countries are followed by Poland, Netherlands, Italy, Spain, Ireland, Denmark, and Romania in the top 10 dairy producing countries in the European Union.[10] The average dairy herd size in the EU-27 is 9.8 cows per farm. Less than 2% of EU-27 dairy farms have 100 cows or more. Mean herd sizes in Germany, France, and the United Kingdom are 40.3, 41.0, and 69.4 cows, respectively. The percentage of farms with more than 100 cows in Germany, France, and the United Kingdom is 5.1%, 2.4%, and 27.3%, respectively. Denmark and Cyprus have the highest average herd sizes in the EU-27, with 101.4 and 94.4, respectively. The percent of dairy farms in Denmark and Cyprus with more than 100 cows is 47% and 33%, respectively, but these countries have significantly lower numbers of dairy farms compared with the larger producing countries in the European Union.[17] Historical EU regulations have limited production on dairy farms by use of imposed quotas. Presently, many European countries are removing their quota systems, which may result in future farm expansion and larger milking herd sizes.

Dairy Production in India

India is considered a major global dairy producer, accounting for 8.0% of worldwide cow milk production. However, when combined with its massive buffalo dairy production, India can be classified as the global leader in liquid milk production (cow + buffalo milk), accounting for 17% of the world's total milk production.[18] India has 38.5 million dairy cows in its national dairy herd. There are approximately 70 million Indian dairy producers.[10] Indian dairy farms are characterized by small producers, which are mainly rural-based. In India, about 75% of the population lives in rural areas and about 38% of them are poor. Therefore, among this population, combined with the large vegetarian segment of the country's population, dairy products provide a critical source of calcium and animal protein to millions of people in India.[18,19] Unlike many developed dairy markets, India's milk production system is fragmented. Dairying is seen as small-scale industry carried on at home by family members using their own equipment, and is primarily a supplementary occupation for small landholders or landless laborers. Some estimates suggest that approximately 70 million rural households (primarily small and marginal farmers and landless laborers) are engaged in milk production. The average herd size is about two milking cows.[20]

Dairy Production in China

China produces 6% of the global milk supply, with a 12.6 million national herd size.[10] China's raw milk production has increased at a rate over 25% per year, placing China among the top five dairy producing countries in the world.[21] This increase in milk production is fueled primarily by domestic demand. Local producers are slowly rebuilding the Chinese dairy herd following a nationwide melamine crisis in 2008 when 15% of China's dairy cows were taken out of production due to weak demand after the food safety scare. The Chinese dairy industry is primarily composed of backyard and small-herd operators. Seventy-six percent of dairy producers have a herd size of 1–4 cows. Less than 1% of producers have herd sizes of 100 or more. Larger operations continue to expand herd sizes, but the pace of increase in dairy cows is constrained by limited land resources.[22] However, dairy development in China is steadily picking up speed and changing from small subsistence farming to very large-scale high-efficiency models. The Chinese government has put an emphasis on dairy development and is buying not only the products, but also the technologies to fast track this process.

Dairy Production in Russia

Russia produces 5.5% of dairy cow milk worldwide, with an estimated 9.0 million herd size.[10] About 50% of Russian milk production comes from household farms (personal subsistence plots). Production on these farms is mainly consumed on the farm or sold at local farmers' markets. Some processing plants accept milk from these operations, but the small-scale production means that the quantities and quality of milk are generally lower than those from more modern farms with more advanced production processes. Seventy-three percent of household farms have only 1 cow each and 20% have 2 cows. In recent years, agricultural enterprises have produced about 45% of the raw milk output in the Russian Federation.[23] The majority of agricultural enterprises in the dairy sector are small farms with up to 500 cows. In the opinion of Russian dairy market experts, large dairy farms guarantee higher profitability and quicker return on investment. The largest dairy operations in the Russian Federation have more than 5000 cows. The National Union of Milk Producers[23] estimated that there is also a maximum size for a profitable dairy farm. Managerial problems arise on farms with more than 3000 head. The lack of skilled specialists who know how to manage such large farms is one of the main problems facing the animal husbandry industry in the Russian Federation. Additionally, difficulties exist in selecting locations for large farms, as they need large areas of land. Farms that are distant from population centers are confronted with difficulties with water and power supplies. Dairy farm size is also limited by a feed supply shortage. Another issue is the lack of qualified labor. All of these factors combined hinder the development of large enterprise farms in the Russian Federation.[23]

Dairy Production in Brazil

The Brazilian dairy industry accounts for 4.8% of worldwide dairy production. Approximately 21.8 million cows make up the country's dairy herd. Most dairy production is concentrated in southeast and southern regions (36% and 31%, respectively) of the country. Milk is produced on farms of different sizes, ranging from small farms that use little milking technology with daily production less than 10 L, to large farms with production over 60,000 L per day. There are approximately 1.3 million dairy producers in Brazil. Small producers (less than 50 L produced daily) are responsible for only 20% of milk production. Medium-sized producers (51–200 L per day) constitute 15% of farms, and are responsible for 20% of production. Larger farms producing more than 200 L per day constitute only 3% of all dairy farms, but account for 60% of milked produced in Brazil. Until 2004, Brazil was a major importer of dairy products. In recent years, Brazil became a major exporter, with exports surpassing imports in volume.[10]

Dairy Production in Australia

The dairy industry is one of Australia's major rural industries. Based on production value, the Australia dairy industry ranks third behind beef and wheat industries. Approximately 40,000 people are directly employed on dairy farms and processing plants. In 2012, owner-operated farms dominate the Australian dairy industry. Corporate farms make up only 2% of the total number of Australian dairy farms. The number of farms has fallen by two thirds over the last three decades, from 22,000 in 1980 to roughly 7000 in 2011. The Australian national dairy herd is 1.6 million cows, with an average farm herd size of 230 cows. Fifty percent of Australian milk production is exported, making Australia the world's third largest dairy exporter.[24] Major export markets include Japan, Greater China, Singapore, Indonesia, and the Philippines.[25] Southeast Australia's climate and abundance of natural resources are favorable to dairy farming and facilitate the industry to be predominantly pasture-based, with 70–75% of cattle feed requirements coming from grazing. Most dairy production is located in coastal areas where pasture growth depends on natural rainfall. Feedlot-based dairy farming remains the exception in Australia, with the use supplementary feed being widespread and increasing significantly in recent seasons as farms have been forced to adapt to drier conditions.[25]

Dairy Production in New Zealand

Like Australia, the dairy industry is one of New Zealand's major agricultural industries. The dairy sector directly accounts for 2.8% of the New Zealand gross domestic product, equivalent to $5 billion. Dairy provides 26% of New Zealand's total goods exports, equating to $10.4 billion. The New Zealand dairy sector employs around 35,000 workers.[26] In 2011, the New Zealand dairy herd size was more than 6 million. In 2011, the average farm herd size was 386. Fifty-three percent of New Zealand dairy farms had 300 or more cows, 24% had 500 or more cows, and 4% had 1000 or more cows. The trend in New Zealand is one of decreasing numbers of dairy farms with increasing dairy herd sizes. Over the past 30 years, the New Zealand average herd size has tripled, increasing by more than 100 cows in the last 8 years.[27] The majority of dairy herds (76%) are located in the New Zealand North Island, with the greatest concentration (30%) situated in the Waikato region. Taranaki is the second largest region, constituting 15% of New Zealand dairy herds.[27] New Zealand is the world's largest dairy exporter, accounting for over a third of international dairy trade and 95% of New Zealand's dairy products are exported.[27] Major dairy export markets include China, United States, Japan, European Union, Malaysia, Australia, Philippines, Taiwan, Singapore, Belgium, Venezuela, and Saudi Arabia.[28] Even though New Zealand's dairy production remains predominantly pasture-based, supplemental feeding strategies with concentrates are quickly aiding to increase production levels. Production has increased 15.5% in the last 5 years.[9] The vast majority of dairy farms in New Zealand produce milk on a seasonal basis. This allows dairy farmers to take full advantages of optimal grazing opportunities and low cost of production. Milking ceases during the winter months on most farms. New Zealand producers can economically use this type of production system, since the majority of milk is exported as manufactured products.

Dairy Production in Developing Countries

Livestock is vital to the economies of many developing countries. Animals are a source of food, specifically protein for human diets, income, employment, and possible foreign exchange. For low-income producers, livestock can serve as a store of wealth; provide draught animal power and organic fertilizer for crop production; and serve a means of transport. Consumption of livestock and livestock products in developing countries is growing rapidly. As compared with mechanized milk production systems found in industrialized countries, dairy production systems in developing countries may be characterized by a few cows kept on mixed crop-livestock farms, in urban backyards, or extensive pastoral systems. Traditional milk producers in developing countries typically keep dairy cattle to meet a range of objectives, including savings for insurance and finance functions, to produce manure, and for social status. Sale of milk may not be the primary objective, and in many cases no milk is sold. Milk production is just one of many activities of the household, and may be integrated with other household/farm activities, particularly crop production. Dairy production in developing countries involves low levels of inputs and outputs. This characteristic is associated with limited use of modern technology, low productivity of land and labor, and generally with an emphasis on labor-intensive technology, as cows are often milked by hand. Soil nutrient deficits remain the key production constraints for most small-scale farms in developing countries. Dairy farmers can partially offset these soil nutrient deficits by using cow manure.[29]

CONCLUSIONS

The international dairy industry is composed of a multitude of countries with unique production practices and consumer markets. The global industry trend is one of increasing farm sizes with larger numbers of cows due to associated economies of scale. Due to farm expansion and increased production, international producers are faced with new challenges related to assuring food safety and a safe working environment for their workforce. Increased global competition for markets has also spurred a focus on milk quality, which national dairy industries are using to gain competitive advantages for their products. The increasing emphasis on quality standards puts additional pressure on dairy farmers and their labor force to meet these standards. These challenges exist in addition to the cultural and language challenges related to the increasing dependence on immigrant labor. As farms increase their herd sizes and modernize production practices, the continued success of the dairy industry is vital, globally. A common risk for dairy workers around the world is working in close proximity to large, dangerous animals. Workers on large-herd operations (500+) are exposed to large machinery, dangers associated with manure pits, respiratory exposures, and ergonomic risks such as repetitive motions or high muscle forces associated with parlor milking. Workers on medium-sized operations of a few hundred cows may be exposed to extreme trunk postures associated with milking tethered cows. Family workers who milk 1–2 cows for family consumption in developing countries are exposed to repetitive motions and awkward trunk postures associated with hand milking, as well as zoonotic diseases, which may not be adequately controlled in developing countries. Research should continue to address the identification of occupational risk factors associated with injuries and illnesses, as well as develop cost-effective interventions and practices that lead to the minimization or elimination of these injuries and illnesses globally, among our valuable population of dairy farm producers and workers. Future research should address the unique features and risks of dairy production in different regions of the world.

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Ergonomics in Modern Dairy Practice: A Review of Current Issues and Research Needs

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REVIEWS

Ergonomics in Modern Dairy Practice: A Review of Current Issues and Research Needs

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ABSTRACT. Dairy farming is an ancient occupation. Traditionally, cows have been manually milked while tethered in stalls or stanchions. In the latter half of the 20th century as machine milking emerged, the parlor milking system has become more popular, especially among larger dairy farms. The transition from manual milking to automatic milking systems as well as the transition from stanchion to parlor milking systems involved a dramatic change in milking tasks. These transitions have resulted in changing patterns of occupational exposure to risk factors for work-related musculoskeletal disorders among dairy workers. However, aspects of the milking task such as sanitization of teats, stripping milk from teats, and attachment and detachment of milking equipment have remained relatively the same. Work-related musculoskeletal symptoms have been reported in the low back, shoulders, hands/wrists, and knees. Research that has measured exposures to risk factors for work-related musculoskeletal disorders among dairy farm workers has been limited, especially when using ergonomic tools to directly measure exposure, such as electrogoniometry or electromyography. Self-reported exposure measures have been most commonly used. The interventions that have been tested to reduce exposure to risk factors for work-related musculoskeletal disorders include assisted lift-hold devices, use of lighter-weight equipment, adjustable flooring, and use of rubber mats. However, research evaluating potential solutions

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to reduce dairy farm worker exposure to risk factors for musculoskeletal disorders is scarce. Future research efforts should further characterize hazards while simultaneously testing viable solutions that fit within the business model of the dairy farm industry.

KEYWORDS. Agriculture, dairy, ergonomics, musculoskeletal disorders

INTRODUCTION

Dairy farming has been part of agriculture for thousands of years.[1] Initially, milk and dairy products were made primarily for home or local use. As nations developed and populations expanded, it became necessary to mass produce and improve the quality of milk for public consumption.[2] Until the late 1800s, cows were milked by hand. With the invention of vacuum bucket milking and the availability of electrical power, the efficiency of milk production was drastically increased.[2] Technological improvements also led to the development of milking pipelines, which eliminated the physical workloads associated with the manual transport of heavy buckets of milk.[3] Introduction of the automatic milking system during the 20th century reduced manual milking and associated physical risk factors, and involved a dramatic change of work tasks for milkers. Additional technological advances such as the introduction of the milking parlor reduced occupational exposure to awkward trunk and lower extremity postures associated with milking in stanchion style barns. However, parlor milking has introduced new exposures to ergonomic risk factors primarily associated with upper extremity, neck, and trunk work-related musculoskeletal disorders (WMSDs). The purpose of this review is to describe the working environments of modern parlor milking as well as present a scientific review of research addressing WMSDs on dairy farms, and specifically focus on the work environment inside milking parlors. Additionally, a review of exposure assessment strategies is presented with significant findings. Interventional studies aimed at reducing ergonomic risk factors will be presented followed by a discussion of research needs to reduce or eliminate the risk for WMSDs on modern dairy farms.

WORKING ENVIRONMENTS

Milking Systems and Designs

Two milking systems predominate modern milking: stanchion and the parlor.[4] Stanchion milking systems involve a milking unit being brought to a tethered cow for milking. Cows are tethered and workers will kneel or squat to perform milking tasks and attach the milking unit (Figure 1). Stanchion systems are more common among smaller milking operations (<100 head).[5] Parlor milking systems involve cows moving into milking stalls where they are milked simultaneously by workers located in a pit adjacent to and at a lower level than the milking platform. Milking parlor capacity is dependent on the number of milking stalls in the parlor. Parlor systems can accommodate larger quantities of cows and are used almost exclusively in large-herd operations.[6] Parlor systems are configured in several ways, including herringbone, parallel, rotary (Figures 2, 3, and 4), and side-open (tandem) (Figure 5). These

FIGURE 1. Milking in stanchion system (color figure available online).

FIGURE 2. Herringbone parlor.

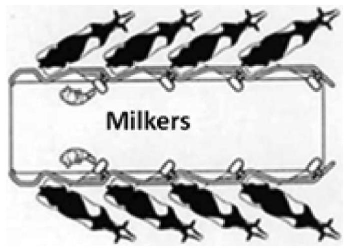


FIGURE 3. Parallel parlor.

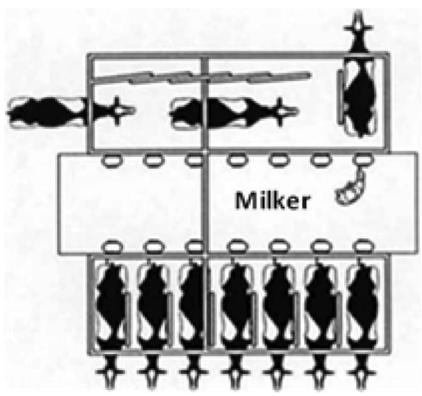


FIGURE 4. Rotary parlor.

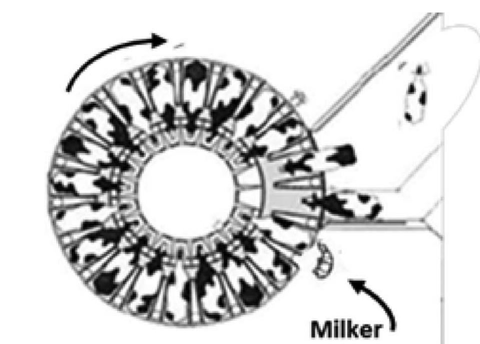


FIGURE 5. Tandem parlor.

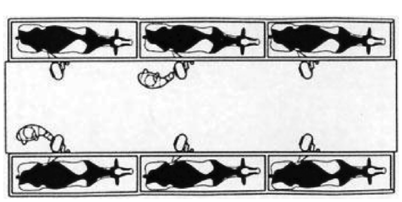


FIGURE 6. Milking in herringbone parlor (color figure available online).

FIGURE 7. Milking in tandem parlor (color figure available online).

configurations present different workstation designs and may create varying worker exposures to physical demands. In tandem parlors, cows stand in a line, one in front of another in individual stalls in parallel to the long side of the milking pit. In herringbone parlors, cows enter and stand next to each other, facing away from the milking pit at an angle. In both herringbone (Figure 6) and tandem (Figure 7) parlors, workers access the udder from the side of the cow. In parallel parlors, cows stand perpendicular to the pit and workers usually access the udder between the hind legs (Figure 8). The advantage of the parallel design is that cows stand closer together so the walking distance for milkers is shorter, and more cows can be milked per area

FIGURE 8. Milking in parallel parlor (color figure available online).

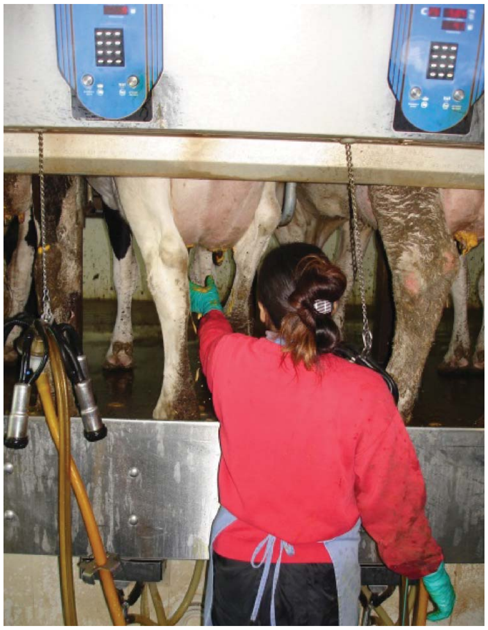


FIGURE 9. Milking in rotary parlor (color figure available online).

in the parlor as compared with herringbone and tandem parlor designs. The disadvantage is that cows must be milked from behind, requiring a longer reach distance for the worker. In tandem parlors, cows are let in and are released individually; therefore, a slow-milking cow does not delay the release of other cows in the parlor once milking is complete. In herringbone and parallel parlors, cows enter and are released in batch. A unique technological feature found in some parlors is a retractable arm located behind the cow to support the milking unit. The support arm is used to suspend and properly position the milking unit below the cow's udder and off the parlor floor. The device is predominantly utilized in herringbone parlors as the udder is accessed by the worker from the side of the cow. A support arm may reduce worker exposure to upper extremity loading, as milking units can weigh up to 3.5 kg.[7] Rotary (i.e., carousel) parlors are gaining in popularity among large-herd operations. The milker stands in the center of the carousel or outside or around its perimeter to perform milking tasks. Cows walk onto a slowly moving platform that rotates in a turntable-like fashion (Figure 9). Since cow movement is largely automated, one operator can run the entire milking operation from the same position while cows enter and exit at a constant rate with little or no pause in milking tasks. From a milking efficiency perspective, the rotary milking parlor design is preferred, as more cows can be milked per unit time compared with other parlor designs. However, rotary parlors cost more to install compared with parallel, tandem, and herringbone designs (D. Reinemann, PhD, December 16, 2009; and R. Sorenson, BS, December 18, 2005; oral communications).

The automatic milking system (AMS or voluntary milking system [VMS]) is a relatively new milking system gaining in popularity especially among European dairy operations.[8] In this system, cows are housed in loose housing systems and move voluntarily to a milking robot, where the cows are milked two to three times a day with minimal to no worker involvement. The capacity of the AMS/VMS is about 60–70 cows per day depending on milk yield. This system is revolutionary, especially for small family farms with 60–120 cow herds.[9]

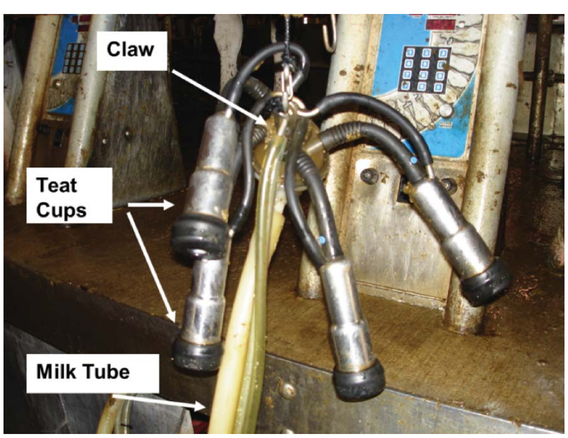
Milking Tasks

Milking has been reported as being the most physically demanding[10] and time-consuming[11,12] activity on dairy farms. The milking procedure involves several tasks that include the following: (1) pre-dipping of teats with a cup or spray for sanitization; (2) wiping of teats; (3) stripping of each teat to stimulate milk flow and inspect pre-milk for signs of infection; (4) cluster attachment; (5) cluster detachment; and (6) post-dipping of teats for sanitization.[13] All milking tasks must be performed in sequence in an efficient and timely manner to maximize milk output from each cow. O'Brien et al.[14] described the interdependency between milking efficiency and parlor performance, and reported that optimum milking efficiency was achieved when the number of milking units was appropriate for the operator work routine and the cow milk production level such that both over-milking and worker idle time are minimized. This finding suggests an efficient milking system in terms of labor demand allows little opportunity for worker rest. The milking routine is similar to assembly-line work, characterized by repetitive specialized tasks.[15–17] Cluster attachment has been identified as one of the more physically strenuous milking tasks (Figure 9).[10] A milking unit consists of a number of parts: claw, teat cups, and milking tubes. Together, the claw and the teat cups together constitute a milking cluster (Figure 10). Job rotation is often not employed in large-herd operations, and the entire herd is milked two to three times per day. Additionally, when parlor turnover times are kept to a minimum, rest breaks may be inadequate to prevent worker fatigue and reduce the risk for injury in the upper extremities.[17,18]

Recent technological advancements have led to the mechanization and automation of the entire milking process via the utilization of automatic milking systems. However, at present, investment costs limit widespread and rapid acceptance of AMS/VMS in the global industry. Dairy science research has led to significant advances in dairy practice, resulting in an optimization of cow milk production and parlor efficiency as it relates to cow throughput. However, little research has addressed worker health and safety or worker productivity and efficiency. As the global dairy industry continues to move towards larger herd sizes[19,20] with the goal of increased milk production at lower costs, focused research should investigate milking practices and parlor designs as they relate to worker safety and health.[4]

Additional trends to consider include modern milking technologies, practices, and parlor designs are being adopted in developing countries. If the impacts of these on worker health and safety are not carefully analyzed and evaluated, poor designs or hazardous practices could be adopted in developing countries where worker health and safety is given much less consideration than in developed countries.

FIGURE 10. Milking unit (color figure available online).



MUSCULOSKELETAL SYMPTOMS, INJURIES, AND ILLNESSES

Several studies have shown that farming is a physically demanding occupation with work tasks that can cause musculoskeletal disorders (MSDs). Research has demonstrated that MSDs are common among dairy farmers especially in the lower back, shoulders, hands/wrists, and knees.[21–30] Due to a lack of reliable and accepted measurement of MSDs, researchers have been forced to rely on self-reported musculoskeletal symptoms (MSS) as an indicator of MSDs. Studies involving the prevalence of MSS and MSDs among Irish, Australian, and Swedish dairy farmers and hired workers have been reported. Researchers estimated over 80% of Swedish dairy farmers and hired workers complain of MSS in a 12-month period.[21,23,25,26,31] Prevalence of MSS in any body part was approximately 81–90% among Swedish dairy farmers and 76–86% among hired workers. Musculoskeletal symptoms were mainly located in the lower back (43–57%), shoulders (32–54%), and knees (22–41%), with lower prevalences in the neck (23–36%), hand/wrists (20–41%), and hips (18–35%) among farmers and workers. In general, females usually report significantly higher frequencies of MSS in all body parts (84–93%) and especially in the hands/wrists (39–61%) than males. Further, studies have also found females report significantly more discomfort from repetitive and monotonous work than their male colleagues.[23,31] Among Irish dairy farmers, 36% reported having low back pain, 22% neck/shoulder pain, and 8% hip pain.[29] Lower et al.[27] reported 57% of Australian dairy farmers experienced back trouble directly related to dairy farming activities. See Table 1 for a study comparison of MSS prevalence in different body regions.

