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**EPIDEMIOLOGICAL INVESTIGATION OF LAMENESS IN SELECTED
DAIRY FARMS OF SULULTA TOWN, CENTRAL ETHIOPIA**

MVSc THESIS

By

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BISHOFTU, ETHIOPIA

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DAIRY FARMS OF SULULTA TOWN, CENTRAL ETHIOPIA**

MVSc THESIS



**A Thesis Submitted to the College of Veterinary Medicine and Agriculture of Addis
Ababa University in partial fulfillment of the requirements for the degree of Master
of Science in Veterinary Epidemiology**

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
BEF	Bovine Ephemeral Fever
BVD	Bovine Viral Diarrhea
CI	Confidence Interval
CSA	Central Statistical Agency
CBPP	Contagious Bovine Pleuropneumonia
DD	Digital Dermatitis
FMD	Foot and Mouth Disease
HHE	Heel Horn Erosion
IA	Intra-articular
IDD	Interdigital Dermatitis
LS	Locomotion Score
LSD	Lumpy Skin Disease
MCF	Malignant Catarrhal Fever
NDF	Neutral Detergent Fiber
OR	Odds Ratio
P-value	Probability value
SA	Septic Arthritis
STDV	Standard Deviation

ABSTRACT

A repeated cross-sectional study was carried out from November 2017 to May 2018 in selected dairy farms of Sululta town, central Ethiopia with the aim of investigating the Epidemiology of lameness in dairy cattle and the impact of lameness on the milk yield. A total number of 245 dairy cattle were clustered within 15 randomly selected dairy farms. In order to determine the prevalence of lameness, a locomotion scoring system described by Sprecher *et al.* (1997) was conducted. One or more cases of lameness was observed in eight farms making the herd level prevalence of 53.33% (95% CI, 28.09 - 78.58). The prevalence of lameness was significantly varied between the farms, ranging from 0 % to 42.86%, with a mean within-herd level prevalence of 20.96% ($p = 0.000$). The overall animal level prevalence of lameness was found to be 8.98% (95% CI, 5.39 - 12.56). This prevalence could be invariably associated with some of the risk factors. Accordingly, multivariable logistic regression analysis result showed that the odds of lameness was 5.13 times more likely to occur in animals of dairy farms with no routine hoof trimming practices as compared to animals in dairy farms with hoof trimming practices (OR = 5.13; 95% CI, 1.34 to 19.57). Similarly, the odds of lameness was 4.32 times more likely to occur in dairy cattle kept under wet & crackly floor type as compared to animals in clean and dry floor type (OR = 4.32; CI, 1.13 – 16.58). The average daily milk yield/cow was found to be significantly declined by 4.22 liters with the case of lameness ($p = 0.000$). In conclusion, lameness was underestimated dairy cattle health problem in the study area; and the prevalence of lameness was found to be beyond the expected level in some of the farms which deserves attention concerning to the prevention of the problem.

Key words: Dairy farms, Epidemiology, Lameness, Sululta Ethiopia

1. INTRODUCTION

Lameness is considered to be among the most important health problems in dairy production in many parts of the world (Tranter and Morris, 1991; Shearer, 1997). Lameness can be defined as an abnormal behavior (for example reduced velocity and altered stride, curved back and lowered head or nodding movement of the head) as a way to reduce the pain (Scott, 1989; Nordlund *et al.*, 2004). It is most likely to result from pain in the limb, usually within the foot, and reportedly hind feet are more commonly affected than front feet (Tranter and Morris, 1991; Blowey, 2005). Which is characterized by limping or not bearing weight on a leg as usual (Hendrick and Abeysekara, 2009). Thus, it is most obvious clinical symptom of impaired animal welfare (Bicalho *et al.*, 2009; Refaai *et al.*, 2013; Solano *et al.*, 2015). On the other hand it results in milk yield reduction, reduced feed intake, weight loss, reduced fertility and premature culling of affected animals as a result accounts for tremendous economic loss (Shearer, 1997; Refaai *et al.*, 2013). In addition, reproductive efficiency was significantly lower in cows becoming lame during the breeding season and cows lame before and during the breeding season compared to non-lame cows (Somers *et al.*, 2015).

Although most lameness is related to housing through the effect of the floor surface and some of the foot lesions are due to nutritional or metabolic factors (Lau *et al.*, 1997), both systemic as well as localized infections may cause animals to have problems to move in a natural way (Greenough, 2007; Konig, 2009; Refaai *et al.*, 2013). Digital dermatitis, interdigital dermatitis (IDD), Phlegmona interdigitalis (foot rot or interdigital necrobacillosis), and Erosion unguulae (heel horn erosion, (HHE) are considered as the main localized digital infections (Greenough, 2007). While systemic infections known to be able to cause lameness in cattle are contagious bovine pleuropneumonia (CBPP), Brucellosis, Tuberculosis, Clostridial diseases, Salmonellosis, Foot and Mouth Disease (FMD), Bovine Viral Diarrhea (BVD), Lumpy skin disease (LSD), Malignant catarrhal fever (MCF), Bovine ephemeral fever and Rabies (Refaai *et al.*, 2013). Whereas, sole ulcers and white line diseases are the non-infectious (often termed as claw horn lesions)

and ubiquitous chronic diseases with the highest associated economic losses among all foot lesions (Bicalho *et al.*, 2009).

Lameness prevalence varies widely between herds (0% to 79%) in different parts of the world (Barker *et al.*, 2010). For example, animal level lameness prevalence was 13.9% in intensive dairy farms of Bishoftu town, Ethiopia (Abunna *et al.*, 2017); while herd level prevalence was 7% in Denmark (Alban, 1995), 18% in Netherlands (Clarkson *et al.*, 1996), 36.8% in England and Wales (Barker *et al.*, 2010) and 28.5% in Canada (Ito *et al.*, 2010). This could be due to the information on individual cows (hock lesions, claw length, parity, days in milk, and milk production), management practices (floor and stall cleaning routine, bedding routine, and footbath practices), and facility design (stall dimensions, stall base and bedding type, width of feed alley, flooring type, and slipperiness) that were hypothesized to be risk factors for lameness (Solano *et al.*, 2015).

Traditionally, lameness is detected by assessing the locomotion score of a cow visually. Its prevalence can be quantified using locomotion scoring systems. Entire herds can be scored quite easily as they walk access lanes (Nordlund *et al.*, 2004). Although visual LS assessment is subjective and time-consuming (Thomsen, 2009), it is usually cheaper and user-friendly (Fabian, 2012) as compared to pedometers or the more advanced accelerometers as stand-alone technology to detect lameness (Alsaad *et al.*, 2012).

In Ethiopia investing in development interventions to the dairy sector will contribute to poverty alleviation by increasing the income of smallholder dairy producers and creating employment and transforming the existing largely subsistent type of milk production to commercial level (Yilma *et al.*, 2011). However, there were various constraints of dairy production like lameness (Abebaw *et al.*, 2016). Moreover, if lameness prevalence exceeds 15% of the herd, it is important to differentiate the cause (Nordlund *et al.*, 2004). Thus, prevalence of lameness was suggested to be becoming high in many dairy production systems irrespective of housing systems in the study area. But there were limited publications on the problem in the country. Therefore, this study was carried out in selected dairy farms of Sululta town, central Ethiopia with the following objectives.

1.1. General objective:

- To investigate the epidemiology of lameness in dairy farms of Sululta town.

1.2. Specific objectives:

- To estimate the prevalence of lameness
- To assess the risk factors associated with lameness
- To determine the impact of lameness on milk yield in selected dairy farms of Sululta town.

2. LITERATURE REVIEW

2.1. Etiology of lameness in dairy cattle

Lameness may be associated with feeding and nutrition, housing conditions, environmental factors, management practices, or a combination of any or all of these (Hristov *et al.*, 2011). Claw disorders associated with chronic subclinical laminitis are primary causes of lameness in most herds, followed by digital dermatitis and foot rot. A wide range of infectious agents can also be associated with lameness problems in cattle (Refaai *et al.*, 2013). Besides genetic or congenital malformations causes of lameness in dairy cattle can be divided in to two different categories: infectious and non-infectious (Konig, 2009).

Infectious diseases causing lameness in cattle are classified into localized digital and systemic infections. Digital dermatitis, interdigital dermatitis (IDD), Phlegmona interdigitalis (foot rot or interdigital necrobacillosis), and Erosion unguulae (heel horn erosion, (HHE)) are considered as the main localized digital infections (Greenough, 2007; Van Amstel and Shearer, 2008). Among these, the most significant causes of lameness are subclinical laminitis and digital dermatitis (Hristov *et al.*, 2011). In particular, digital dermatitis is currently considered a leading cause of severe epidemic lameness in dairy herds, giving rise to major economic losses (Greenough, 2007; Van Amstel and Shearer, 2008).

