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## TUBERCULOSIS AMONG DAIRY WORKERS IN BAILEY COUNTY, TEXAS

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TUBERCULOSIS AMONG DAIRY WORKERS IN BAILEY COUNTY, TEXAS

by

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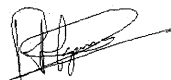
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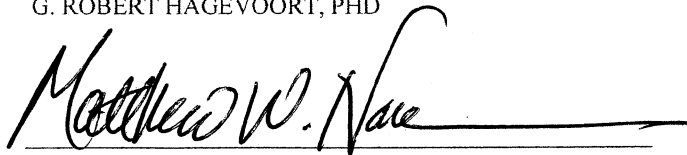
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PUBLIC HEALTH

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## **DEDICATION**

To Manuel Rodriguez

TUBERCULOSIS AMONG DAIRY WORKERS IN BAILEY COUNTY, TEXAS

by

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BS, Saint Edward's University, 2014

MPH, University of Texas School of Public Health, 2016

Presented to the Faculty of The University of Texas

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS  
SCHOOL OF PUBLIC HEALTH

Houston, Texas

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## **PREFACE**

The hard work of dairy workers inspired this dissertation.

## **ACKNOWLEDGEMENTS**

Funding for this research was provided by a Pilot Project through Grant No. T42OH008421 from the National Institute for Occupational Safety and Health (NIOSH)/Centers for Disease Control and Prevention (CDC) to the Southwest Center for Occupational and Environmental Health (SWCOEH), a NIOSH Education and Research Center at The University of Texas Health Science Center at Houston School of Public Health. Anabel Rodriguez was supported by an Occupational Epidemiology Traineeship funded by the same grant from the SWCOEH.

# TUBERCULOSIS AMONG DAIRY WORKERS IN BAILEY COUNTY, TEXAS

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School of Public Health, 2019

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On January 2016, Texas State Department of Health Services (DSHS) Public Health Region 1 (PHR 1) conducted T-SPOT.*TB* tests in response to two requests to screen dairy workers potentially exposed to cattle infected with *Mycobacterium bovis* or bovine tuberculosis (bTB) in Bailey County, Texas. Out of 140 workers tested, 14 had confirmed latent tuberculosis infection (LTBI)—prevalence of 10.0%. This first study gave rise to questions concerning tuberculosis (TB) knowledge and exposure history among dairy workers in this same county. The second study focused on determining TB knowledge among dairy workers through a series of questions administered by research personnel on iPad tablets. Category of cattle exposure was used as a proxy for exposure by categorizing job positions into high and medium/low groups. Overall, the average score was 7.1 (SD 4.9) out of 17 (41.8% out of 100.0%). Results indicated that there was no statistically significant difference between the mean TB knowledge score for the high group compared to the medium/low group ( $t = -1.9193$ ,  $p = 0.0562$ ). This study found TB knowledge deficiencies at all quizzed measures: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. The third study used questions obtained in the same survey to determine the history of TB among the same dairy workers. A large majority of workers (78.2%) reported having been vaccinated with the BCG vaccine as an



infant. A total of 4/225 individuals identified having been diagnosed with active TB in the past. However, only 2/4 reported seeking TB treatment which was successfully finished.

Future research should use TB knowledge deficiencies found to create, deliver, and evaluate a health and safety TB training for dairy workers. In addition, determining the need and feasibility of Total Worker Health ® fairs on dairy farms could contribute to closing the gap on TB history among dairy workers. This dissertation took a public health case to assess need, burden, and potential impact of TB interventions among dairy workers in Bailey County, Texas.

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## **A. BACKGROUND**

### **A.1. Agriculture in the US**

The United States (U.S.) was founded on an agrarian economy.<sup>1</sup> Over 90% of Colonial American families worked in agriculture. Despite most towns and ports being hubs for agricultural trade, farming families' sole income sustainability.<sup>2</sup> By 1820, the Industrial Revolution was in full-swing in the U.S. During this period of time, the U.S. experienced an economic change, large territory expansion, new technological innovations, and societal changes.<sup>3</sup> The Industrial Revolution enabled farmers to expand cropping and grazing land and it introduced new farming techniques that increased food production.<sup>4</sup> However, the Industrial Revolution increased urbanization and decreased the number of farmers and hired labor.<sup>3</sup>

Throughout most of the 19<sup>th</sup> Century, agriculture remained the most prosperous sector share above manufacturing and services; however, by the end of the 19<sup>th</sup> Century, a change in market conditions increased the percentage output of manufacturing making it the most affluent sector share above agriculture and services.<sup>3,4</sup> From 1900 to 1970, there was a decrease of overall national employment in agriculture from 41% to 4% and a decrease in gross domestic product (GDP) agriculture share from 7.7 to 2.3.<sup>4</sup> Fast forward to 2017, 1.7% of the U.S. workforce was employed in agriculture (2.6 million jobs)<sup>5,6</sup> with a GDP share of 0.9% (\$136.7 billion out of \$19.5 trillion US GDP) and share with the smallest output of 0.6% compared to manufacturing with 18.9% and services with 80.2% output.<sup>7</sup> However, the GDP and workforce employed by U.S. agriculture is underestimated and strictly restricted to direct farm contributions. Agriculture plays an important role in manufacturing and services by contributing food, beverages, tobacco products, apparel, leather, textile, and other related

goods. Without the base of agriculture, most manufacturing and service sectors would be nonexistent.<sup>6</sup>

## **A.2. Evolution of U.S. agricultural workers**

The face of farmers and agricultural workers has changed since the colonization of the Americas.<sup>1</sup> Colonial farms were owned, managed, and worked by family members with European migratory history. Subsequently, larger farms, known as plantations, were managed by family members, but worked by African slaves. This was one of the most significant changes in agricultural worker demographics.<sup>2</sup> The practice of slave labor persisted until the end of the 19<sup>th</sup> Century.<sup>1</sup>

The 20<sup>th</sup> Century brought much change to the agricultural community. Former slaves became tenant farmers or sharecroppers and some remained working in agriculture for pay. A new wave of immigrants from southern and eastern Europe became the new farmers and Japanese immigrants became the new workers of the U.S..<sup>8</sup> Eventually, immigrants from rural Mexico added to the U.S. agricultural workforce. Between 1942 and 1964, the Bracero Program was introduced as a solution to the male worker shortage caused by World War II. This new guest worker program allowed 4.6 million Mexican men to enter the U.S. legally for farm and railroad jobs.<sup>9,10</sup>

The Bracero Program is the basis of the current Latin America-U.S. migration.<sup>10</sup> Despite the legality of the program, its termination sprung a new wave of unauthorized Latin American workers. In addition to U.S. farm operators and family members, the modern agricultural worker is an undocumented (50.0%) Mexican (70.0%) male (75.0%) under the



age of 35 (50.0%) with 10 or less years of formal education (66.7%) and limited English-proficiency (LEP) (66.6%).<sup>11</sup>

### **A.3. National security**

Despite its low GDP sector share and workforce composition, U.S. agriculture is still a vital economic contribution and source of food security.<sup>4,12</sup> On July 27, 2001, former President George W. Bush addressed the Future Farmers of America (FFA) about the present and future of U.S. agriculture. More specifically, he presented the urgency of investing and protecting U.S. agriculture as a pressing issue of national security:

*“...how do we make sure American agriculture thrives as we head into the 21st Century? I mean, after all, we're talking about national security. It's important for our nation to build -- to grow foodstuffs, to feed our people. Can you imagine a country that was unable to grow enough food to feed the people? It would be a nation that would be subject to international pressure. It would be a nation at risk.”<sup>13</sup>*

A threat to the future of agriculture is a threat to national security. US agriculture has seen a fair share of threats in the past in the form of high costs, tariffs, disease, climate changes, animal health and safety issues, and the supply of an able-bodied workforce.<sup>4,14</sup> Most recently, the U.S. agricultural sector has faced issues with regulatory, immigration, tax, and trade reform. Most central issues, are immigration reform and trade agreements with neighboring and overseas countries.<sup>15</sup> Currently, in the U.S., there is a shortage of able-bodied, willing workers, an increase in immigration enforcement and regulation, and an absence of an applicable worker-permit program. This complicates domestic agricultural production and places a \$60 billion industry at risk.<sup>12,15,16</sup> Also pending are renegotiations for

the North American Free Trade Agreement (NAFTA), which was created in 1994 to eliminate obstacles to agricultural trade between the U.S., Canada, and Mexico. The result of this free-trade agreement was an increase in U.S. exports from \$8.9 billion to \$38.1 billion in 23-years. However, most recently, NAFTA has been under renegotiation with uncertainty for its future.<sup>15,17</sup> If the U.S. withdrawals from NAFTA, heavy taxes would be placed on U.S.-based farm products, threatening the sustainability of farms.<sup>18</sup>

#### **A.4. U.S. dairy industry**

The U.S. dairy industry is part of the Agriculture, Forestry and Fishing (AgFF) sector and is classified under animal production and aquaculture. This industrial classification includes other agricultural productions such as beef cattle ranching, dairy cattle and milk production, hog and pig farming, and poultry and egg production.<sup>19,20</sup> In 2017, the U.S. dairy industry had 9.4 million cattle and produced 215 billion pounds of milk—a 3 billion pound increase from 2016.<sup>21</sup> Collectively, in 2017, the U.S. dairy industry produced and sold \$628 billion worth of dairy products in the U.S. alone. The U.S. industry also provided almost one million (977,727) direct jobs and two million (1,986,183) indirect jobs.<sup>22</sup> The dairy industry in Texas ranked 5<sup>th</sup> in total milk production in 2017. With a total of 400 licensed dairy herds and 511,000 milk cows. On average, it takes one worker to care and provide for 100 cows on a dairy farm; therefore, this would indicate that there are approximately 5,110 workers employed on Texas dairy farms.<sup>23</sup> The Texas dairy industry has a current total economic impact of over \$3.5 billion.<sup>23,24</sup> The total economic impact of dairy products produced and sold in Texas is \$39.5 billion. In 2017, the Texas dairy industry also provided about 70,000

direct jobs and 133,000 indirect jobs<sup>25</sup>—making it the 3<sup>rd</sup> largest job generating state, after California and Wisconsin.<sup>26</sup>

This magnitude and quality of U.S. dairy production, has allowed the U.S. to become a leader in dairy exports.<sup>23</sup> In 2017, the U.S. dairy industry exported \$5.5 billion (14.7% of pounds produced) to top consumers like Mexico, Southeast Asia, China, and many others.<sup>23,27</sup> Most dairy exports are in forms of non-fat dry milk and skim milk powder (NFDM/SMP), cheese, butterfat, lactose, and whey.<sup>28</sup> American milk production is vital to export countries that may not have the cattle, technology, labor, and geography to provide milk and other dairy-products to their population.<sup>21</sup> In addition to exporting, in 2017, the U.S. imported \$3.3 billion primarily from New Zealand, Canada, and Italy.<sup>23</sup> Imported dairy products differ from a variety of cheeses, butter, NFDM, and WMP.<sup>27</sup> The U.S. dairy industry is projected to continue a steady increase in milk production, herd size, and direct and indirect workforce employed.<sup>23,28,29</sup>

#### **A.5. Evolution of the U.S. dairy industry**

Dairy was a commodity of during the colonization of the Americas. Cattle were first introduced in the Americas in the late 1490s by the Spanish through the Caribbean region, then to Mexico and from there, around the 1690s, to what was to become Texas. Dairy cattle were hand-milked by owners and family members in local communities. While some fresh milk was consumed, most milk was converted into butter, cheese, and sour yogurts due to a short shelf-life without modern refrigeration.<sup>30</sup> During the Industrial Revolution, dairy cattle owners replaced buckets and stools for milking machines attachable to the cow's teats. This innovation allowed farmers to remove hand-milking techniques, to milk more cows more

often, and to expand production. However, the milking machine was very heavy, made of different metals which gave milk a “bad” aftertaste, had to be continuously drained, and was difficult to sanitize. Together, these milking machine limitations led to the creation of a prototype milking cluster attachment: a light, easy to clean, attachment that was pipelined into a bulk tank.<sup>31,32</sup>

The introduction of a bulk tank and direct milking pipelines led to an increase in production, milk quality, and allowed for a larger number of cows being milked. In order to facilitate the growth in production and the development of free-stall housing systems, milking parlor were introduced into dairy farms. Milking parlors resolved organizational challenges by maximizing the amount of cows being milked simultaneously in one efficient location.<sup>32</sup> Throughout the 20<sup>th</sup> Century, different configurations were introduced to increase efficiency: herringbone, parallel, and rotary milking parlors.<sup>32,33</sup> Despite the transition from manual milking to semi-automated milking, one factor that still remains is the close proximity interaction between workers and cows.

#### **A.6. U.S. dairy structure**

From the milking parlor, to the housing system, and crop production area, a modern dairy farm is a highly integrated agricultural system.<sup>34</sup> Dairy operations in the U.S. continue to become larger in size due to economic pressures. Despite their size, all dairy farms have one thing in common: dairy production is year round, 24-hours a day, 7 days a week, and 365 days a year.<sup>35</sup> On large operations, milking is a 24-7 activity with individual cows typically being milked 2-3 times a day. Therefore, these dairy operations employ milking crews that work shifts around the clock.<sup>36</sup>

In order for a dairy cow to produce milk, she will have to calve first, which typically happens at about two years of age. A cow will continue producing milk for about 10 to 12 months after giving birth and then she will be allowed to rest, recuperate, and prepare to carry another calf. Cow reproduction on most U.S. dairies is accomplished with artificial insemination (AI). AI requires specialized technicians, eliminating the need of keeping potentially dangerous bulls on a dairy farm.<sup>37</sup> Female calves (heifers) are kept and raised either on the farm or on a specialized heifer facility, and will eventually become the replacement dairy cows. Male calves (i.e., bulls) are sold to specialized calf raisers for beef production<sup>36</sup>

A cow's daily routines includes eating, grazing, socializing, resting, and milking. Two to three times a day, they are gathered from their pens and guided to the milking parlor. Cows being creatures of habit, enter the parlor one-by-one in, almost, the same order every time.<sup>37</sup> Cows enjoy coming to the parlor to be milked and once aligned, different tasks are conducted by milkers in preparation of milking: (1) the teats are cleaned and disinfected (pre-dip), (2) the milk from each teat is checked for quality, (3) the teats are wiped clean, and (4) the milking unit is attached. After the milking unit is removed, (5) a longer lasting disinfectant (post-dip) can be applied before the cows return to their housing.<sup>38</sup>

Cows spend most of their time in pens where feed and water is readily available.<sup>37</sup> Cows are herding animals; therefore, they are housed in groups based on age or by nutritional requirements or stage of lactation.<sup>36</sup> In milder climate zones, cows are housed in open-lot dairies with shade protection.<sup>36,39</sup>

The liquid part of the manure collected from both the milking parlor and housing system is stored in a manure lagoon. The solids can be composed or directly applied as

fertilizer on the crop land. The storage facility can be a hazardous part of the dairy farm; drowning and asphyxiation are recognized as hazards.<sup>40</sup> Manure handling and nutrient management are parts of the integrated agricultural system.<sup>36</sup>