Previous studies have indicated that larger dairy operations are associated with an increased risk for injury.[32–34] Larger herd sizes, different parlor environments and milking methods, and cultural differences that influence self-reporting of symptoms make comparisons between dairy studies difficult. These factors may have a more significant influence on MSS among parlor workers on farms with growing herd sizes. Between 2005 and 2009, US dairy farms with fewer than 500 cows declined, whereas farms with 500–999 cows remained relatively constant. In contrast, US farms with 1000 or more cows increased 20%, driven by significantly lower costs of production. In 1998, nearly 70% of milk produced in the United States came from small-herd operations (<500 head). By 2011, over 63% of milk produced in the United States came from large-herd operations (>500 head), and 34.6% came from operations of 2000 head or more.[20]

Information regarding the prevalence of MSS among US agriculture workers is scarce. Pratt et al.[33] did concentrate on US dairy farmers when they evaluated "injury" in several anatomical sites. However, this study did not focus specifically on musculoskeletal problems, and the researchers categorized upper extremity injuries only as "arm" or "hand." Dairy farming has the second highest prevalence of injuries among all US agriculture groups.[32,35,36] The majority of these injuries originate from interactions with dairy cattle during milking activities.[33,35,37] Nonnenmann et al.[40] assessed MSS prevalence among Iowa dairy farmers. One of the primary objectives of the study was to examine the association between type of milking facility (stanchion versus parlor) and prevalence of MSS of the upper extremity. No association was found between type of milking facility and upper extremity MSS. Nonnenmann

TABLE 1. Prevalences (%) of Work-Related Musculoskeletal Symptoms Among Dairy Farmers and Hired Workers

Location	Gustafsson et al., 1994[33] Sweden $N = 2085$ ($N = 920$)	Stal and Pinzke, 1991[32] Sweden $N = 197$ ($N = 61$)	Lower et al., 1996[29] Australia $N = 138$	Pinzke, 2003[27] Sweden N = 476 ($N = 185$)	Kolstrup et al., 2006[25] Sweden $N = 42$ ($N = 14$)	Osborne et al., 2010[31] Ireland $N = 103$ 95% male	Lunner Kolstrup, 2012[23] Sweden $N = 66$ ($N = 25$)	Nonnenmann et al., 2008[40] USA $N = 341$
Neck	25 (35)	17 (23)		31 (39)	33 (50)	22	33 (48)	43
Shoulder	37 (49)	31 (46)	14	44 (59)	48 (71)		47 (60)	54
Elbows	18 (22)	15 (18)		20 (28)	10 (21)		23 (28)	24
Wrist/hand	18 (35)	24 (33)	3	24 (46)	26 (57)		23 (44)	40
Upper back	12 (18)	8 (13)	43	12 (15)	26 (43)		15 (20)	
Lower back	55 (50)	46 (43)		54 (47)	41 (50)	36	50 (60)	
Hips	23 (27)	20 (21)		28 (34)	14 (21)	8	12 (8)	
Knees	41 (37)	27 (28)	36	38 (33)	24 (29)		21 (24)	
Feet	13 (16)	8 (16)		14 (20)	14 (14)		21 (32)	
Any body part	82 (86)	73 (74)		83 (90)	86 (93)		85 (88)	75

Note. Female-only sample size and prevalence are given in parentheses.

et al.[38] were the first to estimate MSS of the upper extremity among US dairy farmers and found that shoulder MSS was the most prevalent at 54%. Additionally, hours milking per year was associated with an increased risk for elbow MSS. Since milking involves repetitive motions and muscle forces at the wrist, Patil et al.[39] examined the prevalence of carpal tunnel syndrome (CTS) among US large-herd parlor workers. The prevalence of CTS among parlor workers was 16.6% and 3.6% among non-parlor workers, a statistically significant difference. Results suggested that repetitive motion injuries (RMIs) such as CTS may be a significant health challenge for large-herd parlor workers. Additionally, Stål et al.[40] identified that pronator syndrome may also be a significant health challenge for dairy parlor workers. Karttunen and Rautiainen[41] conducted a retrospective cohort study to evaluate the incidence of and risk factors for compensated occupational injuries and diseases in Finnish agriculture. Findings suggest that dairy farmers have a 2.2 relative risk of injury compared with cereal crop farmers.

EXPOSURE STUDIES

A limited number of prior studies have addressed physical exposures related to the development of musculoskeletal disorders. Worker self-report is one method previously employed[12,23,25,27,38] as well as observation-based exposure assessment.[42–44] Direct measurement exposure assessment techniques have also been used, including heart rate monitoring and oxygen consumption estimation,[43,45] electrogoniometry,[10,17,46,47] surface electromyography (sEMG),[10,48–50] and laboratory-based three-dimensional (3D) optoelectronic motion analysis.[49]

Self-Report

Among factors identified as causing back trouble, 32% of Australian dairy farmers reported milking as being a contributor to back trouble, ranking second behind tractor work (37.3%).[27] Innes and Walsh[12] also investigated dairy work in Australia and reported lifting down cows and calving cows as having the highest mean ratings of perceived exertion (RPE). Boyle et al.[35] reported milking as having the greatest increase in risk for injury among dairy farmers in the Midwest region of the United States. Among small-herd (<500) US dairy farms, hours milking was found to be associated with elbow symptoms.[38] Consistent with this finding, Pinzke[25] reported an association between elbow MSS among female milkers and number of cows milked. Additionally, the number of cows milked in the parlor was associated with elbow MSS among female milkers. Using questionnaires, Kolstrup et al.[23] studied six dairy tasks: machine milking, handling of feed, manure removal, feeding, litter strewing, and parlor cleaning. They found machine milking to be the most harmful operations.

Observational Exposure Assessment

Ovako Working posture Analysing System (OWAS)[51] is a widely used method of observation to identify and evaluate harmful work postures at different work sites, including dairy farms. Using OWAS, Lundqvist[52] found that milking in stanchion barns with tied cows involved unacceptable working postures during 38% of total time, compared with 9% of the time when working in loose housing systems with parlor milking. Using OWAS to analyze video-based observational (VBO) data, Perkiö-Mäkelä and Hentilä[43] reported the most common work posture used during parlor milking on small-herd Finnish farms was standing with the back straight and upper arms below shoulder level. These findings support results of another study involving Finnish dairy farmers on small-herd operations.[44] Hwang et al.[42] also utilized the OWAS and VBO to analyze working postures in a stanchion system, and compare milking processes between stanchion and loose-housing systems. Researchers concluded dairy-farm work relied heavily on the usage of upper-body segments, with the worker frequently standing. Researchers acknowledged the limited practicality of using VBO in these work settings due to inherent researcher time and effort.

Muscle Forces

Surface EMG (sEMG) is an effective ergonomic research method to assess the physiological response to the demands placed on muscles during the performance of work activities. Ergonomic research of milking in Sweden began in the late 1970s. Laboratory studies of simulated milking evaluated shoulder load as well as the load on the knees and leg musculature. Results revealed the importance of minimizing the weight of milking machines and also determined optimal vertical and horizontal distances from the milker's body to the cow's udder.[50,53] Stål et al.[48] demonstrated using sEMG that Swedish small-herd parlor milking systems required high static muscle loads and low rest times. Peak loads for forearm flexor and extensor muscles were close to their maximum capacity, which, in combination with positions and movements of the hand and forearm, might contribute to the development of nerve injuries in addition to other tissue lesions such as tendonitis. Also investigating muscle loads in small-herd Swedish milking parlors, Pinzke et al.[10] reported that the milking tasks of stripping, drying, and attachment involved high muscle loads, with almost no time for rest. The highest load values for the biceps and forearm flexor muscles were found during attachment and drying. The authors concluded high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of injuries. Using a biomechanical model and sEMG, Ekholm et al.,[54] Svensson et al.,[55] Arborelius et al.,[50] and Németh et al.[56] investigated joint loads and muscle activities associated with shoulder, ankle, knee, low back, and hips during milking tasks in parlor and stanchion systems. These studies involving small-herd operations found a parlor system lowered the lower limb muscle activity compared with a stanchion system.

Limb Posture and Motion

Nonnenmann et al.[46] quantified exposures to awkward knee postures among small-herd (<500 head) US dairy workers who performed milking and feeding tasks. Using electrogoniometry and short sample duration (30 min), the authors found that the percentage of time in $\geq 110°$ knee flexion was significantly greater in stanchion milking facilities as compared with parlor facilities. The authors concluded that working in stanchion milking facilities results in greater exposures to awkward knee postures compared with working in parlor milking facilities. Pinzke et al.[10] and Stål[17,47] utilized electrogoniometry to record motion and posture at the wrist among parlor workers on small-herd Swedish farms. Each of these studies used a task-based, short-sampling duration (<30 min). Extreme wrist positions of dorsiflexion were found during the milking tasks of stripping and attachment, and extreme deviation (ulnar and radial) postures were recorded during drying and attachment. High movement velocities were reported for drying and attachment tasks. Using acceleromety to estimate movement and postures at the shoulder, Douphrate et al.[13] conducted the first study to document full-shift (mean sampling duration of 7 h 25 min) biomechanical exposures among US large-herd (>500 head) parlor workers. Results from this feasibility study suggested that large-herd parlor workers may be exposed to exposure levels (posture, movement velocity, repetition, and inadequate rest) that are recognized as being associated with the development of shoulder pathology. Compared with other high-risk occupations involving shoulder-intensive work, these findings suggested that parlor workers may have higher exposure levels involving the shoulder.

Physiological Workload

A Finnish study on small-herd farms estimated oxygen consumption (VO_2) and heart rate (HR) during the milking process. Average sampling duration of VO_2 was 18 min and HR 115 min. Findings suggested that milking involved mostly light work with low VO_2 (0.6 1/min) and mean heart rate (95 beats/min).[44] Ahonen et al.[45] also estimated the physical stress and strain in dairy farming using ambulatory heart rate and oxygen consumption measurements. The handling of feed and manure was the heaviest work task in dairy farming on small-herd (mean 12 head) Finnish farms. Perkiö-Mäkelä and Hentilä[43] studied the physical workload and strain of dairy farming and reported that milking was light work and feeding was moderately heavy work for the cardiovascular system on small-herd (mean 45 head) Finnish farms.

GOOD PRACTICES AND INTERVENTIONAL EFFORTS

Several practices and interventions to prevent MSDs when milking cows were observed by ergonomists during farm visits and meeting with farmers across Belgium, Poland, Sweden, and UK.[57] These good practices included the installation of a milking rail in tie stall barns to ease transportation of milking equipment, and the installation of a floor adjustable to the height of the worker in parlor systems. Installation of perforated rubber matting on existing floors in parlors aimed to decrease the physical load on the lower extremities and reduce fatigue. Other good solutions were found for specific tasks in parlor milking. For udder cleaning, a centralized placement of a bucket for wipe towels or cloths on a cart would reduce both walking distance and exposure to awkward trunk posture among milkers. Installation of a support arm was also considered to reduce the workload when attaching clusters, as well as the use of lightweight clusters and tubes. Instead of using a dip cup for teat dipping, the worker can spray the teats with disinfectant. This spray application reduces the reach distance of the worker.

Despite these solutions found on existing farms, research is scarce addressing specific ergonomic interventions in milking parlors. Jakob et al.[58] investigated the effects of working height and milking unit weight during milking in a laboratory setting. Using 3D optoelectronic motion analysis, sEMG, HR, and perceived exertion, the authors demonstrated that the optimal working height for cluster attachment is having cow teats at the shoulder level of the parlor worker. Additionally, workload reduction was achieved via the reduction in weight of the milking cluster and tubes, which was demonstrated in a study by Pinzke et al.[59] A second laboratory study by Jakob et al.[53] investigated the effects of a new quarter-individual milking unit with a single tube in absence of a claw on the reduction of muscle load and extreme postures. Results suggested that this new milking unit has potential to reduce extreme postures and muscle loads for parlor workers. Stål et al.[7] investigated the impact of the workload on the milker's forearm, wrist, and hands resulting from using a prototype support arm designed to facilitate the cluster attachment task. Using electrogoniometry and sEMG, the authors demonstrated a minimal decrease in muscular load while using the support arm and little change in wrist posture.

CONCLUSIONS

Limited research has demonstrated that dairy operators and parlor workers are exposed to physical risk factors associated with the development of MSDs. Awkward postures, high muscle forces, high movement velocities and repetitions, and minimal opportunity for rest have been documented in the literature to be characteristic of parlor working environments. As the world's population grows, global dairy producers will be forced to produce more dairy products to meet the increasing global demand. Dairy producers will seek more cost-effective means to produce their products. Farms will continue to increase in size reflecting economies of scale associated with larger herd sizes, as well as seek novel and more efficient milking strategies such as AMS. Workers on farms with larger herd sizes are exposed to ergonomic risk factors associated with the development of WMSDs. Continued ergonomic research is needed on dairy farms of all sizes. Due to different parlor configurations, milking practices, herd sizes, cow breed, and varying worker anthropometrics, future research should reflect these unique farm characteristics.

Ergonomic exposure assessment research has been limited by direct measurement technologies. Additionally, limitations in memory capacity have prevented the continuous recording of physiological activity for long sampling durations. Prior research has documented the need for continuous, long duration, direct measurement methodologies.[60,61] Advancements in modern direct measurement technologies such as sEMG, motion capture, and physiological monitoring have enabled more precise and valid estimations of physical exposures. Additionally, advancements in memory capacity have enabled long duration and full-shift measurement. Future ergonomic exposure field researchers should consider using these new technologies that may enable more precise and representative exposure estimation, as well as improved demonstration of intervention effectiveness. Additionally, standardized exposure metrics should be utilized to enable the comparison across studies.

In addition to the need for continued exposure estimation, future research needs to demonstrate intervention effectiveness in reducing physical exposures. Interventions should not only address the health and safety of the worker, but also worker productivity and efficiency, which would result in improved parlor performance and profitability. Furthermore, examining relationships between the organization of milking routines and how exposure times may be reduced by the modification of work tasks or schedules are important issues to consider in future studies. Future research efforts should also utilize the methods and metrics as described to evaluate the effectiveness of different interventions to reduce ergonomic exposures in large-herd milking parlors. The aforementioned feasibility studies demonstrate the successful utilization of modern, direct measurement technologies, as well as objective exposure metrics to characterize full-shift ergonomic exposures in challenging work environments. The methods and metrics used in these studies will be used in future research to investigate exposure-outcome relationships as well as the determination of intervention effectiveness in milking parlors and other occupational settings and industries.

The dairy industry faces a challenge by the introduction of new, technologically advanced milking systems such as the automatic milking system that replaces manual milking. As automated milking replaces traditional milking methods in some regions such as northern Europe, the milking process may be less hazardous, since automated milking eliminates many of the ergonomic stressors and safety hazards associated with traditional parlor milking. However, work-related mental stress or fatigue may result among dairy farmers due to the necessity for continuous monitoring and the potential for mechanical breakdown. Therefore, the impact of these new technologies on worker health should be explored.

Dairy production continues to trend toward large-herd operations in some regions of the world. Large-herd milking parlors may involve ergonomic risk factors associated with the development of WMSDs. Dairy producing regions where herd size enlargement is restricted may adopt new milking technologies such as AMS. Future research should continue to identify best practices and cost-effective technologies and strategies that minimize or eliminate worker exposures in these changing working environments. Future research efforts should involve international, multicenter collaborative studies using standardized study designs and methods. Additionally, industry involvement in future research is paramount to ensure stakeholder input, thereby increasing the likelihood of adoption of identified best practices and injury-reducing strategies.

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Occupational Health and Safety Regulations in the Dairy Industry

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ABSTRACT. The application of occupational health and safety (OHS) legislation in the dairy industry varies throughout the world. Generally there is no specific OHS legislation that applies to the dairy industry and mostly in countries the current OHS legislation applies to all workplaces with specific guidelines that apply to agricultural industries. The main difference between countries is in the application of OHS legislation specifically in relation to the size of the farms. In the USA, the OHS legislation, and therefore enforcement, does not, in most cases, apply to farms with less than 11 employees, whereas in other countries there is no minimum number of employees and in some cases such as the United Kingdom and Australia it covers all people who work on the farm. The other area of difference is in the use and publication of guidelines for the industry; some countries have a wide range of guidelines whereas other counties have few. Generally, this relates to the jurisdiction of the OHS legislation, which in several countries is not at a national level such as USA, Canada, and Australia. The main principal of OHS legislation is that all workplaces, including dairy farms, should be a safe and healthy place to work, and does not vary significantly between the countries reviewed even those with prescriptive legislation.

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INTRODUCTION

The legislation that applies to the health and safety of dairy farmers, their families, and farm workers varies around the world. In most cases, it depends on whether the legislative model is either risk based or prescriptive. Originally, the risk-based models are based on changes in legislation in the United Kingdom following Lord Robens report, in the mid-1970s, into occupational health and safety (OHS) in all work places.[1] Risk-based legislation in general states that an employer must provide a safe and healthy place of work and covers all the potential risks and hazards. Risk-based legislation has been adopted in various format in most countries. Although prescriptive legislation, which states what an employer must do in relation to OHS, is in some cases easier for farmers to follow, as it details what a farmer must do to be compliant, it does not cover all potential hazards.

LEGISLATION AROUND THE WORLD

To get an understanding of the differences in legislation, you need to have a brief understanding of OHS legislation as it has been developed and applied in each country, this includes both compliance and enforcement.

North America

When discussing legislation on the North American continent, you must consider two countries that have different legislative approaches. The additional issue is that often the legislation may be state or region based.

USA

With the Occupational Safety and Health Act of 1970 (OSH Act), the Occupational Safety and Health Administration (OSHA) was created in the USA to ensure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education, and assistance.[2] According to the OSH Act, any dairy farm that employs 11 or more employees at any time during the previous 12-month period or has an active temporary labor camp during that period is subject to OSHA regulatory oversight. A dairy operation is exempt from all OSHA enforcement if it

1. employs 10 or fewer employees currently and at all times during the last 12 months, and
2. has not had an active temporary labor camp during the preceding 12 months.

According to OSHA regulation 29 CFR 1975.4(b)(2), family members of farmers (farm employers) are not counted when determining the number of employees for OSHA oversight. A part-time employee is counted as one employee. Under OSHA's current appropriations law, OSHA is not allowed to spend any funds appropriated to enforce any standard, rule, and regulation on any farming operation that employs 10 or fewer employees and does not maintain a temporary labor camp. Although current appropriations law forbids federal funds to be spent on enforcement of the OSHA Act on small farms with 10 or fewer employees, the actual OSHA Act does not address enforcement based on operation size. Therefore, despite OSHA being prohibited from inspecting small farming operations, these operations are not exempt from OSHA regulations and the standards are still relevant.

States with OSHA-approved state plans may enforce on small farms and provide consultation or training, provided that 100% state funds are used and the state has an accounting system in place to assure that no federal or matching state funds are expended on these activities.[2]

In addition to regulatory standards outlined for businesses classified as General Industry employers, seven standards specifically apply to agriculture:

1. slow moving vehicle (SMV) emblem;
2. anhydrous ammonia;
3. pulpwood logging;
4. temporary labor camp housing;
5. roll over protective structures;
6. agricultural machinery guarding; and
7. cotton dust.[2]

When there are no specific standards applicable to a particular hazard found on a dairy operation, the OSHA General Duty Clause may be cited. The General Duty Clause stipulates that each employer shall furnish to all employees a workplace free from recognized hazards that are causing or are likely to cause death or serious physical harm.[3]

During a 10-year span from 2003 through 2012, a total of 614 US dairy farms received OHSA inspections. Of these, 57% were planned inspections, 19% were the result of an accident, 12% were the result of an employee complaint, and 8% were the result of a referral.[4] From 2003 through 2012, the General Duty Clause has only been cited 29 times on US dairy farms. Some other more common citations were related to the following[4]:

- Lack of proper injury and illness prevention program;
- Lack of work injury recording and reporting;
- Lack of mounting or proper tagging of portable fire extinguishers;
- Inadequate communication program about hazardous chemicals;
- Inadequate process safety management of highly hazardous chemicals;
- Inadequate hazardous waste operation management and emergency response;
- Inadequate respiratory protection;
- Lack of roll-over protective structures (ROPS);
- Inadequate guarding floor and wall openings and holes;
- Inadequate eye and face protection;
- Inadequate medical services and first aid;
- Inadequate guarding of field and farmstead equipment;
- Lack of training and injury prevention strategies related to animal handling.

Canada

In Canada, although principles of occupational health and safety legislation are fairly consistent across provinces, occupational health and safety legislation is primarily a provincial responsibility, with a few exceptions that fall under federal jurisdiction. Provincial ministries of labor (whose names vary slightly from province to province) are each responsible for their own occupational health and safety Acts and Regulations. Most, but not all, provinces in Canada cover farming, including dairy production, under their respective OHS Acts and legislation.[5] The one agricultural exception to this rule are grain elevators licensed by the Canadian Grain Commission, certain feed mills and warehouses, flour mills, and grain seed clearing plants, which fall under federal jurisdiction.

Occupational health and safety Acts and Regulations in Canada have General Duty clauses that outline general responsibilities of employers, including farmers, with respect to looking after the health and safety of their farm workers. Dairy production is typically covered under more general OHS requirements for hazard identification and risk reduction strategies, often centered around specific hazards such as chemical, biological, physical, and ergonomic hazards. For example, in cases where specific legislation for hazardous exposures exists, such as noise exposure, those regulations would apply equally to the dairy industry. There is an overriding expectation of workplace safety based on principles of hazard recognition and control measures that applies to all industries, including agriculture and the dairy industry.

European Union

General legislation in Europe must meet standards set by the European Community (EC); but as with most legislation, each country has made minor changes to suit the local conditions.

United Kingdom

The current OHS system in the United Kingdom has been in place for over 30 years and its foundation was established by the Health & Safety at Work etc. Act 1974 (HSWA).[6] One fundamental principle of the system is that those who create risks in the course of carrying out their work activities are responsible for controlling these risks, by assessing them and taking appropriate action to reduce them "so far as is reasonably practicable." This means that a duty holder must take all possible precautions up to the point where taking further measures would be grossly disproportionate to any residual risk. This principle applies to the self-employed as well as to employers and, in addition, employees also have a duty to take reasonable care for the health and safety of themselves and others.

Since the HSWA was passed, the Health & Safety Executive (HSE) has been engaged in progressive reform of the law, seeking to replace detailed industry-specific legislation with an approach in which regulations, wherever possible, express goals and general principles. More detailed requirements are placed in codes and guidance. Legislation has also been refined by European directives and/or regulations.

The HSWA and related legislation are primarily enforced by HSE or local authorities, according to the main activity carried out at individual work premises. In general, HSE will enforce in "higher-risk" industries, including agriculture. As well as its enforcement role, HSE has statutory responsibilities to propose health and safety law and standards to ministers and to provide policy, technological, and professional advice.

Although dairy farming and agriculture in general, have very specific health and safety issues,[7] including high and increasing levels of self-employment and an aging workforce, UK OHS legislation applies in exactly the same way as it would in any other industry. HSE is responsible for enforcing health and safety law in dairy farming and has a number of operational inspectors and visiting staff who deal with the industry by a range of methods, including on-site visits (announced and unannounced); investigation of accidents and complaints; providing guidance and support at visits, by phone, or at agricultural events; safety and health awareness days (SHADs); and enforcement where necessary. Enforcement can take several forms, from the informal (verbal or written), through the issuing of Improvement or Prohibition Notices to the initiation of a prosecution.[7]

In addition to operational staff, HSE has an "Agriculture and Food" sector that takes an active role in working with the industry and other key stakeholders. The sector is also responsible for writing the wide range of industry-specific guidance, which is available on the HSE Web site.[8]

Italy

In Italy, agriculture and dairy industry are not specifically addressed by OHS legislation, and the sector falls in the field of application of the more general OHS legislation of Italy, which was reformed in 1996, with the law decree 626/94, and amended in 2008 (law decree 81/08) and 2009 (law decree 106/09).[8] All these changes (law decrees) relate to the adoption in Italy of EU directives and/or regulations. Therefore, in many aspects, the Italian OHS legislation is similar that in other European countries. In particular, especially in Italy, it has been established that those who create occupational risks are responsible, at their own expense, for risk assessments, management, and control of the risks as well as for health surveillance of the exposed workers.

Each enterprise (workplace), independently of the size, must undertake risk assessments, under the guidance of a person responsible for the process being assessed, prepare a written "Risk Assessment Report" (RAR), and provide workers with the level of training/education appropriate to risks. In small-sized enterprises with less than 10 employees, which is the case for the majority of the agricultural and dairy enterprises in the Italy, characteristics and contents of the report are simplified and the responsible person may be the employer himself.[8]

Health surveillance of workers is mandatory when RAR identifies significant health risk(s), and an occupational health physician (OHP) must develop a health surveillance protocol specifically targeted, in periodicity and contents, to the health risk(s) identified in the RAR.[8]

Workers must be involved in the OHS risk assessment and management process through one or more representatives elected or appointed, based on the enterprise's size or trade unions. At least once per year, for enterprises with more than 10 workers, all the participants in the enterprise prevention system (employer, responsible for preventive activities, OHP, and worker's representatives) must meet, discuss, and share contents and priorities of RAR and any epidemiological and/or statistics data available to the OHP. Health surveillance and training/education must be provided to all employees, whereas family and self-employed workers "have the right ask to be provided with health surveillance as well as training/education."[8]

In theory, the OHS legislation seems very sound and suffers several weaknesses, but in reality it seems to be hardly applicable in the dairy industry. The main problem in the Italy, similar to many other countries, is that more than 95% of agricultural enterprises are family or self-employment based. Consequently, these enterprises seldom decide to activate health surveillance and training/education programs. This situation brings about not only a lack of preventive activities, but also a significant underreporting of occupational diseases and injuries, which makes epidemiological data from agriculture and dairy industries very weak. The second problem is the difficulties faced in undertaking risk assessments in very small enterprises, where the variability of job and tasks is very high, and consequently the significant variability of occupational exposures. The third problem is the high proportion of seasonal/transient workers, who are often ruled out from OHS health prevention programs. Finally, the increase in the proportion of migrant workers (in Italy a significant proportion of dairy milkers come from Asia) makes it difficult to undertake health surveillance in addition to providing training/education programs.

The final issue in the Italian situation is that OHS legislation is strongly connected to EU legislation that addresses food production, which generally relates to animal welfare, which highlights animal needs that in many cases may conflict with protecting the workers, robustness of the farms, and traceability of food. It is worth noting that with the increase in the size of farms, the situation becomes more similar to the situation that exists in industry and the specifics relating to agriculture tend to disappear. This is happening most importantly in dairy food production regions.[8]

Sweden

The statutory foundations are laid in the Work Environment Act (AML), passed by the Riksdag (Sweden's parliament). The Work Environment Act defines the outer framework of work environment regulation.[9]

The Work Environment Authority has been tasked by the government with issuing more detailed regulations on the subject. This is done by issuing, in their own statute book, AFS, provisions and general recommendations specifying the requirements to be met by the work environment.

Provisions can, for example, refer to hazards, mental and physical strain, dangerous substances, or machinery. They are drawn up in consultation with the labor market parties.

It is always the employer who is responsible for the operation being conducted in such a way that ill health and accidents are prevented and a satisfactory work environment achieved. The task of the Work Environment Authority is to verify that the employer lives up to the stipulations made in the Work Environment Act and in the provisions issued by the Authority itself. This verification is usually based on inspection.[9]

Work environment inspections at workplaces in Sweden are carried out by inspectors from the Work Environment Authority. The inspectors are stationed in 10 districts. In the course of an inspection, they check that the employer has an effective organization for systematic work environment management. They also check the work environment in the holistic perspective of the risks (physical, mental, and social) that the operation entails, but there are cases of an inspection targeting a particular hazard (such as a certain type of machine or a certain type of job). The choice of workplaces for inspection is based on an assessment of the workplaces presenting the greatest risk of ill health or accidents.

If inspection shows that the employer is not discharging his obligations under the Work Environment Act, they can issue him with stipulations. Applied in the agricultural sector, this means in practice that

- Some provisions are issued with agriculture as the main target, such as "Pesticides, working with animals, and use of tractors," whereas others, such as "Ergonomics for the prevention of musculoskeletal disorders," are more general but also includes agriculture.
- The farmer has the main responsibility for the working conditions on the farm. Employees has a responsibility to help out and follow the safety rules and alarm if they discover any major health and safety issues.
- The farmer has a responsibility to have an effective organization for systematic work environment management. The farmer has to provide instructions for risky work operations such as working in a silo, moving animals, working with animals, working alone, or handle dangerous substances.[9]

Australia, New Zealand, and the Pacific Region

The general legislative approach to OHS in this region is similar as it is all risk based.