Systemic infections known to be able to cause lameness in cattle are contagious bovine pleuropneumonia (CBPP), Brucellosis, Tuberculosis, Clostridial diseases, Salmonellosis, Foot and Mouth Disease (FMD), Bovine Viral Diarrhea (BVD), Lumpy skin disease (LSD), Malignant catarrhal fever (MCF), Bovine ephemeral fever (Somers *et al.*, 2015) and Rabies (Refaai *et al.*, 2013).

The non-infectious causes of lameness in dairy cattle are often termed as the claw horn disruption lesions (Bicalho and Oikonomou, 2013): includes laminitis, sole ulcer/sole hemorrhages and white line diseases (Konig, 2009). Among these, sole ulcers and white line abscesses are ubiquitous chronic diseases with the highest associated economic losses among all foot lesions (Bicalho *et al.*, 2009).

2.1.1. Foot problems that result in an altered locomotion (lameness)

Most lameness originates from lesions of the feet. Only 15% of cases are caused by other disorders of the limb (Winckler and Willen, 2001). Bovine foot lesions can be divided grossly in to laminitis related-lesions, infectious lesions and lesions caused by physical and (or) chemical damages (Manske *et al.*, 2002). Moreover, Foot lesions are commonly categorized according to their etiology into infectious and non-infectious lesions (Potterton *et al.*, 2012).

Anatomically, the bovine hoof consists of a hard outer casing or hoof horn, the corium, which contains the blood vessels and horn forming cells, and the skeletal portion of the foot. The coffin bone is the large, terminal, weight-bearing bone around which the hoof is formed and to which the tendons are attached (Ishler *et al.*, 1999). Thus, figure 1 describes parts of bovine hoof and claw zones affected by each type of the most common foot lesions in 28,607 cows on 156 Alberta, Canada, dairy farms. Percentages indicate the percentage of each type of lesion occurring in a specific claw zone; percentages add to > 100% due to simultaneous occurrence in >1 claw zone (International Lameness Committee, 2008).

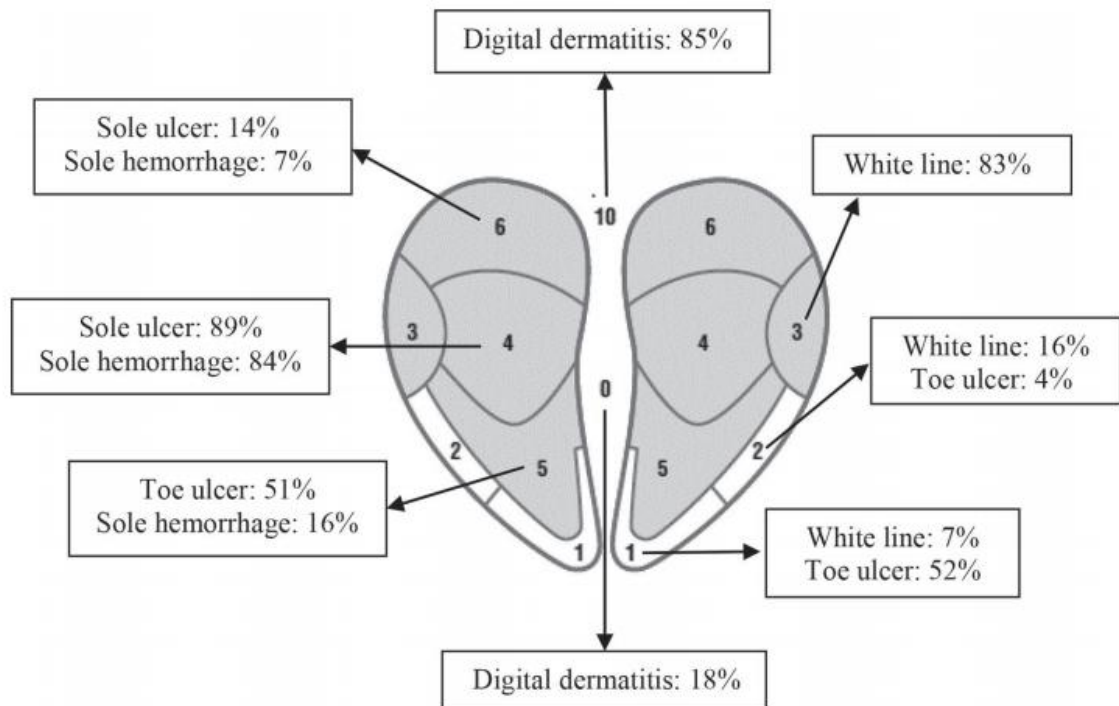


Figure 1: Claw zones affected by each type of the most common foot lesions (International Lameness Committee, 2008).

Laminitis

Laminitis is an aseptic inflammation of the sensitive lamina (corium) of the foot (Manson and Leaver, 1988; Refaai *et al.*, 2013). Since more than just the laminar portion of the corium is involved, coriosis is considered by some a more accurate term (Refaai *et al.*, 2013).

Lesions of the claw horn, which include sole hemorrhage, sole ulcer and white line disease, are very common causes of lameness in dairy cattle and have traditionally been referred to collectively as ‘laminitis’ (Greenough, 2007). White line diseases are areas of hemorrhage and necrosis of the corium which are often most noticeable and severe in the white line region of the sole caused by laminitis. Although these areas of hemorrhage are not visible during the acute stage of laminitis, they gradually rise to the surface of the sole over a period of weeks. At this point they become visible and useful as

indicators of disease of the corium (subclinical laminitis) as indicated in figure 2 while a sole ulcer is described as a circumscribed loss of the horny sole which exposes the corium (Shearer, 1997) (Figure 3). Sole ulcers are usually associated with clinical manifestations of laminitis. As a general rule of thumb, if 10 percent of a herd has documented sole ulcers, the herd should be suspected for laminitis. However, there are other factors that can predispose cows to sole ulcers such as moisture and manure, excessive wear, and poor hoof trimming (Ishler *et al.*, 1999).



Figure 2: Example of white line disease (International Lameness Committee, 2008).



Figure 3: Example of sole ulcer (International Lameness Committee, 2008).

The pathogenesis of laminitis is believed to be associated with a disturbance in the micro-circulation of blood in the corium which leads to breakdown of the dermal-epidermal between the hoof and pedal bone (Shearer, 2005). Thus, any increase in size of the corium due to fluid accumulation (blood and lymph) will increase pressure, pain, and tissue damage (Shearer, 1997). With restricted blood supply, the laminae and papillae begin to die. The dead tissue swell, increasing the pressure within the rigid hoof wall (Erin, 2000). However, laminae are a specific region within the claw; and true laminitis does occur (Logue *et al.*, 2004). Feedings leading to rumen (lactic) acidosis is also considered to be a major predisposing cause of laminitis and presumably mediates its destructive effects through various vasoactive substances released in coincidence with development of rumen acidosis (Shearer, 1997; Ishler *et al.*, 1999). This is due to the hypothesis of endotoxin being the trigger factor for laminitis. Thus such vasoactive substances initiate a cascade of events in the vasculature (blood vessels) of the corium including increased blood flow, thrombosis (Clotting), ischemia (restricted blood flow), hypoxia (lack of oxygen), and arterio-venous shunting (channels from arteries to veins that shunt blood away from the capillary bed) (Shearer, 1997). In addition, hormonal changes associated with parturition and the lactation cycle can impact certain physiological changes. Infectious diseases, such as mastitis, metritis, and foot rot can impose specific endotoxic insults (Ishler *et al.*, 1999). The end result is edema (swelling), hemorrhage (bleeding), and necrosis (death) of corium tissues (Boosman *et al.*, 1991).

Laminitis can occur in three phases: acute, subclinical and chronic type. Acute laminitis may occur due to feeding diets too high in concentrates so that a condition called acidosis can be resulted which leads the release of chemicals gradually destroy the vessels supplying the hoof tissue with blood. Subclinical laminitis is the most common form of laminitis found in modern dairy operations. This phase can result from physical injury to the hoof or from damage sustained during acute laminitis. During the chronic phase of laminitis, the mechanical damage occurring within the hoof becomes permanent. In severe cases, the tip of pedal bone described in figure 3 may actually come through the sole or entire pedal bone may sink down to the level of sole (Boosman *et al.*, 1991; Erin, 2000). Laminitis can result in long, overgrown and deformed feet or toes by which the

highest incidence of laminitis often occurs during the first 100 days postpartum (Ishler *et al.*, 1999).