### **A.7. U.S. dairy worker**

The ownership of dairy farms has not changed much since the early days of the colonization of the Americas. Currently, 99% of dairy farms are still family owned. However some characteristics of dairy farms has changed over time. The number of dairy operations has decreased by over 90% since 1970.<sup>41</sup> Over the last decade (2007-2017), there has been an increase in overall milk production, number of cattle, average herd size per farm, and milk produced per cow.<sup>23,24</sup> This substantial change in the dairy industry has been able to increase productivity and efficiency to sustain increased demand of dairy products throughout the past couple of decades. Consequently, these dynamics in the dairy industry have shifted the demands of labor towards an increased dependence on hired, and typically foreign-born help.<sup>42</sup>

In summary, the modern dairy worker is predominantly an immigrant,<sup>43</sup> Hispanic male,<sup>12</sup> of approximately 30 years of age<sup>44</sup> with limited English proficiency and formal education.<sup>45</sup> Previous studies on dairy workers have estimated an average age of 30.3 years<sup>41</sup> - 33 years and a range of 18 to 67 years.<sup>44</sup> The majority of dairy workers in the U.S. are of Mexican descent (88.5%-97.1%).<sup>44-46</sup> However, New Mexico, Texas, Colorado, Kansas, and New York recently experienced a large proportion of dairy workers of Central American descent, in particular Guatemalan descent (22.7%), and a decreasing percentage of Mexican descent workers (52.4%).<sup>47</sup> Additionally, communication on modern dairy farms has also

changed. Over 55% of dairy workers speak little to no English and have an elementary/middle school level education.<sup>45,47</sup> In synchrony, all of these demographic characteristics translate into a vulnerable workforce.<sup>44,45</sup>

### **A.8. Occupational injuries, illness, and fatalities**

The AgFF sector experiences much higher rates of fatal and nonfatal workplace injuries and illnesses compared to other industrial sectors commonly recognized as hazardous, such as transportation (14.3 fatal injuries per 100,000 full-time equivalent workers), construction (10.1), and mining (10.1).<sup>19,20</sup> In 2016, the AgFF sector experienced 23.2 fatal injuries per 100,000 full-time equivalent workers—the highest fatal work injury rate among all industrial sectors.<sup>20</sup> In 2016, the AgFF sector experienced 6.1 nonfatal occupational injuries and illnesses per 100 full-time workers—also making it the highest incidence rate of nonfatal occupational injuries and illnesses among all industrial sectors.<sup>19</sup>

In 2016, the U.S. dairy industry experienced a rate of 23.1 fatal injuries per 100,000 full-time equivalent workers.<sup>20</sup> The U.S. Bureau of Labor Statistics (BLS) reported an incidence rate of 5.6 injuries and illnesses per 100 full-time dairy cattle and milk production workers.<sup>19</sup> In general, dairy farm tasks have inherent safety and health hazards which increase the risk for fatal and nonfatal injuries and illnesses among workers.<sup>41</sup> However, foreign-born Hispanic workers have higher rates of fatal and nonfatal injuries and illnesses compared to native-born Hispanic workers.<sup>48</sup>

#### **A.8.a. *Mycobacterium tuberculosis* (TB)**

One health hazard on a dairy farm is the potential exposure to *Mycobacterium tuberculosis* (TB).<sup>49-54</sup> In general, TB affects one out of four individuals globally.<sup>20,55</sup> Most recently, the U.S. reported a rate of 2.9 TB cases per 100,000 persons, reaching an all-time low.<sup>55</sup> Despite diminishing rates, cases of TB remain particularly high among foreign-born individuals residing in the U.S. In 2016, 67.9% of reported TB cases were from foreign-born individuals residing in the U.S.<sup>55</sup> The impact of TB among U.S. dairy workers is unknown.

#### **A.8.b. *Mycobacterium bovis* (bTB)**

Besides the human version, there is also a bovine (cattle) version of the disease called *Mycobacterium bovis* (bTB) or bovine tuberculosis. Bovine TB is predominantly found among cattle and other grazing animals; however, its zoonotic nature allows it to infect cattle and humans.<sup>50,51,56</sup> Globally, an estimated 147,000 bTB cases were confirmed and 12,500 deaths recorded in 2016.<sup>57</sup> Bovine TB is endemic in countries without consistent quality control standards.<sup>57</sup>

In the U.S., *M. bovis* is *not* endemic due to the U.S. Department of Agriculture (USDA) and the Food and Drug Administration (FDA) quality control standards enforced on dairy farms.<sup>58</sup> Whole herd bTB infections have adverse economic, public health, and governmental implications.<sup>59</sup> In 1995, an estimated 50 million beef and dairy cattle were infected with *M. bovis* which caused a U.S. economic loss of \$3-4 billion a year.<sup>56</sup> Most recently in 2015, two out of 13 dairies in Castro County, located in the Texas Panhandle, confirmed positive bTB cattle. Castro County is part of the Texas/New Mexico milkshed, which is the 3<sup>rd</sup> largest dairy producing region in the U.S.<sup>60,61</sup> Being a border state with



Mexico, Texas has struggled to keep bTB-free. Texas earned its USDA TB accredited-free status in 2000; however, in 2002 infected cattle were reported and their free status was revoked. Texas regained its status in 2006, then revoked in 2015, and, finally, regained as of July 1, 2018.<sup>61,62</sup>

Bovine TB occurrences among cattle have been drastically reduced through sanitation and migration efforts.<sup>63</sup> However, bTB re-emerges every so often in different dairy and beef herds across the U.S.<sup>64</sup> Most importantly, random surveillance testing is done by USDA veterinarians at slaughter houses. Veterinarians inspect lymph nodes randomly and conduct routine necropsy on suspected deceased cattle—*postmortem*.<sup>59</sup> On dairy farms, if a cow was suspected of dying from a possible bTB infection or from a subsequent illness due to a bTB infection, then veterinarians inspect and test lymph nodes, lungs, and lesions on extra-pulmonary organs.<sup>54</sup> Most recently, the USDA, as part of their Uniform Methods and Rules for Bovine Tuberculosis eradication program, approved four *antemortem*, before death, tests for bTB identification among dairy herds: (1) caudal fold tuberculin (CFT), (2) cervical test, (3) comparative cervical tuberculin (CCT), and (4) bovine interferon gamma assay ( $\gamma$ -IFN).<sup>59,62,63,65</sup> These tests are expensive and time consuming.<sup>65</sup> Therefore, these *antemortem* tests are rarely, and only, applied when there is high suspicion of bTB infection or when a live or dead cow has tested positive for bTB among the herd.<sup>58</sup>

A positive bTB result in one dairy cow can lead to a number of subsequent events. A positive bTB result on a single cow must be disclosed immediately to the USDA.<sup>62,63</sup> Disclosure is followed by a complete epidemiological investigation. All cows or herds in close contact (e.g., pen mates) or any with past contact with the confirmed case must be

tested for bTB infection.<sup>59,62,63,65</sup> Cattle or herds with a positive reaction must be depopulated for the health and safety of workers and the common public.<sup>58,59,62,63,65</sup>

The eradication of *M. bovis* among cattle in the U.S. has been challenging due to its zoonotic nature.<sup>64</sup> *M. bovis* can be introduced to an individual cow or an entire herd in several ways. Transmission of bovine TB can occur through the purchase of infected cattle from a bTB prevalent country. In the past, U.S. dairy farms purchased a large number of cattle from Mexico as a way to expand herds.<sup>65</sup> Despite the increase in herd size, purchased cattle were at times infected and subsequently infected other cattle.<sup>66</sup> Another cross-contamination encounter happens with shared or leased grazing land. Sometimes, producers rent out or buy out grazing land to different farms in need of land to allow their cattle to graze. The issue is that *M. bovis* can remain in the soil and vegetation and expose subsequent uninfected grazing cattle. Third, a failure to depopulate bTB infected herds can also impede its eradication within the farm [and, sometimes, within the region].<sup>67</sup> Most recently, the interaction between domesticated animals, such as dairy cows, and wildlife *M. bovis* reservoirs, like American white-tailed deer, can cause an uncontrollable and unpredictable cycle of bTB infections.<sup>56</sup> These diverse routes of exposure have made eradication of bovine TB in the U.S. a great challenge.

#### **A.9. TB and bTB differentiation**

TB and bTB are both mistakenly referred to as clinical TB due to their parallel clinical manifestations, similar health consequences, and indistinguishable confirmative clinical tests.<sup>20,55,57</sup> There is a limited number of tools able to differentiate *M. bovis* from *M. tuberculosis* in humans and, thus, the true burden of the zoonotic TB disease in humans is

mostly unknown and largely underestimated.<sup>57</sup> TB is an airborne bacterial disease transmitted from person-to-person. However, TB is not the only tuberculosis-causing bacterium among humans in the *Mycobacteriaceae* family. Bovine TB is a zoonotic disease transmitted from cattle-to-cattle, cattle-to-person, and person-to-cattle and person-to-person via airborne droplets in close-proximity encounters, such as working on a dairy farm.<sup>51</sup> bTB can also be transmitted via the consumption of unpasteurized dairy products, a common practice in certain foreign countries.<sup>54</sup> These infectious features of bTB make it particularly concerning among dairy workers who are routinely exposed to such risk factors and increasingly in the U.S. with the resurgence of the dangerous “raw-milk” movement.<sup>50,51,54</sup> Active TB and bTB human infections have identical signs and symptoms: consistent cough for weeks, chest pain, blood sputum, fatigue, weight loss, loss of appetite, chills, fever, and night sweats.<sup>55</sup> Both can become pulmonary infections if the immune system cannot contain the infection. In addition, both can progress to extra-pulmonary disease, which is highly fatal if left untreated.<sup>55,68</sup>

#### **A.10. Clinical detection methods for TB**

Clinically, there are two general types of detection methods for humans: (1) Mantoux tuberculin skin test (TST) and (2) T-SPOT.*TB* test.<sup>69</sup> The less invasive clinical test, TST, is easily performed by injecting a small amount of tuberculin purified protein derivative (PPD) into the forearm subdermal surface and following-up 72-hours for a positive skin reaction  $\geq$  10 mm or negative skin reaction  $<10$  mm. However, administering a TST to foreign-born individuals can result in the high likelihood of false-positives. This clinical detection test has a sensitivity of 70% and a specificity of 98%, meaning that 70% of the time the TST correctly identifies those with TB.<sup>55</sup> This issue consists because more foreign-born

individuals are vaccinated as newborn infants with the live-vaccine, bacilli Calmette-Guerin (BCG); consequently, the circulating antibodies react to the tuberculin PPD injected resulting in a false-positive test.<sup>70</sup>

Contrastingly, the T-SPOT.*TB* test is a type of interferon-gamma release assay (IGRA), which requires one 6-mL blood vial draw. This sample undergoes a fast-reacting laboratory blood test completed in 24-48 hours.<sup>69,71</sup> Fortunately, the T-SPOT.*TB* test yields few false-positives (sensitivity 95.6%; specificity 97.1%) due to its *M. tuberculosis* and *M. bovis* antigen-specificity and controls; and, it does not require patient follow-up, unless there is a positive or questionable result. T-SPOT.*TB* is the preferred clinical diagnostic tool for foreign-born and previous BCG vaccinated individuals.<sup>69</sup> However, just like the TST, the T-SPOT.*TB* does not differentiate between *M. tuberculosis* and *M. bovis*.<sup>55,69,71</sup>

#### **A.11. Positive cases of TB**

In the case of a positive test result, the patient is called back into the diagnostic clinic for a medical evaluation. During this clinic visit, the patient is asked past exposure and diagnoses/treatment of TB, if applicable. In addition, a chest x-ray and a couple of sputum samples help with giving an accurate diagnosis.<sup>72</sup> A diagnosis can be for latent TB infection (LTBI) or active TB.

If the patient is diagnosed with a LTBI, then four different antibiotic combinations and lengths of treatment are considered. Further antibiotic susceptibility testing is conducted in order to administer the appropriate therapy with the appropriate length of time (3-12 months).<sup>73</sup>

Similarly, if the patient is diagnosed with an active TB infection, then an antibiotic regimen and length is deliberated through susceptibility tests and other diagnosis information. Once a therapy regimen is matched for an active TB case, it takes at least six months for clearance; however, it can take up to a year or more to completely eliminate all the persistent bacteria. Due to the transmission nature of TB, a contact investigation is conducted in order to ensure the health and safety of the patient's close contacts and the general public. Close contacts to the patient, such as family, friends, close acquaintances, and co-workers, are tested for TB using appropriate clinical diagnostic tools and assessments. Positive cases are evaluated and started on an appropriate therapy. Negative cases are not fully dismissed, but re-tested 8-10 weeks after their initial test.<sup>74</sup>

Once on a therapy plan, the patient enters into direct observed therapy (DOT). During DOT, a certified health department nurse personally delivers medications and observe the intake of those medications by the patient in order to ensure therapy compliance. In addition, patients continue to visit their assigned TB clinic and receive TB educational material in order to ensure treatment success.<sup>74</sup> A final clearance is given when a patient's three subsequent sputum samples test negative.<sup>72-74</sup> The tedious management of TB makes it one of the most expensive, time-consuming, and impactful types of therapies. The direct costs of TB therapy are estimated at \$17,000 per non-drug resistant TB patient, \$134,000 per multi-drug resistant (MDR) TB patient, and \$430,000 per patient with an extreme multiple-drug resistance (XDR) TB infection. In the U.S., approximately 1.0% of cases are MDR TB and, more rarely, a total of two cases of XDR TB were reported in 2014.<sup>55,75</sup>

### **A.12. bTB and dairy workers**

Among humans, zoonotic diseases are accountable for, approximately, 60.3% of emergent diseases.<sup>51,56,76</sup> Even though human bTB infections are considered sporadic in the U.S., they remain poorly understood among foreign dairy workers. The etiology of bTB infections on a dairy farm is difficult to establish. What remains unclear is the exact direction(s) of the cross-infection between cattle-to-cattle, cattle-to-person, person-to-cattle, and person-to-person.<sup>49</sup> The issue is that foreign dairy workers in the U.S. migrate from *M. tuberculosis* and *M. bovis* endemic countries, such as Mexico and Guatemala.<sup>53,77,78</sup> As a result, pinpointing the origin of a bTB infection among cattle and/or dairy workers gets complicated, because workers are not tested before starting their jobs on a dairy farm.<sup>50,62</sup>

Testing foreign dairy workers for a bTB or TB infection is not a current occupational health standard. As a proxy, some occupational exposures, such as job position, have been proposed for epidemiological investigation concerning bTB on dairy farms.<sup>49,76</sup> For instance, Torres-Gonzalez *et al.* (2013) created three categories of cattle exposure groups based on activity, duration, and conditions of exposure to cattle—high, medium, low. High exposure job position was described as workers with direct contact with cattle in confined spaces (e.g., milkers, veterinarians), medium exposure job position was described as workers with direct contact with cattle in non-confined spaces (e.g., feeders, breeders, tractor operators, maintenance), and low job position exposure was described as workers with no direct contact with cattle in any type of space (e.g., owners, secretarial staff). These job position groups can help categorize workers into proxy exposure groups.<sup>54</sup>

Ideally, a dose-response measure for each specific worker would be the best measure of exposure. However, in practice, there is a limitation in collection feasibility and

measurement data; therefore, inferring indirectly from previous studies is often common practice.<sup>79</sup> A way of assigning risk can be done by occupation and taking into consideration a worker's job position and job duties. Another way can be by self-reported perceived risk.<sup>79</sup>

High exposure job positions, such as milking and veterinarian services, are at higher risk of communicable transmission of bovine TB.<sup>50,52,54</sup> These job positions involve direct contact with cattle in closed or confined spaces of the farm. In particular, milkers work in crowded parlors with direct interaction with hundreds to thousands of cows during their 8 to 12-hour work shifts.<sup>52</sup> The majority of milking parlors have an indoor and outdoor component, that is, they are *not* completely enclosed and air conditioned full-time; however, they do have ceiling fans, top windows, and an open crowd gate at the end to guide the herd towards the milking line. Despite the diverse layout of most parlors, ventilation and circulation of air are key to dispersion.<sup>80</sup> This precise parlor characteristic is problematic because bTB positive cattle entering a crowded waiting gate to be milked—for 10 to 15 minutes a day, two to three times a day—has the potential of leaving behind infectious droplet nuclei of *M. bovis*, which can remain suspended in air from hours to days.<sup>55</sup> In this confined space, both milkers and cattle are potentially at higher risk of transmission.<sup>54</sup>

Similarly, veterinarians and hospital workers have daily interactions with cattle. Sick cattle are housed in a separate, indoor or outdoor, corral. Often, veterinarians and hospital workers come in direct contact with cattle saliva, blood, urine, feces, and other bodily fluids during medical procedures.<sup>52,54,66</sup> In addition, they administer bTB tests on suspected cattle and necropsies on deceased cattle. Correspondingly, these fluids can have infectious droplet nuclei of *M. bovis* suspended in air and readily available for transmission.<sup>54</sup>

Large animal veterinarians undergo extensive bTB training during professional schooling.<sup>81</sup> Through this training, veterinarians learn the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of bTB among cattle. They are also trained on the inherent health hazards while working with bTB suspected cattle and the potential health consequences.<sup>82</sup> However, milkers and all other job positions on a dairy farm do not undergo this type extensive professional training education.<sup>45,47</sup> There is a lack of body of literature addressing bTB and TB knowledge among dairy workers. It is unknown how much dairy workers know about the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of TB as well as the potential exposure of bTB on a dairy farm. Currently, there are no standard TB knowledge questionnaires for dairy workers or other vulnerable high risk occupations.<sup>83</sup> Knowing this type of information helps future eradication efforts.