Australia

OHS legislation is state-based legislation, which means that over the last 100 years there have been differences between states on how OHS legislation is been applied to the dairy industry. Until the mid-1980s little general OHS legislation applied directly to dairy. What did apply, related mainly to safety issues such as rollover protection for tractors and provision of services such as housing for rural workers.

Following the publication of Lord Robens report, most Australian states held their own review into OHS legislation and changed their legislation to risk based and included all workplaces. This was the first time most agricultural businesses really had to worry about ensuring a health and safe workplace, but it did not go far enough in that it did not cover self-employed or family-run farms where there are no employees.

In the last few years, there has been major revision of the OHS legislation in Australia with the publication of model Workplace Health and Safety (WHS) legislation, which includes an act and regulations, which have been enacted in five states as well as the Commonwealth of Australia by the beginning of 2013.[10] The revision in legislation not only has broadened its application to employers, employees, and suppliers, but also has strengthened the act in relation to people conducting businesses that includes farms. This means that this legislation will apply to all dairy farms in the states that have adopted the WHS legislation, which are Queensland, New South Wales, Australian Capital Territory, Tasmania, and Northern Territory. It is interesting to note that the largest dairy state in Australia, Victoria, announced that they would not be implementing current model.[11]

The new WHS legislation[10] requires the dairy farmers to ensure that their farm is safe and that they meet the new regulations, which are very lengthy and include codes of practice on specific topics, such as

- Electrical Risks in the Workplace;
- Hazardous Chemicals Risks in the Workplace;
- First Aid in the Workplace;
- Plant Risks in the Workplace;
- Hazardous Manual Tasks;
- Confined Spaces;
- Managing the Work Environment and Facilities;
- Managing Noise and Preventing Hearing Loss at Work;
- Managing the Risk of Falls at Workplaces;
- Excavation Work.

The changes in the OHS legislation will be a challenge for many of the smaller dairy farms as they move to meet all the new requirements over the next few years.[11]

New Zealand

New Zealand's legislative framework was based on a prescriptive model until the early 1990s. The rural sector was administered by Health Act 1956, Shearers Act 1962, and the Agricultural Workers Act 1977, to name but a few.

When the Health and Safety in Employment Act 1992 (HASE Act) was introduced in April 1993, it resulted in 14 regulations being repealed, but the Agricultural Workers Accommodation Regulations until the HASE Act were enacted in Regulations 1995.[12] The primary requirement of the HASE Act was to identify hazards, and assess them to determine whether they could cause serious harm (defined in Schedule 1). Hazards are managed by a hierarchy of control that was to be followed, to eliminate, isolate, or minimize the consequence of the exposure.[12]

Elimination means that the hazard was engineered out or the hazard was discontinued completely. This control measure is seldom practical. Isolation means machine guards, barriers, or distance or time frames; this measure is used where practicable. Minimization means controls including PPE, training, signage, supervision, etc. Where minimization is used, atmospheric sampling must be done plus individual monitoring conducted to ensure the controls are effective. This by far is the control of choice by many employers.

Underpinning the HASE Act is the term "all practicable steps." All duty holders are required to use this test when considering their obligations and duties under the Act and regulations. The term includes concepts of

1. the nature and severity of the harm;
2. the likelihood of the harm occurring;
3. the current state of knowledge about the harm;
4. the means available to manage the issue; and
5. the availability and cost of those means.

These provisions only apply where the person knows or ought reasonably to have known about the issue(s).[13]

The Regulator has produced around 130 codes of practice, guidance notes, and fact sheets on a wide range of topics. These are sector specific and can include business collaboration in the development stages.[13]

There are 25 specific codes of practice or other information documents relating to agriculture, for example, "Guideline for the provision of safety, health and accommodation in agriculture." This is a wide scoped general information guidance note.[13]

There are several groups assisting the rural sector. These include Farmsafe, Growsafe, AgITO (training), DairyNZ (information on farming and being an employer), ACC, and Min BIE. Farmers are better informed and are more willing to address OHS issues by being proactive and demonstrating a systems approach to OHS.

At the time of writing (October 2012), the entire OHS regulatory framework was under a ministerial review. The final outcomes and recommendations from this are due in April 2013.

Pacific Region

As the dairy industry in most countries in the Pacific Region is nonexistent, no local OHS legislation will apply. It should be noted that most dairy-based products in this region are imported.

South America

The size of the dairy industry varies throughout South America dependent on the country. The OHS legislation that may apply also applies to all farmers, but in this region it is very dependent on the general OHS legislation framework in the country concerned, which in most cases is aimed at mining, manufacturing, and construction, all of which are large employers.

Africa

The dairy industry in African countries varies depending on the country, as does the related OHS legislation. In many African countries, the dairy industry is relatively small, except South Africa where the dairy industry has farms that are similar in size to farms in USA, Australia, and New Zealand, with an average herd size greater than 100 head/farm.

In South Africa, the dairy farms are covered by the same risk-based OHS legislation as all work places (except mines), the Occupational Health and Safety Act (No. 85), which was enacted in 1993 and is designed to cover all workers. There appears to be no restriction on the minimum number of workers except in relation to the provision of safety representatives. Worker exposure to biological agents and chemical substances is monitored through the Regulations for Hazardous Biological Agents and Hazardous Chemical Substances, respectively, under this Act. Health and safety measures comply with ISO14000 (Environmental Management).[14]

Asia

OHS legislation throughout of Asia varies significantly in respect to its design and implementation, but the majority is risk based. In many cases, it only applies to large organization or worksites, in particular mine sites and manufacturing and construction industries. As the dairy industry in most Asian countries is relatively small and in most cases is family based, little OHS legalization applies.

DISCUSSION

An analysis of the OHS legislation that has been briefly reviewed shows little applies directly to the dairy industry. The majority of the OHS legislation uses a risk-based approach that applies to all work places. In most cases, this legislation only relates to farms where the workers are appointed as employees and not on farms where they are either family farmed or classified as self-employed. The exemptions to this are the United Kingdom and the new Australian model legislation, which requires all people at a place of work and/or business activity (paid workers, volunteers, self-employed, and family members) be covered, this includes dairy farms. In many countries, dairy farms are classified as small businesses and employ less than 10 people, which is an issue in countries that have a minimum of employees before the legislation needs to be considered, for example, USA. The other consideration in relation to the impact of OHS legislation on the diary industry is that in some countries, such as USA, Canada, and Australia, the OHS legislation is regionally based. This means that similar types of farms, even in close proximity such as over the state/province border, may have to meet difference OHS legislative requirements. In some cases, this may put an additional cost on the dairy farmers and their workers

It has been suggested that the agricultural industries should have their own OHS legislation, similar to mining and the resources industries. But this may have a negative impact on the farming community because of the lack available funds to support major OHS programs and OHS professionals working extensively in the field. This is strengthened, because in many countries the move is away from industry-based OHS legislation and towards generic legislation that applies across all industries. A major problem for many farmers is keeping up with the changes in legislation, codes of practice, and standards, as it is very time-consuming. In some countries, the farm workers need to have specific OHS training, which is difficult for the farmer to provide. A solution to this is that all farm workers should have completed an agriculture-specific OHS training program prior to working in the industry.

CONCLUSION

There is little OHS legislation in the world that applies directly to the dairy industry. For many, this is an issue that is unlikely to be resolved as the move is towards generic OHS legislation. The major question is how OHS legislation can improve the health and safety of all people who work on dairy farms. The easiest way of doing this is to improve the OHS training to farmers, farming families, and farm workers. A generic training, which covers the major health and safety issues, should be required for any work on a dairy farm.

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Systematic Review of Respiratory Health Among Dairy Workers

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ABSTRACT. The dairy industry is changing on a global scale with larger, more efficient operations. The impact of this change on worker health and safety, specifically, associations between occupational lung disease and inhalation exposures, has yet to be reported in a comprehensive review of the scientific literature. Therefore, a three-tier process was used to identify information using a keyword search of

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online databases of scientific literature. Of the 147 citations reviewed, 52 met initial screening criteria, and 30 were included in this review. Dairy workers experience lung conditions such as asthma, chronic obstructive pulmonary disease, hypersensitivity pneumonitis, chronic bronchitis, and cancer. Recent pulmonary function studies have identified obstructive lung changes among dairy farm workers. The increased scale of dairy production with significant changes in technology and work practices has altered inhalation exposure patterns among dairy workers. The inhalation exposure in the dairy work environment may elicit differing inflammatory responses in relation to timing of initial exposure as well as to repeated exposures. Few studies have measured inhalation exposure while simultaneously assessing the impact of the exposure on lung function of dairy farm workers. Even fewer studies have been implemented to assess the impact of aerosol control technology to reduce inhalation exposure. Future research should evaluate worker exposure to aerosols through a task-based approach while utilizing novel methods to assess inhalation exposure and associated inflammatory responses. Finally, potential solutions should be developed and tested to reduce inhalation exposure to inflammatory agents and respiratory diseases in the dairy farm work environment.

KEYWORDS. Dairy, bioaerosol, inflammation, inhalation exposure, respiratory disease

INTRODUCTION

Lung diseases have been recognized among dairy farmers for decades. Studies of dairy farmers in Europe and the United States have shown increased rates of chronic bronchitis, and occupational asthma, hypersensitivity, and organic dust toxic syndrome. Researchers have consistently reported obstructive disease, with decreased flows, bronchial hyperresponsiveness (BHR), and increased symptoms of wheezing, cough, and phlegm production.[1–11]

The dairy industry is rapidly changing on a global scale, with growth of much larger, more efficient operations, especially in the United States, Denmark, China, Russia, South Africa, Australia, and New Zealand.[12] Geographic variations in dairy design and practices also exist. The increased workforce demands have been met primarily through immigrant workers, many of whom have not worked on a farm previously and use the agriculture sector as entry-level employment. The increased scale of production (>400 milking cows), new technology (e.g., robotic milking), and changing work practices have altered exposure patterns at modern dairies. Therefore, the introduction of new workers raises concerns about their susceptibility to respiratory disease. Reduced worker productivity, increased workers compensation, and high rates of worker turnover are of concern to the dairy industry.

Earlier research on organic dust exposures and lung disease among traditional dairy, swine, poultry, and other livestock producers is highly relevant to the modern dairy industry.[13–17] The objective of this article is to review the current state of knowledge concerning inhalation exposures and respiratory disease among modern dairy workers. Emerging trends in inhalation exposure assessment and understanding of other intrinsic and extrinsic factors playing a role in respiratory disease are also examined. Potential interventions to reduce inhalation exposures and respiratory disease are addressed, and future research needs are discussed.

METHODS

A three-tier process was used to systematically identify and select publications to include in this review: A broad keyword search of online databases, followed by shortlisting, review, and tabulation of findings from pivotal studies exploring the relationship between workplace inhalation exposures and respiratory health outcomes among workers in the dairy industry.

The initial online search of multidiscipline academic databases (PubMed, Web of Science, Proquest, Agricola, Science Direct, and Ebesco) and Google Scholar was carried out September 2012 using a combination of keywords (Table 1). The search was limited to

TABLE 1. Keywords for Database Search

Primary	Secondary	Tertiary
Dairy	Worker	Bioaerosol
Cattle	Manager	Aerobiology
Agriculture	Respiratory	Organic dust
Farming	Lung function	Endotoxin
Milking parlor	Exposure	Fungi
CAFO	Occupational health	Bacteria
	Pulmonary function	Virus
	Inflammatory	Dander
	Innate immunity	Muramic acid
		Ergosterol
		Lipopolysaccharide

dairy-related journal articles and dissertations published between January 2002 and September 2012.

Over 100 articles were initially identified through the search and a short list was compiled. Studies were excluded if they did not include workers from the dairy industry, did not contain original data/findings, and did not address exposure-response relationships. In addition to database searching, other relevant information sources were identified by checking the published references among the identified studies and consulting experts in the field.

RESULTS

Of the 147 citations reviewed, 52 met the initial screening criteria, and 30 were included in this review. The 30 studies were selected on the basis that they included both exposure and health data for aerosol exposure in the dairy industry. A summary of these studies exclusively evaluating both workplace inhalation exposures and respiratory health outcomes is presented in Table 2.

Respiratory Health—Symptoms

This section will review the recent literature on respiratory symptoms and diseases among dairy farmers (typically smaller farms with <400 cows) and workers on large dairy operations. Associations between specific extrinsic inhalation exposures and respiratory impairment are summarized in a separate section.

Asthma

Several researchers have confirmed an increased prevalence of self-reported adult-onset asthma among US dairy workers compared with rural controls.[18,19] Similar, but less-pronounced findings were observed in a population-based study of 2903 dairy workers from New Zealand.[20] In a 12-year follow-up study among 380 Swedish (mostly dairy) farmers, an increase in asthma prevalence was found that was considerably greater for dairy farmers (from 2% to 9%) compared with the general Swedish population (from 3% to 6%).[21] A nested case-control study among 2000 farming apprentice's and 400 rural controls showed that new onset of asthma was associated with dairy production (odds ratio [OR] = 2.5).[22] In another study reevaluating symptoms in the French Doubs cohort of 219 dairy farmers, 130 other agricultural workers, and 99 controls, they observed an increased OR for indices of asthma (OR = 1.5–2.5, not significant) among dairy farmers compared with controls.[23] Results from the same cohort suggest early cessation of work to be associated with the presence of asthma.[24]

Chronic Obstructive Pulmonary Disease (COPD)

In a cross-sectional study of 4735 Norwegian farmers, dairy farmers were more likely to have COPD (defined as forced expiratory volume in 1 second/forced vital capacity [FEV_1/FVC] < 5% lower limit of normal), OR = 1.30, and reduced FEV_1 compared with crop farmers.[11] The prevalence of COPD among dairy farmers was 13.5%. Farmers with atopy were more susceptible to developing COPD.[11]

No significant difference in lung function was found in a cross-sectional analysis of farmers and nonfarmers among 150 subjects from the United States with COPD (FEV_1/FVC < 70%).[25]

Monsó et al. conducted a cross-sectional study of COPD among 105 European (Denmark, Germany, Spain, Switzerland) farmers in animal confinement buildings.[26] Thirty-three dairy farmers were included, but data were

TABLE 2. Characteristics and Results of Studies Evaluating Both Work Exposures and Respiratory Health Outcomes Among Dairy Farmers (2002–2012)

Study (Year)	Location	Population	Exposure[a] endpoint	Health[b] endpoints	Association[c] between dairy exposure and respiratory disease	Comments
Bailey et al.[25] (2008)	United States	$N = 150$ (farmers) $n = 20$ (dairy)	Surrogate	PFT	+	Reviewed all pulmonary function tests at Omaha VA Hospital from November 2004 to March 2005. Subjects with moderate to severe COPD (70% FEV_1/FVC) were included. No significant difference in lung function between agriculture and nonagriculture groups. Nonsignificant trend in decreasing FEV_1 with increasing years worked in agriculture.
Baker et al.[45] (2012)	United States	$N = 120$ (farmers) $n = 50$ (dairy)	Surrogate	Symptom	0	Data from two surveys conducted between 2009 and 2011 were analyzed. 91% worked as milkers. 22.5% had worked in agriculture less than 1 year. Assessed self-reported health status defined as ability to work. Major issues (more than 5% of participants reported) included back/neck pain, dental health, and mental health. Unclear whether respiratory issues were included in survey.
Bang et al.[31] (2006)	United States	$N = 814$ (farmers)	Surrogate	Mortality	+	National Center for Health Statistics data were analyzed on deaths related to hypersensitivity pneumonitis (HP) from 1980 to 1992. The proportionate mortality ratio for HP was calculated by industry and occupation, which were significantly high for agriculture production. More than 55% were due to unspecified organic dusts and 37.3% were classified as farmer's lung. Differences in surveillance are one potentially important limitation.
Basinas et al.[59] (2012)	Netherlands Denmark	$N = 877$ (farmers) $N = 1933$ (farmers)	End Dust	Symptom	++	The paper presents findings from pooled analysis of bioaerosol exposure and health symptom data from a variety of agricultural industries, including dairy farming. Living on farms as a child had a protective effect for atopy and asthma, as did endotoxin for atopy and hay fever. The authors also identified a dose response between endotoxin exposure and organic dust toxic syndrome and chronic bronchitis symptoms. Results specific to dairy farmers not presented.

Blais Lecours[143] (2012)	Canada	$N = 64$ (dairy)	Dust Molecular	Immune	+	Airborne dust was collected from 13 Holstein dairy barns to characterize bacterial and archael loads of bioaerosols. Archael methanogens (e.g., *Methanobrevibacter* species) and bacteria (e.g., *Saccharopolyspora rectivirgula*) were detected up to 10^6 and 10^7 16S rRNA genes per m^3 of air. An elevated response of total IgGs specific to *S. rectivirgula* in worker plasma was confirmed.
Burch et al.[64] (2009)	United States	$N = 125$ (dairy $n = 15$)	Dust End Mur Erg Surrogate	PFT Symptom Immune	++	The efficacy of 3-hydroxy fatty acid moieties (3-OHFA) as an indicator of inflammatory airway responses was evaluated against rFC and inhalable measures among a variety of agricultural workers, including dairy. Geometric mean of endotoxin exposure among participants was 888 ± (6.5) EU/m^3. Even numbered 3-OHFAs were strongly associated with a robust response in nasal lavage fluid inflammation markers, which were 2–3-fold higher among workers in the upper quartile of 3-OHFA exposure compared with lowest exposure quartile.
Chaudemanche[6] (2003)	France	$N = 325$ (dairy)	Surrogate Allergen	Symptom PFT Immune Oximetry	++	Cross-sectional and longitudinal analyses were performed in 1994 and 1999 in a cohort of dairy farmers and control subjects. The prevalence of chronic bronchitis was higher in 1999. Current FEV_1 was lower in dairy farmers than controls, and dairy farming was associated with an accelerated decline in FEV_1/VC over time. No relation was found between allergy and respiratory function changes.
Eastman et al.[18] (2010)	United States	$N = 232$ (dairy)	Surrogate	Symptom	+	Asthma symptoms were elevated among dairy workers compared with controls that smoked and never smoked. Dairy workers had an OR of 2.73 and 0.33 associated with asthma and eye irritation respectively compared with controls. Dairy workers self-reported better health than control workers after controlling for smoking status.
Eduard et al.[9] (2009)	Norway	$N = 4735$ (farmers) $n > 25\%$ (dairy)	Dust BIO End Allergen Silica Amm H_2S	PFT Symptom	++	Livestock farmers had a greater predominance of chronic bronchitis and COPD in comparison with crop farmers, as well as lower FEV_1. Mean endotoxin exposure in cattle farmers 46×10^3 EU/m^3 and organic dust 2.1 mg/m^3. The prevalence of chronic bronchitis among dairy farmers was 6.4% and for COPD 14.2%. Total dust, silica, hydrogen sulfide, and ammonia exposure were risk factors in the development of COPD in atopic farmers.

(*Continued*)

TABLE 2. (Continued)

Study (Year)	Location	Population	Exposure[a] endpoint	Health[b] endpoints	Association[c] between dairy exposure and respiratory disease	Comments
Eng et al.[20] (2010)	New Zealand	$N = 2903$ (farmers) $n = 102$ (dairy)	Surrogate	Symptom	+	Excess risk of adult-onset asthma for ever working as an animal producer (OR = 1.66) and other agricultural worker (OR = 2.08)
Fenton[144] (2009)	United States	$N = 624$ (dairy)	BIO Dust	Symptom	+	Total bacteria 2.55–4.43 log 10 CFU/m^3. Antimicrobial resistant bacteria identified (*Staphylococcus* sp.). 10.4% of women indicated they had contacted a disease from an animal. 9.8% indicated difficulty breathing. 16.7% reported skin disorders.
Fenton et al.[49] (2010)	United States	$N = 624$ (dairy)	Surrogate	Symptom	+	Cross-sectional study among women working on dairy farms to assess zoonotic exposures. A survey instrument was mailed to dairy farms ($N = 3709$) of various sizes. A total of 624 responses were received. 65 respondents (10.4%) reported a disease contracted from an animal. Risk factors associated with difficulty breathing and skin disorders also indicated.
Gainet et al.[30] (2007)	France	$N = 316$ (dairy)	Surrogate	Symptom PFT Oximetry	++	Twelve-year longitudinal study that demonstrated a higher prevalence of chronic bronchitis and decreased blood oxygen saturation in dairy farmers, but not asthma. Accelerated declines in FVC and FEV were associated with age, smoking, and male sex. Accelerated decline in FVC was associated with fodder handling and time spent in barn on traditional farms.
Heutelbeck et al.[55] (2009)	Germany	$N = 42$ (dairy)	Allergen	Immune Symptom	+	Comparison of commercial and locally derived cattle allergen protein profiles, and their ability to induce an immune response in farmers diagnosed with cattle related asthma and rhinoconjunctivitis. The authors conclude that commercially prepared cattle allergen extracts may lack relevant proteins, causing inconsistent results when comparing clinical symptoms with in vivo and in vitro diagnostic methods.
Hoppin et al.[33] (2007)	United States	$N = 18{,}379$ (farmers) $n = 1056$ (dairy)	Surrogate	Symptom	+	The exposure of farmers and their spouses to dairy cattle had a positive, but nonsignificant association with farmer's lung. Other risk factors included pesticide application, and preparation and handling of animal feed.

Hoppin et al.[46] (2003)	United States	$N = 20{,}468$ (farmers) $n = 1124$ (dairy farmers)	Surrogate	Symptoms	+	Animal interactions were identified as the highest risk for wheeze. Dairy had an OR of 1.26 (1.08–1.48) for the development of wheeze, and a dose-response relationship between wheeze and milking/veterinary frequency. The combination of atopy and asthma had an effect modification on wheeze for both dairy farmers (OR = 3.84; 1.14–12.98) and milkers (OR = 5.51; 1.28–23.72). Current smoking was protective for the development of wheeze.
Jenkins et al.[19] (2005)	United States	$N = 11{,}272$ $n = \sim 798$ (dairy)	Surrogate	Symptom	+	Assessment of the prevalence and incidence of self-reported asthma, diabetes, heart disease, hypercholesterolemia and hypertension. Farming was associated with a significantly elevated risk of asthma (OR = 1.542; $p < .001$).
Jouneau et al.[43] (2011)	France	$N = 147$ (dairy)	Surrogate	PFT Symptom	+	Preliminary screening with the electronic mini-spirometer identified 45 suspected bronchial obstruction cases (FEV_1/FEV_6 <0.8), of these, 14 were confirmed as obstructive ($FEV_1/FEV_6 \leq 0.7$) using standardized spirometry testing. 4 asthmatics, 3 smoking-induced chronic obstructive pulmonary disease (COPD), and 7 farming-induced COPD. Feeding duration (foddering) was a significant risk factor for farming-induced COPD.
Kolstrup and Hultgren[48] (2011)	Sweden	$N = 61$ (dairy)	Surrogate	Symptom	+	Exploration of the relationship between dairy cow health with the exposure of dairy owners/workers to physical and psychosocial stressors. No specific discussion of respiratory disease. Chronic disease cases were combined including asthma, diabetes, allergy etc.
Monso et al.[26] (2004)	Europe	$N = 105$ (farmers) $n = 23$ (dairy)	Dust Ammonia End CO_2	PFT Symptom	+	Eighteen cases of COPD identified. A dose-response relationship between COPD bioaerosol exposures. Data for dairy farmers not presented separately.
Rask-Andersen[21] (2011)	Sweden	$N = 380$ (farmers)	Surrogate (facility)	Symptom PFT Immune	+	Twelve-year follow-up among 380 farmers, 270 with clinical investigation. 67% still farmers, the majority dairy farmers. Asthma prevalence in 1982 and 1994 converted to Swedish faming population estimates. Steeper increase in asthma prevalence among farmers from 1982 to 1994 (2% and 9%, respectively) compared with general Swedish population (3 vs. 6%), most asthma cases non–IgE mediated. Average yearly decline in FEV_1 47 mL and FVC 44 mL. Estimated incidence Hypersensitivity pneumonitis 2–3/10,000 farmers.

(*Continued*)

TABLE 2. (Continued)

Study (Year)	Location	Population	Exposure[a] endpoint	Health[b] endpoints	Association[c] between dairy exposure and respiratory disease	Comments
Omland et al.[22] (2011)	Denmark	$N = 2371$ (farm students and controls) $n = 59$ (dairy)	Surrogate	Symptom PFT Immune	++	Risk factors for the development of asthma in farming school students included dairy production (OR = 2.5, 1.1–5.3), swine rearing (OR = 3.4, 1.6–7.0), welding (OR = 7.0, 1.2–41.6), and smoking (OR = 3.3, 1.7–6.3). Being born and raised on a farm significantly reduced the risk (OR = 0.5, 0.3–0.98)
Reynolds et al.[40] (2012)	United States	$N = 137$ $n = 15$ (dairy)	Dust End 3OH	PFT Immune	++	Evidence for dose dependent association between exposures and cross-shift FEV_1 and FVC, most pronounced for grain workers. Indications for effect modification by smoking, pesticide exposure, job duration, and TLR4 polymorphisms.
Reynolds et al.[41] (2009)	United States	$N = 134$ $n = 18$ (dairy)	Dust End 3OH	PFT Immune	++	Dairy workers had a mean cross-shift decline in FVC, whereas cattle farmers had a decline in FEV_1/FVC ratio. 44% of the dairy workers surveyed had an FEV_1 less than 95% of predicted value.
Richiardi et al.[34] (2012)	Italy	$N = 3803$ (all occupations) $n = 24$ (dairy)	Surrogate	Clinical cancer	+	Case-control study on occupation and upper aerodigestive tract cancer. For cattle and dairy farmers, increased risk (adjusted ORs) were seen for oral/oropharynx cancer, OR 3.45 (0.97–12.3); esophagus cancer, OR 6.88 (1.44–32.8); but not for hypopharynx/larynx, OR 1.03.
Smit et al.[66] (2008)	Netherlands	$N = 877$ (agricultural and horticulture) $n = 314$ (dairy)	End Surrogate	Symptom	++	Exposure estimates were available for 116 agricultural process workers and 82 farmers. Endotoxin exposure was inversely related to hay fever and self-reported allergy, and positively to wheezing, shortness of breath and cough with or without phlegm.
Smit et al.[47] (2007)	Netherlands	$N = 1798$ (farmers) $n = 812$ (dairy)	Surrogate	Symptoms	+	Asthma symptoms fewer in all farmers compared with general population and less frequent in organic farming with waking up with shortness of breath (OR = 0.4), or wheezing (OR = 0.7). Hay fever was more common in organic animal farmers but related more to family history and prior farm exposure as a child.