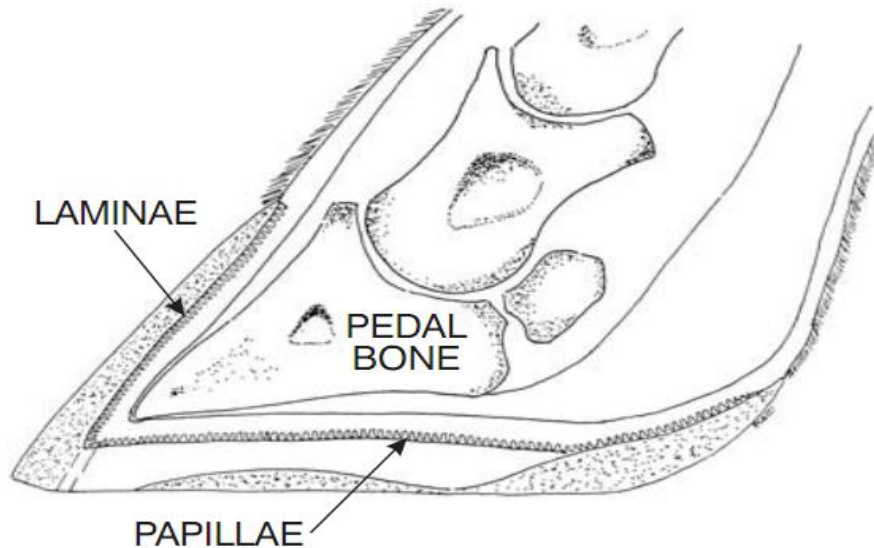


Figure 4: Anatomical description of bovine hoof associated in the occurrence of laminitis (Erin, 2000).

Digital Dermatitis

Foot problem termed as digital dermatitis (papillomatous digital dermatitis, hairy heel warts, foot warts) of cattle has been identified as a major cause of lameness in dairy cattle in many countries (Berry, 2001). It accounts for 62% of the lameness in bred heifers and 49% of the lameness in cows (Krull, 2015). Bovine DD was first morphologically described in 1974 at the 8th international meeting on diseases of cattle in Milan, Italy (Nielsen and Yu, 2010). Etiologically, Spirochetes from the genus *Treponema* have been identified the most consistently, comprise the bulk of the colonizing bacterial mat found on active lesions, and are the organisms found to invade the epidermis and dermis thus associated with DD (Berry, 2001; Krull, 2015). The first report of a spirochete like, filamentous organism within DD lesions was described by Blowey and Sharp in 1988 (Van Amstel and Shearer, 2008). However, in bovine, digital dermatitis can be caused by

bacterial or viral infections, parasitic infestations, or by various physical or chemical factors (Manske *et al.*, 2002).

The disease is reported primarily in housed dairy cattle, and reports of the disease in beef cattle or dairy cattle on pasture are rare. Lameness due to DD is most commonly seen in first- and second-lactation cows, usually after entry into the milking string (Berry, 2001). Morphologically, the majorities of the lesions were circumscribed, erosive to papillomatous and surrounded by a ridge of hyperkeratotic skin bearing hypertrophied hairs (Krull, 2015). Large herds, herds with predominately Holsteins, herds with corral housing in winter (muddy conditions prevail at this time) and herds not using footbaths were risk factors cited in California by recent surveys (Shearer, 1997).

Note that interdigital dermatitis (IDD) is a condition of acute or chronic inflammation of the interdigital skin that does not usually causes lameness should be considered as differential diagnosis of DD both at cow and herd level. It is characterized by diffuse hyperaemia and erosions of epidermis in the interdigital cleft (often with abundant grayish foul smelling exudates, but without ulcers) as described in figure 5. It also differs from interdigital phlegmon (foot rot), in which infection extends into the dermis, leading to fissure formation, infection of deeper structures, and cellulitis of the pastern and fetlock (Berry, 2001). Whereas digital dermatitis can cause changes in the growth of horn and thus result in the deterioration of heel-hornas described in figure 6 & 7 and generally dermatitis restricted to interdigital cleft is recorded as DD when it had a localized, ulcerative appearance (Manske *et al.*, 2002). As a result in cattle it has been identified as a major cause of lameness (Berry, 2001); And affected animals had circumscribed, erosive to papillomatous, intensely painful lesions often surrounded by a ridge of hyperkeratotic skin bearing hypertrophied hairs. Moreover, DD is characterized by lameness, walking on toes and clubbing of hooves (Read and Walker, 1994, 1998).

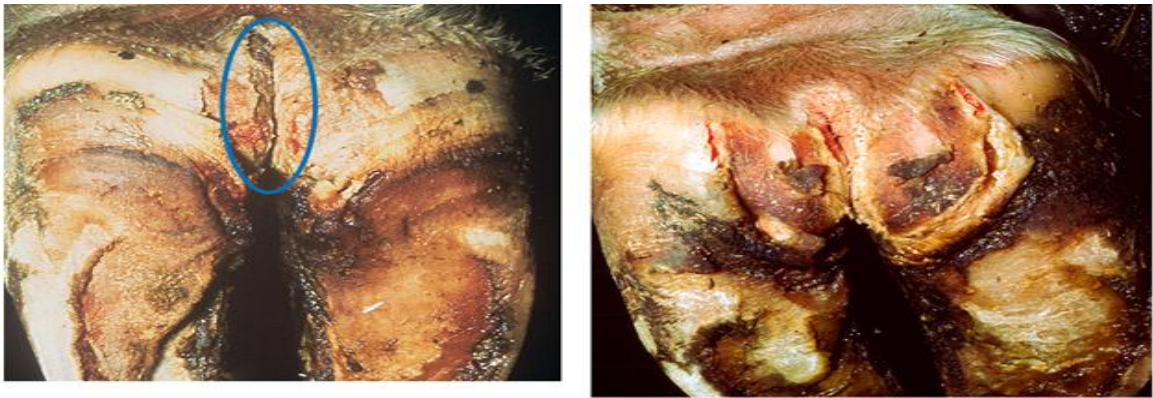


Figure 5: Example of IDD (International Lameness Committee, 2008).

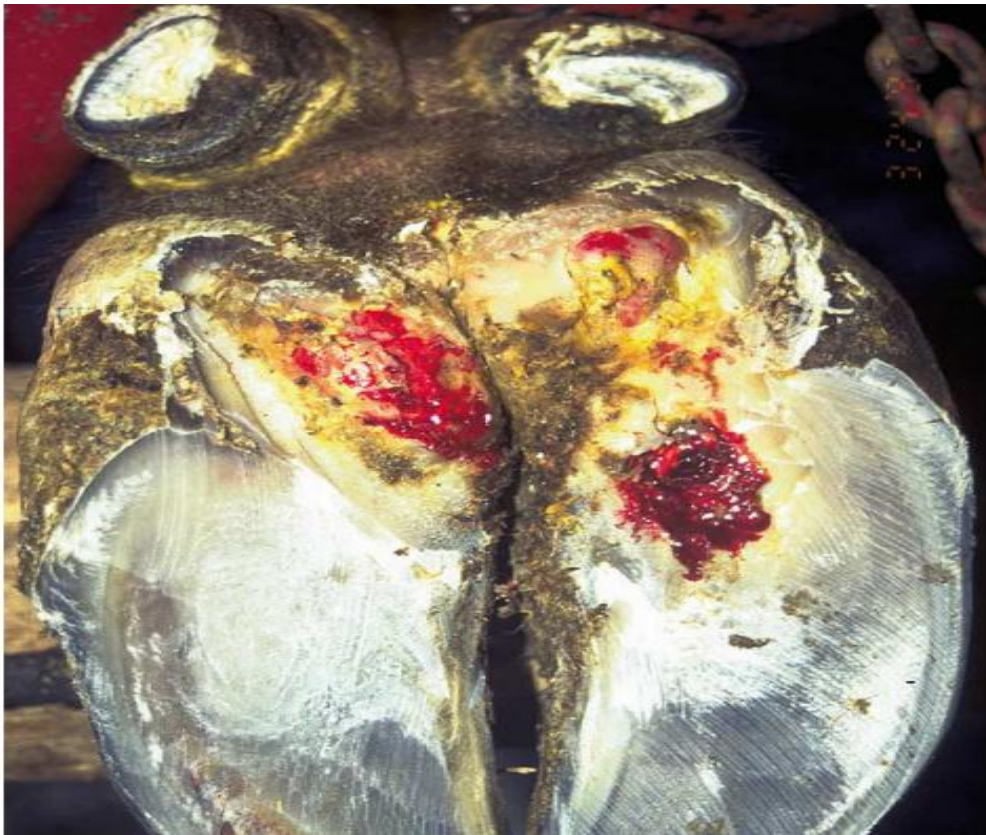


Figure 6: Dermatitis with sever heel–horn erosions and sole ulcer (Manske *et al.*, 2002).



Figure 7: Example of digital dermatitis (International Lameness Committee, 2008).

Foot rot

Foot rot is a contagious disease of cattle characterized by the development of a necrotic lesion (caseous necrosis) in the interdigital skin (Shearer, 1997; Berry, 2001). More recently, it has been termed as "Super Foul" or "Super Foot Rot"(Shearer, 1997). Other common names for the disease are "sore foot" and "foul foot" (Currin *et al.*, 2005). The bacterium most commonly isolated from this infection is *F. Necrophorum*, and most common secondary invaders are the pigmented anaerobes of the genus *Porphyromonas*, with *Porphyromonas levii* being most common. Other secondary invaders include members of the genera *Prevotella*, *Peptostreptococcus*, and other *Fusobacterium* (Berry, 2001). However, *Fusobacterium necrophorum* (*Sphaerophorus necrophorus*) and *Bacteroides melaninogenicus* were the predominant bacteria isolated from biopsy specimens of lesions in cattle affected with foot rot. The organism may buildup in barnyards, exercise lots, mud-holes, and pastures (Ishler *et al.*, 1999).