Apart from occupational exposures, there are other social history bTB risk factors. The majority of dairy workers migrate from countries where tuberculosis is still endemic, where consumption of unpasteurized dairy products, close-proximity to bTB infected animals, and lack of strong TB and bTB eradication programs is a norm.<sup>53,54,75</sup> In addition, medical records or history for most immigrant workers, if known, is unavailable. Some risk factors include: nationality, BCG vaccination status, tobacco usage, alcohol consumption, past and current living situation, past employment history, past diagnosis of TB, bTB, or other infectious diseases, and if applicable—past bTB/TB treatment status.<sup>84</sup> Both occupational and social risk factors must be considered for this vulnerable population.



### **A.13. Current bTB interventions**

Efforts have been designed and implemented to eradicate TB such as surveillance, routine occupational testing, direct-observational treatments (DOT) by health departments, and TB information sheets online and at clinics.<sup>20,55</sup> However, these TB eradication techniques have not been expanded to bTB and dairy workers in the U.S. The reality is that dairy workers are not tested before starting their jobs at a dairy farm nor are they trained on bTB identification, transmissibility, symptomology, prevention, and health outreach resources as are other high risk occupations, such as healthcare workers on TB prevention.<sup>50</sup> Currently, the U.S. Department of Labor's Occupational Safety and Health Administration (DOL-OSHA) does not require producers to have a formal bTB management program for infected workers nor does it require producers to provide necessary personal protective equipment (PPE) or a form of safety training on bTB as a potential transmissible disease. The few studies which have investigated the prevalence of bTB among dairy workers have suggested worker PPE and bTB education programs as an addition to the existing governmental eradication programs.<sup>50,52-54</sup>

A small fraction of studies have specifically researched TB among dairy workers in other countries.<sup>51</sup> One study conducted in Mexico estimated the prevalence of active TB of 643 cases per 100,000 inhabitants.<sup>54</sup> A second study in Ethiopia estimated the prevalence of latent TB at 64% among 25 volunteers working on 10 different dairy farms.<sup>50</sup> A third study in Nigeria estimated that 10% of 70 dairy workers tested positive for a culture specific bTB test.<sup>49</sup> Most reports of bTB in the U.S. are case studies of outbreaks that occurred on dairy farms.<sup>58,59</sup> As previously discussed, in the U.S., we employ a high percentage of foreign born

workers which is why it is essential that we understand and anticipate a potential breach of health and safety.<sup>16</sup>

## **B. Public Health Significance**

In 2018, the World Health Organization (WHO) released a report on the challenges preventing the eradication of tuberculosis. This report stated that in order to eradicate tuberculosis among humans, “we must find and treat every patient with tuberculosis.”<sup>57</sup> This alludes to the One Health model approach which considers the idea that the “health of animals, people, and the environment are inextricably linked.”<sup>85</sup> This means that the eradication of tuberculosis cannot be accomplished by only following USDA cattle health testing compliance. While routine testing is a quality control essential, the environmental and human aspects of tuberculosis must be taken into consideration in order to balance out the One Health model approach on a dairy farm.

The prevalence of tuberculosis among dairy workers in the U.S. is unknown.<sup>50</sup> Estimating the prevalence of tuberculosis among dairy workers would be beneficial to the industry because it could potentially reveal a possible mode of transmission of a zoonotic pathogen among dairy workers, which has not been identified to date.<sup>51</sup> Dairy workers and whole herd outbreaks have heavy economic, public health, and regulatory implications.<sup>59</sup> It is important to recognize that a threat to the future of agriculture and its workforce is a threat to national security.<sup>12</sup>

The lack of literature estimating TB knowledge and history of TB exposure among dairy workers remains a critical gap in knowledge. Determining the knowledge and prevalence of TB among dairy workers will contribute to the overall eradication efforts in the U.S. In light of these gaps, the objectives of this study are to determine the knowledge and history of exposure of TB among dairy workers in Bailey County, Texas. The expected outcome is understanding and estimating the level of knowledge and the history of TB

exposure among dairy workers in Bailey County, Texas. By understanding the level of TB knowledge and history of TB exposure, we could impact how tuberculosis is managed on dairy farms. The long-term impact of this study could lead to in-farm health fairs with free TB.TSPOT tests and the creation and delivery of educational vignettes of TB and bovine TB characteristics, transmissibility, symptomatology, treatment, and prevention.

### **C. SPECIFIC AIMS**

**Aim 1:** Determine the prevalence and risk factors of **latent tuberculosis infection (LTBI)** among dairy workers tested using the **T.SPOT.TB assay** in a bovine tuberculosis (bTB) intervention in Bailey County, Texas.

**Aim 2:** Examine the association of category of cattle exposure with **TB knowledge** among dairy workers in Bailey County, Texas, after adjusting for workers' sociodemographic characteristics.

**Null Hypothesis 2:** There is no association between category of cattle exposure and TB knowledge among dairy workers in Bailey County, Texas, after adjusting for workers' socio-demographic characteristics.

**Aim 3:** Examine the association of category of cattle exposure with **history of TB** among dairy workers in Bailey County, Texas, after adjusting for workers' sociodemographic characteristics.

**Null Hypothesis 3:** There is no association between category of cattle exposure and history of TB among dairy workers in Bailey County, Texas, after adjusting for workers' socio-demographic characteristics.

## **METHODS**

**Aim 1:** Determine the prevalence and risk factors of **latent tuberculosis infection (LTBI)** among dairy workers tested using the **T.SPOT.TB assay** in a bovine tuberculosis (bTB) intervention in Bailey County, Texas.

This study involves a secondary analysis of data that were collected by Texas State Department of Health Services (DSHS) Public Health Region 1 (PHR 1) in response to two requests from the FDA to screen dairy workers potentially exposed to cattle infected with *Mycobacterium bovis* or bovine tuberculosis (bTB) in Bailey County, Texas. The requested dataset contained a total of 140 dairy workers who were interviewed and screened for TB. There were a total of 51-variables in the dataset. Summary statistics of demographic characteristics of dairy workers with T-SPOT.TB test. We evaluated the association between all variables and a T-SPOT.TB test result. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886) and was given exemption status by the Texas DSHS Institutional Review Board (IRB) (IRB# 18-044).

**Aim 2:** Examine the association of category of cattle exposure with **TB knowledge** among dairy workers in Bailey County, Texas, after adjusting for workers' sociodemographic characteristics.

**Aim 3:** Examine the association of category of cattle exposure with **history of TB** among dairy workers in Bailey County, Texas, after adjusting for workers' sociodemographic characteristics.

A cross-sectional study design was used to collect survey responses concerning knowledge and history of TB among dairy workers in Bailey County, Texas. A total of 225

dairy workers were included in the study. Data collection took place between February and March 2019. The survey included 15 demographic questions, 17-item TB knowledge quiz, and 13 history of TB questions. TB knowledge, was measured via several questions on six different aspects of TB knowledge: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. History of TB was measured via several questions on six different aspects of past TB exposure: (1) occupational status, (2) vaccination history, (3) TB diagnosis and treatment history, (4) TB contact history, (5) consumption of unpasteurized dairy products, and (6) bovine TB exposure. Following previous research by Torres *et al.* (2013), job position on a dairy farm was used as a proxy for categories of cattle exposure—high and medium/low. Multivariate models were fitted for individual TB knowledge questions and TB history questions utilizing Hosmer and Lemeshow's model building methods. Last, crude prevalence odds ratio (POR), adjusted prevalence odds ratios (aPOR), and corresponding 95% confidence intervals (95%CI) were reported. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886).

## **RESULTS**

The following section includes three manuscripts addressing three aims of this dissertation. Aim 1 is addressed in manuscript 1 titled, “Bovine tuberculosis case intervention using the T.SPOT.*TB* assay to screen dairy workers in Bailey County, Texas,” aim 2 is addressed in manuscript 2 titled, “Association of category of cattle exposure and tuberculosis knowledge among dairy workers in Bailey County, Texas,” and, last, aim 3 is addressed in manuscript 3 titled, “Association of category of cattle exposure with history of tuberculosis among dairy workers in Bailey County, Texas.”



## **JOURNAL ARTICLE 1**

**Paper 1:** Bovine tuberculosis case intervention using the T.SPOT.*TB* assay to screen dairy workers in Bailey County, Texas

**Potential Journals:** Journal of Community Health, Journal of Agromedicine, Journal of Industrial Medicine

**Keywords:** dairy, bovine tuberculosis, LTBI, workers, Texas

## ABSTRACT

**Background:** A recognized health hazard on a dairy farm is the potential exposure to the zoonotic agent *Mycobacterium bovis* or bovine tuberculosis (bTB). A foreign-born worker from a tuberculosis (TB) endemic country and dairy farm work are both risk factors for latent tuberculosis infection (LTBI) and active TB. The aim of this study was to determine the prevalence and risk factors of LTBI among dairy workers potentially exposed to cattle infected with bTB in two Bailey County, Texas dairy farms in 2016.

**Methods:** This study involved a secondary analysis of data that were collected by Texas State Department of Health Services (DSHS) Public Health Region 1 (PHR 1). A total of 140 dairy workers were tested using the T.SPOT.TB assay. As a proxy for occupational exposures, we used three categories of cattle exposure groups based on activity, duration, and conditions of exposure to cattle—high, medium, low.

**Results:** Positive LTBI was found among 14/140 (10.0%) of the dairy workers tested (12/87 (13.8%) in Dairy A and 2/53 (3.8%) in Dairy B). All LTBI cases were determined to be Hispanic with 71.4% indicated having been vaccinated with the BCG vaccine in their country of birth and none indicated previously known exposure to TB. Most notable, the high category of exposure group experienced a prevalence of 64.3%, followed by the medium exposure group (28.6%), and the low exposure group (7.1%).

**Conclusion:** Our findings suggest that the prevalence of LTBI among dairy workers in Bailey County, Texas is higher than demographically comparable workforces.

## BACKGROUND

Over the last decade (2007-2017), there has been an increase in overall milk production, number of cattle, average herd size per farm, and milk produced per cow in the United States (U.S.).<sup>1,2</sup> Consequently, these dynamics in the dairy industry have led to an increase in the demands of labor and the number of employees needed per farm.<sup>3</sup> In the U.S., the modern dairy worker is predominantly foreign-born,<sup>4</sup> Hispanic male,<sup>5</sup> of approximately 30 years of age<sup>6</sup> with limited English proficiency and formal education.<sup>7</sup> In synchrony, all of these demographic characteristics translate into a vulnerable workforce.<sup>6,7</sup>

In general, dairy farm tasks have inherent safety and health hazards, which increase the risk for fatal and nonfatal injuries and illnesses among workers.<sup>8</sup> One health hazard on a dairy farm is the potential exposure to the zoonotic agent *Mycobacterium bovis* or bovine tuberculosis (bTB).<sup>9-14</sup> The prevalence of TB among dairy workers in the U.S. is unknown.<sup>10</sup> Some putative risk factors for latent tuberculosis infection (LTBI) and active tuberculosis (TB) are age, foreign-born status, and previous exposure to TB.<sup>15</sup> In 2018, the U.S. reported a rate of 2.9 TB cases per 100,000 persons—reaching an all-time low.<sup>16</sup> Despite diminishing rates, cases of TB remain particularly high among foreign-born individuals residing in the U.S., with 67.9% of reported TB cases originating from foreign-born individuals residing in the U.S.<sup>16</sup>

In the U.S., bTB is *not* endemic. The U.S. Department of Agriculture (USDA) and the Food and Drug Administration (FDA) have oversight of enforce and surveillance of quality control standards on agriculture.<sup>17</sup> Whole herd bTB infections have adverse economic, public health, and governmental implications.<sup>18</sup> In 1995, an estimated 50 million beef and dairy cattle were infected with *M. bovis* which caused a U.S. economic loss of \$3-4 billion.<sup>19</sup> Most recently in 2015, two out of the 13 dairies in Castro County, located in the Texas Panhandle, confirmed

positive bTB cattle. Castro Country is part of the Texas/New Mexico milk shed, which is the 3<sup>rd</sup> largest dairy producing region in the U.S.<sup>20,21</sup>

The etiology of bTB infections on a dairy farm is difficult to establish.<sup>22-24</sup> What remains unclear is the exact direction(s) of the cross-infection between cattle-to-cattle, cattle-to-person, person-to-cattle, and person-to-person.<sup>9</sup> Foreign-born status from a TB endemic country is a risk factor for LTBI and TB.<sup>13,25,26</sup> Additionally, dairy farm work is also a risk factor for LTBI and TB.<sup>14</sup> Currently, the Department of Labor's Occupational Safety and Health Administration (DOL-OSHA) does not require producers to test each worker prior to initiation of employment nor does the enforcement agency require producers to provide a form of health and safety training on bTB as a potential transmissible disease on the farm.<sup>10</sup>

The primary objective of this investigation is to determine the prevalence and risk factors of LTBI among dairy workers tested using the T.SPOT.TB assay on two dairy farms in Bailey County, Texas in 2016. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886) and was given exemption status by the Texas DSHS Institutional Review Board (IRB) in Austin, Texas (IRB# 18-044).