Thaon et al.[23] (2011)	France	$N = 448$ (farmers) $n = 219$ (dairy)	Surrogate	Symptoms PFT	+	This study looked at the changes in respiratory status between two study periods 1994 and 2006 of the same subjects. Respiratory disease was self-reported (using a questionnaire) to be more frequent (OR = 2.85) in dairy workers than controls, also farmers who handled hay or straw had a greater prevalence (OR = 3.49) for wheezing and hay fever. In 2006, dairy farmers were reported to have significant decline in FEV_1/FVC which was attributed to handling animal feed.
Venier et al.[36] (2006)	France	$N = 215$ (dairy)	Surrogate	PFT Symptom Immune	+	An accelerated decline in lung function was associated with age, male, traditional farm, high total IgE. Modernization of the farm was linked with a lower lung function decline.

[a]Exposure endpoints: Dust = organic dust; End = biological endotoxin; Erg = ergosterol; Mur = muramic acid; 3OH = 3-hydroxy fatty acid; BIO = viable and culturable bacteria and fungi; Molecular = molecular speciation for microorganisms; Allergen = allergens including cattle hair and dander, mites and bird droppings; Surrogate = no direct measurement, exposure by groups (activity, facility type); Glu = $\beta(1\rightarrow3)$-glucans; Amm = ammonia; CO_2 = carbon dioxide; H_2S = hydrogen sulfide.

[b]Health endpoints: PFT = pulmonary function testing; Symptom = health symptoms questionnaire; Immune = immune response testing; Medical = medical examination (including weight, size, blood pressure, auscultation of heart and lungs, and skin inspection); Focus = focus group discussion/expert panel; Clinical = clinical case report for infectious disease/cancer; Oximetry = arterial oxygen saturation and cardiac frequency measures.

[c]Exposure–respiratory disease association: ++ = strong; + = weak/moderate; 0 = none.

not presented separately. Lung function was measured before and after work using portable spirometers, and symptoms documented using questionnaires based on the European Community Respiratory Health Survey.[27] FVC and FEV_1 were expressed as a percentage of the European Community for Steel and Coal (ECSC).[28] COPD was defined according to Global Initiative for Chronic Obstructive Lund Disease (GOLD) criteria.[29] Eighteen of the farmers (17%) had COPD (7 mild, 8 moderate, 3 severe), and 20 (19%) had a variability of over 10% during the work shift. The mean baseline FEV_1 was 98.5% predicted, whereas FVC was 103.8% predicted.

Chronic Bronchitis

In a study of Norwegian farmers, dairy farmers were more likely to have chronic bronchitis (OR = 1.6) compared with crop workers.[11] The prevalence of chronic bronchitis among dairy farmers was 6.4%.[11] Gainet et al. also reported the prevalence of chronic bronchitis among dairy farmers at 17.2% compared with 5.7% in the control group (adjusted OR = 2.2), whereas Thaon et al. found an increased risk of "morning phlegm" among 219 dairy workers (OR = 4.3) after adjusting for age and smoking.[23,30]

Hypersensitivity Pneumonitis (HP) and Farmer's Lung

Hypersensitivity pneumonitis is an immunologically mediated inflammatory lung disease in the lung parenchyma induced by the inhalation of a variety of organic or inorganic antigens and characterized by hypersensitivity to the antigens. In farmers, the disease is generally called "farmer's lung" and in Europe HP is called "allergic alveolitis." Although there has been a decrease in the incidence of farmer's lung due to changes in farming practice (e.g., handling of hay replaced by silage bags), a low prevalence of HP continues to be associated with dairy farming. The National Center for Health Statistics in the United States estimated age-standardized annual death rates for HP among industries and occupations.[31] Proportionate mortality ratios (PMRs) for HP were among the highest for workers in livestock production. Wisconsin counties with highest PMRs also had a higher proportion of dairy operation workers.[31] Two percent of farmers and 0.2% of spouses in the Agricultural Health Study (50,000 farmers and spouses) reported lifetime doctor-diagnosed farmer's lung.[32] Current exposure to dairy cattle was positively associated (not significant) with farmer's lung (OR = 1.3). A similar trend was observed among spouses (OR = 1.5).[33] An estimated incidence of HP of 2–3/10,000 was reported among a Swedish cohort of farmers (mostly dairy).[21]

Cancer

A European multicenter case-control study among 1851 cancer patients found increased risks for oral/oropharynx cancer of 3.5 and for esophagus cancer only among male cattle and dairy farmers (OR = 6.8). An association to hypopharynx or larynx cancer was not observed, neither among male nor among female dairy farmers.[34] There are no reports of an excess risk of lung cancer in dairy farmers.

Respiratory Health—Pulmonary Function

Several publications report on two cohorts of dairy farmers established in the Doubs region of France.[2,5,35] Gainet et al. reevaluated the original 1986 cohort after 12 years with respiratory function tests performed by the same investigator using the same portable pneumotachograph as at baseline and expressed as a percent of predicted per ECSC reference values.[30] The original cohort included 250 dairy farmers and 250 controls,[2] whereas the follow-up included 157 dairy farmers and 159 controls.[30] Mean lung function outcomes for dairy farmers in 1998 were 96.1% for vital capacity (VC), 94.7% for FEV_1, 98.3% for FEV_1/VC, and 81.3% for forced expiratory flow between 25% and 75% (FEF_{25-75}). Accelerated declines in FVC and FEV_1 were associated with age, smoking, and male sex. The authors concluded that dairy farming was associated with increased risk of lung disorders and that a relationship exists between cumulative exposure to organic dusts and decrease in blood oxygen saturation and respiratory function. An important observation with this study was that decline in FVC was associated with exposure.[30]

In 1999, Chaudemanche et al. reevaluated a Doubs cohort from 1994 and compared 215 dairy farmers with 110 controls.[6] Respiratory function tests were also performed using the same portable pneumotachograph and the same ECSC reference values that were used to estimate percent predicted pulmonary function in the previous study.[2,27] Current FEV_1 was lower among dairy farmers than controls, and dairy farming was associated with an accelerated decline of FEV_1 (−16.58 mL/year) and FEV_1/VC (−0.36 mL/year) over time. Venier et al. published another analysis of this same longitudinal evaluation, focusing on comparison of those working on "traditional" versus "modern" dairies using electrical ventilation and barn drying of fodder.[36] Similar to Gainet et al.'s findings, accelerated decline in lung function (VC, FEV_1, $FEF_{25–75}$) was associated with increased age, being male, a high rate of immunoglobulin (Ig)E, and "traditional" farming. Mounchetrou et al. conducted a 12-year follow-up of this 1994 cohort, reevaluating 219 dairy farmers with data from either 2000 or 2006.[24] Again, the same spirometer and reference values were used. The key findings of this study were that those working on "traditional" dairy farms stopped working on the farm earlier than those who worked on "modern" farms. Other predictors of early cessation of work were the presence of asthma or lower lung function, and age at inclusion. Stratified analysis by gender suggested a greater association of asthma in women, and of farm modernity in men. Although FEV_1/FVC below 70% was not a significant predictor of early work cessation, FEV_1/FVC between 70% and 80% was, possibly due to the low prevalence of obstructive syndrome—only 4.7%. In 2006, Thaon et al. performed another follow-up on this same cohort, including 219 dairy farmers, 130 nondairy farmers, and 99 controls.[23] A different spirometer was used, with the same reference group (ECSC). Adjusted for smoking, age, height, and altitude, dairy farmers had a greater decline in FEV_1 (−16.4% vs. −8.2% mL/year) and FEV_1/FVC (−0.21% vs. −0.005%/year) than controls. Increased decline in FEV_1 and FEV_1/FVC was associated with handling animal feed and years of exposure.[23] These studies show a consistent excess of chronic bronchitis among dairy farmers, with a continuing decline in pulmonary function in this cohort over more than a decade.

Rask-Andersen conducted a 12-year follow-up among 380 Swedish farmers, mostly dairy farmers, focusing on asthma.[21] Two hundred seventy dairy farmers participated in the clinical evaluations in 1994. A wedge-type spirometer was used to measure pulmonary function and results were referenced to Hedenström et al.[37,38] Immunological testing provided a marker of exposure to *Thermoactinomycetes*, *Saccharopolyspora*, *Rhizopus*, *Cladosporium*, *Alternaria*, and *Aspergillus*. Pulmonary function values decreased more than expected between 1982 and 1994. Overall, FEV_1 decreased from 100% to 94% of predicted, whereas FVC decreased from 97% to 92% of predicted. Greater declines were seen in farmers with asthma and chronic bronchitis. For men, the average yearly decline in FEV_1 was −47 mL/year and in FVC −44 mL/year; however, it is unclear if the observed associations were adjusted for smoking in this study.[21]

Eduard et al.'s study of Norwegian farmers included personal exposure assessment of participants who had undergone clinical evaluations.[11] About 12% of participants were dairy farmers. Spirometry was performed using a volumetric spirometer and referenced to general population values from a subsequent study in central Norway. FEV_1 (−41 mL) was significantly reduced for livestock farmers, but FVC (−15 mL) was not. This observation was contrary to the previous studies showing reduced FVC but not FEV_1.[11]

Several studies performed measurement of pulmonary function in the field in concert with inhalation exposure assessment. COPD was associated with higher exposures to dust and endotoxin in Monsó et al.'s study of European farmers.[26] Work in large California dairies was associated with mild acute airway obstruction, with both baseline and cross-shift reductions in FEV_1 and FVC.[39] In a cross-sectional study of 174 agricultural workers in Colorado and

Nebraska (2005–2006) Reynolds et al. measured personal work shift exposures to inhalable dust, endotoxin, and 3-hydroxy fatty acid (3-OHFA) constituents, evaluated post–work shift nasal lavage fluid inflammation markers, and performed pulmonary function testing before and after the work shift.[40,41] Eighteen dairy workers were included. Results were reported in reference to Hankinson with interpretation based on the American Thoracic Society–European Respiratory Society (ATS-ERS) taskforce on standardization.[42] Ten percent of the population had baseline FEV_1 and FEV_1/FVC below the GOLD criteria defining obstructive lung disease.[29] Close to half of the population had FEV_1 and FEV_1/FVC less than 95% of predicted. For dairy workers the mean baseline FVC was 98.4% of predicted, FEV_1 was 95.9% of predicted, and FEV_1/FVC was 98.7% of predicted.[41] On average, lung function measures did not drop greatly over the work shift, but 26% had an FEV_1 decrease exceeding 5%, and 10% had a decrease exceeding 10%. Cross-shift changes in FVC were similar.[41] Decrements in pulmonary function were largest in farmers, followed by dairy workers and grain handlers. Both correlations and regression models indicated that smoking, endotoxin/dust exposure, and facility type were significant predictors of baseline FVC and FEV_1, and of cross-shift decrease in FEV_1.

Jouneau et al. conducted a trial of an electronic mini-spirometer (PiKo-6, nSpire Health Inc., Longmont, CO, USA) for on-site pulmonary function testing of French dairy farmers ($N = 147$).[43] This device, used as a screening tool, measures FEV_1, 6-second forced expiratory volume (FEV_6), and FEV_1/FEV_6. Individuals with FEV_1/FEV_6 less than 0.8 underwent standard pulmonary function tests using a spirometer (Masterscreen) according to ATS-ERS recommendations.[44] Preliminary screening with the PiKo-6 identified 45 suspected bronchial obstruction cases; of these, 14 were confirmed as obstructive ($FEV_1/FEV_6 \leq 0.7$) using standardized spirometry testing. The cases included four asthmatics, three smoking-induced COPD, and seven farming-induced COPD. The duration of feeding (foddering) was identified as a significant risk factor in the occurrence of farming-induced COPD.[43]

These recent studies have shown a moderate consistency in pulmonary function change generally showing obstructive changes. Many of the studies included only a small percentage of dairy workers.

Contributing Factors—Extrinsic (Inhalation Exposure)

Lung disease in nondairy agricultural farmers is strongly associated with occupational exposures to organic dusts and their microbial constituents, especially endotoxin. This exposure-response relationship has been substantiated from a strong body of evidence provided by in vitro, in vivo, and epidemiological studies. Although these studies are relevant and informative, the dairy industry is quite different, especially with the dramatic changes in technology, work organization and tasks, and workforce demographics over the past decade.[45] As previously described, increased rates of respiratory disease and decreased lung function have been documented among dairy farmers; however, many of these studies used surrogate measures of exposure (e.g., questionnaires). Risk factors for respiratory effects identified through questionnaires include exposure to dust and noxious gases; duration of task (e.g., foddering); type of fodder; being a smoker; being male; age; lack of respirator use; childhood exposures; and altitude.[2,3,30,43,46–48] Work in larger (>400 cows), more modern dairy farms has been associated with lower rates of respiratory symptoms, better pulmonary function, and longer careers compared with dairy farmers or workers on smaller farms.[10,21,23,24,36,49] The reason for this association is unclear; however, modern dairy farms use more mechanical and natural ventilation, barn drying of fodder, automatic feeders, silage instead of hay, and separated milking and housing compared with older and smaller dairy farm operations. Occupational exposure to inhalation hazards may have been reduced with modernization.

Organic dust aerosols in dairies are a complex mixture of fecal material, urine, cow dander and other animal proteins and hair, plant material (feed), insects, mites, bacteria, fungi, and other agents.[1,9,11,41,50–57] The most common allergens among dairy farmers are cow dander, pollens, and storage mites.[58] Exposure to ammonia, hydrogen sulfides, and other chemicals may be substantial for short periods of time. Much research into both etiology and exposure control in dairies and other agricultural settings has focused on gram-negative bacterial endotoxins; however, emerging evidence suggests a potentially strong role for nonendotoxin components such as peptidoglycans (PGN) from gram-positive bacteria. In one of the earliest studies of aerosol exposures in dairies, Kullman et al. evaluated airborne dusts (total, inhalable, and respirable-size fractions), bacteria, fungi, endotoxin, histamine, cow urine antigen, and mite antigen in 85 Wisconsin dairy barns.[50] Personal breathing zone dust concentrations averaged 1.78 mg/m^3 for inhalable fractions and 0.07 mg/m^3 for respirable fractions. Inhalable endotoxin concentrations ranged from 25 to 35,000 EU/m^3. Characterization of inhalation exposures on modern large scale dairies in the United States (California, Colorado, Iowa, Texas) and Europe (The Netherlands, Denmark) have found concentrations of organic dust and endotoxin to be highly variable, with a significant proportion of workers exposed at concentrations exceeding suggested occupational exposure guidelines—2.4 mg/m^3 and 90 EU/m^3.[40,41,52,59–62] The geometric means and ranges of inhalation exposures over a typical 8–10-hour work shift have been comparable among these studies. Inhalable dust concentrations have averaged near 2 mg/m^3, with individual full-work-shift inhalation exposures ranging up to 8 mg/m^3.[41,53,57,60,62] Inhalable endotoxin concentrations have averaged near 300 EU/m^3, with individual exposures exceeding 10,000 EU/m^3.[11,41,53,57,59,60,62] Although inhalation exposures can vary over several orders of magnitude, they can be predicted by location/task with some of the highest concentrations associated with feeding, moving cows, milking cows, and rebedding stalls.[41,52,60] The aerosol size distribution may also vary by dairy farm task and aerosol generation source. Larger aerosol particles ($>$10 μm) have been found to have greater endotoxin loading compared with respirable particles.[60,63] Exposure to 3-OHFA chemical constituents of endotoxin has been evaluated in a few studies.[40,41,54,60,64] The distribution of specific 3-OHFAs in dairies varies by task and location, and has been found to correlate with endotoxin concentrations.[41,54,60]

Seven studies published to date have evaluated both health outcomes and measured exposure to organic dust and endotoxins.[11,26,40,41,61,63,65,66] Most of these studies did not focus strictly on dairy farm workers, but included substantial numbers of dairy farm workers.[11,26,40,41,61,65,66] Rask-Andersen et al. conducted a case-control study of Swedish dairy farmers with and without allergic alveolitis or febrile reaction. Personal exposure to endotoxin and total spores was measured over 1–2-hour periods, representing “normal” and “worst-case” scenarios.[63] Endotoxin exposures were similar for both cases and controls ranging up to 500 EU/m^3. No correlation was found between exposure to endotoxin and symptoms, suggesting other causative factors. This study was limited by the small sample size and short period of exposure assessment. Pulmonary function was not measured and other respiratory end points such as chronic bronchitis were not evaluated. Also, at the time of the study there was limited knowledge on endotoxin-monitoring variables that can significantly influence exposure measurements (e.g., sample loss and assay inhibition/enhancement) that have subsequently been explored in a series of laboratory trials.[67–72] More recent studies have benefited from greater standardization of environmental endotoxin-monitoring methodologies over the last decade.

Monsó et al. studied COPD determined by spirometry in association with quantitatively measured stable contaminants (dust, endotoxin, ammonia, and carbon dioxide) and farm characteristics (area, temperature, and relative humidity) in 105 never-smoking farmers.[26,73] The authors found a dose-response relationship between COPD and levels of total dust and endotoxin exposure. No association was found with COPD and other measured exposures The conclusions are, however, limited by the small sample size and the use of area sampling for exposure determination. Personal exposure sampling would have provided a more representative and accurate measure for the assessment of lung function responses to these agents. In addition, the study offers no information on potential differences in responses across different types of production. The levels of personal exposure to dust and endotoxin among poultry and swine farmers can exceed those among dairy farmers by several fold.[53,74–76] Therefore, lung function responses among poultry and swine farmers could have driven the estimated exposure-response relationships.

Basinas et al. pooled data from four epidemiological studies to examine exposure-response relationships between occupational endotoxin exposure, allergic sensitization, and nonallergic respiratory diseases.[61,65] The study included 3883 Dutch and Danish employees in veterinary medicine, power plants using biofuel, agricultural processing, and farming. Endotoxin exposure was estimated by quantitative job-exposure matrices specific for the study samples, based on detailed measurement of exposure among the studies. Inverse dose-dependent associations between endotoxin exposure and allergic sensitization and hay fever were reported, most lly among agricultural workers, but in coincidence with an increased risk for organic dust toxicity syndrome (ODTS), and for exposure to concentrations above 100 EU/m^3 also for chronic bronchitis. In stratified analysis by self-reported farm childhood exposure, endotoxin exposure was inversely associated with allergic sensitization only among workers without a farm childhood. The authors concluded that childhood and occupational endotoxin exposure appears to result in a protective effect for allergic sensitization and hay fever, but also appears to result in an increased risk for ODTS and chronic bronchitis.[61]

These results largely confirmed those from a previous cross-sectional study among Dutch individuals occupationally exposed to endotoxin.[66] Questionnaire data from 337 agricultural processing industry workers and 504 mostly (62%) dairy farmers were included in regression analysis with modeled endotoxin exposure on the basis of 247 personal full-shift exposure measurements. The authors reported a steep inverse exposure-response relationship between endotoxin exposure and hay fever that was independent from childhood farm exposure. At the same time increased endotoxin exposure was associated with an increased risk of asthma-like symptoms such as wheeze, daily cough, and shortness of breath. No interaction by allergic status was observed. Comparable findings were reported when analyses were performed in a subgroup of 338 agriculture industry workers and 89 farmers with objectively measured health outcomes, specifically serum IgE to common allergens and nonspecific BHR.[77] These findings as well as those of Basinas et al. indicate differences in health response to endotoxin exposure, which in addition appears to play a dual role on the development of health symptoms among humans.[65]

In a cross-sectional study, Reynolds, Burch, and colleagues quantified personal work-shift exposures to inhalable dust, endotoxin, and 3-OHFA, and evaluated both pre- and post-shift nasal lavage fluid inflammatory markers and lung volume changes among workers in cattle feedlots, dairies ($n = 18$), grain elevators, and corn farms in Colorado and Nebraska (total $N = 174$).[40,41,64] The presence of genetic polymorphisms such as Toll-like receptor 4 (TLR4) were also determined. Geometric mean endotoxin exposure was highest among feedlot workers (1,093 EU/m^3) and dairy workers (900 EU/m^3). Livestock dusts contained approximately 2 times higher concentrations of 3-OHFAs than grain dusts, with high 3-OHFA exposures (upper quartile 13,325 pmol/m^3) associated with a 2–3-fold increase of polymorphonuclear lymphocytes (PMNs), myeloperoxidase (MPO), albumin, and eosinophil cationic protein (ECP) expression in comparison with the lowest exposure quartile.[64] 3-OHFAs with even numbered carbon chains were most strongly associated with nasal inflammation. Symptom prevalence was not associated with exposures in this analysis.[64]

Both correlations and regression models suggest that smoking, endotoxin/dust inhalation exposure, and facility type (i.e., cattle feedlot, dairy) were statistically significant predictors of symptoms (eye and throat irritation, cough) and pulmonary function (cross-shift decrease in FEV_1, preshift FVC and FEV_1). These results suggest that workers with less chronic exposure to work environments with elevated concentrations of endotoxin-containing dusts are more susceptible to the acute effects of endotoxin and that extended workplace exposures confer a degree of resistance to the effects of endotoxin, or that sensitive workers who do not adapt leave the industry over time.[41]

Additional analysis was conducted on a subset of 137 male workers ($n = 15$ dairy workers) with complete exposure and pulmonary function data to further explore extrinsic and intrinsic factors that might modify the relationships between dust/endotoxin exposures and cross-shift pulmonary function changes.[40] Larger cross-shift reductions in lung function were observed among workers within the highest quartiles of exposures (quartile geometric means of 7.38 mg/m^3, 5243 EU/m^3, and 6157 pmol/m^3). Smoking, exposure time on the job, and self-reported use of pesticides or herbicides increased the impact of exposure of inhalable dusts, endotoxin, and 3-OHFA on respiratory morbidity. There was also limited evidence of the potential modifying effects of obesity, preexisting respiratory conditions, and the presence of genetic polymorphisms (TLR4), which were biologically plausible and consistent with results from other studies.[40]

Eduard et al. performed personal task-based exposure assessment among Norwegian farm workers and reported mean annual exposure concentrations of 46×10^3 EU/m^3 for endotoxin exposure and 2.1 mg/m^3 for total dust exposure among cattle farmers.[11] Total dust, silica, hydrogen sulfide, and ammonia exposure were identified as risk factors for COPD in atopic farmers. Apart from endotoxin, fungal spores may also play a role in health symptoms. Fungal spore levels (2.9×10^6 spores/m^3) exceeded proposed inhalation exposure levels.[78] On average cattle farmers were also exposed to concentrations of actinomycetes (1.7×10^5 spores/m^3), bacteria (1.1×10^7 spores/m^3), (1,3)-β-glucans (8.8 μg/m^3), mites (5.0 mite units/m^3), inorganic dust (0.79 mg/m^3), silica (0.14 mg/m^3), ammonia (11 ppm), and hydrogen sulfide (36 ppb).[11]

Although there is strong evidence linking respiratory disease to endotoxin and 3-OHFA exposures, it is also clear that a number of other agents and modifying factors play an important role.[1,11,40,63] Although there have been fatalities on dairies associated with entry into manure handling systems, there is little published research on modern dairy worker exposure to ammonia, hydrogen sulfide, and other gases and chemicals.[11,26,52] The fatalities have all been related to the cleanout of stored manure, including stirring up of slurry with subsequent release of high concentrations of hydrogen sulfide. The reported concentrations of ammonia in particular have been lower than those reported historically; however, the evidence for synergism with organic dust from poultry and swine operations suggests that this is an issue in need of research.[79] Immunological studies of dairy workers have provided evidence for the role of bacteria, fungi, histamine, cow urine antigen, and cow hair antigen.[1,9,11,55,80] Mice and human lung cells exposed to dairy dust extracts have demonstrated the proinflammatory effects of endotoxin-rich dairy dusts.[81,82] An important study by Poole et al. demonstrated that secretion of proinflammatory markers from human monocytes and epithelial lung cells was not dependent on the presence of endotoxin.[80] These dusts contained high concentrations of muramic acid (gram-positive bacteria) and ergosterol (fungi). Fox et al. also demonstrated high concentrations of muramic acid ranging from 0.7 to 11.2 ng/m^3 in dairy barns.[83] Recent research using powerful new molecular biology approaches (polymerase chain reaction, and pyrosequencing) has suggested that bioaerosols in agricultural environments, including dairies, are dominated by a diverse population of gram-positive bacteria.[56,84–86] The application of these methods to air sampling are still relatively new and have yet to be used in studies to assess associations with health outcomes. Coexposure to pesticides was found to modify the relationship between respiratory disease and exposure to organic dusts in two recent studies that included dairy farmers.[32,40] Exposure to mineral dusts and silica in particular may be substantial.[11,87] A growing number of studies are providing evidence of the strong modifying effects of intrinsic factors such as genetic mutations.[40,88–90]

Contributing Factors—Intrinsic

Immune responses in relation to dairy barn inhalation exposures are not completely understood but appear to be similar to those experienced by workers exposed in other confined animal environments. Immune responses appear to relate most closely to the diverse microbial environment present in these atmospheres. The airborne microbes appear to elicit differing innate immune responses in relation to receptor signaling pathways. Inflammatory responses differ in relation to timing of initial exposure as well as to repeated exposures. The role of the host's genetic makeup remains poorly understood.