The organism inter in to the deeper tissue when mechanical injury or softening and thinning of the interdigital (between the toes) skin by puncture wounds or continuous exposure to wet conditions are there since normal healthy skin will not allow the bacteria involved in foot rot to enter the deeper tissues (Wohlgemuth, 1987). Another

environmental risk factor for lameness associated with foot rot is cows to walk through or stand in manure slurry for extended periods (Shearer, 1997).

Cattle with foot rot show lameness, usually on one leg only. The foot swells above the coronet and the toes spread. Cracks and fissures develop in the interdigital space (Ishler *et al.*, 1999). Extreme pain leading to sudden onset of lameness, acute swelling and redness of interdigital tissues and adjacent coronary band, often necrotic lesions in the interdigital space are along its edges and having a characteristic foul odor, symmetrical swelling in interdigital space extending around coronary band, fever and loss of appetite are the first signs of foot rot (Wohlgemuth, 1987) (Figure 8).



Figure 8: Foot rot lesions (Wohlgemuth, 1987).

Seasonally foot rot occurs with increased incidences during wet, humid conditions being the incidence is usually sporadic (Wohlgemuth, 1987; Currin *et al.*, 2005). When case incidence increases in hot and dry conditions, attention must be directed to loafing areas, which are often crowded and extremely wet from urine and feces deposited in small shaded areas (Wohlgemuth, 1987).

Laboratory diagnosis of foot rot cannot be the sole basis for diagnosis but can be supportive because *F. necrophorum* can be isolated on non-diseased feet, as well as in the rumen and feces of normal cattle (Wohlgemuth, 1987; BC&MS Policy, 2006).

2.1.2. Systemic infections that result in an altered locomotion (lameness)

Lameness in cattle originates from the digits. The second most common cause of lameness is from the joint; 47.0% to 72.2% of all lameness other from the foot is located to the joint and ligament (McLennan, 1988). The most common joints infected are front fetlock, hock, and elbow. Although few data are available on the importance of septic arthritis (SA) in cattle, arthritis was found to account for 13.8% of lameness cases in Israel. Bacterial arthritis is the most common form of septic arthritis in cattle. The umbilicus is a very common route of infection. Although rare in cattle, iatrogenic infection following intra-articular (IA) injection is also possible. *Trueperella pyogenes*, Streptococci, Enterobacteriaceae, Staphylococci, Pasteurellaceae, Pseudomonas, Enterobacteriaceae and Mycoplasma were bacterial pathogens that have been isolated from infected joints in cattle by culture (Desrochers and Francoz, 2014).

Systemic infections known to be able to cause lameness in cattle are contagious bovine pleuropneumonia (CBPP), Brucellosis, Tuberculosis, Clostridial diseases, Salmonellosis, Foot and Mouth Disease (FMD), Bovine Viral Diarrhea (BVD), Lumpy skin disease (LSD), Malignant catarrhal fever (MCF), Bovine ephemeral fever (BEF) and Rabies. Pathway by which systemic diseases may cause lameness in cattle is different. For example, erosions and ulcerations of the digital and interdigital skin have been demonstrated in infections with FMD, BVD, and MCF. Bursitis, polyarthritis and tenosynovitis have been described in animals suffering from Brucellosis and CBPP, while osteomyelitis often with articular involvement has been described in Brucellosis and Tuberculosis (Refaai *et al.*, 2013). Among these bone and joint involvement are the most frequently complication of brucellosis occurring in up to 40% of cases (Lyimo, 2013). For example, experimentally, intra-articular injection of *B. abortus* strain 19 produced chronic synovitis in young cattle (Johnson *et al.*, 1994). Although attempts to culture

Brucella or other pathogens gave negative results, organisms of *Brucella* morphology were seen in fluorescent antibody-stained cryostat sections of synovial tissue. The synovial fluids contained high titres of antibodies to *B. abortus* (Bracewell and Corbel, 1980).

2.2. Risk factors associated with the prevalence of lameness in dairy cattle

Typically lameness is consequence of disturbed morphological and functional integrity of musculoskeletal system of locomotor apparatus. Locomotor apparatus diseases in dairy cattle have complex multi causal etiology, referring to certain classical and many other specific factors in intensive production (Hristov *et al.*, 2011). Season, gestation and stage of lactation, previous disease and parity were some of intrinsic and unavoidable risks for lameness (Mulling *et al.*, 2006; Hristov *et al.*, 2011); also with some genetic determined intrinsic risk for development of lesions (Koenig *et al.*, 2005) while cow comfort (maximizing lying times, comfortable lying surface, good walking and standing surfaces), cow hygiene (dry environment, slurry free environment, good herd biosecurity), social and physical integration for heifers and dry cows, cow flow on the farm (good routes around buildings, parlour, to pasture, to feed), diet (macronutrients, micronutrients), correct routine professional functional preventive hoof trimming are extrinsic risks for lameness (Mulling *et al.*, 2006).

The predisposing causes of lameness are considered to be genetic, nutritional and environmental (Manson and Leaver, 1988). Nutritionally, subclinical form of ruminal acidosis should be regarded as a herd rather than an individual problem because subclinical acidosis could be associated with laminitis (Enemark *et al.*, 2004). Normal pH differ according to type of food as ranges between 6 - 7 in animals on a mostly forage diet but is lower at 5.5 - 6.5 in animals fed mostly grain. The pH of rumen fluid should preferably be 6.0 or greater (Srinivasan and Gnanaprakasam, 1990). On the other hand, Shearer (1997) reviewed that the biomechanics of weight -bearing in cattle describes more than just nutrition and feeding management errors are responsible for lameness

disorders. Thus, housing and environmental considerations such as standing or lying time, free-stall design and comfort, herdsman ship (like pushing their cows to the parlor and back, rushing cattle over rough flooring surfaces) and concrete (where new concrete is more abrasive than old, and wet concrete is up to 83 % more abrasive than dry concrete) were considered as important risk factors significantly associated with increased incidences of lameness. In addition, abrupt introduction to confinement systems from pastures or bedded packs is environmental risk factor for laminitis (Scott, 1989; Nordlund *et al.*, 2004). The reason is that these physical effects are further complicated by the fact that the unyielding nature of hard-flooring surfaces tends to irritate the corium and accelerate hoof growth. Excessive hoof growth (particularly of the outside claw of rear feet) leads to overgrowth and eventually overloading of the affected claws. The end result is a greater likelihood of developing claw disease (Shearer, 1997). Management decisions such as claw trimming routine or overcrowding are also considered having an impact on claw health (Sulayeman and Fromsa, 2012).

Foot infections, abscesses or sole ulcers may stem from cracks that result when feet are too soft or hard. Excessively soft feet are more apt to occur in free stall systems from standing in manure and urine. This may result in heel and sole cracks allowing ulcers, abscesses, or infections to occur. While tie-stall barns, especially when kiln-dried shavings or sawdust are used for bedding may result in cracks at the top of the foot, which may extend down from the hairline and allow infections relatively high in the foot (Ishler *et al.*, 1999). In addition, Cook and Nordlund (2009) introduced that housing, management and calving were identified as risk factors that are associated with an increased prevalence of laminitis-associated lesions by experimental studies and epidemiological surveys.

In general, increased lameness prevalence is associated with solid concrete flooring, decreased lying times due to the discomfort, slippery walking alleys, uncomfortable and dirty barns, increased degree of dirtiness in cows' legs, free-stall sheltering and the lack of biotin supplementation in lactating cows (Cook and Nordlund, 2009; Konig, 2009). Cleanliness of cows is a good general indicator of hygiene status and thus hygiene is

considered as the second area of extrinsic risk for lameness. Dry feet have greater integrity than wet, the hoof horn and the barrier of the skin between and above the claws is intact reducing the chances of bacteria invading the tissue (Mulling *et al.*, 2006).

2.3. Diagnosis of lameness

2.3.1. Locomotion scoring systems

Traditionally, lameness has been evaluated using one of a large number of lameness scoring systems (Thomsen, 2009). But some new scales are also used to assess gait in dairy cattle and are modified versions of those already existing since adaptation proved necessary to suit on-farm conditions (Konig, 2009). These scales can be divided between numerical rating scale (Tranter and Morris, 1991) and a visual analogue scale (Welsh *et al.*, 1993). Numerical rating scale consists of a limited amount of categories and is considered to be ordinal level data (Meilgaard *et al.*, 1999). This type of data is of qualitative origin and have, compared to other types of qualitative variables, an actual order (Houe *et al.*, 2004). Each category may have a detailed description and include as many parameters as the observer is able to evaluate (Sprecher *et al.*, 1997); and while visual analogue scale is a linear scale where the observer marks the observation directly on a line of typically 100 mm. Usually the endpoints represent the absence (zero to the left) and maximum presence (placed to the right) of a given clinical sign with a description (Welsh *et al.*, 1993).