## **METHODS**

Study design. This study involves a secondary analysis of data that were collected by Texas State Department of Health Services (DSHS) Public Health Region 1 (PHR 1) in response to two requests from the FDA to screen dairy workers potentially exposed to cattle infected with *Mycobacterium bovis* or bovine tuberculosis (bTB). Dairy workers were employed on two large-herd dairy farms (Dairy A and Dairy B) in Bailey County, Texas (geographically located in the Texas Panhandle) with confirmed cattle bTB active infections. Dairy A and Dairy B are 14.6

miles apart from one another. Texas DSHS PHR 1 personnel conducted primary, field-based data collection among dairy workers on Dairy A and Dairy B. Dairy A had 115 workers employed and Dairy B had 66 workers employed at the time of testing. Texas DSHS personnel entered data into an agency, secured-access, relational database. For this study, a request was made to the Texas DSHS to provide de-identified data collected on Dairy A (January 13, 2016; January 15, 2016; April 13, 2016; and April 20, 2016) and Dairy B (July 27, 2016 and October 19, 2016) as well as follow-up data collected on Dairy A (April 20, 2016) and Dairy B (October 19, 2016).

Study subjects. The requested dataset contained a total of 140 dairy workers who were interviewed and screened for TB. Subject eligibility included being a male or female worker  $\geq 18$  years of age working on both farms with confirmed bTB cattle cases, regardless of job position.

Data collection. Texas DSHS bilingual (English and Spanish) personnel administered and logged worker responses to fifty-one questions concerning demographic characteristics, medical history, and previous TB exposure. In addition, certified phlebotomy personnel extracted a 6-mL blood sample required for the T-SPOT.TB (Oxford Immunotec, Inc., Marlborough, MA, USA) screening assay. Final results were entered data into an agency, secured-access, relational database.

Data analyses. Summary statistics of demographic characteristics of dairy workers with T-SPOT.TB test. We evaluated the association between all variables and a T-SPOT.TB test result. Because all positive T-SPOT.TB test results in this study were derived from foreign-born dairy workers, statistical analysis resulted in foreign-born being a perfect predictor for a positive T-SPOT.TB test result. Therefore, further logistic regression analyses could not be conducted.

Proxy exposure. Job position has been proposed as a proxy of occupational exposure to TB for epidemiological investigation concerning bTB on dairy farms.<sup>9,27</sup> For instance, Torres-

Gonzalez *et al.* (2013) created three categories of cattle exposure groups based on activity, duration, and conditions of exposure to cattle—high, medium, low. High exposure job position was described as workers with direct contact with cattle in confined spaces (e.g., milkers, hospital, maternity, calf-care, supervisors), medium exposure job position was described as workers with direct contact with cattle in non-confined spaces (e.g., breeder, feeder, general worker), and low job position exposure was described as workers with no direct contact with cattle in any type of space (e.g., owners, secretarial staff, ranch/farmers).<sup>14</sup> Work positions provided were categorized appropriately into high, medium, and low exposure groups. A type I error level of 0.05 was used to declare significance. Statistical analyses were performed using Stata/SE v.14.0.<sup>28</sup>

Human subjects. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886) and was given exemption status by the Texas DSHS Institutional Review Board (IRB) (IRB# 18-044).

## **RESULTS**

Table 1 shows the mean age of workers in our sample was 35.5 (SD 12.0) with a range of 18-65 years and 90.0% of participants were male. On the dairies tested, 89.3% of tested workers were Hispanic with 59.0% of participants reporting Mexico as their country of birth, 19.4% Guatemala, 15.1% United States, and 5.8% Honduras. Nearly 31% of workers reported as having recently arrived in the U.S. (within the last five years), but only 12.7% had traveled outside the U.S. in the past 12-months, with Mexico (6.4%) being the most common destination. On average, tested workers had been employed on their current dairy farm for 3.7 (SD 10.3) years and 46.4% had a history of working with livestock in their country of origin. The majority of

workers reported their job position as milkers (34.1%), general workers (15.9%), and feeders (12.3%). Almost 60.0% of participants indicated as having been vaccinated with the bacilli Calmette-Guerin (BCG) vaccine in their country of birth. However, only 2.9% indicated history of TB and only one person reported receiving treatment for LTBI. In addition, 5.7% reported having a history of consuming raw milk from their dairy of employment and 5.7% had a history of butchering their own meat at home.

Table 2 presents the characteristics of dairy workers with positive T-SPOT.*TB* test results. Positive LTBI was found for 10.0% of dairy workers tested (13.8% in Dairy A and 3.8% in Dairy B). A follow-up visit was completed for all positive cases. All positive cases tested negative for active TB but were confirmed as LTBI cases. The majority of LTBI cases came from Dairy A (12 out of 14); whereas, Dairy B had two (out of 14) confirmed LTBI cases. All LTBI cases were determined to be Hispanic with 71.4% indicated having been vaccinated with the BCG vaccine in their country of birth and none indicated previously known exposure to TB. Most notable, the high exposure category group experienced a LTBI prevalence of 64.3%, followed by the medium exposure group (28.6%), and the low exposure group (7.1%). More specific, one individual with confirmed LTBI had a history of butchering their own meat at home and another confirmed LTBI dairy worker had a history of eating cheese made from raw milk (not shown on Table 2).

**Table 1.** Sociodemographic characteristics of dairy workers tested for TB on two Bailey County, Texas dairies in 2016

<b>Characteristics</b>	<b>Bailey County, Texas</b>		
	<b>Total</b> (n=140)	<b>Dairy A</b> (n =87)	<b>Dairy B</b> (n=53)
	<i>Mean (SD) or n(%)</i>		
<b>Age</b>	35.5 (12.0)	37.6 (13.5)	32.0 (8.1)
<b>Sex</b>			
Male	126 (90.0)	76 (87.4)	50 (94.3)
Female	13 (9.3)	10 (11.5)	3 (5.7)
<b>Ethnicity</b>			
Hispanic	125 (89.3)	76 (87.4 )	49 (92.5)
Non-Hispanic	15 (10.7)	11 (12.6)	4 (7.6)
<b>Country of birth</b>			
United States	21 (15.1)	17 (19.8)	4 (7.6)
Mexico	82 (59.0)	51 (59.3)	31 (58.5)
Guatemala	27 (19.4)	15 (17.4)	12 (22.6)
Honduras	8 (5.8)	2 (2.3)	6 (11.3)
<b>Recent arrival to U.S. (≤ 5 years)</b>	43 (30.7)	23 (26.4)	20 (37.7)
<b>Travel outside of U.S. past 12 mo.</b>	22 (15.7)	14 (16.1)	8 (15.1)
Mexico	19 (86.4)	14 (100.0)	5 (62.5)
Guatemala	1 (4.5)	0 (0.0)	1 (12.5)
Honduras	1 (4.5)	0 (0.0)	1 (12.5)
Philippines	1 (4.5)	0 (0.0)	1 (12.5)
<b>Years on dairy</b>	3.7 (10.3)	3.1 (4.1)	4.7 (15.9)
<b>Work position</b>			
Milker	47 (34.1)	29 (34.1)	18 (34.0)
General Worker	22 (15.9)	13 (15.3)	9 (17.0)
Feeder	17 (12.3)	11 (12.9)	6 (11.3)
Maternity	14 (10.1)	9 (10.6)	5 (9.4)
Rancher/Farmland	11 (8.0)	8 (9.4)	3 (5.7)
Supervisor/Manager	9 (6.5)	7 (8.2)	2 (3.8)
Breeder	6 (4.4)	1 (1.2)	5 (9.4)
Hospital	6 (4.4)	1 (1.2)	5 (9.4)
Calf caretaker	3 (2.2)	3 (3.5)	0 (0.0)
Secretary	2 (1.5)	2 (2.4 )	0 (0.0)
Owner	1 (0.7)	1 (1.2)	0 (0.0)
<b>History of working with cattle</b>	65 (46.4)	48 (55.2)	17 (32.1)
<b>History of BCG vaccine</b>	81 (57.9)	46 (52.9)	35 (66.0)
<b>History of TB treatment</b>	0 (0.0)	0 (0.0)	0 (0.0)
<b>History of LTBI treatment</b>	1 (0.7)	0 (0.0)	1 (1.9)
<b>History of TB exposure</b>	4 (2.9)	1 (1.2)	3 (5.7)
<b>Other medical history</b>			
Unknown HIV status	27 (19.3)	12 (13.8)	15 (28.3)
Diabetes	4 (2.9)	2 (2.3)	2 (3.8)
Leukemia	2 (1.4)	1 (1.2)	1 (1.9)
Body weight <10% ideal	4 (2.9)	0 (0.0)	4 (7.6)
<b>History of raw dairy consumption</b>			
Raw milk from dairy	8 (5.7)	4 (4.6)	4 (7.6)
Raw milk from dairy taken home	2 (1.4)	1 (1.2)	1 (1.9)
Past raw milk consumption	7 (5.0)	2 (2.3)	5 (9.4)
Cheese from raw milk	3 (2.1)	2 (2.3)	1 (1.9)
Butchered own meat at home	8 (5.7)	7 (8.1)	1 (1.9)



**Table 2.** Characteristics of dairy workers with positive T-SPOT.*TB* test results

<b>Characteristics</b>	<b>Positive T-SPOT.TB test results</b>		
	<b>Total</b> (n=14)	<b>Dairy A</b> (n=12)	<b>Dairy B</b> (n=2)
	<i>Mean (SD) or n(%)</i>		
<b>Age</b>	40.4 (13.6)	42.8 (13.2)	26 (1.4)
<b>Sex</b>			
Male	13 (92.9)	11 (91.7)	2 (100.0)
Female	1 (7.1)	1 (8.3)	0 (0.0)
<b>Ethnicity</b>			
Hispanic	14 (100.0)	12 (100.0)	2 (100.0)
<b>Country of birth</b>			
Mexico	9 (64.3)	9 (75.0)	0 (0.0)
Guatemala	5 (35.7)	3 (25.0)	2 (100.0)
<b>Category of exposure</b>			
High	9 (64.3)	9 (75.0)	0 (0.0)
Medium	4 (28.6)	2 (16.7)	2 (100.0)
Low	1 (7.1)	1 (8.3)	0 (0.0)
<b>History of BCG vaccine</b>	10 (71.4)	9 (75.0)	1 (50.0)

## DISCUSSION

This study found a prevalence of positive LTBI of 10.0% among dairy workers on two dairies under bTB surveillance. These dairy farms represent 20% of dairy farms in Bailey County, Texas in 2016. This is the first case description of an active investigation of bTB on Texas dairy farms. Previous literature characterized dairy farm workers in Texas and in other dairy states as predominantly an immigrant,<sup>4</sup> Hispanic male,<sup>5</sup> of approximately 30 years of age<sup>6</sup> with limited English proficiency and formal education.<sup>7</sup> However, the prevalence of TB among dairy workers had not been previously established.<sup>10</sup> A contact investigation of workers and families on a California dairy farm with a confirmed bTB outbreak reported 43.0% of workers had positive Mantoux tuberculin skin test (TST) results, but no active disease diagnoses with a confirmative chest x-ray follow-up.<sup>17</sup> However, this study reported TB prevalence using the TST, which has a sensitivity of 70%, compared to the sensitivity of the T-SPOT.*TB* test which is 95.6%.<sup>16,29</sup> The challenge with using TST results is that most foreign-born individuals in TB endemic countries are vaccinated as newborn infants with the live-vaccine, BCG; consequently, the circulating antibodies cross-react with the tuberculin purified protein derivative (PPD) injected resulting in a false-positive test.<sup>30</sup> The T-SPOT.*TB* test is the preferred clinical diagnostic tool of choice for foreign-born and previously BCG-vaccinated individuals, including predominately foreign-born dairy workers.<sup>29</sup> However, this contact investigation was conducted in 2005, three years before the FDA commercial approval of the T-SPOT.*TB* assay.<sup>29</sup> In addition, 62% of dairy workers and family members reported drinking raw milk from the dairy<sup>17</sup> compared to 5.7% of dairy workers in this study. Also to be noted is the fact that this study tested dairy workers, family members, and slaughterhouse staff (where 50% of cases came from family and

slaughterhouse workers); whereas, our study only tested dairy workers employed on affected farms.<sup>17</sup>

A more recent study conducted by Torres-Gonzalez *et al.* (2013), which used work positions as a proxy for exposure (high, medium, and low categories) reported a prevalence of 76.2% using the TST and a lower prevalence of 58.5% using an alternative assay to the T-SPOT.TB assay. However, this study was conducted in Mexico, a TB endemic country.<sup>13,25,26</sup> Similar to Torres-Gonzalez *et al.* (2013), our study found that the high exposure group had the highest prevalence of LTBI. In addition, the prevalence reported in our study (10.0%) was higher than the lifetime TB-prevalence found for U.S. crop-workers between 2000 and 2012 of 0.48%.<sup>31</sup> Despite being a demographically comparable workforce, U.S. dairy workers and crop-workers work in different environments and are exposed to different hazards.<sup>32</sup> Whereas crop work is seasonal, dairy production is year round and involves animal handling.<sup>33</sup> Modern dairy farms are highly integrated agricultural systems which consist of numerous work areas involving close interactions with cattle.<sup>34</sup> This production system introduces different tasks around the farm with different durations, conditions of exposure to cattle, and routes of bTB exposure.<sup>14</sup>

### ***Intervention challenges and study limitations***

Much like the issues faced by dairy farm producers, Texas DSHS experienced similar challenges while following FDA compliance. The FDA contacted Texas DSHS to emergency screen dairy workers at Dairy A and Dairy B. Emergency interventions on dairy farms are uncommon. The first challenge faced was the absence of standard guidelines to test dairy farm workers for bTB. An intake ‘Dairy TB Evaluation Form’ was created using Texas DSHS PHR 1 TB Elimination Program’s ‘TB Initial Health Risk Assessment/History’ intake

form with the subsequent addition of livestock exposure and raw dairy consumption/meat processing sections. Another challenge faced was the lack bilingual staff trained on TB interventions. Staff who assisted on this call were chosen only on the basis of speaking both English and Spanish. The majority of staff members had not worked on TB projects or had ever been trained on TB intervention cases. Due to the emergency nature of this intervention, no trained interpretation services were hired.<sup>35</sup>

Study limitations included recall bias of content collected in the evaluation form such as demographic, exposure risks, raw dairy product consumption, TB symptomology, other medical risks, and previous TB treatment and BCG vaccination. Some workers struggled answering questions and opted to choosing ‘Unknown’ or not answering the question(s).<sup>35</sup> This could have underestimated the history of TB exposure among dairy workers. The majority of dairy workers in the U.S. are of Mexican descent (88.5%-97.1%).<sup>6,7,36</sup> However, a recent study conducted in New Mexico, Texas, Colorado, Kansas, and New York experienced a large proportion of dairy works of Central American descent, in particular Guatemalan descent (22.7%), and a decreasing percentage of Mexican descent workers (52.4%). The majority of workers identified Spanish as their native language (64.5%); however, 22.4% of workers identified K’iche’ (one of 32 Guatemalan languages) as their native language.<sup>37</sup> Texas DSHS expressed having a difficult time translating questionnaire and logging answers from the majority of Guatemalan workers.<sup>35</sup> Therefore, the unexpected language barrier between staff and K’iche’ speaking workers could have led to information bias; and subsequently, differential misclassification of exposures between native English and Spanish speaking workers and native K’iche’ speaking workers. Another study limitation is non-response bias. Despite the urgency of the situation, both dairies did not experience a

100% participation rate. Both Dairy A and Dairy B have three working shifts (4:00 AM, 1:00PM, and 8:00PM). Due to the remoteness of the dairy locations, Texas DSHS PHR 1 staff missed the first shift of the day (4:00 AM).<sup>35</sup> In order to make up for this, staff returned to the dairies to conduct follow-up testing and to test workers missing a complete screening. In addition, follow-up also did not experience a 100% participation rate. Currently, the U.S. dairy industry is experiencing significant labor challenges as a result of immigration regulatory policy and differing regional wages and benefits. Consequently, farms are challenged with high worker turnover rates, which complicates any type of follow-up with workers.<sup>38,39</sup>

### ***Future plans and conclusions***

Workers should receive a safety training pertaining to bTB on a dairy farm. Large animal veterinarians undergo extensive bTB training during professional education.<sup>40</sup> Through this training, veterinarians learn the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of bTB among cattle. They are also trained on the inherent health hazards while working with bTB suspected cattle and the potential health consequences.<sup>41</sup> However, milkers and all other job positions on a dairy farm do not undergo this type extensive professional training education.<sup>7,37</sup> There is a lack of body of literature addressing bTB and TB knowledge among dairy workers. Currently, it is unknown how much dairy workers know about the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of TB as well as the potential exposure of bTB on a dairy farm.<sup>42</sup> Knowing to what extent dairy workers know and don't know about TB and bTB characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention can help narrow down on the content that needs to be included in a health and safety training

pertaining to TB and bTB on a dairy farm. This information can also be used by dairy producers to address training gaps among employed workers. Further development, delivery, and evaluation of TB and bTB health and safety training can be part of a more comprehensive safety management and training program on dairy farms.<sup>37</sup>

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## **JOURNAL ARTICLE 2**

**Paper 2:** Association of category of cattle exposure with tuberculosis knowledge among dairy workers in Bailey County, Texas

**Potential Journals:** American Journal of Industrial Medicine, Journal of Agromedicine

**Keywords:** dairy, workers, knowledge, tuberculosis, Texas

## **ABSTRACT**

**Background:** Bovine TB can be transmissible to workers on dairy farms due to its zoonotic characteristic. Dairy workers do not undergo extensive professional training education on bTB. There is limited understanding on how much dairy workers know about the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of TB as well as the potential exposure of bTB on a dairy farm. The primary objective of this study is to determine the knowledge of TB among dairy workers in Bailey County, Texas.