Timing and length of exposures to agricultural work environments appear to result in differing inflammatory responses. The majority of this work is not specific to dairy operations, but relates to other intensive animal production operations. Certain acute respiratory reactions specific to farming exposures, such as farmer's lung are immunological, whereas ODTS is nonimmunological.[8,9,91] Timing of workplace exposures results in variable inflammatory reactions. Whereas initial workplace exposures and inflammatory activation can result in a very robust respiratory inflammatory response, repetitive exposures to intensive animal production operations appears to modulate immunity and result in little effect, chronic respiratory inflammatory outcomes, and/or protection against allergic diseases.[92–99]

Studies have shown that the prevalence of asthma and atopy is reduced in children raised on traditional dairy farms.[100] The protective effect of exposure to animals and animal confinement operations and activities appears to be strongest when exposure occurs in utero or early in life.[101–106] Toll-like receptor 2 (TLR2) appears to have a role in this effect.[107] Exposure of the mother to the farm during pregnancy, rather than exposure of the infants after birth, appears to relate to an increase in innate immune receptor expression.[108] In studies of asthmatic children, microbial diversity was significantly higher in farmhouse dust, and was strongly and inversely associated with the probability of an asthma diagnosis.[109] In addition, in children, the expression of TLR2, TLR4, and CD14 on blood cells has been found to be higher in farm as compared with nonfarm children at school age.[110] It also appears that some of the protective inflammatory effects may carry over to adulthood.[111,112] Contact with cows and straw appears to account for a majority of the suggested protective farm effect for asthma.[113,114]

Microbial diversity and immune responses have been studied epidemiologically as well as in nasal lavage, human cell models, and mouse models. Microbial diversity has been shown to be strongly and inversely associated with asthma, but only weakly associated with atopy, suggesting that there may be distinct inflammatory mechanisms for asthma and atopy.[115,116] TLR2- and TLR4-independent pathways appear to play a role in the human airway responsiveness on exposure to intensive animal production contaminants.[107,117] Exposure of human respiratory cell lines to organic dusts and gram-positive bacteria have been shown to induce inflammation.[118,119] These dusts can upregulate TLR2 pathogen-associated molecular pattern (PAMP) receptors in epithelial cells and monocytes; the ligands for TLR2 include, for example, lipotechoic acid from gram-positive bacteria.[25] TLR2 blocking or deficiency appears to result in a dampening of proinflammatory cytokine release after organic dust exposure in vitro.[120,121] It has been suggested that there is a specific role for endotoxin in inducing lung inflammation. Specifically, dairy barn dust extracts have been shown to induce significant tumor necrosis factor alpha (TNF-α), interleukin-6 (IL-6), and CXCL8/IL-8 secretion in human monocytes. In these same cells, removal of endotoxin significantly reduced TNF-α responsiveness, but had no significant effect on IL-6 and CXCL8 responsiveness.[96] In mouse models, TLR2 and TLR4 appear to play a role in lung inflammation related to intensive dust exposures.[121–123] A recent study provided evidence that endotoxin components on particles collected on dairies play a major role in mediating inflammatory responses through activation of TLR4 and nuclear factor kappa B (NF-κB) in human macrophages.[82] Furthermore, current work in mouse models is revealing novel cellular and molecular mechanisms through which the microbiota may modulate immune responses and allergic inflammation, and thus contribute to the farm effect.[116,124] There has been demonstration in mouse models that commensal gut bacteria may promote tolerance by exploiting the classical TLR pathway.[125,126]

Different reactions in the nasal mucosa to environmental exposures have been explored by lavage of the nose and subsequent analysis of proteins in the lavage fluid. Biomarkers in nasal lavage reflect different reactions in the nose. For example, ECP reflects the presence and activity of eosinophil granulocytes; MPO reflects the presence and activity of neutrophil granulocytes; albumin concentration reflects the vascular leakage and glandular secretion; and lysozyme concentration is a measure of the secretory activity of the nasal mucosa, although smaller amounts are also released by neutrophils, macrophages, and monocytes. A study among agricultural workers (including dairy farmers) showed that endotoxin levels in inhalable dust were associated with increases in IL-8 concentrations from nasal lavage samples, and the sum of 3-OHFA (pmol/mg) concentrations were associated with elevated PMNs, MPO, and ECP.[64]

Concentrations and properties of particulate matter can generally elicit an inflammatory response. Course particulate matter (PM) emitted from the ambient air of a working dairy barn and instilled into mouse lungs resulted in an inflammatory response, which was predominantly caused by heat-labile materials, especially endotoxin. It was shown that course particles ($PM_{2.5–10}$) were more proinflammatory on an equal weight basis than fine particles ($<PM_{2.5}$) and both fractions gave rise to a neutrophilic response.[81]

Atopy has been proposed as one of the factors associated with increased susceptibility to organic dusts. Smit et al. reported that there is an increased symptomatology and lower lung function in farmers with atopy and hay fever.[47] People with mild asthma or with BHR do have an increased reactivity towards endotoxin exposure,[127,128] and workers with occupational asthma after exposure to organic dust in garbage sorting industries were not able to recruit nasal PMNs after nasal installation of endotoxin in contrast to healthy colleagues.[129] Furthermore, atopics seem to react differently to endotoxin in the ex vivo whole-blood assay.[130]

A few studies have shown α_1-antitrypsin to be a risk factor for respiratory symptoms among workers exposed to organic dusts such as cotton dust and farming.[129,131] TLR4 is a central factor in a complex and long response pathway that may extend to mutations in other components of the pathway.[132] Mutations in the TLR4 gene have been shown to change susceptibility to endotoxin. Schwartz found that a few missense mutations in the TLR4 gene were associated with lipopolysacharide (LPS) hyporesponsiveness in human volunteers (minor allele frequency = 8%).[133,134] Arbour et al. showed likewise that polymorphisms of the TLR4 gene were relatively resistant to the effect of LPS exposure.[135] However, TLR4 polymorphisms have not been associated to asthma in studies of population, and it has not been possible to demonstrate any association to the protective effect on atopy that is seen among farmers' children.[136,137] Endotoxin tolerance is a common feature of organic dust exposed persons.[40,138,139] Reynolds et al. also reported new evidence for the potential modifying effects of obesity, preexisting respiratory conditions, and the presence of genetic polymorphisms (TLR4), which is biologically plausible and consistent with results among other populations.[40] The results suggest that interventions among agricultural workers may need to include more comprehensive wellness and smoking cessation programs in addition to exposure reduction strategies.

Interventions

Interventions that follow a hierarchical approach to reduce illness and injury among dairy workers have shown promise, but implementation feasibility and effectiveness remain largely untested. Few studies have been specifically designed to evaluate control strategies to reduce occupational exposure to inhalation hazards among workers on dairy farms. Traditional strategies to control occupational exposures include engineering controls (e.g., ventilation to remove the hazardous agent from the work environment), substitution of another less problematic product (e.g., feed or bedding) for the offending agent, and administrative measures (e.g., worker rotation). In principle, engineering controls are perferable because of a higher level of effectiveness. As a lower tier for protection, the use of personal protective equipment is implemented (e.g., N95 disposable filtering face piece respirator).

To our knowledge, only one study has been performed to directly assess the impact of an administrative control on reducing occupational exposure to agents such as dust, bioaerosols, or components of bioaerosols (e.g., endotoxin, 3-OHFA, and muramic acid).[62] Choudhry et al. increased the use of a washing system in a dairy parlor to assess impact on both inhalable and respirable exposure to dust and endotoxin.[62] The frequency of use of automated parlor washing system was doubled from twice during an 8-hour work shift to 4 times during each work shift. The authors observed a statistically significant reduction in personal exposure to respirable dust, and concluded that increasing the cleanliness of the parlor may result in decreased occupational exposure to respirable dust.

Few studies have looked at personal exposure to inflammatory agents or bacteria in dairy farms and found associations between reduced exposure and farm practices (e.g., bedding type). Samadi et al. examined whether levels of personal exposure to inflammatory agents or bacteria vary between dairy farmers on the basis of differences in animal density and applied milking methods and bedding materials.[57] Robotic milking was associated with increased personal exposure to inhalable dust when compared with parlor milking, and both dust and endotoxin concentrations were found to be lowest among workers in barns that used sawdust (0.40 mg/m^3; 137 EU/m^3) compared with barns that used composted vegetable and green manure (1.59 mg/m^3; 1006 EU/m^3) as a main bedding material. The latter observation is interesting, as the concentration of endotoxin in aerosolized dust was much higher in farms using composted manure; all other types of bedding examined (i.e., rubber mats, different combinations of sawdust-, chalk-, chopped straw-, and rubber-filled mattresses) resulted in increased levels of airborne endotoxin. Missing from this study was the analysis of endotoxin content of airborne dust among farms that use sand as a bedding material. Sand bedding has become popular among dairy producers in the United States, and has been reported to suppress the growth of *Escherichia coli* O157:H7.[140] However, few studies have evaluated agricultural worker exposure to inorganic components of dust (e.g., silica).[11,87] Drying or aerobic treatment of manure also appears to result in decreasing or eliminating microbial populations of *Firmicutes*.[84] Lester evaluated the effectiveness of an improved manure lagoon treatment system and demonstrated a reduction in emissions of peak hydrogen sulfide.[52] However, as with other studies of manure treatments to date, the impact on occupational exposures was not clear. Future studies of occupational exposure to dust and endotoxin among dairy farm workers should report type of bedding used on the farm. Also, as dairy operators deliberate on the type of bedding to use on the farm, the endotoxin content of the airborne dust should be considered for both worker and cow health.

No studies were found that assessed the use or effectiveness of engineering controls such as ventilation on reducing occupational exposure to inflammatory agents in enclosed areas (e.g., milking parlors). One study reported the workplace protection factor for disposable filtering face piece respirators (e.g., N95) while being used in agricultural settings.[141] The study determined that an N95 filtering face piece respirator may be appropriate to reduce dust exposure, but offers inadequate protection against bioaerosol exposures on farms.[141] Only one dairy farm was included in this study, therefore, the generalizability of the conclusions from this study is unclear.

Summary of Key Findings

- Global dairy operations have undergone dramatic changes in the last decade, with increases in herd size, shifts in worker demographics, and significant changes in technology. The impact of these changes on respiratory health of workers is important and requires assessment of both exposure and control strategies.

- In comparison with control populations such as grain handlers and nonfarm workers, workers in dairy operations exhibit a higher degree of obstructive respiratory conditions, including lower baseline pulmonary function and greater cross-shift decline.
- The respiratory symptoms and conditions documented among modern dairy workers are similar to those found among swine and poultry workers, but the prevalence is lower.
- Inhalation exposure to gram-positive bacteria and their chemical constituents (e.g., PGN) in dairies is much higher than previously thought, and there is strong in vitro evidence demonstrating their inflammatory effects.
- The exposure-response relationship between aerosol exposure and respiratory malfunction in dairy workers is modulated by intrinsic factors, for example, genetic polymorphisms.
- The application and effectiveness of intervention strategies to reduce worker inhalation exposures on dairies has received limited attention and requires further study with a view to the incorporation of comprehensive worker health programs in addition to exposure reduction strategies.

GAPS IN KNOWLEDGE AND PRACTICE

Gaps exist in the scientific literature in four primary areas of research:

1. Novel tools to measure inhalation exposure to aerosols and inflammatory changes of the lung among dairy workers.
2. Longitudinal examination of specific lung inflammatory changes and respiratory effects associated with dairy workers' personal measures of task-specific inhalation exposure to inflammatory aerosols.
3. Evaluation of the role of intrinsic factors, especially gene-environment interactions, gender, and underlying health status, particularly obesity.
4. Development and testing of known and experimental solutions to reduce dairy farm worker exposure to inflammatory aerosols.

Novel approaches to measure inhalation exposure and inflammatory lung changes have been identified in this review, for example, performing inhalation exposure assessment using size-selective aerosol samplers to assess aerosol exposure among workers and using the mini-spirometer as a screening tool for lung changes.[43,62] Innovations in respiratory health screening among dairy workers may be a way of detecting sensitive individuals who can then be informed of measures to prevent or reduce worsening of lung disease. Other novel measures of exposure include using molecular methods to characterizing personal exposure to bioaerosols, recombinant factor C endotoxin assay, and gas chromatography to measure inflammatory bacterial components of aerosols.[60] Additional tools should be evaluated to measure lung inflammation among dairy workers (e.g., peak flow, exhaled nitric oxide).

Few published studies have used a longitudinal design to provide information about the incidence and causes of lung changes and lung disease among dairy farm workers.[24,35] Furthermore, there is some evidence linking extrinsic and intrinsic factors, but more research is needed, especially field studies that include measures of both exposure and respiratory outcomes longitudinally. Standardization of pulmonary function testing has improved significantly, but improved tools and approaches for measuring pulmonary function in field studies are needed. Clearly, studies with robust designs, especially longitudinal epidemiological studies, are needed to comprehensively evaluate exposures and their relationship to respiratory health outcomes among dairy workers.

Currently, few studies were identified that specifically target evaluating potential interventions to reduce inhalation exposure to inflammatory agents among workers in the dairy industry. Future research should focus on modifying existing systems to reduce dust generation in the milking parlor or cow holding areas. For example, vegetable oil applied to animals and surfaces reduces dust generation and limits airborne concentrations in animal production.[142] Perhaps, a similar technique could be used on the cows as they enter enclosed environments (e.g., milking parlor). Some US producers do use a water spray on cows entering milking parlors, but this has not been evaluated. Furthermore, automated dust sensors could be installed to engage the ventilation system once dust concentrations reach a benchmark in enclosed areas. Interventions should also include controlling worker exposure to ammonia, hydrogen sulfide, other gases, and chemicals. Lastly, agricultural health and safety researchers should work closely with the dairy industry to determine potential solutions to reduce worker and animal inhalation exposure to inflammatory agents that are low cost, effective, and fit within the business model of the dairy industry.

CONCLUSIONS

Recent studies focusing on larger modern dairies are consistent with historical studies providing evidence of an association between lung disease and both the extent and duration of exposure to endotoxin-containing aerosols in dairies. Generally mild obstructive changes are reported, but decreases in FVC have been noted in some studies rather than or in addition to decreases in both baseline, cross-shift, and longitudinal FEV_1. Although a few studies have shown a reduction in respiratory effects among workers in modern dairies, both exposures and health effects remain significant. There is new evidence concerning the important role of inhalation exposures in addition to endotoxin and indicating that intrinsic factors such as genetic factors are likely powerful modifiers of exposure-response relationships. Future efforts should focus on the development and evaluation of cost-effective interventions that reduce the burden of lung disease among dairy workers.

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Occupational Health in the Dairy Industry Needs to Focus on Immigrant Workers, the New Normal

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Occupational Health in the Dairy Industry Needs to Focus on Immigrant Workers, the New Normal

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This journal issue focuses on the many health and safety outcomes associated with dairy work, including changes resulting from new technologies associated with modern, larger dairies. However, there is another more dramatic change that has occurred in the dairy industry and that has an even more profound impact on the ultimate goal of improving the health and safety of dairy workers. That change is the transition to an immigrant workforce, a transformation that has occurred over the past 10 to 15 years. In the United States, this has largely been a transition to immigrant Latino workers, whereas elsewhere in the world other immigrant ethnic groups represent this transition. For example, growth in the large New Zealand dairy industry has been largely sustained by increasing the migrant workforce, half of whom come from the Phillipines.[1] Immigrant labor is becoming an increasingly important part of agriculture and animal husbandry in the European Union, particularly since the 2005 EU enlargement. Over 40% of agricultural workers in Italy are from outside the European Union, with the remainder coming from EU countries. In some regions of Italy, the majority of cow milkers come from India. Similarly across the EU countries, unique immigration patterns exist for each country, but all the countries have the similar reality that an increasing percentage of agricultural workers, including dairy workers, are immigrant.

The magnitude of this transition to an immigrant workforce in the global dairy industry is documented in the paper in this volume, "A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms." But even this paper by Hagevoort, Douphrate, and Reynolds, though recognizing that immigrant workers face challenges of low education levels, illiteracy, and culture and language barriers, does not address some of the core issues nor provide serious discussion of tools to improve their health and safety. It is critical that efforts to improve health and safety in dairies address the unique health needs, and social, cultural, and legal realities of immigrant workers.

Sadly, there is a centuries-old history of immigrant workers suffering a greater burden of fatal and nonfatal occupational injuries and illnesses than do nonimmigrant workers.[2,3] This history is reflected in higher fatal and nonfatal occupational injury rates. In the United States, this can be seen in the major industries with large immigrant workforces—agriculture, construction, transportation, and domestic service. These industries have higher occupational injury and more severe disability than do other major industrial sectors. Even within industry sectors,

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immigrant workers have higher fatality rates than do nonimmigrant workers in the same job categories. Unfortunately, there has been little research on the occupational health of immigrant workers, and most of the limited research has been done in the United States.

Why do immigrant workers have worse health and safety outcomes at work? One major finding of recent research is that "precarious employment" is a contributing factor.[4] Precariousness refers to the lack of employment security, a typical condition of immigrant workers that is most extreme for those who are undocumented. Such workers, particularly those fearful of immigration law enforcement, may take greater risks at work, not complain about unsafe conditions, and work without appropriate safety equipment and procedures. Even mental health and other chronic conditions may be worse among workers with precarious employment. Other factors contributing to worse health outcomes include low salary and working two or more jobs, limited or absent health care, language barriers, and lack of transportation.[5]

The largest immigrant population in the United States is of Latino origin, which now represents over 50 million people, or 16% of the population.[6] This is a dramatic increase over the past decade, during which time over half the growth of the US population was due to Latinos. Although three fourths of Latinos live in the West and the South, other parts of the country such as the Midwest and Northeast have experienced dramatically increased growth rates of Latinos.

Agriculture has always been a first occupation for immigrants, and that continues to be the case in the United States as immigrants make up an increasing percentage of farm labor. Thus, the farm labor workforce is now 40% immigrant for the country as a whole, but in some areas such as California immigrants make up over 85% of the agricultural workforce. This transition is dramatically reflected in the dairy industry. Over the past decade, immigrant workers have increased to 70% of the milk production workforce.[7,8] Increases in this largely Latino population are expected to account for all growth in the industry in coming decades.[9]

Why is it important to understand the changing nature of the workforce to improve health and safety among dairy workers? Quite simply, different approaches are needed to address health and safety among immigrant, often non–English-speaking workers. The traditional focus of health education programs on "Anglo farm families" is a model that won't work with this new workforce. However, the demographic transition among dairy workers has been so rapid that health and safety personnel experienced in working with immigrant workers are limited or nonexistent in some areas with large dairy industries such as the Midwest and the Northeast. The obvious first requirement is for health and safety personnel to be fluent in Spanish or other immigrant languages, but that is not sufficient. Establishing trust is a critical requirement that requires listening to workers and working with them to address their needs. The use of *promotoras* or lay health workers from the community is an effective tool to achieve many of these goals. Health care providers should also be knowledgeable about immigrant beliefs about health and disease, traditional medicine, and cultural beliefs.

Health care delivery and public health programs must also be tailored to the needs and realities of immigrant workers. This includes monitoring and studying the health of migrant workers, migrant sensitive health systems, creating policy and legal frameworks that enable, instead of blocking, health care for migrants, and even exploring multinational approaches to health care for this population.[10]

The dairy workforce *and* the workplace have both dramatically changed in the United States and other developed countries in the past two decades. Efforts to improve health and safety need to adapt to that changing reality. Most importantly, an understanding of occupational risk factors causing specific health problems (musculoskeletal injury, asthma, skin rash, infection, etc.) is not sufficient. A critical piece is the dairy worker. With immigrants representing the majority of dairy workers, understanding the causes of illness and injury need to take into account the different perceptions, understanding, and behaviors that may be associated with being an immigrant. Equally as important, efforts to prevent injury and illness, or to treat those outcomes when they do occur, need to be sensitive to the realities of the immigrant worker. It is perhaps worth recalling the Haddon matrix for injury prevention and intervention.[11] This model addresses the pre-event, event, and post-event factors associated with injuries. The intersecting factors influencing these phases of an injury are host, agent/vehicle, physical environment, and social environment. Clearly the host and social environment influences would be very different for the immigrant worker, and need to be addressed differently for the prevention and intervention efforts to improve health and safety of dairy workers.

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International Perspectives on Psychosocial Working Conditions, Mental Health, and Stress of Dairy Farm Operators

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ABSTRACT. Dairy farm operators—farmers, workers, and family members—are faced with many demands and stressors in their daily work and these appear to be shared across countries and cultures. Dairy operators experience high psychosocial demands with respect to a hard work and production ethos, economic influences, and social and environmental responsibility. Furthermore, both traditional and industrial farms are highly dependent on external conditions, such as weather, fluctuating markets, and regulations from government authorities. Possible external stressors include disease outbreaks, taxes related to dairy production, and recent negative societal attitudes to farming in general. Dairy farm operators may have very few or no opportunities to influence and control these external conditions, demands, and expectations. High work demands and expectations coupled with low control and lack of social support can lead to a poor psychosocial work environment, with increased stress levels, ill mental health, depression, and, in the worst cases, suicide. Internationally, farmers with ill mental health have different health service options depending on their location. Regardless of location, it is initially the responsibility of the individual farmer and farm family to handle mental health and stress, which can be of short- or long-term duration. This paper reviews the literature on the topics of psychosocial

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working conditions, mental health, stress, depression, and suicide among dairy farm operators, farm workers, and farm family members in an international perspective.

KEYWORDS. Agriculture, burnout, farmers, mental strain, suicide

INTRODUCTION

Farming, especially livestock farming, differs in many ways from other occupations. Epidemiologists consider the working environment on farms to be especially challenging, because of the diversity and complexity.[1] Globally, dairy farming has undergone extensive structural changes in recent decades. Dairy farms have become fewer, but herd size larger. The expansion from a small family business to a large operation with thousands of dairy cows means increased investments, greater financial responsibility, adaptation to new technologies, and new risks, changed employee-employer responsibilities, different hours and type of work, and a transformation from family farmer to entrepreneur.

Greer[2] describes the current role of farming as multifaceted; in addition to traditional food production, this sector increasingly has other responsibilities such as promoting sustainability related to the environment; development of rural areas; animal welfare; and quality and safety of food products. These changes and transitions may be difficult for most dairy operators and may put a mental strain on members of the farming community.[3,4]

The objective of this paper is to provide a review of the psychosocial working conditions, mental health and level of stress, depression, and suicide among dairy farm operators, farm workers, and farm family members from an international perspective.

METHODOLOGY

This review article was a conjoint project with researchers from Europe, USA, and Australia and the authors have been working in the research field of psychosocial work environment and mental health among farmers, farm workers, and farm families for several years. In developing this review, a snowballing and saturation approach was adopted with the following databases searched: PubMed, Google Scholar, PsycINFO, Scopus, Ebrary, and Web of Science. The key words used in the search procedure were agriculture, farming, livestock farming, dairy farming, dairy farmer, dairy farm operator, dairy farm worker, dairy farm family, migrant workers, rural population, employer, employee, psychosocial work environment, psychosocial working conditions, psychosocial factors, stress factors, stressors, demand, control, social support, internal factors, external factors, health, illness, mental health, mental problems, ill mental health, mental symptoms, mental strain, distress, anxiety, stress, burn out, exhaustion, fatigue, depression, alcohol and drug abuse, suicide, occupational health care, and health services.

Scientific peer-reviewed, English-language research articles, books, e-books, dissertations, and reports were included as literature in this review. The process of selection was (1) reading the title and abstract of the articles or summary of other books, dissertations and reports; (2) reading the full-length articles on the topic and related to dairy farming or livestock farming; and (3) complementing with relevant new references in the found literature.

THE PSYCHOSOCIAL WORK ENVIRONMENT IN DAIRY FARMING

Webster[5] classified the past, current, and future of livestock farming into four categories: (a) traditional; (b) industrial; (c) value-led; and (d) one-planet agriculture. In the present review, we reduced this classification to two types: traditional dairy farming with smaller herd size and manual work; and industrial dairy farming with automated systems, employed workers, and larger herd size.

Traditional Dairy Farming

Dairy farming has unique attributes that impact on farmers' health. Within the traditional dairy farm, the farming family often lives on the farm, including husband, wife, children, grandparents, and perhaps grown-up children and extended family also taking part in the dairy tasks. A special characteristic of the agricultural work force in western countries is the larger proportion of older (over 65 years) and younger (under 16 years) workers compared with other occupational sectors.[1]

Operating a dairy farm involves working early mornings to late evenings, every day, 365 days a year, tending the herd and milking the cows daily. A case study on women's working conditions on 10 dairy farms in Finland found that the working day started on average at 6 AM and ended on average at 6.30 PM.[6] Small dairy farm operators are especially busy, running their farm with no employees and limited opportunities to take a leave or a holiday. Sudden illness or injury may also be a difficult situation to cope with.[6,7] Furthermore, being a small dairy operator means having home and work combined, which leaves little room for full relaxation away from work. Overall, work and home, professional life and private life, and fellow worker and husband/wife may be difficult to separate on farms.[8] Therefore, a personal or family crisis, e.g., serious disabling injury, divorce, or bankruptcy, can cause serious concerns for farmers and their families, resulting in remarkable mental pressure.[3,4]

Despite the global trend of fewer but larger dairy operations, there are still many small family dairy farms, but the decrease in the number of farms also implies an increase in the distance between farms. Many dairy operators work in daily solitude and have limited social contacts. The spouse may have a job outside the farm and not share the same daily work life anymore. Isolation and loneliness have reemerged as a social problem in agriculture today.[9] In a 1997–2001 monitoring study among dairy farmers, the social interaction between family members and neighbors decreased during the study period, indicating a change towards more individualistic values.[10] Farmers under these conditions might be facing and dealing with farm problems on their own, without nearby support.[3,4]

Industrial Dairy Farming

Specialization of livestock production on industrial dairy farms elevates the risk of dairy operators doing fewer work tasks, during longer hours and in adverse working conditions.[1] On the other hand, increased use of automated technology such as milking and forage distribution may relieve the physical demands of work and reduce or alter working times in the dairy. A new responsibility for operators is to monitor these new systems (automatic and robotic milking).

Large dairy operations employ a number of workers. For the farmer, this creates a new kind of professional role as an employer, including extended supervision of staff, wider responsibility for occupational safety, and wider overall management of the farm. The new demands also require new skills and knowledge,[11] such as good leadership, which has been observed to be an important element for work motivation in farm work.[12]

The trend in many Western countries is to use foreign/migrant workers in the dairies. These workers face different psychosocial work environments than farmers or domestic workers, including long work hours in a foreign country away from their family and friends, and social isolation caused by linguistic and cultural barriers. These conditions are often found to be associated with ill mental health, anxiety, depression, alcohol and drug abuse, and even suicide.[13,14]

Multifaceted Psychosocial Demands and Conditions

The International Labour Organization (ILO)[15] defined psychosocial factors at work as including the interplay within and among the work environment. In addition to the content and organization of work, a worker's competence, needs, cultural beliefs and practices, and personal issues may have an effect on work performance and work satisfaction. Most

TABLE 1. ILO[15] Psychosocial Factors at Work and International Characteristics of Dairy Farming

Psychosocial factors at work (ILO, 1986)[15]	Characteristics of dairy farming (source)
1. Physical work environment	Diverse and complex.[1] Traditional vs. industrial farming. Possibly physically demanding and injury risk tasks. New technology in use. High cognitive and sensory requirements.[16]
2. Factors intrinsic to the job; e.g., workload, repetitive work	Intensification of production and long working days. Meaningful work and positive features of work supporting mental health.[16,17]
3. Arrangement of work time	Working periods in cattle houses are outside the ordinary 9–5 working day. Long working days, especially during harvesting/calving.
4. Management and operating practices a. Worker role b. Worker participation c. Relationships at work d. Implementation of changes	a. A new role as an employer requires new skills.[11] Good leadership important for worker motivation.[12] Overlapping roles for farm woman, combination of farm worker and family responsibilities.[6,7] Employed workers with different ethnic and cultural background.[13,14] b. Participation in agricultural decision making may be limited or impossible.[18] c. Private and professional life difficult to separate.[8] Isolation and loneliness.[9] Lack of support and control.[19] d. Structural change; specialization, increased herd size per farm, and increased risks.
5. Technological changes a. Industrialization b. Introduction of new technologies	a. Industrial dairy farming may decrease human-animal contacts and this may be contradictory to, e.g., animal welfare.[20] b. New technologies may improve work conditions but during breakdowns the situation may be difficult to balance. Uses of new technologies often alter the working time and its daily rhythm compared with that on traditional farms.
6. Other factors	Declining economic situation.[2] Symptoms of exhaustion[21] and burnout.[22]

importantly, these factors may have an influence on workers' physical and mental health. The internationally reported characteristics of dairy farming are categorized in Table 1 using the ILO's psychosocial factors at work,[15] highlighting the link to psychosocial influences and possible ill mental health.