Currently, the most widely cited locomotion scoring system is the five-point method of Sprecher *et al.* (1997). Mobility scoring is therefore more sensitive than only recording clinically lame cows and most commonly used technique for lameness detection (Manson and Leaver, 1988; Van Amstel and Shearer, 2008). For this scoring system lameness could be diagnosed by observing the animal's stance. Attention should first be paid to the posture of the animal, including the back, shoulders, pelvis, and major limb joints. With the animal standing, the general stance is observed first; and then attention is drawn toward the limbs from the digit to the proximal limb (Desrochers and Francoz, 2014).

Clinical inspection of lameness can be performed by physical examination with emphasis on the extremities followed by a characterization of the gait. This is best observed on a straight and clean concrete path where the cow can move freely. After observing the gait a claw examination including the inter-digital space should be performed (Konig, 2009).

Signs of lameness in dairy cattle include a nodding movement of the head in a vertical plane as the lame foot makes contact with the ground; arching of the spine associated with pain (cows in extreme discomfort may salivate from grinding of the teeth); shortening of the stride length and sinking of the dew claws of the unaffected contralateral hind limb as it bears weight; and a reduction in walking speed, with frequent stops to rest the affected limb (Nordlund *et al.*, 2004).

Arching of the back could be not recorded when a cow was standing in the cubicle, eating at the feed bunk, urinating or defecating (Thomsen, 2009). When implementing locomotion score routine, it is crucial that the score is reliable and repeatable (Winckler and Willen, 2001). Since mobility scoring is based solely on perception and interpretation by each observer, subjectivity may be the problem encountered with (Konig, 2009). Thus, morning lameness scores and afternoon backing arching will be recorded on two separate sheets of paper in order to blind the observer to the lameness score given previously (Thomsen, 2009).

2.4. Treatment and prevention of lameness in dairy cattle

Minimizing hoof traumas by standing times, providing cows with good, non-slip, but trauma-free, surfaces, keeping optimal foot hygiene (by ensuring cubicle and feed passages are of adequate width (e.g., 3 m and 4.5 m, respectively, regular scraping of passages, supplying ample bedding), avoiding dietary upsets that disrupt the corium and lead to excess slurry (by ensuring correct concentrate to fiber ratio, adequate long fiber in the ration) and ensuring prompt treatment of lame cows to produce rapid healing with reduced recurrence rates (Lifting and examining foot when lame, performing radical

removal of under run horn to allow drainage of infection, applying hoof blocks (e.g., Cowslips, Gilt spur) to promote healing, covering raw digital dermatitis lesions to prevent spread of infection to other cows) are priorities for lameness investigation and prevention (Ishler *et al.*, 1999; Blowey, 2005).

Another preventive measure like appropriate ration formulation is also recommended to minimize the risk of laminitis. As a guidelines to prevent nutritionally induced acidosis/laminitis: depending on the grain source, the non-structural carbohydrates should not exceed 40 to 45 percent of the ration. Grains also must be properly processed to reduce ruminal upsets and maximize starch digestion. Feeding low NDF percentage levels (below 27 percent of the ration dry matter) can predispose cows to lameness, metabolic disorders, and overall poor performance. At the very least, ADF should be fed at 21 percent of the dry matter. It was suggested that feeding mature hay may be beneficial during times of high risk because immature forages often do not provide enough fiber (Van Amstel and Shearer, 2008). Some researchers reported that 20 mg/cow/day supplemental dietary biotin reduced the laminitis-related hoof lesions, white-line separation and improved sole ulcer healing (Hedges *et al.*, 2001; Lischer *et al.*, 2002).

On top of this, routine foot trimming at drying off period has an important influence on the development of lameness than at parturition which predisposes to coriosis (Blowey, 2011). However, it is important to know what constitutes normal claw size and conformation and improper trimming may result in sole damage (Shearer, 2005).

Surgical excision, footbaths and/or topical treatment with various disinfectants and caustic chemicals, cryosurgery (freezing), and electrocautery (burning) are important therapeutic approaches for digital dermatitis (Shearer, 1997; Manske *et al.*, 2002). The uses of 5% to 100/0 zinc sulfate or copper sulfate foot bath are preventive measures for DD (Berry, 2001). In addition, tetracycline or oxytetracycline at rates of 1-10 grams/liter of water have been advised and are reported to be effective if managed properly. While others prefer to medicate their footbaths with a lincomycin/spectinomycin (LS-50)

combination product or lincomycin alone, at the rate of 0.1-0.5 g/liter of water (Shearer, 1997).

Since the causative organisms (especially for foot rot) are believed to originate from the gastrointestinal tract of the cow it would be reasonable to expect that manure management would be helpful to reducing the occurrence of the disease (Shearer, 1997).

2.5. Economic losses associated with lameness

A large proportion of the losses associated with lameness are due to progressive inefficiency of production without complete cessation. It is not uncommon for a severely lame cow to produce 30 liters of milk per day (O'Callaghan, 2002). When milk production losses associated with treatment, decreased reproductive performance, and treatment were incorporated, the losses were estimated at \$126 to \$133 for every clinical case of DD (Read and Walker, 1994). Whereas, a typical case of a sole ulcer occurring in early to mid-lactation has been estimated to cost an average of £72 in direct costs and up to £246 overall, including the cost of reduced fertility and production (O'Callaghan, 2002). Ettema and Ostergaard (2006) made an economic decision that the loss per first case of lameness was found to be €192 in the default herd that represented the modern, average Danish dairy herds. An increase of the margin per cow-year of €22.7 was the result of halving the risk of lameness in the default herd. Implementation of foot baths and rubber flooring increased margin per cow-year by €4.2 and €17, respectively. In Ethiopia, economic modeling of the problem was not studied. However, Sulayeman and Fromsa (2012) found that a mean loss in milk yield was 1.63 liter per cow per day in Hawassa dairy cattle.

2.6. Prevalence and incidences of lameness in Ethiopia

In Ethiopia there are limited studies on the prevalence of lameness and associated risk factors, which are mainly concentrated on intensive and extensive dairy farms mostly in and around the capital. For example, an exploratory survey was undertaken to describe and quantify the magnitude of lameness in 964 dairy cattle between October and December 1999 under urban (Addis Ababa), peri-urban (Sebeta and Kaliti), and urban farms in a secondary town (Bishoftu). Out of this, 73 animals (7.696%) clinically exhibited clear signs of lameness in at least one of their limbs (Lobago *et al.*, 2001). Another observational and repeated cross-sectional study carried out by Sulayeman and Fromsa (2012) on 432 dairy cattle that belonged to 23 randomly selected farms from Hawassa town showed the overall lameness prevalence of 3.5%. More recently, study by Abunna *et al.* (2017) indicated that the average incidence rate of lameness at cow level was found to be 2.8 cases (16.47 standard deviation) per 100 cow-years at risk (0.028 per cow-year at risk), while the overall animal level prevalence of lameness was 13.9% in intensive dairy farms in Bishoftu town, central Oromia, Ethiopia. Abunna *et al.* (2017) also reported that one or more cases of lameness were detected in 16 (94%) farms out of 17 farms studied. So information's on the status of lameness in intensive and extensive dairy farms of Ethiopia are limited.

3. MATERIALS AND METHODS

3.1. Description of study area

The study was conducted at Sululta town, especial zone of Oromia region, central Ethiopia. Sululta is situated between 09°17'84" North and 38°75'79" East latitude and longitude, respectively. It is located at a distance 23 km northwest of the capital Addis Ababa. It lies at an altitude of 2505 meters above sea level. The town takes the lion's share in terms of its milk production potential and contribution to Addis Ababa milk market. The main agricultural practice of the Sululta is mixed, crop-livestock production system. The annual average maximum and minimum temperature is 25⁰C and 10⁰C, respectively. Its annual average maximum and minimum rainfall is 1500 and 800 mm, respectively. Animal products, especially dairy products, play a headstone role in household food security both by direct consumption and purchasing of other food items in the area (CSA, 2009). According to the information obtained from the agricultural Office of Sululta town, the town has 30 medium scale (10-50 dairy cattle) and 20 Small scale (< 10 dairy cattle) dairy farms with a total of 816 dairy cattle. The town and its neighboring peasant association are also known by hay production and selling to other parts of the country. There is only one milk processing agro-industry in the town. However, Selale dairy cooperative unions were among the major dairy cooperative unions in Ethiopia play a significant role in ensuring sustainable supply of raw milk to the dairy industry in the area (Yilma *et al.*, 2011) (Figure 9).