**Methods:** A cross-sectional study design was used to collect 225 survey responses concerning knowledge of TB among dairy workers on ten dairy farms in Bailey County, Texas. iPad tablets were used to log responses to 15 demographic questions and 17-item TB knowledge quiz measured by: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. A proxy for exposure, dairy workers were classified into categories of cattle exposure—high, medium, and low.

**Results:** Relative to the medium/low group, workers in the high group tended to be younger (32.6 (SD 11.0)), Guatemalan (52.6%), K'iche' speaking (37.8%), males (89.1%) with less years living in the U.S. (10.8 (SD 12.5)) and lower levels of formal education completed (59.6% with no formal/elementary level). Overall, the average score was 7.1 (SD 4.9) out of 17 (41.8% out of 100.0%). Relative to one another, the medium/low group (6.7 (SD 5.1) out of 17) scored better than high group (8.0 (SD 4.6) out of 17). No significant associations were found between category of exposure and TB knowledge score.

**Conclusion:** Deficiencies in TB knowledge were identified at all categories of exposure. TB training on dairy farms should include all measured tested in this study and should be administered to all workers regardless of category of exposure.

## BACKGROUND

A health hazard on a dairy farm is the potential exposure to *Mycobacterium tuberculosis* (TB).<sup>1-6</sup> In general, TB affects one out of four individuals globally.<sup>7,8</sup> Most recently, the U.S. reported a rate of 2.9 TB cases per 100,000 persons—a record low.<sup>8</sup> However, 67.9% of confirmed TB cases in 2018 originated from foreign-born individuals residing in the U.S.<sup>8</sup> Besides the human version, there is also a *bovine* (cattle) version of the disease called *Mycobacterium bovis* (bTB) or bovine tuberculosis. Bovine TB is predominantly found among cattle and other grazing animals. However, bTB is also transmissible to humans due in part to its zoonotic characteristic.<sup>2,3,9</sup> Globally, an estimated 147,000 bTB cases were confirmed and 12,500 deaths recorded in 2016.<sup>10</sup> The overall impact of TB/bTB among U.S. dairy workers remains unknown.<sup>3</sup>

Large animal veterinarians undergo extensive bTB training during professional schooling.<sup>11</sup> Through this training, veterinarians learn the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of bTB among cattle. They are also trained on the inherent health hazards while working with bTB suspected cattle and the potential health consequences.<sup>12</sup> However, milkers and all other job positions on a dairy farm do not undergo this type of extensive professional training education.<sup>13,14</sup> There is a small body of literature addressing bTB and TB knowledge among dairy workers. In addition, there is a limited understanding on the level of knowledge dairy workers have concerning the characteristics, transmission, symptoms, diagnostic tests, treatment, and prevention of TB as well as the potential exposure of bTB on a dairy farm. Currently, there are no standard TB knowledge questionnaires for dairy workers or other vulnerable high risk occupations.<sup>15</sup> Knowing this type of information will help future eradication efforts.

Currently, the Department of Labor's Occupational Safety and Health Administration (DOL-OSHA) requires training on applicable hazards, but does not specifically address a form of safety training on TB and bTB as potential transmissible diseases on the farm.<sup>3</sup> The few studies which have investigated the prevalence of bTB among dairy workers have suggested worker PPE and bTB education programs as an addition to the existing governmental eradication programs.<sup>2,4-6</sup> However, before a TB and bTB educational course/program can be created, delivered, and evaluated on dairy farms, a need exists to assess what content needs to be included and deficiencies in knowledge that need to be addressed.<sup>13,16</sup> The primary objective is to determine the awareness and knowledge of TB among dairy workers in Bailey County, Texas. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886).

## **METHODS**

Study design. A cross-sectional study design was used to collect survey responses concerning knowledge of TB among dairy workers in Bailey County, Texas. Bailey County has a total of 10 farms, employs approximately 225 workers, and milks an estimated 22,537 cows.<sup>17</sup> All ten dairy farm producers were called, personally visited, and invited to participate in this study. A total of 225 dairy workers were included in the study. Data collection took place between February and March 2019.

Eligibility criteria. A total of 225 consenting dairy workers were invited to participate and surveyed in Bailey County, Texas. Subject eligibility included being a male or female worker  $\geq 18$  years of age employed full-time/part-time/temporary on any of the ten dairy farms visited.

Consent procedures. Research staff read and explained the consent form to participants before the survey was completed. Participants were asked to consent and sign an electronic

informed consent on an iPad© tablet in order to participate. All participants were given a hard copy of their consent form in English or Spanish. Once consent was collected, research staff proceeded to administer the survey. Surveys were administered in privacy in breakrooms, conference rooms, parlors, maintenance sheds, tractors, and other accessible dairy farm work spaces. Participants were compensated for their time with a \$10 gift card.

Survey measures. The survey included 15 demographic questions and a 17-item TB knowledge quiz. Currently, there are no standard TB knowledge questionnaires for dairy workers or other vulnerable high risk occupations.<sup>15</sup> Therefore, the help of a dairy extension specialist and previously published peer-reviewed literature was used to finalize the survey content. All TB knowledge questions were adopted from material publicly released by the CDC,<sup>18</sup> WHO,<sup>19</sup> University of Rochester Medical Center,<sup>20</sup> and a current study on workplace TB interventions by Eggerth *et al.* (2018). All questions were placed on the survey platform Qualtrics Mobile Survey Software® with both English and Spanish options. Subsequently, surveys were uploaded to iPad© tablet devices for offline use. Trained bilingual (English and Spanish proficient) research staff used these iPad© tablet devices to read questions to participants and log, in real-time, their responses (**Figure 1**). Completed surveys were uploaded to our private and encrypted Qualtrics online account once internet services were available.

Outcome variable. TB knowledge, was measured via several questions on six different aspects of TB knowledge: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. Questions testing knowledge were asked in both “True-False” and multiple choice format. In addition, administrators had the option of selecting “I don’t know” if the participant expressed not knowing the answer to a question or also had the option of selecting “Did not answer” if the participant did not choose an answer or did not want

to answer the question. Each participant had a maximum of 17 points: one point for a correct answer and zero points for an incorrect answer (*Knowledge questions in Appendix A*).

Exposure measure. Following previous research by Torres *et al.* (2013), job position on a dairy farm was used as a proxy for categories of cattle exposure: (1) high exposure among workers with direct contact with cattle in confined spaces (e.g., milkers, pusher, veterinarians, supervisor/manager, hospital workers, and slaughter); (2) medium exposure among workers with direct contact with cattle in non-confined spaces (e.g., feeders, tractor operators, breeders, calf caretaker, maternity, hoof trimmer, maintenance technicians); and, (3) low exposure among workers with no direct contact with cattle in any type of space (e.g., owners, office staff).

Data analyses. A preliminary dataset check was completed in order to assess the percentage of missing data. Subsequently, a complete case analyses (CCA) was preformed because < 10% of the data was missing. Basic descriptive statistics (e.g., frequencies, proportions, means, and standard deviations) of all sociodemographic characteristics by category of exposure were estimated and reported in **Table 3**. Both chi-square and the nonparametric Kruskal-Wallis tests were conducted to explore potential confounders between category of exposure and sociodemographic variables.<sup>21</sup> Corresponding p-values are also shown in **Table 3**. A type I error level of 0.05 was used to declare significance.

**Table 4** shows individual TB knowledge questions by category of exposure (high, medium, low). The medium and low groups were collapsed due to a limited sample size. After analyzing TB knowledge scores separated on the basis of “Correct,” “Incorrect,” and “Don’t know,” by high, medium, and low category of exposure (**Appendix B**), we noticed the sample size for the low group was much lower (n=5) compared to high (n=156) and medium (n=64). The medium and low group frequencies for “Correct,” “Incorrect,” and “Don’t know” were

statistically similar; therefore, we decided to collapse these groups in to one labeled medium/low. In this same preliminary analysis, we also collapsed the “Incorrect” and “Don’t know” categories of TB knowledge due to sample size and conceptual methods. A separate analysis found that several “Incorrect” cells had counts  $< 5$ . Conceptually, an incorrect answer indicates a gap in knowledge or a state of not knowing the answer to a question.

Correspondingly, previous studies assessing content knowledge, using similar methodological techniques, collapsed “Incorrect” and “Don’t know” categories.<sup>4,22,23</sup>

Frequencies are reported for correct and incorrect answer choices for each of the 17-questions by all, high, and medium/low groups (**Table 4**). An independent samples *t*-test was conducted in order to compare the TB knowledge score means of the high groups compared to the medium/low group.<sup>21</sup> In addition, multivariate models were fitted for individual knowledge questions utilizing Hosmer and Lemeshow’s model building methods.<sup>24</sup> Based on the *p*-values obtained in **Table 3**, we selected potential confounders with a *p*-value  $< 0.05$ —age, nationality, years in the U.S., primary language, secondary language, education, and years of experience on dairy farm. First, a univariable analysis was used to examine unadjusted associations between potential confounders selected and individual TB knowledge questions. The majority of associations explored were statistically significant (*p*-value  $< 0.25$  cutoff) for the exception of secondary language which was subsequently dropped. In order to avoid correlation between the variables selected, a power correlation analysis was conducted. Nationality, years in the U.S., and primary language were all moderately correlated. Both nationality and years in the U.S. were dropped and primary language was kept because language is important for our outcome of interest. Next, full models with age, primary language, education, and years of experience on dairy farm were created for each individual TB knowledge question. Based on the full model,



individual reduced models were created including variables with a p-value  $< 0.05$ . A likelihood-ratio test was completed for each individual TB knowledge question in order to determine the better fit between the full and reduced models. Based on the null hypothesis stating that the reduced (simpler) model has the better fit, models were chosen for each individual TB knowledge question. To finish model building methods, a goodness-of-fit test was completed for each individual TB knowledge question in order to determine differences between observed and expected values. Based on the null hypothesis stating that there are no differences between observed and expected values, all final models were a good fit. Last, crude prevalence odds ratio (POR), adjusted prevalence odds ratios (aPOR), and corresponding 95% confidence intervals (95%CI) were reported (**Table 3**). All statistical analyses were performed using Stata/SE v.14.0.<sup>25</sup>

Human subjects. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886).

## RESULTS

The mean age of workers was 34.4 (SD 12.0) with a range of 17-65 years of age and 89.3% of surveyed dairy workers were male. Almost all dairy workers (96.9%) were full-time employees with 7.4 (SD 8.2) years of dairy farm work experience in the U.S. and 4.8 (SD 8.8) years of experience working with cattle in their country of origin. The majority of dairy workers were Hispanic (88.0%) with 43.1% of participants reporting Mexico as their country of birth, 45.3% other Latin American countries, and 11.6% United States. On average, workers had 13.0 (SD 14.0) years residing in the U.S. Almost 60.0% of workers reported Spanish as their primary language, 9.8% English, and 30.7% spoke another language. In contrast, 36.9% reported Spanish

as their secondary language, 20.9% as English, 6.7% spoke another language, and 35.6% claimed they had no proficient secondary language. The majority of workers reported no formal education/elementary (51.6%) as the highest level of education achieved, followed by high school/college/graduate (30.2%) levels and middle school (18.2%).

**Table 3** also reports the sociodemographic characteristics of surveyed dairy workers by category of exposure: high and medium/low groups. Workers in the high category of exposure group tended to be younger, Guatemalan, K'iche' speaking males with less years living in the U.S. and lower levels of formal education completed. Relative to the medium/low group, high group had less dairy farm work experience in the U.S. and less work experience with cattle in their country of origin, but worked similar days per week and hours per day.

In this study, general awareness refers to consciousness that a condition (e.g., TB) exists and knowledge refers to understanding facts/information about a subject (e.g., TB).<sup>26</sup> Overall, 37.3% of surveyed workers had general awareness of TB. There was no statistically significant difference of TB awareness between the high group (34.0%) compared to the medium/low group (44.9%) (**Appendix B**). **Table 4** presents individual TB knowledge questions by category of TB exposure. Overall, the average score was 7.1 (SD 4.9) out of 17 (41.8% out of 100.0%). Results indicated that there was no statistically significant differences between the mean TB knowledge score for the high group compared to the medium/low group ( $t = -1.9193$ ,  $p = 0.0562$ ). Besides correct answers, most notable were the frequencies for incorrect answer choices. In general, dairy workers reported higher frequencies of incorrect answers than selecting the correct answers for 12 out of the 17 questions administered. In general, higher frequencies of incorrect answers than correct were found for all aspects of TB knowledge: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB.

**Table 4** also shows crude and adjusted POR and corresponding 95% CIs for the medium/low group with the high as the reference group. For crude POR, statistical TB knowledge score differences between the medium/low group relative to high occurred for three items (questions 2, 13, and 14) pertaining to TB characteristics and TB treatment. After adjustments, statistical TB knowledge score differences between the medium/low group relative to high occurred for two different items (questions 8 and 11).



**Figure 1.** Bilingual research staff member administering survey to dairy worker outside maintenance shed in Bailey County, Texas.