Dairy farm operators—farmers, workers, and family members—face many demands, expectations, and stressors in their daily work that are shared across countries and cultures. They may experience high internal demands with respect to hard work and production performance, stable farm income, and social and environmental responsibility. Furthermore, both traditional and industrial farms are highly dependent on external conditions, for which they have little or no control. These external factors include weather conditions, government laws and regulations, disease outbreaks, taxes and expenses related to dairy production, and negative societal attitudes to farming in general. However, farmers have few or no opportunities to influence and control those external conditions. Experiencing a high demand work environment coupled with low control and low social support[19] can lead to stress and strain, ill mental health, and depression, as described by Karasek.[23]

In everyday situations, dairy farmers may face challenges such as high workload, time pressure, machinery breakdown, difficulties understanding new technology, and hazardous working conditions. Economic factors, such as irregular and uncertain income, financial debt, and high interest rates, may elevate the strain. In addition, personal health problems, poor work-life balance, working with multigenerational family members, record keeping, and paper work cause mental strain for farmers.[18,24–27]

In the Nordic countries, studies have shown that young dairy farmers (30–44 years old) experienced more conflict situations, worked longer hours, and were more worried than older colleagues.[28] They were also more concerned about financial problems and lack of holidays and had difficulties managing the conflicting demands of work and family. Swedish farmers and dairy farmers experienced high demands at work, but also a high degree of control and considered their work meaningful.[29,30] However, they felt more insecure regarding their work situation compared with other occupations. Swedish studies also found that dairy farm employees experienced less influence over decisions made on the farm and a faster work pace than dairy farm owners.[30] Female dairy workers in particular experienced excessive work demands, inadequate control and influence, and few opportunities for development and felt that leadership, feedback, and social support were poor on dairy farms.[18]

Danish farmers ($N = 374$) found the psychosocial work environment favorable in general but experienced high cognitive and sensory demands.[16] Development opportunities within the profession were valued as good and the farmers felt that they performed meaningful work. Although a number of Danish farmers worked alone, they had a large degree of social support from the surroundings.[16] Melberg[17] concluded, based on a wide survey ($N = 3383$) conducted in 1995, that Norwegian farmers also did not experience distress. This lack of distress may be because their way of living provided positive features for mental health, e.g., freedom, independence, fresh air, and work with farm animals.

In general, global dairy farming is associated with small family farms with no employees, long work hours, and limited possibilities for relaxation and holidays, home and work at the same place, spouse often working off farm, and few social contacts, but global dairy farming is also associated with large and technically well-equipped dairy operations with many dairy cows, several employees, and comprehensive employer responsibilities. Dairy farm operators, workers, and family members face a number of internal and external psychosocial demands and societal expectations, which they to some degree are able to control. High demands and few possibilities for influencing and controlling these can, however, be mentally straining and lead to stress and depression, especially if the farmers have poor social contact and are forced to deal with the problems on their own. As shown in Table 1, these psychosocial demands, expectations, mental strain, and stress seem to be shared across countries and cultures.

MENTAL HEALTH PROBLEMS AND STRESS ASSOCIATED WITH PSYCHOSOCIAL DEMANDS AND STRESSORS IN DAIRY FARMING

A review of farming, mental health problems, and mental illness indicated that farmers, farm workers, and their families face an array of stressors related to the physical environment, the structure of farming families, economic difficulties, and uncertainties associated with farming, which may be detrimental to their mental health.[26] In Finland, a study by Saarni et al.[19] found that farmers had the lowest rates in all factors measured concerning work ability, subjective quality of life, and health-related quality of life, when compared with salary earners and other entrepreneurs.

Work-related stress is often defined as a conflict where the demands of work are higher than the worker can manage, control, or cope with.[31,32] There are several factors that may moderate stressful situations, including social support, control of work, personal efficiency,[33] a relaxed, positive attitude, and a balance between work and family life.[34]

The National Institute for Occupational Safety and Health (NIOSH) has listed farming as one of the ten most stressful occupations in the world.[34] Research in the USA and Australia has linked stress and mental strain to a variety of factors, including solitary work, financial worries, weather dependency, and family problems. The mental strain can cause sleeping and concentration problems, psychosomatic disorders, increased injury rates, family problems, substance abuse, and at worst suicide.[26,27,35–37]

A recent review of mental health in the rural sector identified the most common stressors as being commodity prices; financial pressures; debt; climate change; overwork; seasonal conditions; government regulations; and compliance.[27] Another study added another factor as an increasing new stressor—the lack of skilled labor.[38] A literature review that gathered research results from 15 scientific articles identified the following as the most common stressors among farm entrepreneurs: (a) the farm economy; (b) regulations, including farming bureaucracy, the amount of paperwork, and the political framework related to agriculture; (c) the weather and natural conditions of agriculture; and (d) dangers in farm work, injuries, and deficiencies in the work environment.[39]

A study in England and Wales investigated sources of stress for farmers in general and found that they had problems with record keeping and paperwork (62%), difficulty understanding forms (56%), and problems arising from the effects of new legislation and regulations (49%).[40] Nearly a quarter reported financial problems and most were worried about money. Very few were socially isolated, with over 90% having at least one confidant. Nearly a third had health problems that interfered with their work. The farmers most vulnerable to financial and other problems were those with small farms and mixed farming operations. The survey confirmed findings from several regional studies that many farmers experienced considerable stress from various causes.[40]

An Australian study showed that dairy farmers had extremely high distress levels, which increased significantly over a 12-month study period, exceeding those of a number of other Australian occupations.[22] Specific measures, such as globalization, finances, and demands from society, explained the variance in psychological distress. The analysis indicated that the theoretical job demand-control model was not sufficient to explain the high levels of distress.

In a survey conducted in New Zealand among dairy farmers ($N = 985$), the stress level was reported as moderate.[24] The new technology in use on farms did not increase stress, but the stress level was higher among older farmers and among women respondents. Farm women's double or triple role as farmer, family member responsible for family issues, and/or off-farm worker may increase the prevalence of stress. In the study by Alpass et al.,[24] stress symptoms were associated with time pressures, machine breakage, weather conditions, and governance policies. Berkowitz and Perkins[41] concluded, however, that stress symptoms were not associated with workload or farm complexity among dairy farm wives ($N = 126$) in the USA, and that family relationships served as a buffer to prevent stress symptoms. In that study, psychosocial stress symptoms were nervousness, restlessness, insomnia, shortness of breath, and fainting. Van Haaften et al.[42] observed that the foot and mouth disease crisis was associated with differences in levels of stress, marginalization, and depression among Dutch dairy farmers.

Kallioniemi et al.[21] observed in their study of Finnish full-time farm entrepreneurs that 34% reported symptoms that could be classified as exhaustion. In another study on Swedish dairy farms, female workers reported poorer mental health and lower vitality and felt more stressed than male workers.[18] Lunner Kolstrup and Hultgren[30] found work-related psychosocial symptoms such as irritation, fatigue, and insomnia in 25% of employed dairy workers. In comparison, the dairy farm owners experienced few work-related psychosocial symptoms except for irritation and fatigue.

Deary et al.[25] compared stress symptoms among farmers ($N = 318$) representing different production sectors and found that dairy farmers had higher levels of stress related to time pressure. A telephone survey conducted in 2004 reached a total of 1182 full-time farmers in Finland and found that the prevalence of stress was about the same (33%) among 491 dairy farmers and full-time farm entrepreneurs in general (34%).[43] The prevalence of stress was higher among the working population (44%) than among the full-time farm entrepreneurs and dairy farmers.[44]

A study on possible associations between worker health and animal health showed that employed workers felt more stressed or frustrated when dairy cows had a high incidence of disease and mastitis.[30] The stress or frustration was explained by the increased workload due to the extra physical labor involving in cleaning, separating, and treating mastitic cows, or the increased mental workload due to pressure or demands from management to improve dairy herd health. An alternative explanation was that workers might have felt empathy and concern for the unwell cows and thus experienced these feelings as mentally unsettling.[30]

Farming has been listed as one of the 10 most stressful occupations in the world.[34] Work-related stress and ill mental health among dairy farmers, workers, and family members have in several international studies been found associated with high workload, time pressure, machinery break down, disease outbreaks, hazardous working conditions and dangers in farm work, difficulties understanding new technology, irregular and uncertain income, financial debt and high interest rates, seasonal conditions, weather dependency, effects of new governmental regulations and compliances, bureaucracy and huge amount of paper work, climate change, employer responsibilities, lack of skilled workers, solitary work and lack of social support, family problems, poor work-life balance, and increased environmental demands and consumer expectations. In addition, studies report increased stress-related symptoms among dairy operators such as sleeping and concentration problems, psychosomatic disorders, irritation, anxiety, nervousness, restlessness, fatigue, exhaustion, increased injury rates, alcohol and drug abuse, depression, and suicide.

SUICIDE AND DEPRESSION IN DAIRY FARMING

People respond to mental strain or stress in many different ways. People may develop physical health problems or they may develop emotional or mental problems, which could lead to depression, alcohol and drug abuse, family violence, or suicide.[27]

Elevated rates of suicide among farmers compared with other occupational groups and the general population have been reported in many Western countries.[45–51] Many factors have been proposed to account for the high rates of suicide among farmers, including access to firearms, the prospect of unemployment, financial difficulties and a sense of personal failure when this involved the loss of a family farm, a functional attitude toward death, increased psychiatric morbidity, personality factors, isolation, lack of social support, lack of personal meaning in life, and high levels of occupational stress. Other studies have addressed the traditional belief that farmers do not like to complain or ask for help, and therefore may be less likely to seek medical care for physical or psychiatric problems.[52]

In a South African case study ($N = 5$) by Holtman et al.,[53] suicide survivors identified contextual factors that included economic problems (poverty), low education, childhood within dysfunctional family environments, alcohol use, interpersonal conflicts and violence, a sense of hopelessness, the absence of coping mechanisms, and easy access to pesticides as a means of self-harm.

Other studies have suggested that exposure to cholinesterase-inhibiting agents may lead to anxiety and depression.[54,55] This mechanism may be a key to the increased risk of suicide observed in some studies, as anxiety and depression are established risk factors for suicidal behavior. Some studies have reported an increased prevalence of depression among farmers compared with other occupational groups,[56–58] and the prevalence of depressive symptoms among farmers who have a history of acute pesticide poisoning is higher than among farmers who have had no history of acute poisoning.[59–62]

Van Wijngaarden[63] reported that suicide was associated with working in occupations exposed to pesticides among men and women. Despite the evidence that selected classes of pesticides may influence mental health, limited work has been done to assess the impact of these compounds on farmers and farm workers. In fact, studies targeting highly exposed workers are rare. Dairy workers are among the farm population that might be exposed to organophosphate chemicals due to the use of these compounds in controlling insects. More work is needed to assess this population of exposed workers.

In the study by Canton and Williams,[64] hearing problems had serious consequences in dairy farm communities in New Zealand ($N =$ 74 participants). These hearing problems could lead to communication difficulties and thus, e.g., development of coping strategies, social isolation, frustration, anxiety, stress, resentment, depression, and fatigue. Peres et al.[65] reported on an AMI (Aging Multidisciplinary Investigation) cohort on France ($N = 1002$), focusing on health and aging in elderly farmers living in rural areas, and found that symptoms of depression were one of several factors cited.

Clingerman and Brown[66] observed that migrant farm workers ($N = 40$) in Texas experienced significant levels of stress during premigration. Arcury et al.,[67] in a study focusing on Latino migrant farm workers ($N = 300$) in the USA, observed that although the work safety climate was considered poor and 27.9% had elevated depressive symptoms, work safety climate itself was not associated with depressive symptoms. However, in the presence of depression, low safety knowledge may increase the probability of injuries.[68]

Mental and physical health is interconnected. Osborne et al.[69] observed in a review that depression was one risk factor for musculoskeletal disorders among farm owners and workers. Depression was the fifth most common health problem (7% mentioned it) in a study by Luque et al.,[70] which examined illnesses and work-related injuries among Latino migrant farm workers ($N = 100$) in Georgia, USA. Depression scores were associated with musculoskeletal problems, which were the major occupational health condition for these farm workers.

Several international studies show elevated rates of depression and suicide among dairy farmers, farm workers, and migrant workers compared with other occupations. Many factors have been proposed to account for these high rates of depression and suicide such as high level of occupational stress, easy access to firearms, pesticides, and medication as a means of self-harm, prospect of unemployment, financial difficulties, sense of personal failure, loss of family farm, lack of social support, lack of personal meaning of life, sense of hopelessness, isolation caused by culture or linguistic, absence of coping strategies, psychiatric morbidity, and personal attitude towards accepting the situation and seeking mental counseling. Exposures to pesticides and acute pesticide poisoning have also been identified as risk factors for depression and suicidal behavior among farmers.

HEALTH SERVICE AVAILABILITY FOR FARMERS, FARM WORKERS, AND FAMILIES WITH MENTAL HEALTH PROBLEMS

Farmers with mental health problems have different possibilities to access health care. To a great extent, it is up to the individual farmer and the farm family to handle the stress, which can be of short- or long-term duration. Besides self-help, the next step is often to get in touch with a local health center or general practitioner, who is often imbued with a high degree of trust by farmers and their families.[71]

Many parts of Australia during 2002–2010 have been in drought, causing associated stress and an increased risk of mental health problems in farming populations. A study by Gunn et al.[72] showed that the most commonly employed coping strategies were planning, acceptance, and active coping, and the least used were alcohol/drug use, denial, behavioral disengagement, and religion. Strong social networks may help farmers cope with stress.[73]

There are a number of different self-help materials available for farmers and farm families, such as resource books for good mental health[74] and guidelines and checklists.[75,76]

A Swedish study carried out among farmers to determine whether psychosocial risk factors were correlated with membership in an occupational health service program. Thelin et al.[77] found that those with occupational health care were less often single and had more education and more social contacts than those without such care. Eating times were more regular and meals were better for those with occupational health care. The Karasek-Theorell indices for psychological demands and decision latitude at work were also higher in those with occupational health care. Better-educated farmers and those with larger farms were more often members of an occupational health care program. In addition, this group had fewer psychosocial risk factors.[77]

Brumby et al.[78] observed that farmers with multiple risk factors for chronic disease (cardiovascular disease, diabetes) benefited from participating in health education and assessment programs with high levels of individual participation. Further, an association between obesity and higher levels of psychological distress in farm men and women was found in a cohort of 1192 farmers.[79]

Finland is one country with a well-developed voluntary occupational health service for farmers.[39] An occupational health nurse and local agricultural advisor visit farms according to an established schedule to survey working conditions at least every 4 years. Mental well-being is assessed by observing the working conditions and the interaction between farmers and others who work or live on the farm. An overview of the mental well-being of farmers is obtained at least every second year in health examinations, including tests of work ability, burnout, depression, and alcohol consumption. If needed, the farmer will be directed to contact further medical experts.[80] There are also some other systems aiming to encourage good working conditions and well-being on farms, e.g., “Resource barn,” a consultancy service provided by a farm advisory organization, and the “Support network for the rural population,” which involves volunteers providing a phone helpline for farmers.[39]

Countries around the world have more or less developed systems or measures aiming to ensure good psychosocial working conditions and mental well-being on farms. Often it is up to the individual farmer and farm family to handle and cope with the stress using self-help material. Health service centers with counseling are also provided in several countries and studies show that farmers benefit from participation in occupational health care programs. Farmers or farm family members with serious injuries, health problems, or disabilities, who have severe financial problems or are having a personal crisis, might need extra support in assessing risks and professional help in order to avoid stress and depression.

CONCLUSION

Globally dairy farmers belong to an occupation facing a large number of multifaceted psychosocial demands, expectations, and stressors. Hazardous and mentally straining working conditions, such as high workload and time pressure, machinery breakdowns, unfavorable weather conditions, and possibly disease outbreaks may be difficult to balance. Economic aspects, e.g., irregular and uncertain income, financial debt, and high interest rates, may also elevate daily stress. In addition, there may be social difficulties, e.g., in balancing work and family and working with multigenerational family members or migrant workers. Several studies report increased bureaucracy, record keeping, and paperwork—and all this seems to cut across countries and cultures.

Dairy farm operators, workers, and farm families living and working with and under these demands and stressors on a daily basis are exposed to mental strain. Research shows evidence of existing and increasing levels of stress symptoms, ill mental health, depression, substance abuse, and even suicide among dairy operators and workers. However, some studies report a high degree of control, a perception of meaningful work, and a favorable psychosocial work environment on dairy farms. A crucial question is how to achieve and maintain positive working conditions within this occupational sector.

This paper highlights the commonality of psychosocial and mental issues globally across dairy farmers (traditional and industrial) and highlights the lack of profound systematic studies to address the psychosocial working conditions and mental health of dairy farmers. Several studies have been performed regarding the psychosocial working conditions and mental health of dairy farmers, farm workers, and their family members. However, the structural and technical development in the sector is rapidly changing and there is a need for further research and studies in order to understand the cause and effect of stress, ill mental health, depression, and suicide in dairy farming. Health service centers that offer professional counseling are available in several countries. However, future research should investigate the effectiveness of these programs and if improvements could be made to these health service centers. Some potential research questions include the following: Geographical location—Do farmers have to travel far to seek help because the health service is located in larger urban areas and not in rural areas? Flexible opening hours—Do farmers work during the day and do the health service centers provide evening appointments? Rural knowledge—Do mental practitioners have profound knowledge regarding rural farm lifestyle?

We recommend that research be undertaken to develop and test self-help measures and further develop, implement, and evaluate mental health programs to assist farmers, workers, and their families to identify and manage stress and ill mental health. Given the findings from this paper and the commonality of these issues globally, this further work should be undertaken at an international and collaborative level to provide economies of scale, robustness of approach, and universal transferability. Extension of this initial work and proposed further work should be communicated through an international conference or other forum.

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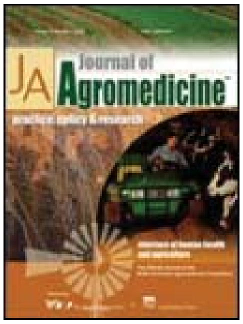

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ABSTRACT. Agriculture is among the most hazardous sectors for workers globally, and dairy farming has been associated with a high risk of injury among workers in several countries. The purpose of this paper is to provide an update on what is known about modern dairy farms and related injuries and fatalities in different regions of the world. As in other sectors of agriculture, fatalities appear to be associated with heavy equipment usage, whereas injuries occur at higher rates with animal production, specifically cattle and milk production. Dairy farming is associated with higher rates of injury as compared with other industrial sectors, but a lack of work-related injury reporting continues to be an issue in several countries. Worker fatality associated with heavy equipment use is not a new observation (e.g., tractors); however, manure-handling systems, livestock handling, and quad bike operation continue to be associated with worker injuries and fatalities on modern farms. Opportunities exist for improvement of safety-related equipment to reduce injury and fatality risk during worker interactions with large animals and farm equipment.

KEYWORDS. Agriculture, dairy, fatality, injury, occupational

INTRODUCTION

Agriculture is one of the most hazardous sectors in the world.[1] The International Labour Organization estimates that 335,000 fatal work-related incidents occur annually worldwide, and 170,000 involve agricultural workers. Additionally, agricultural workers suffer serious nonfatal injuries in workplace incidents caused by machinery, chemicals, and animals.[1,2] The agricultural sector comprises different types of agricultural production (e.g., cash crop, livestock), which results in agricultural workers being exposed to a diverse array of occupational hazards. Farmers and farm workers are exposed to a variety of work factors or hazards (e.g., injuries caused by machines and animals), which can affect their safety and health.[3–8] Dairy farming has long been known to be associated with a high risk of injury among workers.[1–4] The purpose of this paper is to provide an update on what is known about dairy farms and related injuries in different regions of the world.

INTERNATIONAL STUDIES ON DAIRY FARMER AND DAIRY WORKER INJURIES AND FATALITIES

Sweden

Because an underreporting of injuries among workers is a commonality in the agricultural sector,[9] a Swedish study sought to provide in-depth knowledge about the origin and extent of agricultural injuries.[10,11] A stratified sample of 7000 farms was drawn from the total number of Swedish farms (67,061) in 2004. These farms were mailed a questionnaire related to on-farm injuries. A total of 5646 farms completed the questionnaire. A total of 462 accidents occurred on these farms. With these data researchers were able to estimate that about 5000 injury events occurred on Swedish farms in 2004 that resulted in bodily injury and hindered work activities. However, only 400 farm injuries were officially reported to the Swedish Social Insurance Agency and the Swedish Work Environment Authority during this same time period. Approximately 70% of these injuries occurred on livestock operations and of those injuries, 30% were among dairy farms. Fifteen percent of all farms with milk production had one or more injury incidents during that year. Most injuries occurred during milking, handling, and movement of animals (especially kicks, step on, striking, crushing, etc., from animals). Fall incidents (e.g., slipping/tripping) were relatively common during tasks such as milking, manure handling, stall cleaning, and feeding.[11,12] Among the 127 nonworking male dairy farmers responding to the survey, about 20% identified work-related health problems and injuries from farming incidents to be among the reasons they no longer were working on the farm.[13]

The findings by Pinzke and Lundqvist[11] contributed significantly to Sweden's decision to implement an injury prevention strategy in agriculture with a national program and coordination of activities from major stakeholders. The program included semistructured in-depth interviews of 12 dairy farmers to deepen understanding of the farmer's experience and perception of animal-related injuries. Lindahl et al.[14] identified three factors with an impact on risks and safety when handling cattle: the handler, the cattle, and the facilities. These factors interact to influence the risk for injury to the handler and the livestock.

New Zealand

The New Zealand Accident Compensation Corporation (ACC) is the national provider of comprehensive, no-fault personal injury coverage for all New Zealand residents. According to the ACC, a New Zealand farmer is injured on the job every 28 minutes, and a farmer dies from a work-related incident every 23 days. In 2010, about 18,700 New Zealand farmers were injured while at work.[15] Given that only 33,000 people are employed in the New Zealand agriculture sector, the risk of being injured appears to be substantial. However, gaps exist in the data available to examine occupational health–related problems within New Zealand,[16] as dairy-specific injury and fatality rates were unable to be found.