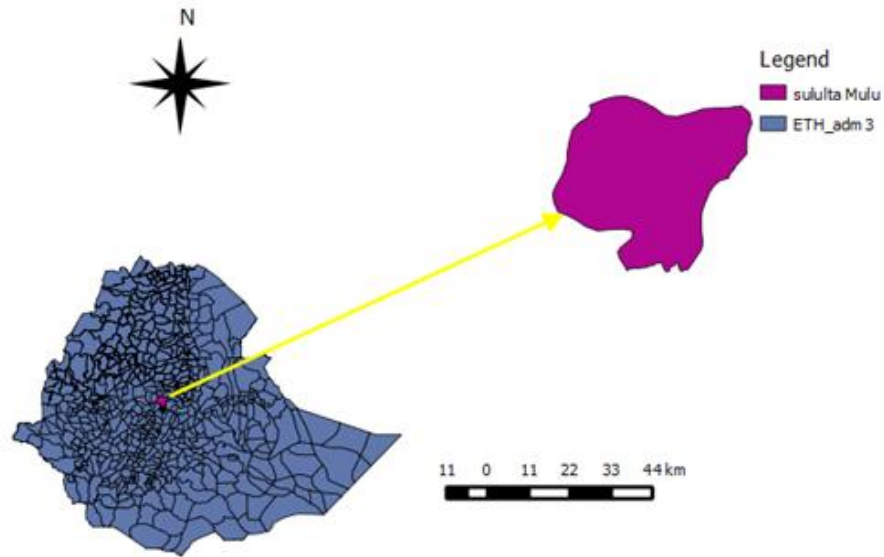


Figure 9: Map of the study area (Sululta).

3.2. Definitions

In Ethiopia dairy cattle production systems are classified into rural smallholder (mixed crop-livestock) production, pastoral and agro-pastoral production, urban and peri-urban smallholder dairy production, and commercial dairy production systems (Asmare *et al.*, 2013). The urban systems involve the production, processing and marketing of milk and milk products that are channeled to consumers in urban centers while peri-urban livestock keeping fits different livelihood strategies and contributes to food security, income and employment generation, saving and insurance (Tegegne *et al.*, 2000). These smallholder dairy farms predominantly keep a small number (≤ 10 animals) of cross-bred cows in a zero grazing system to produce milk for both home use and sale. Commercial dairy farms are also farms located in urban and peri-urban areas mainly in and around the major cities and produce milk exclusively for sale (Geresu *et al.*, 2016). Thus, this study has focused

on both urban and peri-urban smallholder dairy production and commercial dairy production systems. Individual animals were categorized as young (≤ 36 months) and adult (> 36 months) (Asfaw, 2014).

Age structure of the respondents were categorized as early working age (age range of 15-24 years), prime working age (age range of 25-54 years), mature working age (age range of 55-64 years) and elderly (age range of 65 years and over) based on the information obtained from World Fact book (2018).

3.3. Study design

A repeated cross-sectional study was carried out in proportionally and randomly selected dairy farms from the lists of dairy farms of Sululta town to estimate the herd and animal level prevalence of lameness by cluster and proportionally stratified sampling technique. The target populations were cattle in urban and peri-urban dairy farms (both smallholder and commercial) of Sululta town that are composed of Holstein-Friesians and crosses. Each animal was identified by farm origin, age, sex, breed, parity, days in milk, and milk production and herd size using history from the dairy personnels. A locomotion scoring system described by Sprecher *et al.* (1997) was conducted by regular visits at which locomotion was scored on a scale of 1 to 5. Lameness was assessed based on the locomotion score, devised by Sprecher *et al.* (1997), considering as lame dairy cattle those ones obtaining scores ≥ 3 . All the dairy cattle in selected farms were repeatedly observed for the presence of abnormal gait. Questionnaire survey was conducted prior to locomotion score. Data was collected using structured questionnaire format for questionnaire survey and using separate data recording sheets for locomotion scoring systems. In addition, individual cow's foot and leg problems (lesions) were recorded for descriptive statistics of foot and leg problems. Information on management practices (bedding routine, hoof trimming and footbath practices, confinement (indoor keeping only) and barn type (bedding type, flooring type, and slipperiness) was collected as hypothesized risk factors.

3.3.1. Sampling strategy and sample size determination

Cluster sampling technique was employed as it was easier to get a list of farms (clusters) than it would be to get a list of individuals (dairy cattle) and less expensive to sample a smaller number of farms (clusters). Furthermore, in veterinary epidemiologic research clustered samples arise frequently in practice (*e.g.* cows clustered within herds) with units within the cluster (*e.g.* cows) being more similar to each other with respect to the outcome than observations drawn randomly from the population. More likely, if the factor of interest is something that occurs at the herd level (*e.g.* barn type: free stall vs. tie stall), then the number of herds in the study becomes a more critical concern than the number of cows (even though the outcome is measured at the cow level (Dohoo *et al.*, 2003). In addition, any herd in which the lameness incidence exceeds 15% can be termed a problem herd. Such herds should not be treated in a sporadic, empirical fashion by the veterinary surgeon or farmer but probably have one or more common etiological factors contributing to most cases of lameness (Weaver, 1985). Thus one stage cluster sampling technique was applied to select the number of dairy farms. The dairy herds in the town was also stratified in to small scale, medium scale and large scale dairy farms based on the herd size as farms which keep < 10 animals, 10 - 50 animals and > 50 animals, respectively as described by Geresu *et al.* (2016) because herd size was assumed to have effect on the outcome (prevalence of lameness) (Van Amstel and Shearer, 2008); and an advantage of ensuring that all strata are represented in the sample (Dohoo *et al.*, 2003). Thus stratification fixes the level of the confounders and produce groups within which the confounder does not vary. Then evaluate the exposure-outcome association within each stratum of the confounder (Pourhoseingholi *et al.*, 2012). Accordingly, there were no large, 30 medium (60%) and 20 small scale (40%) dairy farms in Sululta town according to the information obtained from the agricultural office of the town. The required number of farms sampled in order to estimate the herd and animal level prevalence of lameness, an expected herd level prevalence (P_{exp}) of 94% found by Abunna *et al.* (2017), desired absolute precision (d) of 5% and a confidence level of 95% was calculated using the formula described by (Thrusfield, 2005).

$$g = \frac{1.96^2 \{nV_c + P_{exp}(1 - P_{exp})\}}{nd^2}$$

Where,

g = number of clusters (farms) to be sampled;

n = predicted average number of animals per cluster;

P_{exp} = expected prevalence;

d = desired absolute precision;

V_c = between-cluster variance

However, when information derived from previous cluster samples was not available, the between-cluster variance component can be obtained by assuming the standard deviation (i.e., the average difference expected between an individual cluster prevalence and the overall mean cluster prevalence), and then squaring it to give the between-cluster variance component (Thrusfield, 2005). Since the between cluster variance as well as individual cluster (herd level) prevalence was not available, the variance of different studies conducted by Lobago *et al.* (2001), Sulayeman and Fromsa (2012) and Abunna *et al.* (2017) in Ethiopia was taken as it was suggested and used by some authors (Bekele *et al.*, 2016). As a result the between- cluster variance component was suggested to be 0.0018 and predicted average number of animals per cluster (farms) was 16. Using the above formula the total number of dairy farms to be sampled was 8 farms. However, it was increased to 15 farms in order to consider confounding and interaction (Dohoo *et al.*, 2003); and to increase precision (Thrusfield, 2005); and thus a total number of 15 dairy farms with total herd size of 245 dairy cattle (average = 16; STDV = 11.81) were proportionally and randomly selected from all the dairy farms that were stratified into small scale and medium scale since there were no large scale dairy farms based on the stratification criteria (Kothari, 1990 ; Dohoo *et al.*, 2003). Therefore, 9 medium scale dairy farms and 6 small scale dairy farms were sampled. But all the dairy cattle in proportionally selected dairy farms were sampled (Dohoo *et al.*, 2003; Thrusfield, 2005). As result a total number of 245 dairy cattle were observed in all the selected dairy farms.

3.3.2. A five point locomotion scoring system

A five point locomotion scoring system described by Sprecher *et al.* (1997) was carried out once in a day by repeated observation of animals for abnormal gait. If an animal had normal gait and level back posture while walking, it was considered as having locomotion score 1 which is normal. Similarly, when an animal has normal gait and level back posture while standing, but back arched while walking was considered as having locomotion score 2 which is mildly lame. But animals with gait affected, short striding, back arched while standing and walking were determined as having locomotion score 3 (moderately lame) while animals with back always arched, only one deliberate step at a time and one or more limbs favored were considered as having locomotion score 4 (Lame). Moreover, animals additionally with extreme reluctance to bear weight one or more limbs were determined as having locomotion score 5 (severely lame). Thus locomotion score ≥ 3 was used for prevalence calculation.