**Table 3.** Demographic characteristics of surveyed dairy workers by category of TB exposure.

Characteristics	Category of TB exposure			<i>p</i> *
	All (n=225)	High (n=156)	Medium/Low (n=69)	
	Mean (SD) or n (%)			
<b>Age</b>	34.4 (12.0)	32.6 (11.0)	38.3 (13.1)	0.0022
<b>Male</b>	201 (89.3)	139 (89.1)	62 (89.9)	0.8660
<b>Nationality</b>				
United States	26 (11.6)	11 (7.1)	15 (21.7)	<0.0001
Mexico	97 (43.1)	57 (36.5)	40 (58.0)	
Other Latin American Countries	102 (45.3)	88 (56.4)	14 (20.3)	
<b>Years in the US</b>	13.0 (14.0)	10.8 (12.5)	18.0 (16.0)	0.0002
<b>Primary Language</b>				<0.0001
English	22 (9.8)	11 (7.1)	11 (15.9)	
Spanish	134 (59.6)	83 (53.2)	51 (73.9)	
Other	69 (30.7)	62 (39.7)	7 (10.1)	
<b>Secondary Language</b>				0.0010
English	47 (20.9)	23 (14.7)	24 (34.8)	
Spanish	83 (36.9)	67 (43.0)	16 (23.2)	
Other	15 (6.7)	13 (8.3)	2 (2.9)	
None	80 (35.6)	53 (34.0)	27 (39.1)	
<b>Education</b>				0.0010
No Formal/Elementary school	116 (51.6)	93 (59.6)	23 (33.3)	
Middle school	41 (18.2)	24 (15.4)	17 (24.6)	
High school/College/Graduate	68 (30.2)	39 (25.0)	29 (42.0)	
<b>Years of experience on dairy farms</b>	7.4 (8.2)	7.0 (8.6)	8.3 (7.5)	0.0410
<b>Years working with cattle in origin country</b>	4.8 (8.8)	4.3 (8.6)	6.0 (9.3)	0.1482
<b>Full-time employment</b>	218 (96.9)	151 (96.8)	67 (97.1)	0.5800
Hours per day	10.6 (6.0)	10.7 (6.5)	10.4 (4.8)	0.0715
Days per week	6.0 (0.6)	6.0 (0.6)	6.0 (0.6)	0.8773

\*p-value from  $\chi^2$ ; p-value from Kruskal-Wallis

**Table 4.** TB knowledge scores by categories of TB exposure (n=225)

TB knowledge evaluation content	Category of TB exposure							
	All (n=225)		High (n=156)		Medium/Low (n=69)		Medium/Low (High as reference)	
	n(%)		n(%)		n(%)		POR (95%CI) <sup>c</sup>	
	Correct <sup>a</sup>	Incorrect <sup>b</sup>	Correct <sup>a</sup>	Incorrect <sup>b</sup>	Correct <sup>a</sup>	Incorrect <sup>b</sup>	Crude	Adjusted
TB CHARACTERISTICS								
1. TB is caused by germs called bacteria. <sup>d</sup>	123 (54.7)	102 (45.3)	79 (50.6)	77 (49.4)	44 (63.8)	25 (36.2)	1.7 (1.0-3.1)	0.9 (0.4-1.8)
2. The flu vaccine protects me from TB infections. <sup>d</sup>	77 (34.2)	148 (65.8)	47 (30.1)	109 (69.9)	30 (43.5)	39 (56.5)	1.8 (1.0-3.2)	0.8 (0.4-1.6)
3. TB affects the lungs and other organs. <sup>d</sup>	117 (52.0)	108 (48.0)	75 (48.1)	81 (51.9)	42 (60.9)	27 (39.1)	1.7 (0.9-3.0)	0.9 (0.4-1.7)
TB TRANSMISSION								
4. How do you get TB? <sup>d</sup>	64 (28.4)	161 (71.6)	44 (28.21)	112 (71.8)	20 (29.0)	49 (71.0)	1.0 (0.6-1.9)	0.8 (0.4-1.6)
5. TB can be transmitted from person-to-person through touching or sharing plates and cups. <sup>e</sup>	22 (9.8)	203 (90.2)	14 (9.0)	142 (91.0)	8 (11.6)	61 (88.4)	1.3 (0.5-3.3)	0.9 (0.3-2.4)
6. Who is at risk of developing TB in this country? <sup>d</sup>	82 (36.4)	143 (63.6)	54 (34.6)	102 (65.4)	28 (40.6)	41 (59.4)	1.3 (0.7-2.3)	0.5 (0.3-1.1)
TB SYMPTOMS								
7. What are the main symptoms of TB disease? <sup>d</sup>	74 (32.9)	151 (67.1)	51 (32.7)	105 (67.3)	23 (33.3)	46 (66.7)	1.0 (0.6-1.9)	0.5 (0.3-1.1)
8. You could have TB and not have symptoms. This is called latent tuberculosis. <sup>f</sup>	76 (33.8)	149 (66.2)	57 (36.5)	99 (63.5)	19 (27.5)	50 (72.5)	0.7 (0.4-0.2)	0.3 (0.2-0.7)
TB DIAGNOSIS								
9. TB can be tested by your local clinic. <sup>g</sup>	105 (46.7)	120 (53.3)	69 (44.2)	87 (55.8)	36 (52.2)	33 (47.8)	1.4 (0.8-2.4)	0.7 (0.4-1.4)
10. How is TB diagnosed? <sup>h</sup>	47 (20.9)	178 (79.1)	29 (18.6)	127 (81.4)	18 (26.1)	51 (73.9)	1.5 (0.8-3.0)	0.9 (0.4-1.8)
TB TREATMENT								
11. How is TB treated? <sup>g</sup>	96 (42.7)	129 (57.3)	67 (43.0)	89 (57.1)	29 (42.0)	40 (58.0)	1.0 (0.5-1.7)	0.4 (0.2-0.7)
12. TB can be cured. <sup>f</sup>	106 (47.1)	119 (52.9)	69 (44.2)	87 (55.8)	37 (53.6)	32 (46.4)	1.5 (0.8-2.6)	1.0 (0.5-1.8)
13. Untreated TB can be fatal. <sup>d</sup>	142 (63.1)	83 (36.9)	86 (55.1)	70 (44.9)	56 (81.2)	13 (18.8)	3.5 (1.8-6.9)	1.9 (0.8-4.2)
14. TB can be cured drinking tea and making natural home remedies. <sup>d</sup>	103 (45.8)	122 (54.2)	59 (37.8)	97 (62.2)	44 (63.8)	25 (26.2)	2.9 (1.6-5.2)	1.2 (0.5-2.5)
BOVINE TB								
15. Cattle can also experience a TB infection called bovine tuberculosis. <sup>i</sup>	145 (64.4)	80 (35.6)	96 (61.5)	60 (38.5)	49 (71.0)	20 (29.0)	1.5 (0.8-2.8)	0.7 (0.3-1.5)
16. Transmission of bovine TB can happen between cattle and humans. <sup>g</sup>	139 (61.8)	86 (38.2)	95 (60.9)	61 (39.1)	44 (63.8)	25 (36.2)	1.1 (0.6-2.0)	0.6 (0.3-1.1)
17. How can bovine TB be transmitted? <sup>d</sup>	76 (33.8)	149 (66.2)	49 (31.4)	107 (68.6)	27 (39.1)	42 (60.9)	1.4 (0.8-2.5)	0.9 (0.5-1.8)
Mean (SD) TB Knowledge Score (max. 17)	7.1 (4.9)		6.7 (5.1)		8.0 (4.6)		0.0562 <sup>k</sup>	

<sup>a</sup> Frequency and percentage of correct answers chosen; <sup>b</sup> Incorrect is the sum of wrong and 'don't know' answers; <sup>c</sup> Prevalence odds ratio (POR) and corresponding 95% confidence interval; <sup>d</sup> Adjusted for age primary language, education, and years of dairy work experience; <sup>e</sup> Adjusted for education; <sup>f</sup> Adjusted for primary language; <sup>g</sup> Adjusted for primary language and education; <sup>h</sup> Adjusted for age and education; <sup>i</sup> Adjusted for primary language, education, and years of dairy work experience; <sup>k</sup> p-value from t-test

## DISCUSSION

This study found TB knowledge deficiencies at all quizzed measures: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. In addition, these deficiencies in TB knowledge were also found in both the high and medium/low exposure groups. Overall, the average score was 7.1 (SD 4.9) out of 17 (41.8% out of 100.0%). Relative to one another, the medium/low group (8.0 (SD 4.6) out of 17) scored better than high group (6.7 (SD 5.1) out of 17). This study also found that 37.3% of surveyed workers had general awareness of TB—the high group was less aware of TB (34.0%) compared to the medium/low group (44.9%). Similarly, bTB knowledge assessments were conducted among 510 Nigerian dairy workers. Results indicated that 58.6% of herdsman and 46.9% of abattoir workers were knowledgeable of bTB prevention.<sup>27</sup> Another study performed in Cameroon found that 73.9% out of 164 dairy farmers were aware of bTB. Despite this high bTB awareness, 55.9% were not able to correctly identify clinical signs and symptoms among themselves, coworkers, or cattle on farm.<sup>4</sup> A similar study from Malawi found that 74.3% out of 140 dairy farm workers were aware that bTB was a zoonotic disease; yet, only 15.7% were able to identify preventative measures (e.g., medical check-up) and only 7.9% identified contact with infect animals as a mode of transmission.<sup>28</sup> However, bTB is endemic in Nigeria, Cameroon, and Malawi; whereas, quality control standards have helped Texas manage sporadic bTB outbreaks among cattle.<sup>29</sup> This may be the reason for the difference in awareness levels between dairy workers in these countries and dairy workers in Texas.

Torres-Gonzalez *et al.* (2013) created three categories of cattle exposure groups based on activity, duration, and conditions of exposure to cattle—high, medium, low. These categories were used in this study to help categorize workers into proxy exposure groups.<sup>6</sup> Results indicated

that there were no significant associations between category of exposure and TB knowledge score by question. An alternative to categories of cattle exposure could have been level of education. The no formal education/elementary group scored a 27.5% (out of 100%) compared to the middle school group at 48.4% and the high school/college/graduate with the highest percentage at 61.8%. The study previously described assessing knowledge of dairy workers in Nigeria found that dairy workers with post-primary education were 2.70 (95% CI: 1.68-4.33) more knowledgeable of bTB prevention compared to individuals with no formal education.<sup>27</sup>

### *Study limitations*

Study limitations included potential recall bias of information collect on the survey. A total of 15 demographic questions and 17 TB knowledge quiz questions were administered. Asking workers to recall the exact number of years in the U.S., years of experience working on dairy farms, years of experience working with cattle in their country of origin, hours a day and days per week (which can vary in agriculture), among recalling TB knowledge information (if learned in past education) could have led to an underestimation or overestimation of these variables and/or the overall individual TB knowledge score. However, demographic characteristics obtained in this study resulted similar to previous studies indicating dairy workers are predominantly an immigrant,<sup>30</sup> Hispanic male,<sup>31</sup> of approximately 30 years of age<sup>16</sup> with limited English proficiency and formal education.<sup>14</sup> Another source of error could have come from respondent bias. There could have been a difference in reluctance to answer between individuals who had a personal experience or knew someone with TB or had an encounter/familiarity with bovine TB on the farm. In addition, participants could have felt the urgency to answer a question even if the attempt was wrong instead of electing to select “I don’t know.”



According to the USDA National Agricultural Statistics Service (NASS), as of July 1, 2018, Bailey County had a total of 10 licensed farms and milked an estimated 22,537 cows.<sup>17</sup> All ten dairy farm producers listed were called, personally visited, and invited to participate in this study. A total of 225 dairy workers were included in the study. When dairies were visited, producers were asked to provide the number of workers currently employed in order to best prepare for the day of survey administration and gift card compensations. As of March 23, 2019, a total of 293 dairy workers on the ten dairy farms that participated in Bailey County, Texas were tallied. This means that 77.0% (225/293) of available workers participated in this study. This information created a more correct census of dairy workers in Bailey County, Texas. Unfortunately, this census will never be accurate because of high worker turnover rates.<sup>32,33</sup> This participation rate came about eight workers choosing not to participate. Despite the possibility of non-response bias and these eight workers being different compared to those who chose to participate in this study, the number is small enough to not affect overall results obtained. In addition, the remaining 60 workers not included were out on vacation, resting the days we visited the farms, or their work day was too busy for non-work related interruptions. Last, the methods of this study ensured interviewer bias remained low. A detailed script was created to guide research staff through survey administration and ensured quality assurance. A total of two researchers administered all 225 surveys. Both researchers were fluent and literate in English and Spanish. Several team meetings were held before and after data collection trips to train and guarantee consistency of survey administrations.

### ***Future plans and conclusions***

This study found TB knowledge deficiencies at all assessment measures among all categories of TB exposure groups. The results found in this study have allowed us to conclude

that a TB educational training could be beneficial for dairy workers at all job positions in Bailey County, Texas. Due to gaps identified in knowledge, the training should include content pertaining to: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. Effective occupational health and safety trainings is a method that can be used to reduce fatal and nonfatal incidents on dairy farms.<sup>34</sup> Health and safety training can be delivered as class lecture, computer training, and hands-on demonstration.<sup>16,35</sup> Mobile learning (m-learning) uses mobile devices for learning experiences.<sup>36</sup> M-learning has been used in occupational settings to provide learning experiences to individual workers or a group of workers.<sup>13,36</sup> Most recently, safety awareness training was delivered to 1,436 dairy workers in Texas, New Mexico, Colorado, Kansas, and New York using iPad® tablets. This safety training proved effective with a score change from 74.2% in the pre-test (baseline) to a 92.5% average in the post-test.<sup>13</sup> Similar methods can be used to create, deliver, and evaluate a TB educational course in Bailey County, Texas. Pre- and post-tests would be used to assess the change in knowledge gained from training. The majority of workers surveyed identified Spanish as their primary language (60.0%) and 51.6% stated they had no formal education/elementary level education; therefore, this training must be culturally, linguistically, and literacy conscious.<sup>33</sup> Despite the medium/low group scoring slightly higher than the high group, both groups showed low levels of TB knowledge and awareness. This training should be made available and required for all new employees and currently employed workers regardless of their years of experience on dairy farms.

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### **JOURNAL ARTICLE 3**

**Paper 3:** Association of category of cattle exposure with history of TB among dairy workers in Bailey County, Texas

**Potential Journals:** American Journal of Industrial Medicine, Journal of Agromedicine

**Keywords:** dairy, workers, prevalence, tuberculosis, Texas

## **ABSTRACT**

**Background:** *Mycobacterium bovis* (bTB) or bovine TB can be transmissible to workers on dairy farms due to its zoonotic characteristic. Even though human bTB infections are considered sporadic in the U.S., they remain poorly understood among foreign dairy workers. The primary objective is to determine history of TB among dairy workers in Bailey County, Texas.

**Methods:** A cross-sectional study design collected 225 survey responses concerning history of TB among dairy workers on ten dairy farms in Bailey County, Texas. Mobile tablets were used to log responses to 15 demographic questions and 13-item history of TB survey. As a proxy for exposure, job positions were used to create groups based on category of cattle exposure—high, medium/ low.

**Results:** No statistically significant associations were found between history of TB and assigned categories of TB exposure. Workers in the high exposure job position group tended to be younger, Guatemalan males with lower levels of formal education completed, were more likely to be single with no children renting a home/apartment with co-workers, and more likely to smoke but less likely to drink throughout the week compared to the medium/low group.