Quad bikes appear to be a major source of injury among agricultural workers in New Zealand. The Department of Labour reports that in 40% of the fatal farm incidents involving a quad bike, the operator experienced some degree of head injury. Efforts to increase use of head protection have resulted in an increased adoption of head protection among quad bike operators.[17]

New Zealand Accident Compensation Commission (ACC) research demonstrates that many farm workers are given no formal training in the correct operation of quad bikes.[18] Research indicates that having no formal training contributes to the severity of quad bike injuries.[18] Quad bike injury investigations suggest about 10% of serious injury quad bike incidents involve towing activities.[17]

Completed ACC research indicates that the following factors contributed to preventable farm injuries: fatigue, time pressures, poor equipment maintenance, and human error.[19] Other major causes of farm-related injuries include, motor bikes/vehicles, chain saws, other tools, trees, sharp objects (not knives), and animals. Unpublished ACC data indicate that farm fatalities may be decreasing, but farm injuries are increasing.[16] This trend occurred simultaneously with increased usage of heavy equipment, lower staff numbers, and larger farm sizes.[16]

Australia

Frager et al.[20] reported 4009 workers' compensation claims for injury in the Australian agriculture sector in the year of 2003. Of these, 264 claims were made by dairy industry workers, equating to a claim incidence rate of 2.8 per 100 workers. Eighty percent of dairy industry claims were made by males. From 2001 to 2003, tractors were associated with 2.8% of claims, 10% were associated with motorcycles (which include all-terrain vehicles [ATVs]). Motorcycle injuries primarily involved lower limbs and resulted in fractures (35%) and sprains (25%). Of all dairy claims from 2001 to 2003, at least 24% of injuries were inflicted by cattle. Cattle-related injuries occurred mainly to the upper limbs, particularly the hands and fingers, and were primarily fractures (40%) and sprains/strains (30%). The environmental mechanism of injury associated with dairy injury claims were slips, trips, and falls of workers in both indoor and outdoor work environments. These injuries were primarily to upper and lower limbs, and resulted in sprains (nearly 50%) and fractures (29%).[20]

Franklin analyzed compensation claims, emergency department records, hospital discharge records, and surveillance fatality data to investigate injuries and fatalities on Australian farms.[21] The average age of people seeking workers' compensation in the dairy industry was 36.4 years, and average age of workers killed on dairy farms was 40.2 years. Over a

10-year period from 1992 to 2001, the average annual claim incidence rate was 11.8 claims per 100 workers. The mean lost time for injured dairy workers was 9.6 weeks. Nearly 17% of injury claims in all agricultural industries analyzed came from the dairy industry. The largest numbers of compensation claims were from incidents involving nonpowered hand tools, appliances, and equipment (22.3%), followed by animal, human, and biological agents (17.7%), materials and substances (15.5%), environmental agents (13.6%), and mobile plant and transport (13.1%). Common mechanisms of injury were being hit by moving objects (31.9%), body stressing (24.9%), and slips, trips,and falls (18.0%).[21]

Franklin et al.[22] investigated farm-related fatalities in Australia from 1989 to 1992. During this period there were 19 nonintentional traumatic deaths on Australian dairy farms, equating to an average of approximately 5 fatalities per year. Of the 19 fatalities, 10 were of persons working on the farm at the time of the incident and nine were of bystanders. Paddocks (confined areas for cattle) were the most common (37%) locations of fatal incidents. Thirty-two percent of fatal incident agents involved farm vehicles (trucks, quad bikes, trailer), and 42% of agents involve farm structures such as dams and irrigation channels. Being hit by falling objects, drowning, or vehicular incidents were the most common mechanisms of the fatal incident for workers.[22] A major change since this study period is the increased use of all-terrain vehicles or ATVs (also known as quad bikes), which are associated with over 10 on-farm deaths per year in Australia.[20] A review of fatal workers' compensation claims in the Australian dairy industry revealed 17 fatalities since 1994. Vehicles, motorcycles, tractors, and production machinery remain a risk on Australian dairy farms.[20]

United States

In 2011, the highest occupational fatality rate in the United States was in the agriculture, forestry and fishing, and hunting sector, with 24.4 deaths per 100,000 full-time workers, about 7 times the national average for all industries combined.[23] During a 9-year period from 2003 through 2011, a total of 349 people were killed while working on US dairy farms.[23] The nonfatal injury rate (1-year cumulative incidence) for agriculture, forestry, fishing, and hunting (AgFF) was 5.5 per 100 workers in 2011.[24] The AgFF industrial sector was one of only two private industry sectors to experience an increase in the rate of injuries and illnesses in 2011 compared with 2010, driven by increases in cases in both the crop production and animal production (primarily dairy cattle and milk production) industries.[25] The cattle industry had an injury rate of 6.8, with beef and dairy industries experiencing rates of 8.7 and 6.2 per 100 full-time workers, respectively.[24]

One of the most common causes of death and serious injury on US dairy farms involve heavy machinery, specifically tractors. Other causes of fatalities include silage bunker collapse, manure pit entrapment, tractor power takeoff (PTO) entanglements, and injuries from large animals (e.g., bulls). Recent studies demonstrate that the two main causes of workers' injuries (fatal and nonfatal) are incidents with machinery and animals.[26] Machine-related incidents include tractor rollovers, being run over by tractors and entanglement in rotating shafts. Animal-related injuries include kicks, bites, and being pinned between animals and fixed objects. Researchers have identified dairy farming as having the second highest risk for injuries among all US agriculture groups.[27–29] The majority of injuries originate from interactions with dairy cattle during milking activities.[27,30,31] Other causes of injuries include chemical hazards, confined spaces (e.g., manure lagoons), use of power tools, and improper use or lack of personal protective equipment.[26]

Douphrate et al. completed two analyses of workers' compensation data among US dairy workers.[3,32] Results indicated that dairy workers had an injury claim rate of 8.6 claims per 200,000 work hours (equivalent to 8.6 claims per 100 full-time workers per year), higher than the national injury rate (6.2 per 200,000 hours) reported by the Bureau of Labor Statistics (BLS) for 2003.[32] The largest percentage of claims involved the upper extremity (33.5%) and were caused by the cow (28.9%) during animal-handling activities.[32]

The People's Republic of China

Limited research in China has been done to study agricultural injuries as a public health problem. In 2009, the US-China Agricultural Injury Research Training Project funded a pilot study on nonfatal injury among dairy farm workers in China.[33] Researchers at the School of Public Health of Hebei United University conducted in-person interviews among 1300 dairy farmers in Tangshang, Hebei Province.[34] Work-related injuries that occurred in the previous 12 months, for which either medical care was sought or normal activities were limited more than 4 hours, were self-reported in the survey.[34] A total of 125 dairy workers reported at least one work-related injury, corresponding to a 1-year cumulative incidence of 9.6 injured per 100 workers. Workers of family farms had a slightly higher rate (9.9 per 100 workers) than workers of organized dairy operations (7.5 injured per 100 workers).[34] Statistics indicated that 41.5% of injuries occurred with milking, and 20.8% of injuries occurred during feeding activities. None of the 125 injuries was caused by machinery or tractors, likely reflecting the relative lack of mechanization in the Chinese dairy industry. The highest percentage of injuries (52.0%) took place in cattle houses, and 28.0% in the milking parlor. This study also revealed that 21.2% of interviewed dairy farm workers reported serious back pain that lasted for more than 1 year.[34]

HAZARDS ASSOCIATED WITH INJURIES AND FATALITIES ON DAIRY FARMS

Machinery

Worldwide, agricultural work involves the use of hazardous machinery and processes. The most commonly used machinery include tractors, trucks, wagons, manure spreaders, and elevating equipment for feed storage. All of these types of machinery are used on dairy farms. In 2010, the International Labour Organization published a code of practice on health and safety in agriculture that provides guidance on management of farm hazards.[35] Although the code did not address specific agricultural operations, the information provided can be used by dairy farmers to ensure safe practices for themselves, their employees, and their families. Machinery has long been known to be the leading agent of injury and deaths on farms.[36–40] Dairy workers often use heavy equipment for feeding and milking tasks, which places them at risk for equipment-related injuries. Furthermore, dairy farmers often grow crops to feed their livestock. These farmers are also exposed to the risks associated with operating heavy equipment during crop production; therefore, their risk of machinery-related injuries may be higher than dairy farmers who do not produce crops.[30]

Livestock Handling

Livestock handling is a dangerous activity on dairy farms, but few workers often view livestock as a source of danger.[41] Animal handlers on dairy farms are involved in a variety of activities such as milking, feeding, moving, or "pushing" cattle to different locations, artificial insemination (AI), hoof care, dehorning, administering medications, ear tagging, loading cattle onto trucks, and calving and euthanization.[41]

Douphrate et al.[3] analyzed workers' compensation data to investigate livestock handling injuries among US dairy farms. The majority of livestock-handling injuries involved large operations (more than 10 workers), male, young, and less-experienced workers. The highest percentage (27%) of injuries were to the wrist, hand, and fingers.[3] Nearly 50% of livestock-handling injuries took place in the parlor while performing a milking task.[3]

A 1-year prospective study of injuries resulting from direct contact with cattle in a rural hospital in New Zealand reported similar findings. Among injuries reported in this study, ninety percent ($n = 70$) occurred on dairy farms. The primary injury mechanisms were involving worker interactions with cattle, specifically, being kicked (58%), crushed between cattle and other objects (22%), stood on (9%), and head butted (5%). The areas of the body most frequently injured were the hand and wrist, which accounted for 58% of all injuries.[42]

Dairy bulls present a high risk for worker injury. Dairy bulls have a reputation for being dangerous and the most aggressive type of bulls, and contribute to the most attack-related injuries. Despite reduced dependence on bulls and increased practice of artificial insemination (AI) on modern dairies, bulls continue to be a substantial source of injuries and fatalities on dairy farms. An analysis of 287 bull-related cases from 14 countries revealed that (1) workers were at higher risk for injury when working with bulls compared with cows; (2) the risk of a bull-related fatality was higher than other known hazards such as tractor operation, based upon hours of exposure; (3) victims generally had previous experience working with bulls; (4) bulls raised from calves on site were more aggressive; and (5) most incidents involved the victim being inside the bull holding area.[43] Therefore, the use of bulls on dairy farms should be carefully considered. Continued worker training about the dangers of dairy bulls and proper handling should be implemented. Perhaps the use of machinery and or the development of safe areas inside of bull holding facilities should be considered with future bull work.

Confined Space and Manure Storage

Modern dairy operations are making increased use of manure storage systems as part of their operations. Manure pits are potentially dangerous, gas-containing confined spaces that may generate hazardous levels of hydrogen sulfide.[44] Various types of manure storage systems are used on dairy farms. Some are more hazardous than others. Belowground storages, or pits, are more hazardous than aboveground storages, but all systems increase the risk for a fatal incident. Tragically, experiences in the United States indicate that when an incident does occur, it is likely to involve more than one fatality.[45] Beaver and Field summarized 77 documented fatalities involving livestock manure storage and handling facilities in the United States over a 26-year period.[46] Over half of the fatalities involved dairy operations and 21% involved persons under the age of 16. The largest percentage (34%) of fatalities occurred to persons conducting repair or maintenance activities on manure-handling equipment, and the second largest percentage (22%) involved workers attempting to perform a rescue of another person. The most frequently identified cause of death involved asphyxiation. In some cases, elevated levels of sulfide were found in the blood, indicating the presence of hydrogen sulfide. The seasonal period of peak incidents occurred during the hottest part of the summer and were associated with transferring of manure for application to crop ground.[46]

Slips, Trips, and Falls

Slips, trips, and falls (STF) continue to be leading causes of occupational morbidity across many industries, and agriculture is no exception. The New Zealand dairy industry has particularly high numbers of STF injury and compensation claims compared with other New Zealand industrial sectors.[47,48] Despite a known prevalence of STF in the New Zealand dairy sector, limited research has focused on the problem of STF on New Zealand farms. Bentley et al.[49] were the first in New Zealand and internationally to focus on STF in the dairy industry. Their research identified and analyzed key factors and their interactions in STF injury risk for the purpose of designing research-based interventions for New Zealand dairy farms.[49] Slippery concrete working/walking surfaces primarily in the milking parlor and yard due to the presence of water, milk, manure, or other contaminants, such as alkaline for cleaning, were identified as contributing factors to injury. The variety of surfaces on which dairy farmers worked indicated that they may require a range of different footwear. Findings indicated a propensity for STF-involved workers to not visually see or identify hazards due to concurrent visual task distractions, and for workers to use improper footwear. Additional risk factors included problems associated with time pressure and related time-saving behaviors and the presence of structural design errors of equipment.[49] Clearly, gaps exist for the identification as to the causes of STF injuries. Future research should identify, implement, and test interventions known to reduce STF injuries in other industries.

Quad Bikes/ATVs

All-terrain vehicles (ATVs), commonly described as quad bikes, are increasingly becoming an essential mode of transportation on modern dairy operations. Quad bikes are considered inherently unstable with a narrow wheel base and high center of gravity, making them likely to tip over on steep, rough, or uneven terrain.[50] Quad bike loss-of-control events (LCEs) occur frequently and are a major cause of injury and death in agriculture.[51] In New Zealand, there were 45 fatalities from quad bike incidents between 2000 and 2008,[18] whereas in Australia there were 51 deaths from LCEs recorded from 2001 to 2004, accounting for 13.4% of all farm-related deaths.[52] Information on injuries and fatalities among agricultural workers who use ATVs in the United States is scarce. Even less is known about injuries and fatalities among ATV users who work in the dairy industry. Future injury research should consider collecting information about ATV use and associated injuries and fatalities on the farm.

CONCLUSION

This paper highlights the challenges associated with collecting and comparing worker injury and fatality data in the dairy industry globally. Data on occupational accidents are not available from all countries in the world. Furthermore, underreporting, limited coverage by reporting and compensation schemes, and nonharmonized injury recording and notification systems undermine efforts to obtain and compare global information on occupational injury incidents on dairy farms around the world. Renewed efforts are needed to report, determine causes, and implement solutions, with the intent of reducing agricultural injuries and fatalities. Creating a global data repository for recording injuries and fatalities among workers in the dairy industry would contribute to the understanding of global occupational health challenges faced by the dairy industry. Global research efforts should adopt standardized definitions and categories of occupational injuries, as well as report injury and fatality rates to enable global comparisons.

Working on a dairy farm is a hazardous occupation. Continued research efforts should be directed toward the development of cost-effective injury and fatality prevention strategies. Worker training is needed to increase awareness of hazards that are present on dairy farms. Lastly, care should be taken to implement solutions that contribute to the sustainability of this vital agricultural sector.

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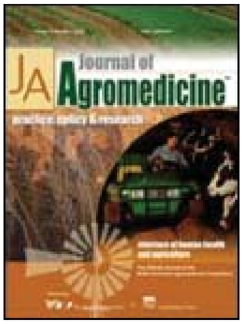

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A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms

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ABSTRACT. As modern dairy operations around the world expand, farmers are increasingly reliant on greater automation and larger numbers of hired labor to milk cows and perform other essential farm tasks. Dairy farming is among the most dangerous occupations, with high rates of injury, illness, and employee turnover. Lower education levels, illiteracy, and limited language proficiency increase the possibility of injury or death associated with higher risk occupations such as dairy. Sustaining a healthy, productive workforce is a critical component of risk management; however, many owners and managers have not received formal training in employee management or occupational health and safety. Optimal dairy farming management should address milk production that is sustainable and responsible from the animal welfare, social, economic, and environmental perspectives. Each of these aspects is interdependent with each other and with a sustainable, healthy, productive workforce. Very few studies address the effectiveness of risk management in the dairy industry. Studies suggest that labor management practices are a potential competitive advantage for dairy farms, but the connection with efficiency, productivity, and profitability has not been clearly demonstrated. Transformational leadership has been associated with improved safety climate and reduced incidence of injury, whereas passive leadership styles have opposite effects. There is a need to develop and evaluate the effectiveness of safety-specific transformational leadership among dairy owners and managers. A systematic approach to risk management should address worker health and safety as an integral component of production, food safety, and animal welfare. A successful program must address the cultural and linguistic barriers associated with immigrant workers.

KEYWORDS. Dairy, injury, leadership, management, safety

INTRODUCTION

As dairy farms expand capacities and increase production, operations rely on greater automation and larger numbers of hired labor. Globally, these workers are primarily immigrants who often have little dairy experience. Dairy farming is among the most dangerous occupations, with high rates of injury, illness, and employee turnover. Sustaining a healthy, productive

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workforce is an important component of risk management. A recent study by Leigh[1] estimated that work-related injuries and illnesses in the United States cost $250 billion in 1 year (2007)—yet there are very few studies addressing the effectiveness or return on investment of risk management strategies in any industrial sector. Many dairy owners and managers have not had formal training in employee management or occupational health and safety. Effective human resource management becomes increasingly important as dairies employ more advanced technological tools to become more efficient and productive. This paper provides an overview of current management practices as they relate to worker health and safety on modern dairies.

CURRENT PRACTICES ON DAIRIES

Farm Sustainability

Modern large-scale dairy operations are characterized as capital intensive with multiple interrelated systems and processes.[2] As a property of agricultural production, farm sustainability may be interpreted as either the ability to satisfy a diverse set of goals or an ability to continue through time.[3] Schematically, farm sustainability consists of three interrelated components: economic, social, and ecological.[3–6] Economic sustainability relates to the profit dimension, which includes production levels and their associated costs. Social sustainability relates to the people dimension including farm workers as well as the local community. Ecological sustainability relates to the environmental dimension. According to the *Guide to Good Dairy Farming Practice*, a joint publication of the International Dairy Federation and the Food and Agriculture Organization, good dairy farming practice ensures that milk is produced by healthy animals in a manner that is sustainable and responsible from the animal welfare, social, economic, and environmental perspectives.[7] Implementing good dairy farming practice is good risk management for the short- and long-term future of the dairy farming enterprise. This *Guide* encourages dairy farmers to adopt proactive preventative practices rather than waiting for problems to occur.[7] Research suggests dairies implement practices aimed at ensuring animal welfare[8]; but despite being a component of farm sustainability, issues related to the physical health and well-being of owners, managers, or hired labor are not often proactively addressed on modern dairy farms.[4]

MANAGEMENT PRACTICES AND FARM EFFICIENCY

Dairy production has seen phenomenal growth worldwide in terms of milk productivity during the last 50 years. For example, US milk productivity has quadrupled since 1944. Fifty-nine percent more milk has been produced with 64% fewer cows, thereby reducing the carbon footprint (per pound of milk) by two thirds by utilizing less feed, water, and land, as well as resulting in less manure and CO_2 emissions.[9] These improvements are due to several technological improvements in areas such as genetics, nutrition, animal welfare, and housing. Superimposed on technological improvements is the degree of managerial effectiveness when these improvements are implemented by owners, managers, and employees.

Prior studies have addressed herd management practices and their influence on various performance measures related to herd health. The influence of management practice on bulk tank somatic cell count (BTSCC) has been evaluated in several studies.[10–20] Bulk tank SCC is a function of the prevalence of intramammary infection (IMI) within a dairy herd and is an important indicator of milk quality.[19] Wenz et al.[19] evaluated associations between BTSCC and herd management practices such as rolling herd average, herd size, cattle importation practices, animal housing, milking and cow management, and waste management.

From an economic perspective, technical efficiency (TE) is the effectiveness with which a given set of inputs is used to produce an output. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum quantity of inputs, such as labor, capital, and technology. In a technically efficient operation, resources are not wasted in the production process. Many studies have estimated the degree of TE among dairy farms in different regions and countries using an array of statistical approaches.[21] These studies examine the effects of management practices and level of intensification (i.e., increase in number of cows per quantity of land; or stocking rate) in an effort to explain the relative importance of inputs in dairy performance. Cabrera et al.[21] investigated parameters that had the greatest impact on dairy farm performance and found that productivity resulted from an increase in technology and efficiency, not farm size. Cabrera et al. also reported an association between farm intensification and increased efficiencies (less feed purchases per cow), which was also reported in other studies involving farms in Spain[22] and Australia.[23] The use of a total mixed ration (TMR) was found to be positively associated with higher levels of TE, likely because cows have less opportunity to sort feed and are forced to consume a more consistent balance of nutrients. As these findings relate to worker performance, the mixing of a proper TMR is totally dependent on correct mixing and feeding of the ration by the feed mixer and feed truck operator. Chidmi et al.[24] determined that TMR does not significantly affect TE of the most efficient farms, but only the less efficient farms. Cabrera et al.[21] reported an increase of TE with a higher proportion of family labor versus total labor, indicating that the return on family labor is higher than that of hired labor. Additionally, milking frequency improved technical efficiency, but parlor design did not influence efficiency. Chidmi et al.[24] investigated other variables and their relationships to technical efficiency. Nonfarm activities or activities other than dairy (i.e., non–value-added activities) showed a negative effect on TE, indicating the importance of focusing on one enterprise (milking cows) or having additional people attempt the diversification (farming, calf program, etc.). Singh and Sharma[25] conducted a TE analysis on the dairy industry in India and reported that TE was negatively influenced by producer age, whereas producer innovativeness, education level, and economic status had positive impacts on technical efficiency.

The global industry trend is one of increasing farm sizes, with larger numbers of cows due to associated economies of scale. Due to farm intensification and increased production, owners are faced with new challenges related to increased numbers of workers and ensuring safe working environments. Historically, dairy farms have been and continue to be family-owned operations. On smaller farms, most management and labor activities were performed by just a few people or by one individual. With farm expansion, management responsibilities are performed by one or a few managers and additional people are hired to perform the majority of daily production tasks such as milking, feeding, cow health, and calf care.[26] As more employees are hired to perform different tasks on expanding farms, managers must find more effective mechanisms to ensure that employees are performing high-quality work.[27] The measurement of TE is a viable approach to gauge dairy farm performance. However, our literature review did not find any studies that investigated human resource management (HRM) practices and their potential influence on farm technical efficiency.

Human Resource Management

Human resource management is the set of practices that managers use to ensure quality employee performance. This includes recruitment, selection, training, communication, evaluation, and termination.[28] With an increasing reliance on immigrant labor, the availability of employees is a common challenge confronted by owners.[29] Additional human resource challenges include employee performance evaluation, achievement of employee performance goals, worker training, and recruitment and identifying qualified employees.[29] As herds grow in size, owners spend less time on farm work and more time managing employees, which they perceive as a key challenge.[30] Prior research suggests that managers on expanding dairy farms struggle with the transition to human resource management. Bewley et al.[30] suggested that Wisconsin dairy producers who expanded their farm operations experienced more difficulty and less satisfaction with HRM than with other aspects of farm management. The researchers attributed these findings to the farm managers' lack of training in human resource management.

Prior to 1990, labor management research in the agriculture sector was limited.[31] Since this time, empirical research has concentrated on human resource functions such as recruitment and selection,[32] compensation,[33–37] and employee retention.[37,38] There is limited research on the integration or interaction of human resource practices and farm performance.[29] Mugera and Bitsch[29] described labor management practices of dairy farmers, and determined how these practices contributed to farm competitiveness. Their findings suggest that human resources and the emanating human resource system are potentially the source of sustained competitive advantage for dairy farms. Stup et al.[27] sought to identify relationships between HRM practices used on dairy farm operations and the productivity and profitability of the dairies. A significant positive relationship was found between return on equity and the use of continued training, and a significant negative relationship was found between the use of standard operating procedures (SOPs) for feeding and somatic cell count. Profitability and productivity did not appear to be major factors in producers' decision to use or not use HRM practices. Stup et al.[27] concluded that technical HRM practices do not significantly affect dairy farm productivity or profitability, and further research was needed to determine the effects of strategic HRM practices.

Research addressing HRM practices as they relate to worker safety behavior and performance specifically on dairy farms is scarce. Mugera and Bitsch reported human resource practices on six case dairy farms in Michigan. Only one of these farms had Occupational Safety and Health Administration (OSHA) regulatory compliance as a HRM goal.[29] Lower et al.[39] determined the proportion of Australian farming enterprises with systems and processes that met industry and regulatory standards for health and safety. Among 100 Australian dairy operations, only 39% had written farm health and safety plans. Newly hired workers received safety training on 43% of sampled dairy farms, and workers received specific safety briefing before starting a high-risk job on 47% of farms. Ninety-eight percent of sampled dairy farms had regular hazard inspections. Safety was discussed in meetings with farm workers on 44% of farms.[39]

MANAGEMENT AND LEADERSHIP STYLES

Barkema et al.[20] investigated management style and its association with BTSCC and the incidence rate of IMI in Dutch dairy herds. Results suggested that herds managed by farmers who worked precisely, paid more attention to individual cows, and implemented measures to prevent mastitis more often had lower BTSCC. Young and Walters[40] investigated the relationship between dairy farmer personality types and farm production measures in the US state of Utah. Using the Myers-Briggs Type Indicator (MBTI) to classify personalities, Young and Walters reported limited associations between farmer personality classifications and herd production values. The authors suggested that future studies should address relationships between personality traits and labor and business management practices on dairy farms.[40]

Prior research demonstrates that organizational leaders play a central role in influencing safety-related attitudes and actions in the workplace.[41] Hofmann and Morgeson reported that high-quality leader-member exchange contributed to improved safety communication and safety commitment, which in turn contributed to reduced injuries.[42] Barling et al.[43] demonstrated that perceptions of supervisor safety-specific transformational leadership were related to safety consciousness, perceptions of safety climate, safety events, and injuries. Accumulated data suggest that when leaders promote safety, organizations experience improved safety records and positive safety outcomes.[41]

A successful leader is an individual who is effective and has a positive effect on his/her environment.[44] Poor leadership can be characterized in two ways: abusive or passive. Abusive leaders are overly punitive or aggressive, and they may violate commonly accepted codes of conduct.[45] Passive or ineffective leaders lack positive leadership skills and do not achieve desired outcomes.[44,45] Active leadership can be characterized in terms of the transformational leadership model.[46,47] Transformational leadership style enhances employee motivation, morale, and performance through several mechanisms. These mechanisms include connecting the follower's sense of identity and self to the collective identity of the organization; being a role model for followers that inspires them and makes them interested; challenging followers to take greater ownership for their work; and understanding the strengths and weaknesses of followers so the leader can align employees with tasks that enhance their performance. Transformational leaders thus exhibit four characteristics: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration.[48] With these characteristics, transformational leaders positively affect organizational and individual outcomes, including organizational commitment, business unit performance, employee satisfaction with leadership, and employee performance.[41] Transformational leaders are considered to be highly effective agents in the workplace who are concerned about the well-being of their employees.

Limited research has examined the impact of both passive (ineffective) and active (transformational) leadership on safety-related outcomes in the workplace. Zohar[49] found that transformational leadership style was associated with improved safety climate and reduced incidence of injury. Kelloway et al.[41] simultaneously examined leadership characteristics in the prediction of safety-related outcomes. The authors demonstrated that transformational and passive leadership styles have opposite effects on safety climate and safety consciousness. Safety-specific passive leadership was associated with an increase in the number of safety-related events and ultimately the incidence of injury. Safety-specific transformational leadership style was associated with a reduction in safety-related events and injuries. Kapp[50] investigated the influence of leadership practices on the safety compliance and safety participation of employees. Results indicated that greater levels of transformational leadership are associated with greater levels of safety compliance and behavior; however, safety climate moderates the leadership–safety compliance relationship. Under a positive safety climate, employee safety behavior improved as supervisor leadership practices increased. No improvement in safety behavior was observed in nonpositive safety climates. These findings provide support to the value of strong safety climates for improving safety behavior among employees, as well as the value in improving the leadership practices of managers and supervisors.[50] No studies have specifically addressed safety-specific transformational leadership among dairy owners or managers, and future studies should address this research need.

CULTURAL, LANGUAGE, AND LITERACY BARRIERS AMONG FOREIGN DAIRY WORKERS

As modern dairy operations around the world expand, farmers have become increasingly reliant on immigrant workers to milk cows and perform other essential farm tasks. Hispanic laborers from Mexico, Central, and South America are increasingly being utilized on larger US dairies.[51–53] Filipino workers are staffing large dairies in New Zealand,[54,55] and Western European dairies are employing workers from Eastern European countries.[56]

The US dairy industry is increasingly dependent on Hispanic immigrant labor. The US National Milk Producers Federation (NMPF)[53] reported an average of 3.2 workers per US farm were of domestic origin, and 2.0 workers were of foreign origin. Fifty percent of surveyed farms ($N = 1344$) from 47 states reported employing immigrant labor, which represented 62% of the US milk supply.[53] Researchers have reported percentages of Hispanic labor on US dairies to be 50% in New York,[57] 85–89% in Colorado,[51,58] 92% in Vermont,[59] and 94% in California.[60]

According to Harrison et al.,[61] dairy workers and their family members immigrated to Wisconsin due to poverty or lack of jobs in their native country, war and its devastating economic aftermath, desire to reunite with family members who have already migrated, and/or a family crisis, which is often medical in nature and creates debt and the need to find well-paying jobs. Even though many do not speak English on arrival, Harrison et al. reported that 37% of surveyed immigrant workers reported at least 8 years of education, with 15% graduating from high school, and nearly 11% having attended a university. Thirty-nine percent of immigrant dairy workers in Wisconsin reported having worked in agriculture in their home countries.[61]

Maloney[57] surveyed New York dairy farms employing Hispanic workers to identify employment practices related to language, recruiting patterns, wages, transportation, housing, and cultural issues. Maloney reported that solving the language-barrier problem is the greatest challenge, since few Hispanic workers speak English. Additionally, dairy managers must understand cultural differences to avoid misunderstandings and interpersonal problems. Maloney recommended that dairy farms establish employment policies and carefully communicate them so that all employees understand employer expectation for proper conduct on the job and farm property. Once established, employment policies are uniformly enforced with all employees.[52]

Dávila et al. reported that Hispanic immigrant men in the United States, particularly those with limited English skills, worked in occupations with significantly higher rates of fatal and nonfatal injuries and illnesses than US-born Hispanic, non-Hispanic black, and non-Hispanic white men in 2000.[62] Statistics show that Latino and foreign-born workers in the United States occupy lower-wage, higher-hazard jobs and sustain higher numbers of work-related injuries than non-Hispanic, native-born workers. Lower education levels, illiteracy, and limited English proficiency increase the possibility of injury or death associated with higher risk occupations.[63] Safety issues related to low English literacy levels of Hispanic workers on US dairy farms are a potential concern to employers. A survey of safety behaviors among US dairy producers known to employ Latino workers in a single county in a Midwest US state was conducted. At least two thirds (total sample size of 19 dairy farms) of respondents rated 5 of 10 safety behaviors as of moderate, high, or extreme concern due to their employees' ability to read, write, speak, or understand English.[64] Inadequate safety education and inadequate instruction are two factors directly related to safety training, and can be compounded by a language barrier.[65] Smith et al.[66] suggest that cultural, linguistic, and attitude barriers should be addressed in safety trainings of foreign-born workers.