For the locomotion assessment of the dairy cattle kept in tie stalls, these were loosened and were taken out of the barns. Similarly in some of the farms where the dairy cattle were being let to exercise and/cleaning purpose were assessed after the morning milking.

3.3.3. Assessment of foot lesions

Since locomotion scoring indicated that the herd has a lameness problem, the second step of an investigation was determining the predominant foot lesions (Nordlund *et al.*, 2004). Thus for any of locomotion scoring ≥ 2 , each type of foot and leg problems (lesions) were recorded on separate data recording sheets together with hypothesized risk factors for descriptive statistics of foot lesions. In addition, some observations regarding to the environmental and management risk factor like sanitation and housing design (slipperiness, cracks, concrete type or not) were recorded for the analytical statistics.

3.3.4. Questionnaire survey

Structured questionnaire was prepared and pre-tested before implementation. The design of the survey was pre-tested on two dairy farms in Sululta town. Training was given to facilitator on how to forward the questionnaire to capture appropriate data; and accelerate communication to be easily. The questionnaire used for the pre-test was excluded from the final data entry and analysis. Interview was carried out from November 2017 to April 2018, and done by the researcher together with the trained facilitator. The questionnaire was interviewed by local languages (Afan Oromo and Amharic). The facilitator was expert from the agricultural offices of the town who listen, read, write and speaks both Amharic and Afan Oromo languages. The facilitator was also used as a local guide to lead to the selected farms. The questionnaire contained hypothesized risk factors for lameness (e.g. do you have foot bath practices (Yes or No). The questionnaire was also structured in a way that enabled to capture general information from the owners and/or attendants.

3.3. Data management and statistical analysis

Data was entered and stored in separate data base in Microsoft Excel spreadsheet MS office (2010) program. Due attention on proper coding of the data was given. Data stored in MS- excel was imported to STATA version 12 IC statistical software (Statacorp, Texas, USA). Descriptive statistics on prevalence of lameness between the farms as well as association of putative risk factors with the animal and herd level prevalence of lameness was compared by Fisher's exact test for the significant variation. Since random effect of clustering of farms was suspected and mixed model was used. However, the intra-cluster correlation was extremely low and less than one ($2.94e-07$) and thus clustering effect was ignored and univariate logistic regression was used for the causal association of hypothesized risk factors after considering for interaction and possible confounding of some predictor variables. In addition, descriptive statistics of foot lesions, owner's attitude and awareness was done based on observational and questionnaire

survey data. Average daily milk yield data of 127 dairy cows was analyzed by simple linear regression for the prediction of average daily milk yield decline with the cases of lameness. A significance level ($p < 0.05$) and confidence level of 95% was considered as statistically significant. Appropriateness or fitness of the models was diagnosed before the interpretation of the output.

3.4. Ethical considerations

Ethical clearance protocol was approved and issued according to the rules set by the senate of Addis Ababa University College of Veterinary Medicine and Agriculture. The protocol was certified by Ref. No: VM/ERC/09/05/102018. This study therefore gave due attention to animal welfare issues while observing each animal.

4. RESULTS

4.1. Locomotion scoring system

Out of 245 observed dairy cattle of all age and sex, 214 (87.34%) presented with normal locomotion (LS = 1), 9 (3.67%) were slightly lame (LS = 2), 13(5.30%) showed moderate lameness (LS=3), 7 (2.87%) were lame (LS = 4) and 2 (0.81%) presented with severe lameness (LS = 5), respectively. Thus locomotion scoring system's result showed that 31 animals were observed as having $LS \geq 2$ (Figure 10); and twenty two (22) of them were recorded as animals with $LS \geq 3$ in eight of the dairy farms visited. Locomotion Score ≥ 3 was more recorded in medium scale farms (17 cases) as compared to small scale farms (5 cases) (Table 1).

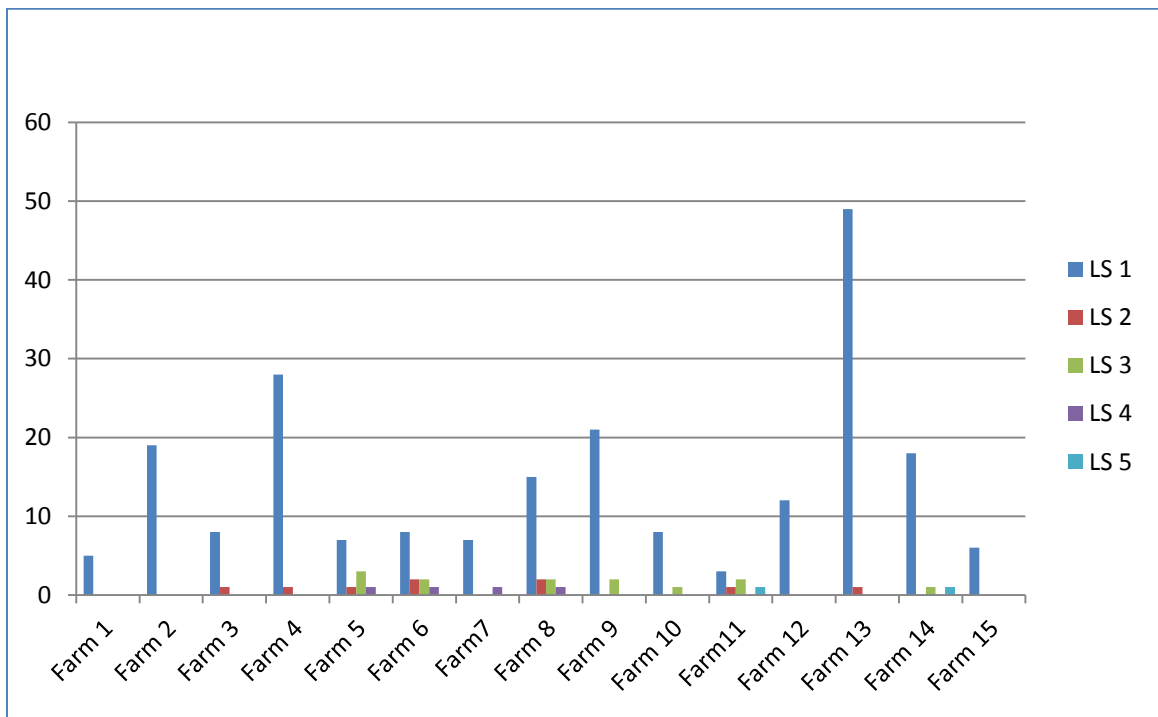


Figure 10: Frequency of all locomotion scores in dairy farms under investigations

Although, 15.92% (39) of the total dairy cattle sampled were males especially calves, clinical lameness was scored in female animals only. Among them $LS \geq 3$ was observed

in only one (0.41% of the total sample) animal at an age range of ≤ 36 months (young) and in 21 (8.57%) of the total sample) animals at an age range of greater than 36 months (adults).

Table 1: Proportions of locomotion score ≥ 3 in dairy farms of the study area

S. No	Farm name(code)	Herd size	Farm scale	Frequency	Prevalence (%)
1	Farm1	5	Small	0	0
2	Farm2	19	Medium	0	0
3	Farm3	9	Small	0	0
4	Farm4	29	Medium	0	0
5	Farm5	12	Medium	4	33.33
6	Farm6	13	Medium	3	23.07
7	Farm7	8	Small	1	12.50
8	Farm8	23	Medium	6	26.09
9	Farm9	23	Medium	2	8.70
10	Farm10	9	Small	1	11.11
11	Farm11	7	Small	3	42.86
12	Farm12	12	Medium	0	0
13	Farm13	50	Medium	0	0
14	Farm14	20	Medium	2	10.00
15	Farm15	6	Small	0	0
Total	15	245		22	8.98

4.2. Prevalence of lameness and associated risk factors

4.2.1. Prevalence of lameness

The prevalence of lameness was measured by regular visits at which locomotion was scored on a scale of 1 to 5, and the prevalence of lameness was calculated for each visit as the proportion of cows with scores of 3 or more. The overall animal level prevalence of lameness was found to be 8.98% (95% CI, 5.39 - 12.56). In eight farms one or more cases of lameness was observed making herd level prevalence of lameness to be 53.33% (95% CI, 28.08 - 78.58). The lameness prevalence varied extensively among the farms, ranging from 0% to 42.86%, with a mean within-herd level prevalence of 20.96% in farms where one or more cases were observed ($p = 0.000$). Animal level prevalence of lameness was higher in small scale farms (11.36% (5/44)) than medium scale farms (8.46% (17/201)). However, higher herd level prevalence (55.55%) of lameness was scored in medium scale farms as compared to small scale farms (50

4.2.2. Association of hypothesized risk factors with the prevalence of lameness

Putative risk factors (variables) associated with the prevalence of lameness is presented in table 2 based on Fisher's exact test. In this study putative risk factors for the prevalence of lameness both at herd and animal level were floor type, herd size, bedding practices, animal confinement for 24 hours in tie stall, hoof trimming practices and parity of animals. Although sex and age of study animals and foot bathing practices were supposed to be putative risk factors associated with the prevalence of lameness, no statistical analysis were carried out using this variables; and the differences in the prevalence due to this factors were not compared. A total of 108 (male and female calves, bulls and heifers) were removed from the data as there were no chances of having parity. Of the remaining 137 dairy cows (with parity of one and above): 32 primiparous and 105 multiparous were found to have parity history, respectively. Except herd size and bedding practices, all the remaining hypothesized variables have statistically significant association with the prevalence of lameness based on Fisher's exact test (Table 2). Even

if associations were described by this test, both univariable and multivariable logistic regression analyses were carried out for the biological plausibility and establishment of causal association with the prevalence of lameness.