**Conclusion:** TB history among dairy workers remains vague. As a high risk population, dairy workers could be tested before their start date, tested if suspected of infection, and treated if positive for latent and active TB disease

## BACKGROUND

One health hazard on a dairy farm is the potential exposure to *Mycobacterium tuberculosis* (TB).<sup>1-6</sup> In general, TB affects one out of four individuals globally.<sup>7,8</sup> Most recently, the U.S. reported a rate of 2.9 TB cases per 100,000 persons—a record low.<sup>8</sup> However, 67.9% of confirmed TB cases in 2018 originated from foreign-born individuals residing in the U.S.<sup>8</sup> Besides the human version, there is also a *bovine* (cattle) version of the disease called *Mycobacterium bovis* (bTB) or bovine tuberculosis. Bovine TB is predominantly found among cattle and other grazing animals. However, bTB is also transmissible to humans due in part to its zoonotic characteristic.<sup>2,3,9</sup> Globally, an estimated 147,000 bTB cases were confirmed and 12,500 deaths recorded in 2016.<sup>10</sup> The overall impact of TB/bTB among U.S. dairy workers remains unknown.<sup>3</sup>

Among humans, zoonotic diseases are accountable for, approximately, 60.3% of emergent diseases.<sup>3,9,11</sup> Even though human bTB infections are considered sporadic in the U.S., they remain poorly understood among foreign dairy workers. The etiology of bTB infections on a dairy farm is difficult to establish. What remains unclear is the exact direction(s) of the cross-infection between cattle-to-cattle, cattle-to-person, person-to-cattle, and person-to-person.<sup>1</sup> The issue is that foreign dairy workers in the U.S. migrate from *M. tuberculosis* and *M. bovis* endemic countries, such as Mexico and Guatemala.<sup>5,12,13</sup> As a result, pinpointing the origin of a bTB/TB infection among cattle and/or dairy workers becomes challenging because the history of bTB/TB exposure among dairy workers is unknown.<sup>2,14</sup>

Currently, the Department of Labor’s Occupational Safety and Health Administration (DOL-OSHA) does not require dairy producers to test dairy workers for bTB/TB infections before their employment start date or during their employment—as required and completed for

other high risk populations like healthcare workers.<sup>2,3</sup> As a proxy, some occupational exposures, such as job position, have been proposed for epidemiological investigation concerning bTB on dairy farms.<sup>1,11</sup> For instance, Torres-Gonzalez *et al.* (2013) created three categories of cattle exposure groups based on activity, duration, and conditions of exposure to cattle—high, medium, low. High category of cattle exposure was described as workers in a job position with direct contact with cattle in confined spaces (e.g., milkers, veterinarians), medium exposure job position was described as workers with direct contact with cattle in non-confined spaces (e.g., feeders, breeders, tractor operators, maintenance), and low job position exposure was described as workers with no direct contact with cattle in any type of space (e.g., owners, secretarial staff). These job position groups can help categorize workers into proxy exposure groups.<sup>6</sup> The primary objective is to determine history of TB among dairy workers in Bailey County, Texas. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886).

## **METHODS**

Study design. A cross-sectional study design was used to collect survey responses concerning history of TB among dairy workers in Bailey County, Texas. Bailey County has a total of 10 farms, employs approximately 225 workers, and milks an estimated 22,537 cows.<sup>15</sup> All ten dairy farm producers were called, personally visited, and invited to participate in this study. A total of 225 dairy workers consented to participate in the study between February and March 2019.

Eligibility criteria. Subject eligibility included being a male or female worker  $\geq 18$  years of age employed on any of the ten dairy farms included in this county.



Consent procedures. Research staff read and explained the consent form to participants before the survey was completed. Participants were asked to consent and sign an electronic informed consent on an iPad® tablet in order to participate. All participants were given a hard copy of their consent form in English or Spanish. Once consent was collected, research staff proceeded to administer the survey. Surveys were administered in privacy in breakrooms, conference rooms, parlors, maintenance sheds, tractors, and other accessible dairy farm work spaces. Participants were compensated for their time with a \$10 gift card.

Survey measures. The survey included 15 sociodemographic and 13 history of TB questions. Currently, U.S. health departments have standard TB contact investigation forms used to survey positive cases and contacts. All questions used were adopted from the Texas DSHS Health Service Region 1 dairy TB evaluation form.<sup>16</sup> The questions were placed on the survey platform Qualtrics Mobile Survey Software® in both English and Spanish with offline compatibility. Trained bilingual research personnel used iPad® tablets to read questions and log responses.

Outcome variable. History of TB was measured via several questions on six different aspects of past TB exposure: (1) occupational status, (2) vaccination history, (3) TB diagnosis and treatment history, (4) TB contact history, (5) consumption of unpasteurized dairy products, and (6) bovine TB exposure. Questions varied from both “fill in the blank” to multiple choice. Research personnel had the option of selecting “I don’t know” if the participant expressed not knowing the answer to a question or selecting “Did not answer” if the participant chose not to answer the question.

Exposure measure. Following previous research by Torres-Gonzalez *et al.* (2013), job position on a dairy farm was used as a proxy for categories of cattle exposure. Job positions were categorized into the following groups:

Category of cattle exposure	Definition	Job positions
<i>High</i>	Direct contact with cattle in confined spaces	Milker, pusher, veterinarians, supervisors, manager, hospital workers, slaughter
<i>Medium</i>	Direct contact with cattle in non-confined spaces	Feeders, tractor operators, breeders, calf caretaker, maternity, hoof trimmer, maintenance
<i>Low</i>	No direct contact with cattle in any type of space	Owners, office staff

Data analysis. Basic descriptive statistics (e.g., frequencies, proportions, means, and standard deviations) of all sociodemographic characteristics by category of exposure were estimated. Both chi-square and the nonparametric Kruskal-Wallis tests were conducted to explore potential confounders between category of exposure and sociodemographic variables and corresponding p-values.<sup>17</sup> A type I error level of 0.05 was used to declare significance.

**Table 6** shows history of TB by category of TB exposure. The medium and low groups were collapsed due to limited sample size. After analyzing history of TB frequencies by high, medium, and low category of TB exposure, we noticed the sample size for the low group was much lower (n=5) compared to high (n=156) and medium (n=64). The medium and low group frequencies were statistically similar; therefore, we decided to collapse these groups in to one labeled medium/low.

Summary statistics on history of TB by all, high, and medium/low groups are reported in **Table 6**. In addition, multivariate models were fitted for individual TB history questions utilizing Hosmer and Lemeshow's model building methods.<sup>18</sup> Based on the p-values obtained in **Table 5**,

we selected potential confounders with a p-value  $< 0.05$ —age, nationality, education, having children, and living situation. First, a univariable analysis was used to examine unadjusted associations between potential confounders selected and individual TB history questions. The majority of associations explored were statistically significant (p-value  $< 0.25$  cutoff) for the exception of having children which was subsequently dropped. In order to avoid correlation between the variables selected, a power correlation analysis was conducted. Having children and age were moderately correlated. However, this issue was avoided since having children had been previously dropped. Next, adjusted full models with age, nationality, education, and living situation were created for each individual TB history question. Based on the full model, individual reduced models were created including variables with a p-value  $< 0.05$ . A likelihood-ratio test was completed for each individual TB history question in order to determine the better fit between the full and reduced models. Based on the null hypothesis stating that the reduced (simpler) model has the better fit, models were chosen for each individual TB history question. To finish model building methods, a goodness-of-fit test was completed for each individual TB history question in order to determine differences between observed and expected values. Based on the null hypothesis stating that there are no differences between observed and expected values, all final models were a good fit. Last, crude prevalence odds ratio (POR), adjusted prevalence odds ratios (aPOR), and corresponding 95% confidence intervals (95% CI) were reported (**Table 6**). All statistical analyses were performed using Stata/SE v. 14.0.<sup>19</sup>

Human subjects. This study was approved by the University of Texas Health Science Center at Houston Committee of the Protection of Human Subjects (CPHS) (HSC-SPH-18-0886)

## RESULTS

Dairy workers were less than 30 years old (39.5%) and between 30-39 years old (32.9%). The majority of dairy workers were Hispanic (88.4%) with 43.1% from Mexico, 41.8% from Guatemala, and 11.6% from United States. Only 30.0% reported traveling outside the U.S. in the past 12-months (with 90.0% visiting Mexico for an average of two-weeks). Most dairy workers reported elementary (34.7%) as the highest level of education achieved, followed by middle school (18.2%) and no formal education (16.9%). The sociodemographic portion of the survey also asked several lifestyle and living arrangement questions. Close to 67.0% of workers reported being married and about three-fourths of workers claimed to have an average of 2.3 (SD 1.9) children. As far as living accommodations, most dairy workers rented a house/apartment (58.2%). The average number of household residents, including self, reported was 3.7 (SD 1.8). The majority of workers reported living with their spouse and children (37.3%), while 20.0% reported living with an average of 3.4 (SD 1.8) co-workers, 12.4% with only with their spouse, and 11.1% reported living alone. Only 16.0% disclosed being current smokers and having an average of 1.8 (SD 6.0) alcoholic drinks per week.

**Table 5** also reports the sociodemographic characteristics of surveyed dairy workers by category of TB exposure: high and medium/low groups. Workers in the high exposure job position group tended to be younger, Guatemalan males with lower levels of formal education completed. Relative to the medium/low group, workers in the high group were more likely to be single with no children renting a home/apartment with co-workers.

**Table 6** presents the history of TB by category of TB exposure. Groups created were confirmative based on groups recommended by Torres-Gonzalez *et al.* (2013) with the high group working 9.1 (SD 2.9) hours in close-proximity to cattle compared to the medium/low

group working 5.0 (SD 4.4) hours in close-proximity to cattle. A large majority of workers (78.2%) reported having been vaccinated with the BCG vaccine as an infant. A total of 4/225 individuals identified having been diagnosed with active TB in the past. However, only 2/4 reported seeking TB treatment which was successfully finished. A small fraction of workers (2.2%) reported having lived or worked closely with someone who had been diagnosed with TB. Throughout this reported exposure, workers claimed that no respirators had been utilized by them or the person with active TB. About a third of workers reported consuming raw dairy products. Out of that third, 81.4% had consumed these raw dairy products in their non-U.S. home country and 18.6% while working on a U.S. dairy farm. Almost 6.0% of workers had worked with bTB infected cattle on U.S. dairy farms while 33.3% had heard of bTB outbreaks on other farms in Bailey County, Texas. Relative to the medium/low group, the high group had a higher frequency of BCG vaccination. The high group had 3/4 workers previously diagnosed with TB with only one seeking and finishing treatment compared to the one TB diagnosed case in the medium/low group which sought and finished treatment. Similarly, the high group had 4/5 who lived or worked closely with someone who had been diagnosed with TB—all which did not wear respirators. Last, the high group had more workers who consumed raw milk on U.S. dairy farms, but were not as aware of bTB outbreaks on other farms in Bailey County, Texas compared to the medium/low group.

**Table 6** also shows crude and adjusted POR and their corresponding 95% CIs for the medium/low group with high as the reference group. For crude POR, no statistical differences were observed between the medium/low group relative to high for all TB history items. Similarly, after adjustments, no statistical differences were observed between the medium/low group relative to high for all TB history items.

**Table 5.** Sociodemographic characteristics of dairy workers in Bailey County, Texas

Characteristics	Category of TB exposure			<i>p</i> *
	All (n=225)	High (n=156)	Medium/Low (n=69)	
	Mean (SD) or n (%)			
<b>Age</b>				
<30 years	89 (39.5)	68 (43.6)	21 (30.4)	0.0410
30-39 years	74 (32.9)	52 (33.3)	22 (31.9)	
40-49 years	33 (14.7)	22 (14.1)	11 (15.9)	
≥50 years	29 (12.9)	14 (9.0)	15 (21.8)	
<b>Male</b>	201 (89.3)	139 (89.1)	62 (89.9)	0.8660
<b>Nationality</b>				
United States	26 (11.6)	11 (7.1)	15 (21.7)	<0.0001
Mexico	97 (43.1)	57 (36.5)	40 (58.0)	
Guatemala	94 (41.8)	82 (52.6)	12 (17.4)	
Other	8 (3.5)	6 (3.8)	2 (2.9)	
<b>Traveled outside of US in past 12-months</b>	30 (13.3)	21 (13.5)	9 (13.0)	0.9320
Mexico	27 (90.0)	19 (90.5)	8 (88.9)	
Other	3 (10.0)	2 (9.5)	1 (11.1)	
<b>Education</b>				<0.0001
No formal	38 (16.9)	32 (20.5)	6 (8.7)	0.1720
Elementary	78 (34.7)	61 (39.1)	17 (24.6)	
Middle school	41 (18.2)	24 (15.4)	17 (24.6)	
High school	34 (15.1)	14 (9.0)	20 (29.0)	
College/Graduate/Professional	34 (15.1)	25 (16.0)	9 (13.0)	
<b>Marital status</b>				
Single	64 (28.4)	50 (32.1)	14 (20.3)	0.0040
Married	150 (66.7)	98 (62.8)	52 (75.4)	
Divorced/Separated/Widowed	11 (4.9)	8 (5.1)	3 (4.4)	
<b>Children</b>	167 (74.2)	107 (68.6)	60 (87.0)	0.0600
Number of children	2.3 (1.9)	2.2 (2.0)	2.6 (1.6)	0.0820
<b>Living accommodations</b>				
Own home	69 (30.7)	41 (26.3)	28 (40.6)	<0.0001
Rent home/apartment	131 (58.2)	96 (61.5)	35 (50.7)	
Employer provided housing	24 (10.7)	19 (12.2)	5 (7.3)	
<b>Living company</b>				
Alone	25 (11.1)	21 (13.5)	4 (5.8)	0.8366
Parents	6 (2.7)	4 (2.6)	2 (2.9)	
Spouse	28 (12.4)	14 (9.0)	14 (20.3)	
Spouse and children	84 (37.3)	50 (32.1)	34 (49.3)	
Children only	5 (2.2)	3 (1.9)	2 (2.9)	0.2310
no. children living at home	2.9 (1.7)	3.1 (2.0)	2 (1.2)	
Co-workers	45 (20.0)	43 (27.6)	2 (2.9)	
Number of co-workers	3.4 (1.8)	3.5 (1.8)	3 (0.0)	
Other	34 (15.1)	22 (14.1)	12 (17.4)	0.1482
<b>Household residents</b>	3.7 (1.8)	3.7 (1.9)	3.6 (1.4)	
<b>Current smoker</b>	36 (16.0)	28 (18.0)	8 (11.6)	
<b>Alcoholic drinks per week</b>	1.8 (6.0)	1.4 (4.3)	2.7 (8.5)	

\*p-value from  $\chi^2$ ; p-value from Kruskal-Wallis

**Table 6.** History of TB by category of exposure (n=225)

	All (n=225)	Category of TB exposure		Medium/Low (High as reference)	
		High (n=156)	Medium/Low (n=69)	Crude	Adjusted
History of TB	Mean (SD) or n (%)			POR (95%CI) <sup>a</sup>	
History of BCG vaccine	176 (78.2)	127 (81.4)	49 (71.0)	0.8 (0.3-2.0)	0.8 (0.3-2.0)
History of TB diagnosis <sup>b</sup>	4 (1.8)	3 (1.9)	1 (1.5)	0.6 (0.2-1.8)	1.6 (0.4-5.9)
History of TB exposure <sup>b</sup>	5 (2.2)	4 (2.6)	1 (1.5)	0.9 (0.4-1.9)	0.7 (0.3-1.6)
History of raw dairy consumption	70 (31.1)	47 (30.1)	23 (33.3)	1.1 (0.6-2.1)	0.8 (0.4-1.7)
Consumption setting				0.6 (0.1-2.3)	0.6 (0.1-2.3)
Non-U.S. country	57 (81.4)	37 (78.7)	20 (87.0)		
Working on farm in U.S.	13 (18.6)	10 (21.3)	3 (13.0)		
History of working with bTB infected cattle <sup>c</sup>	13 (5.8)	9 (5.8)	4 (5.8)	1.0 (0.6-1.9)	0.8 (0.4-1.6)
Heard of bTB outbreaks on other farms <sup>b</sup>	75 (33.3)	50 (32.1)	25 (36.2)	1.1 (0.6-2.0)	0.7 (0.4-1.4)

<sup>a</sup> Prevalence odds ratio (POR) and corresponding 95% confidence interval; <sup>b</sup> Adjusted for nationality; <sup>c</sup> Adjusted for education and living company.