CONCLUSIONS

As modern dairy operations around the world expand, farmers have become increasingly reliant upon immigrant workers to milk cows and perform other essential tasks on the farm. Optimal dairy farming management should address milk production that is sustainable and responsible from the animal welfare, social, economic, and environmental perspectives (*Guide to Good Dairy Farming Practice*). Each of these aspects is interdependent with each other and with a sustainable, healthy, productive workforce. Physical health and well-being of owners, managers or hired labor are not often proactively addressed on modern dairy farms. There are very few studies addressing the effectiveness of risk management in the dairy industry. Managers on expanding dairy farms struggle with the transition to human resource management, expressing difficulty and low satisfaction with this aspect of farm management. There have been a few limited studies suggesting that labor management practices are a potential competitive advantage for dairy farms, but the connection with productivity and profitability has not been clearly demonstrated. The transformational leadership style (exhibiting idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration) has been associated with improved safety climate and reduced incidence of injury. On the contrary, nonpositive or passive leadership styles have opposite effects on safety climate and safety consciousness, and are associated with increased safety events and injuries. Lower education levels, illiteracy, and limited language proficiency increase the possibility of injury or death associated with higher risk occupations such as dairy. There is a need to develop and evaluate the effectiveness of safety-specific transformational leadership among dairy managers and supervisors. A systematic approach to risk management should address worker health and safety as an integral component of production, food safety, and animal welfare. A successful program must address the cultural and linguistic barriers associated with immigrant workers.

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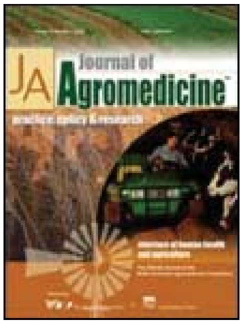

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Occupational Health and Safety Aspects of Animal Handling in Dairy Production

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Occupational Health and Safety Aspects of Animal Handling in Dairy Production

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ABSTRACT. Livestock handling in dairy production is associated with a number of health and safety issues. A large number of fatal and nonfatal injuries still occur when handling livestock. The many animal handling tasks on a dairy farm include moving cattle between different locations, vaccination, administration of medication, hoof care, artificial insemination, ear tagging, milking, and loading onto trucks. There are particular problems with bulls, which continue to cause considerable numbers of injuries and fatalities in dairy production. In order to reduce the number of injuries during animal handling on dairy farms, it is important to understand the key factors in human-animal interactions. These include handler attitudes and behavior, animal behavior, and fear in cows. Care when in close proximity to the animal is the key for safe handling, including knowledge of the flight zone, and use of the right types of tools and suitable restraint equipment. Thus, in order to create safe working conditions during livestock handling, it is important to provide handlers with adequate training and to establish sound safety management procedures on the farm.

KEYWORDS. Agriculture, animal handling, cattle, cows, occupational injury

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INTRODUCTION

Livestock handling is a critical component of worker health and safety on dairy farms. A large number of fatal and nonfatal injuries occur on dairy operations,[1] and livestock handling is a major contributor of these injury incidents. In order to implement effective safety measures, it is important to understand why livestock-handling injuries occur, since in modern dairy production many safety measures are available to prevent these injuries from occurring.

Worker injury and fatality surveillance data often do not provide sufficient information to answer the question why livestock-handling injuries occur, and research addressing livestock-handling injuries and fatalities on dairy farms is limited. This paper aims to give an overview of research on dairy livestock-handling injuries, with special focus on human behavior and facility design as risk factors. Safety management and livestock-handling training programs will also be elucidated.

BACKGROUND

Livestock handling is a hazardous activity involving many potential contributing factors that may lead to worker injury or even death. However, farm workers often do not view livestock as a source of danger.[2] A variety of activities and work tasks on dairy farms involve livestock handling. These include feeding, moving cattle between locations, artificial insemination, animal care such as hoof care, dehorning, vaccinations, applying topical or administering oral medication, ear tagging, milking, loading cattle onto trucks, calving, and euthanasia.[2]

Research suggests that livestock-handling incidents account for a large percentage of the injuries on dairy farms.[3–8] For example, Layde et al.[9] reported that those living on dairy farms in midwestern US dairy-producing states had an increased risk of animal-related injuries, and cattle were involved in the vast majority of animal-related injuries. Similarly, Watts and Meisel[10] conducted a 1-year prospective evaluation of injuries resulting from direct contact with cattle in a New Zealand rural hospital and found that 90% of injuries (n = 70) took place on dairy farms. These injuries were the result of being kicked by a cow (58%), crushed between cattle and other objects (22%), stood on (9%), and head butted (5%). The anatomical location for injury was mostly the hand and wrist, which accounted for 58% of all injuries.[10] Douphrate et al.[5] reported similar findings by analyzing worker compensation claims data involving dairies in a western US state. The majority of livestock-handling injuries on US dairy farms involved large operations employing 10 or more than 10 workers. Additionally, injured workers were mostly male, young, and inexperienced working on a dairy. The highest percentage (27%) of injuries were to the wrist, hand, and fingers, and nearly 50% of livestock-handling injuries took place in the parlor while milking cows.[5]

About 5000 injury incidents that resulted in bodily injury and impeded ability to work occurred on Swedish farms during 2004.[8] About 30% of these occurred on dairy farms. Fifteen percent of all Swedish farms with milk production had one or more injury incidents during that year. Most injury incidents occurred during milking, handling, and movement of animals. These livestock-handling injury events involved the worker being kicked, stepped on, hit, or crushed by cattle. Fall-related injury incidents (e.g., slipping/tripping) were relatively common during milking as well as during manure handling, stall cleaning, and handling concentrate feed.[8,11] In a study of 127 retired male farmers in Sweden, about 20% cited work-related health problems as the primary reason for retirement, with injuries arising from livestock-handling incidents being one of the causes.[12]

Geng et al.[13] reported that differences concerning the overall risk of injury incident were small between a conventional loose housing barn with a tandem stall milking parlor (MPT) and a loose housing barn with a single automatic milking system (AMS) unit. The risk of injuries during milking (e.g., bringing cows to milking, milking, cleaning milking equipment, and washing-up) was twice as high on farms with MPT than on farms with AMS, but the risk of injuries when performing other tasks (e.g., bedding and feeding) was higher on farms with AMS. Thus, when these risks were weighted with working time, the differences between the systems balanced out.

A case-control study of dairy farm activities identified milking and hoof trimming as having an increased risk for worker injury.[6] Other studies have reported feeding activities as a source of injury.[14–16] Research has yet to suggest other activities such as cow/calf treatment, calving, or dehorning as having an increased risk of injury,[6] but other livestock-handling activities can result in injury to those working in close proximity to dairy cows.

Dairy bulls present a high risk for worker injury, and injuries inflicted by bulls are more severe than those inflicted by cows.[17,18] In a study of farm worker injuries associated with bulls, head-butting was the most common cause of injury and bulls often inflicted multiple injuries. The most frequently injured body parts involved the legs and chest, with fractures and contusions being the most common injury types.[17] Despite reduced dependence on bulls resulting from increased use of artificial insemination (AI) on modern farms, bulls continue to cause an unacceptable number of injuries and fatalities. Until the late 1940s, nearly every dairy farm maintained one or more bulls for breeding, as high-quality breeding bulls were seen as the most important element on a successful dairy farm. Artificial insemination was introduced around 1938, with dairy farmers being the first to adopt the practice. Since then, the dairy industry has seen a rapid reduction in the number of bulls maintained on dairy farms,[19] as modern farms rely almost exclusively on AI breeding to improve herd genetics and fertility. However, bulls are still used for "cleanup" purposes in modern dairy herds or raised for beef production.[20]

Dairy bulls have a reputation for being the most dangerous and aggressive type of bulls, and contribute to most attack-related injuries.[21] As long as bulls have a presence on dairy farms, they will continue to pose a risk for the safety of farm workers as well as family members. An analysis of 287 bull-related cases from 14 countries revealed the following: (1) workers were at higher risk for injury when exposure hours to bulls were higher than exposure hours to cows; (2) the risk of a bull-related fatality, based on hours of exposure, was higher than other hazards such as tractor operation; (3) injured workers generally had considerable experience with handling bulls; (4) bulls raised from calves on-site appeared more aggressive; and (5) most injury incidents involved the worker being inside a bull holding area.[19] Casey et al.[17] reported that working alone and not having an escape option were important risk factors in bull-related injuries, and the authors emphasized the importance of proper facilities and worker training.

RISK FACTORS FOR INJURIES IN LIVESTOCK HANDLING

The questions of why and how livestock-handling injuries occur on dairy farms need to be investigated. Various studies have reported factors associated with an increased risk of an animal-related injury. Among these risk factors are younger age,[5,22] older age,[23] male sex,[5,23] number of hours worked,[7,9] hearing difficulties,[22] and arthritis/rheumatism.[22]

Farmers seem to be aware of the dangers of handling large animals.[24–26] However, simply being aware of injury risks and recommended safety practices is not enough to prevent livestock-handling injuries.[25,27] Stress is one factor believed to have an impact on decision-making and risk-taking behaviors.[27,28] Studies have shown that stress and time constraints/pressure are factors that farmers themselves commonly mention as contributing factors to injuries.[25,26,29] Worker stress may be a contributing factor in animal-related injuries, since worker stress can be conveyed to cattle, which may influence their behavior and response to handling. The relationship between worker stress and animal-related injuries is an issue for future research.

The outcome of an interaction between humans and animals is dependent on animal behavior, handler behavior, and the environment in which the interaction takes place. Because little can be done to change behavioral instincts of cattle, there are only two factors that can be modified to decrease the risk of a livestock handling-related injury: human behavior and the working environment.[30] Human behavior including handling techniques as well as the working environment regarding facility design will be further discussed in the following section.

HUMAN BEHAVIOR

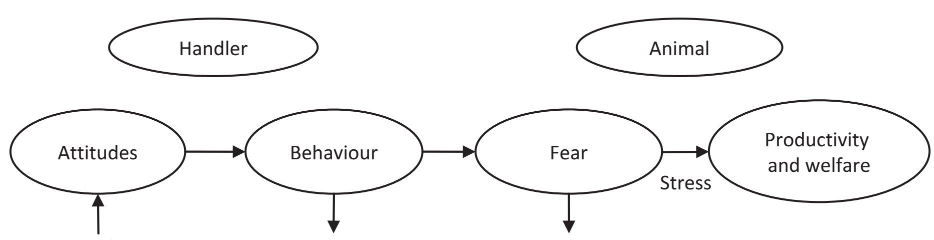
There has been limited research on human-animal interactions in dairy farming. The aim of previous research has been to study human-animal interactions in relation to animal welfare and productivity. However, the knowledge gained from such studies can also be useful when considering handler safety.

One animal motivation that will determine its response to human activity is fear.[31] Rough, aggressive, and unpredictable handling may induce fear in the animal.[32] Studies have demonstrated that a cow's fear response to humans affects their productivity, behavior, and welfare. Fearful animals are more difficult and hazardous to handle and manage,[32] and fearful and agitated animals have been reported to be a major cause of livestock-handling injuries.[33] In situations where farm animals are regularly improperly and are fearful of humans, the animals may experience acute or chronic stress responses. These stress responses affect animal behavior and compromises animal welfare and productivity.[31] A qualitative study of safety and animal-handling practices among female dairy farmers in Finland concluded that one important aspect of safe cattle handling is a trusting and positive relationship between the animal and handler.[24] Similar findings were reported in a qualitative study of Swedish dairy farmers, where handler behavior was concluded to be a main factor influencing the risk of injury during cattle handling.[26] The element most frequently mentioned by farmers in the latter study was the importance of consistently being calm and gentle when handling the animals, but they admitted that in stressful situations it is easy to lose patience and handle them improperly.[26] Bertenshaw and Rowlinson[34] reported that UK farmers believed that humans have an impact on cattle temperament, and negative experiences with humans can result in poor milking temperament. In summary, proper handling has the potential to reduce stress in cattle and reduce the risk of worker injury.[33]

Hemsworth et al.[35] reported a relationship between handler attitudes and behavior and fear in dairy cows. A positive attitude towards cows was found to be negatively correlated with the use of negative tactile interactions such as slaps, pushes, and blows.[35,36] Several studies have reported that restless behavior (flinch/step/kick responses) by cows during milking are correlated with negative tactile or loud, harsh vocal interactions by milkers.[35–37]

Hemsworth proposed a schematic (Figure 1) describing the sequential relationship between the attitudes of handlers and animal response.[38] The relationships illustrated in the schematic indicate that it is possible to invoke fear among dairy cows by handler attitudes and behavior.[35] Hemsworth et al.[39] reported lower levels of fear in cows, measured by flight distance to humans,

FIGURE 1. Model of human-animal interactions. Since fear also affects risk and safety, it could be added to the last circle together with productivity and welfare. Source: Hemsworth (2003).[38]



following a cognitive-behavioral intervention procedure designed to improve the attitude and behavior of handlers toward cows. Therefore, safety interventions addressing handler attitude and behavior may result in reduced fear responses to humans among dairy cattle.

HANDLING TECHNIQUES

Methods of animal handling may also have an influence on livestock handling-related injuries.[9] Worker understanding of the behavioral characteristics of cattle may facilitate gentle yet efficient handling, and reduced risk for worker injury.[40] Grandin[33] reported essential principles of proper cattle handling, which include the cow's flight zone and point of balance.

The area surrounding an animal that irt considers its "personal space" is referred to as the animal's "flight zone" (see Figure 3). The flight zone is the space around the animal that, when entered, causes the animal to move away from the approaching handler. As the name indicates, the flight zone is predicated on the notion that an animal will first try to move away (flee) from an intrusion into its personal space, before it will fight to defend that space. Animals in daily contact with humans have a smaller flight zone (dairy cattle), whereas animals that spend most of their time roaming with a herd have a larger flight zone (grazing beef cattle). By exploiting this concept in a gentle, nonaggressive way, a worker can encourage cows to move in a desired direction or towards a specific location, as shown in Figures 2 and 3. However, a worker not understanding this concept or applying it incorrectly increases the likelihood of the cow responding in a defensive mode or fleeing in panic, potentially increasing the risk of worker injury or even death.[33] Another important concept is the "point of balance," which is the area within the animal (usually in the central region) that if approached from the front will cause the animal to respond

FIGURE 2. Graphical depiction of the "sweet spot" concept that a handler can use as a tool to avoid the cow being surprised when approached (color figure available online).

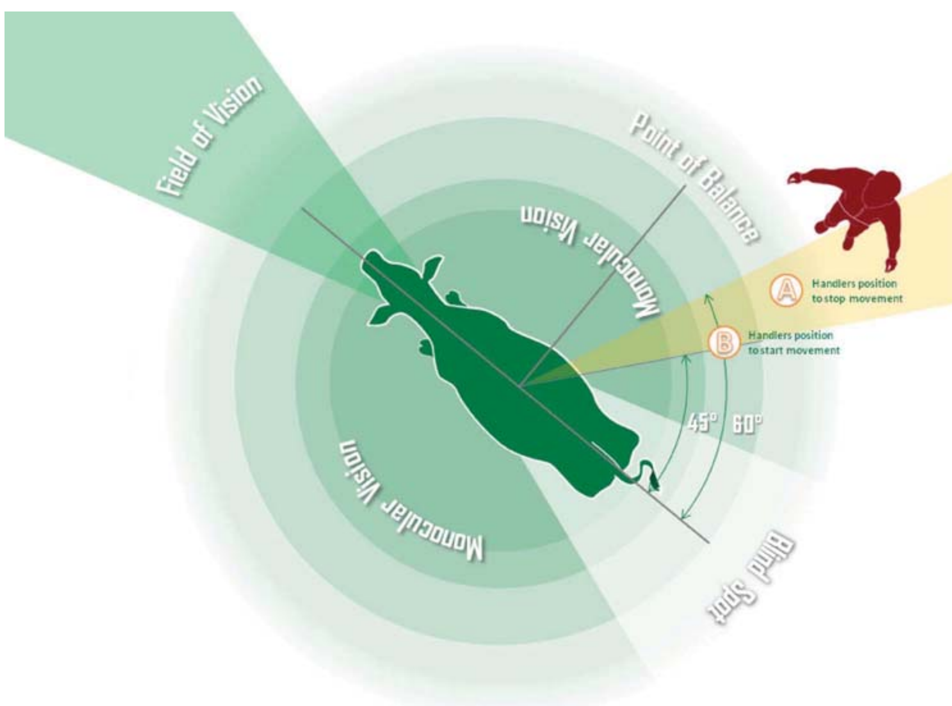
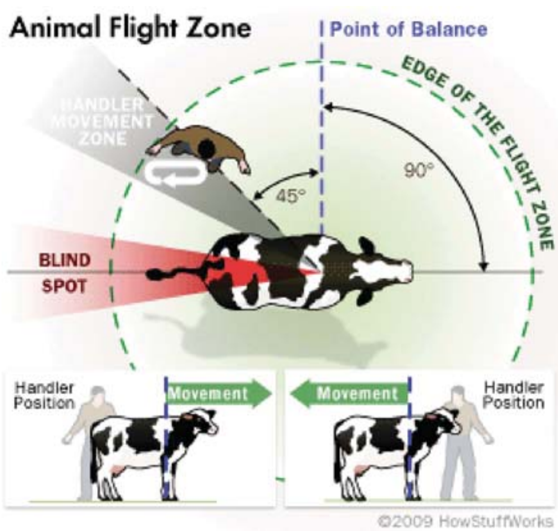


FIGURE 3. Graphical depiction of the "flight zone" concept that a handler can use as a tool to move animals in a desired direction (color figure available online).



by backing up (Figure 4). If the animal is approached from behind the point of balance, it will respond by moving forward. Therefore, the handler must understand and appreciate a cow's point of balance. By utilizing and applying the flight zone and point of balance correctly and in concert, a handler can move a large number of animals safely and almost effortlessly in a desired direction.[33]

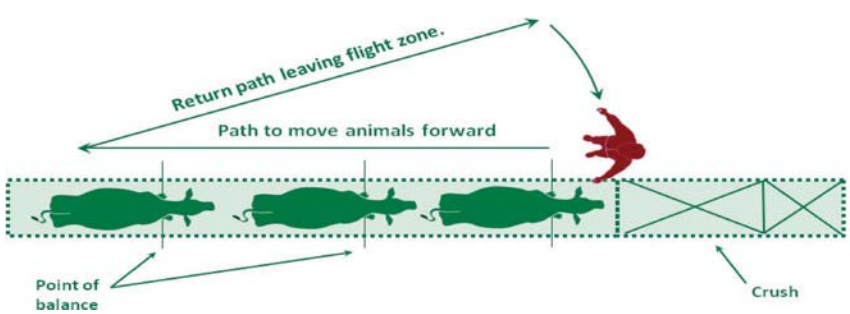
The concept of "low-stress livestock handling" has drawn much attention lately and is described in various textbooks.[41] Workshops teaching these principles have been available for several years in the United States and Australia and reported experiences by livestock handlers confirm its effectiveness and benefits. However, no scientific evaluation of low-stress livestock handling has been reported. Low-stress livestock handling deserves more attention because it explicitly utilizes the animal's behavior as the tool rather than human behavior or other methods that might be foreign to animal and potentially more prone to unforeseen and unexpected animal responses leading to injuries.

DESIGN OF FACILITIES

Proper facility design can play a major role in preventing injury incidents. Grandin has reported on livestock-handling facility design to improve cattle-handling efficiency.[42] A properly designed livestock-handling facility will facilitate the efficient moving of cattle where the animals move on their own accord with limited interaction with the handler. According to Grandin,[42] facility design based on sound ethological principles will reduce the incidence of alarmed, excited cattle as well as the risk for worker injury. Most research by Grandin involved beef cattle-handling facilities, i.e., abattoirs, markets, and yards on ranches. Therefore, recommendations may not be applicable in the traditional dairy barn. However, the basic principles on cattle behavior are universal, which form the basis for proper facility design. Some features of a good facility design are

- Facilities should have nonslip flooring.
- Alleys should be free from visual and auditory distractions causing cattle to balk (i.e.,

FIGURE 4. Graphical depiction of the "point of balance" concept that a handler can use as a tool to move animals in a desired direction (color figure available online).



shadows, reflections, changes in flooring type, and excessive noise).

- Alleys should be designed with a minimum of corners and sharp turns.
- Facilities should have escape routes so that it is possible for the handler to rapidly exit from the cattle area if the animal turns or attacks.
- Facilities should be sturdy and in good repair.[33]

Poor facility design can cause difficulties when moving cattle, which may lead to improper handling of the animals. Maller et al.[43] reported that poor facility design features in the milking parlor may affect cow behavior and ease of handling, which may also affect worker job satisfaction. Milking parlor characteristics and their effects on cow behavior and working conditions is an opportunity for future research.

Risk factors for livestock-handling worker injury include activities that increase exposure and proximity to the animal.[44] In order for an interaction between a human and animal to result in an undesired outcome (i.e., worker or animal injury), there must be a certain proximity between the animal and handler. The handler has to be within a reaching or striking distance (e.g., strike zone) of an animal to be affected by its actions. If humans could perform all animal-related handling tasks outside this strike zone, the risk of being injured by an animal approaches zero. In essence, the closer proximity between a worker and animal, the greater the risk of being injured in the event of an unexpected response or reaction from the animal. However, many tasks cannot be performed from a distance, and close interaction with the animal is often unavoidable in a husbandry scenario. From a safety perspective, it is of critical importance to assign tasks involving close interactions with cows to individuals who are highly trained to perform these tasks.

Many devices are now available to protect handlers from being exposed directly to the full force of the animal. For example, hoof trimming no longer needs to be performed from the side of the cow using a rope and clamp, as sophisticated mobile trimming rigs are available to protect both animal and handler. Treatment chutes allow handlers to restrain an animal for a multitude of procedures, which insures the safety of both the cow and worker. Cow milking is usually performed in specialized parlors that reduce the exposure of the worker to the hind quarters of the cow. Furthermore, automatic milking systems (i.e., robotic milking) remove the worker from the animal-human interface completely, thereby reducing the risk for injury. Personal protective equipment (PPE) can also be worn during tasks involving cow restraint and can diminish the impact of a kick or head butt. Continued development of safety engineering and PPE strategies will facilitate the reduction of worker injuries.[44]

SAFETY MANAGEMENT

Effective safety management may reduce injuries when working with animals.[45,46] Training on appropriate procedures and protocols should be a high priority, as well as proper supervision to ensure safety procedures and protocols are being followed by all employees at all times. This includes night shifts, relief shifts, and holidays. Promoting safe work practices with information sharing interventions that emphasize the greater profitability of safer work practices may be a viable interim supplement to comprehensive occupational safety regulations and enforcement in the dairy industry.[47] Consistency in handling animals is important from both an animal and a human welfare perspective.

ANIMAL-HANDLING TRAINING PROGRAMS

Education is believed to be a key component to prevent injuries in the livestock industry.[48] Several studies focusing on animal-related injuries in agriculture suggest livestock-handling training as one prevention strategy.[18,33,48] Langley and Morrow[48] reported that employees in livestock farms need to be trained on such issues as proper livestock handling, including animal welfare, animal loading and transportation, and proper use of personal protective equipment. Another important issue not mentioned is proper restraint during such tasks as medical treatment and hoof trimming. According to Langley and Morrow,[48] further research is needed to develop training programs that reduce the risk for worker injury. These trainings should be accepted by workers as being and easy to utilize while maintaining animal welfare. Langly and Morrow suggested that future studies should determine if there is a decrease in handler injuries as a result of livestock-handling training.

Interventions aimed at the injury prevention rely on educational strategies.[49] However, studies on safety education have failed to show an association with reduced worker injuries.[50] An evaluation of an education-based intervention (Agricultural Health and Safety Network [AHSN] programs) did not show any observable differences in farm safety practices, physical hazards, or farm-related injury outcomes.[49] A recent review aimed to determine the effectiveness of interventions to prevent occupational injuries in agriculture concluded that educational interventions provided no evidence of having an injury reducing effect.[50] Another review of 25 farm safety interventions found little evidence that farm safety training programs had been effective.[51] However, neither of these two focused on livestock-handling education. Focused educational efforts may be more effective than general safety education and may also be easier to evaluate for their effectiveness in reducing injury.

Because of a lack of evidence of education effectiveness in injury prevention, the extensive use of educational interventions alone has been questioned.[50] Several studies recommend a coordination of different approaches to the problem, combining engineering controls, regulatory approaches, and education to reduce injuries.[44,49,52] Changing behaviors can be difficult, thus in environmental and equipment modifications focus is on providing automatic or passive protections or removing hazards completely, which makes behavior change unnecessary. An example of a very effective regulatory approach is the significantly reduced rate of tractor overturn fatalities in Sweden due to a combination of economic incentives and rollover protection system (ROPS) legislation.[53] Since research indicates that well-designed facilities combined with gentle handling can reduce stress on cattle, improving these factors may improve safety and reduce injuries.

There are a number of difficult issues to overcome related to worker training. One challenge involves the training of migrant workers. European farms employ a mix of migrant workers with different cultural, ethnic, and religious backgrounds, often with different levels of language understanding. Another challenge involves farmers' difficulties in prioritizing enough time for participation in organized injury prevention. According to Jansson and Eriksson,[52] recruitment to safety courses is best stimulated by adapting the course to farmers' work conditions and takes place near the farm and through the agricultural organizations in collaboration with representatives of different safety organizations.

CONCLUSIONS

Handling cows on dairy farms continues to be an activity associated with risk of handler injury or even fatalities. There are many variables that may minimize the risk for livestock handling-related injuries. These include an understanding of animal behavior, as well as protocols and procedures to minimize the risk associated with working in close proximity to cows. Such measures are of paramount importance on modern dairy farms, where large numbers of employees may have little or no agricultural experience and minimal to no livestock-handling skills. Managers and owners should communicate and demonstrate that carelessness and complacency are unacceptable when working with animals.

Despite a lack of evidence demonstrating that education and training leads to a reduction of injuries, further research addressing the effectiveness in livestock handling-specific training in reducing worker injuries is needed. Development of effective training in livestock handling should be developed in collaboration with those active in these type of training. Earlier studies on "farm safety intervention programs" have been criticized for weak design and methods—which needs to be taken care of when new evaluation studies are designed. Safe animal handling in the dairy production is a global issue, which needs to be developed in worldwide collaboration.

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