## DISCUSSION

No statistically significant differences were found between history of TB and assigned categories of TB exposure. In contrast, Torres-Gonzalez *et al.* (2013) found statistically significant differences in positive tuberculin skin test (TST) between the high group and medium and low groups. Torres-Gonzalez *et al.* (2013) clinically tested dairy workers using two confirmative tests: (1) TST and (2) interferon-gamma release assay (IGRA). Due to financial and time restrictions, our study used survey methodology to simultaneously collect previous diagnosis of TB and other characteristics. Potentially, this approach could have led to the difference and subsequent underestimation of TB life prevalence among dairy workers surveyed in Bailey County, Texas.

History of BCG vaccination had a 10.0% difference between the high and medium/low groups. Crude and adjusted POR were not statistically different. Due to a consistent low TB frequency, the U.S. does not vaccinate its population.<sup>20</sup> On the other hand, Mexico has had a 99.0% vaccination coverage since 1996<sup>21</sup> compared to Guatemala with an 81.0% BCG vaccination coverage in 2017.<sup>22</sup> These differences are consistent with the distribution of U.S. born dairy workers (57.7%) in the medium/low group compared to 58.8% Mexican and 87.2% Guatemalan in the high group.

Groups created were confirmative based on groups recommended by Torres-Gonzalez *et al.* (2013) with the high group working 9.1 (SD 2.9) hours in close-proximity to cattle compared to the medium/low group working 5.0 (SD 4.4) hours in close-proximity to cattle. However, results indicated that there were no significant associations between category of exposure and history of TB. An alternative to categories of cattle exposure could



have been nationality. Overall, crude differences were observed between nationalities. All previous TB diagnoses were reported by Central American workers, more Mexican workers (42.3%) reported consuming raw dairy products compared to U.S. (26.9%) and Guatemalan (17.0%) dairy workers. Also, U.S. workers were more likely to report working with bTB infected cattle, >44.0% of U.S. and Mexican workers were aware of previous bTB outbreaks among cattle in Bailey County, Texas compared to Guatemalan (17.0%) dairy workers. Lastly, Guatemalan workers spent 9.4 (SD 2.9) hours working in close-proximity to cattle compared to Mexican workers with 7.0 (SD 3.9) and U.S. workers with 5.2 (SD 4.6) hours.

### ***Study limitations***

Study limitations for Aims 2 and 3 are the same because data was collected simultaneously for both studies. More specific for Aim3 is the measure of dose-response. Ideally, a dose-response measure for each specific worker would be the best measure of exposure. However, in practice, there is a limitation in collection feasibility and measurement data; therefore, inferring indirectly from previous studies is often common practice.<sup>23</sup> Risk can be assessed by occupation and taking into consideration a worker's job position and job duties. Another way can be by self-reported perceived risk.<sup>23</sup>

### ***Future plans and conclusions***

Efforts have been designed and implemented to eradicate TB such as surveillance, routine occupational testing, direct-observational treatments (DOT) by health departments, and TB information sheets online and at clinics.<sup>7,8</sup> However, these TB eradication techniques have not been expanded to bTB and dairy workers in the U.S. The reality is that dairy workers are not tested before starting their jobs at a dairy farm.<sup>2</sup> Currently, OSHA does not

require dairy producers to test dairy workers for bTB/TB infections before their employment start date or during their employment—as required and done for other high risk populations like healthcare workers.<sup>2,3</sup> Healthcare workers are tested upon employment, tested if suspected of infection, and are treated if positive for latent and active TB disease.<sup>12,24</sup> As a high risk population, dairy workers could be tested before their start date, tested if suspected of infection (while working in close-proximity with bTB positive cattle), and treated if positive for latent and active TB disease. Testing healthcare workers is part of the CDC’s TB Infection Control Plan. All parties would benefit from including dairy workers in state/local TB control programs.

Another plan could implement the National Institute for Occupational Safety and Health (NIOSH) Total Worker Health® model to promote a more holistic method to worker health and well-being. Total Worker Health® combines worker health and safety policies, programs, and practices with preventative measures to enhance worker health and well-being.<sup>25</sup> Currently, the OSHA does not require agriculture enterprises to provide health insurance or provide health promotion or disease prevention benefits such as health fairs or wellness programs. Hosting a total worker health fair on a dairy farm would overcome traditional barriers to health care such as cost, transportation, communication difficulties, absence of health insurance, cultural differences, limited knowledge locations, transient lifestyle, and fear of law and immigration enforcement.<sup>26</sup> A health fair could be hosted on dairy farms once a year offering services such as TB tests and other preventative tests/examinations for workers and their families. Determining the need and feasibility of

total worker health fairs on dairy farms could contribute to closing the gap on TB history among dairy workers.

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## GENERAL CONCLUSION

On January 2016, Texas State Department of Health Services (DSHS) Public Health Region 1 (PHR 1) conducted T-SPOT.*TB* tests in response to two requests to screen dairy workers potentially exposed to cattle infected with *Mycobacterium bovis* or bovine tuberculosis (bTB) in Bailey County, Texas. Out of 140 workers tested, 14 had confirmed latent tuberculosis infection (LTBI)—prevalence of 10.0%. This first study gave rise to questions concerning tuberculosis (TB) knowledge and exposure history among dairy workers in this same county. The second study focused on determining TB knowledge among dairy workers through a series of questions administered by research personnel on iPad tablets. Category of cattle exposure was used as a proxy for exposure by categorizing job positions into high and medium/low groups. Overall, the average score was 7.1 (SD 4.9) out of 17 (41.8% out of 100.0%). Results indicated that there was no statistically significant difference between the mean TB knowledge score for the high group compared to the medium/low group ( $t = -1.9193$ ,  $p = 0.0562$ ). This study found TB knowledge deficiencies at all quizzed measures: (1) TB characteristics, (2) TB transmission, (3) TB symptoms, (4) TB diagnosis, (5) TB treatment, and (6) bovine TB. The third study used questions obtained in the same survey to determine the history of TB among the same dairy workers. A large majority of workers (78.2%) reported having been vaccinated with the BCG vaccine as an infant. A total of 4/225 individuals identified having been diagnosed with active TB in the past. However, only 2/4 reported seeking TB treatment which was successfully finished.

This dissertation took a public health case to assess need, burden, and potential impact of TB interventions among dairy workers in Bailey County, Texas. Future research

should use TB knowledge deficiencies found to create, deliver, and evaluate a health and safety TB training for dairy workers in Bailey County, Texas. Pre- and post-tests would be used to assess the change in knowledge gained from training. The majority of workers surveyed identified Spanish as their primary language (60.0%) and 51.6% stated they had no formal education/elementary level education; therefore, this training must be culturally, linguistically, and literacy conscious. This training should be made available and required for all new employees and currently employed workers regardless of their years of experience on dairy farms.

In addition, determining the need and feasibility of Total Worker Health ® fairs on dairy farms could contribute to closing the gap on TB history among dairy workers. Hosting a total worker health fair on a dairy farm would overcome traditional barriers to health care such as cost, transportation, communication difficulties, absence of health insurance, cultural differences, limited knowledge locations, transient lifestyle, and fear of law and immigration enforcement. A health fair could be hosted on dairy farms once a year offering services such as TB tests and other preventative tests/examinations for workers and their families.

## APPENDICES

### Appendix A: 17-Knowledge Questions

#### TB characteristics

1. Tuberculosis is caused by germs called bacteria. [CDC]
  - a. True
  - b. False
  - c. I don't know
  - d. Did not answer
2. The flu vaccine protects me from tuberculosis infections. [Eggerth *et al.*, 2018]
  - a. True
  - b. False
  - c. I don't know
  - d. Did not answer
3. Tuberculosis affects the lungs and other organs. [WHO]
  - a. True
  - b. False
  - c. I don't know
  - d. Did not answer

#### TB transmission

4. How do you get tuberculosis? [URMC]
  - a. Through the air
  - b. Through sexual partners
  - c. Through blood
  - d. Through contaminated food
  - e. I don't know
  - f. Did not answer
5. Tuberculosis can be transmitted from person-to-person through touching or sharing plates and cups? [WHO]
  - a. True
  - b. False
  - c. I don't know
  - d. Did not answer
6. Who is at risk of developing tuberculosis in this country? [URMC]
  - a. Health care workers
  - b. Migrant farm workers
  - c. People with HIV
  - d. All of the above
  - e. I don't know
  - f. Did not answer

#### TB symptoms

7. What are the main symptoms of tuberculosis disease? [WHO]
  - a. Persistent cough for >2-3 weeks
  - b. Weight loss



- c. Fever
  - d. Night sweats
  - e. Coughing up blood
  - f. All of the above
  - g. I don't know
  - h. Did not answer
8. You could have tuberculosis and not have symptoms. This is called latent tuberculosis.[CDC]
- a. True
  - b. False
  - c. I don't know
  - d. Did not answer

#### **TB diagnosis**

9. Tuberculosis can be tested by your local clinic. [CDC]
- a. True
  - b. False
  - c. I don't know
  - d. Did not answer
10. How is tuberculosis diagnosed? [URMC]
- a. Chest x-ray
  - b. Sample of sputum
  - c. Blood sample
  - d. All of the above
  - e. I don't know
  - f. Did not answer

#### **TB treatment**

11. How is tuberculosis treated? [WHO]
- a. Antiviral medication
  - b. Antibiotics
  - c. Surgery
  - d. Chemotherapy
  - e. I don't know
  - f. Did not answer
12. Tuberculosis can be cured. [CDC]
- a. True
  - b. False
  - c. I don't know
  - d. Did not answer
13. Untreated tuberculosis can be fatal.[CDC]
- a. True
  - b. False
  - c. I don't know
  - d. Did not answer
14. Tuberculosis can be cured drinking tea and making natural home remedies. [Eggerth *et al.*, 2018]

- a. True
- b. False
- c. I don't know
- d. Did not answer

**Bovine TB**

15. Cattle can also experience a tuberculosis infection called bovine tuberculosis. [CDC]

- a. True
- b. False
- c. I don't know
- d. Did not answer

16. Transmission of bovine tuberculosis can happen between cattle and humans. [CDC]

- a. True
- b. False
- c. I don't know
- d. Did not answer

17. How can bovine tuberculosis be transmitted? [CDC]

- a. Breathing air contaminated by infected people
- b. Breathing air contaminated by infected cattle
- c. Consuming unpasteurized dairy products
- d. Contact with an infected wound of cattle
- e. All of the above
- f. I don't know
- g. Did not answer

Appendix B: Table A. TB knowledge scores by categories of TB exposure (n=225)

TB knowledge evaluation content	Category of TB exposure								
	All (n=225)			High (n=156)			Medium/Low (n=69)		
	Correct	Incorrect	Don't know	Correct	Incorrect	Don't know	Correct	Incorrect	Don't know
<b>TB CHARACTERISTICS</b>									
1. TB is caused by germs called bacteria.	123 (54.7)	5 (2.2)	97 (43.1)	79 (50.6)	4 (2.6)	73 (46.8)	44 (63.8)	1 (1.5)	24 (34.8)
2. The flu vaccine protects me from TB infections.	77 (34.2)	45 (20.0)	103 (45.8)	47 (30.1)	33 (21.2)	76 (48.7)	30 (43.5)	12 (17.4)	27 (39.1)
3. TB affects the lungs and other organs.	117 (52.0)	5 (2.2)	103 (45.8)	75 (48.1)	3 (1.9)	78 (50.0)	42 (60.9)	2 (2.9)	25 (36.2)
<b>TB TRANSMISSION</b>									
4. How do you get TB?	64 (28.4)	42 (18.7)	119 (52.9)	44 (28.21)	27 (54.5)	85 (54.5)	20 (29.0)	15 (21.7)	34 (49.3)
5. TB can be transmitted from person-to-person through touching or sharing plates and cups.	22 (9.8)	89 (39.6)	114 (50.7)	14 (9.0)	62 (39.7)	80 (51.3)	8 (11.6)	27 (39.1)	34 (49.3)
6. Who is at risk of developing TB in this country?	82 (36.4)	30 (13.3)	113 (50.2)	54 (34.6)	16 (10.3)	86 (55.1)	28 (40.6)	14 (20.3)	27 (39.1)
<b>TB SYMPTOMS</b>									
7. What are the main symptoms of TB disease?	74 (32.9)	42 (18.7)	109 (48.4)	51 (32.7)	24 (15.4)	81 (51.9)	23 (33.3)	18 (26.)	28 (40.6)
8. You could have TB and not have symptoms. This is called latent tuberculosis.	76 (33.8)	12 (5.3)	137 (60.9)	57 (36.5)	6 (3.9)	93 (59.6)	19 (27.5)	6 (8.7)	44 (63.8)
<b>TB DIAGNOSIS</b>									
9. TB can be tested by your local clinic.	105 (46.7)	6 (2.7)	114 (50.7)	69 (44.2)	6 (3.9)	81 (51.9)	36 (52.2)	0 (0.0)	33 (47.8)
10. How is TB diagnosed?	47 (20.9)	70 (31.1)	108 (48.0)	29 (18.6)	45 (28.9)	82 (52.6)	18 (26.1)	25 (36.2)	26 (37.7)
<b>TB TREATMENT</b>									
11. How is TB treated?	96 (42.7)	4 (1.8)	125 (55.6)	67 (43.0)	3 (1.9)	86 (55.1)	29 (42.0)	1 (1.5)	39 (56.5)
12. TB can be cured.	106 (47.1)	19 (8.4)	100 (44.4)	69 (44.2)	17 (10.9)	70 (44.9)	37 (53.6)	2 (2.9)	30 (43.5)
13. Untreated TB can be fatal.	142 (63.1)	5 (2.2)	78 (34.7)	86 (55.1)	4 (2.6)	66 (42.3)	56 (81.2)	1 (1.5)	12 (17.4)
14. TB can be cured drinking tea and making natural home remedies.	103 (45.8)	35 (15.6)	87 (38.7)	59 (37.8)	31 (19.9)	66 (42.3)	44 (63.8)	4 (5.8)	21 (30.4)
<b>BOVINE TB</b>									
15. Cattle can also experience a TB infection called bovine tuberculosis.	145 (64.4)	3 (1.3)	77 (34.2)	96 (61.5)	2 (1.3)	58 (37.2)	49 (71.0)	1 (1.5)	19 (27.5)
16. Transmission of bovine TB can happen between cattle and humans.	139 (61.8)	5 (2.2)	81 (36.0)	95 (60.9)	5 (3.2)	56 (35.9)	44 (63.8)	0 (0.0)	25 (36.2)
17. How can bovine TB be transmitted?	76 (33.8)	57 (25.3)	92 (40.9)	49 (31.4)	37 (23.7)	70 (44.9)	27 (39.1)	20 (29.0)	22 (31.9)
<b>Average Score (max. 17) Mean (SD)</b>			7.1 (4.9)			6.7 (5.1)			8.0 (4.6)
<b>TB Awareness n(%)</b>			84 (37.3)			53 (34.0)			31 (44.9)

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