Table 2: Associations of lameness with animal and herd level risk factors

S.No	Variables	N	Prevalence (%)	p-value*	95% CI
1.	Floor type				
	Wet & crackly	69	26.09	0.001	15.73–36.45
	Clean & dry	68	4.41		0- 9.3
2.	Hoof trimmings				
	Yes(0)	71	4.23	0.000	0 - 8.90
	No(1)	66	27.27		16.53 - 38.02
3.	Confinement				
	Yes(1)	82	24.39	0.000	15.09-33.67
	No (0)	55	1.81		0 –5..34
4.	Parity				
	Primiparous(0)	32	3.13	0.027	0 - 9.15
	Multiparous(1)	105	19.05		11.54-26.56
5.	Herd size				
	Small(0)	24	20.83	0.531	4.6- 37.07
	Medium(1)	113	14.16		7.73-20.59
6.	Bedding				
	Yes(0)	9	11.11	0.585	0 –26.07
	NO(1)	128	15.63		9.3- 21.9
Total	6	137	15.33		9.3 -21.4

CI= Confidence interval, N = number of animals sampled, and p -value*= p-value based on Fisher’s exact test, (1) = is coding for the presence of risk factor and (0) = is coding for the absence of risk factor.

Univariable logistic regression analysis result showed that herd size, bedding practices and parity had no statistically significant association in the prediction of lameness ($p >$

0.05) (Table 3). However, floor type (categorized as wet & crackly and clean & dry), hoof trimming practices (yes or no) and animal confinement (indoor keeping only or not) were found to be statistically significant in the prediction of lameness ($p < 0.05$). Based on this analysis result, the odds of lameness in animal kept under wet & crackly floors was higher as compared to animals from clean & dry ones (OR = 7.64; $p = 0.002$). Similarly, the odds of lameness in dairy cows in farms where cattle are confined for 24 hours was higher than in dairy cows in those who let out their cattle for exercise in a day (OR = 17.4; $p = 0.006$). The odds of lameness was also higher in multiparous animals as compared to primiparous dairy cows (OR = 7.3; $p = 0.057$). Moreover, the odds of lameness was also higher in animals of the farms with no hoof trimming practices as compared to animals in the farms with hoof trimming practices (OR = 8.5; $p = 0.001$).

Table 3: Risk factors of lameness shown by univariable logistic regression model

Risk factors	OR	p -value	95% CI
Floor type			
Clean and dry**			
Wet & crackly	7.64	0.002	2.13 - 27.41
Hoof trimming practice			
Yes**			
No	8.49	0.001	2.37 - 30.46
Confinement			
Yes	17.4	0.006	2.26 - 134.13
NO **			
Parity			
Primiparous**			
Multiparous	7.3	0.057	0.94 - 56.66
Herd size			
Small**			
Medium	0.63	0.413	0.20 - 1.92
Bedding			
Yes**			
No	1.48	0.718	0.17 - 12.50

** is reference variable, Yes = for the presence of management practices and No = is for the absence of management practices

Variables with p- values of ≤ 0.25 in univariable logistic regression analysis result were included to multivariable logistic regression model fitted. Thus, full model of multivariable logistic regression analysis result revealed that except hoof trimming practices none of the predictor variables were statistically significant (Table 4). Confounding effect and interaction of some variables was also considered. However, none of the interaction term was statistically significant and confounding effect of

variables was not observed; and thus the full model was considered as it was but the modal was simplified by removing non-significant variables by “stepwise” function. Thus, simplified model of logistic regression analysis result showed that only hoof trimming practices and floor type were found to be significantly associated with the prevalence of lameness ($P < 0.05$). The odds of lameness is higher by 5.13 times in dairy cattle kept under no hoof trimming practices than dairy cows in farms that demonstrated hoof trimming practices (OR = 5.13; 95% CI, 1.34 -19.57). Similarly, the odds of lameness was higher by 4.32 times in dairy cows kept under wet and crackly floor type than dairy cows kept under clean and dry floor type (house) (OR = 4.32; 95% CI, 1.13 - 16.58) (Table 5).

Table 4: Results of multivariable logistic regression analysis of the effects of risk factors on the prevalence of lameness

Risk factors	OR	Standard Error	p -value	95% CI
Floor type				
Wet & crackly	2.34	1.98	0.316	0.44 - 12.31
Hoof trimming practices				
No(1)	4.32	3.18	0.047	1.02 - 18.31
Confinement				
Yes(1)	2.97	4.16	0.435	0.19 – 45.05
Parity				
Multiparous	6.25	6.72	0.088	0.76 - 51.38
Constant	0.0032	0.0046	0.000	0.00019-0 .054

1 = is coding for the presence of risk factor, Yes = for the presence of management practices and No = for the absence of management practices.

Table 5: Results of simplified multivariable logistic regression model analysis of the effect of risk factors on the prevalence of lameness

Risk factors	Adjusted OR	Standard error	P –value	95% CI
House type				
Wet & crackly	4.32	2.96	0.033	1.13 – 16.58
Hoof trimming				
No (1)	5.13	3.50	0.017	1.34 – 19.57
Constant	0.023	0.017	0.000	0.005 -0.095

1 = is coding for the presence of risk factor and No = for the absence of management practices.

4.2.3. Prevalence of lameness and its impact on milk yield

Lameness in dairy cattle has higher health and economic significance. Although dairy cows with parity of one and above were 137 in all the farms surveyed, information on average daily milk yield of ten dairy cows was not available because this dairy cows were newly purchased and not lactating ones. Thus the average daily milk yield of 127: 110 lactating, 7 dry and 10 pregnant dairy cows was recorded based on the information obtained from dairy personnel and farm records. The average daily milk yield/cow was calculated to be 11.33 liters (minimum = 2, maximum = 20). In order to estimate the effect of lameness on milk production simple linear regression analysis was used (Table 6). Simple linear regression analysis result showed that the average daily milk yield/cow was significantly declined by 4.22 liters with the case of lameness ($p = 0.000$). This result also indicated that the proportion of total variability in milk yield that is accounted for by the model was 0.17 (R-squared = 0.1690).

Table 6: Simple linear regression model for the effect of lameness on average daily milk production per cow

Milk yield (liters)	Coefficients	p-value	95% CI
Lameness	-4.22	0.000	-5.88 - 2.56
_cons	12.06	0.000	11.37 - 12.75

4.3. Description of foot lesions

A total of 245 animals from fifteen dairy farms were regularly visited for any type of foot and leg problems associated with the occurrences of lameness. Lesions were observed in 31 animals with $LS \geq 2$. In 77.42 % (24/31) of the dairy cattle with $LS \geq 2$ foot and leg problems were observed in hind limbs only. Whereas, 12.90 % (4/31) and 9.68 % (3/31) of them had foot and leg problems in forelimbs and both limbs, respectively. A total of 39 foot and leg problems; 33 (84.6 %) claw lesions and 6 (15.4%) joint and/or leg problem were recorded in the study time, respectively. Out of this 12.82% (5/39) were foot rot, 12.82 (5/39) were sole abscesses and hemorrhages, 12.82 (5/39) heel and sole cracks, 46.15 (18/39) were excessive hoof growth with vertical and/or horizontal fissure, 5.13% (2/39) were hip dislocations, 7.69 (3/39) were swollen joints (arthritis) and 2.56% (1/39) were wounds on their legs associated with trauma, respectively.

Although, the above leg and foot problems were recorded in all types of lameness score ≥ 2 , 27 foot (claw) and leg problems were recorded in animals with $LS \geq 3$. The majority of foot and leg problems were observed in rear feet. Types and frequencies of foot (claw) and leg problems observed in animals with $LS \geq 3$ were also described in table 7.

Table 7: Proportions of foot and leg problems in animals with locomotion score ≥ 3

S. No	Type	Frequencies	Percentage	Quarter
1	Foot rot,	3	11.11	Rear feet
2	Sole abscesses and hemorrhages	5	18.51	Rear feet
3	Heel and Sole cracks	4	14.81	Rear feet
4	Excessive hoof growth with vertical and horizontal fissure	11	40.74	Both feet
5	Hip dislocations	2	7.40	Rear feet
6	Swollen joints and abscesses	2	7.40	Both
Total	6	27	100	

4.4. Questionnaire survey results

4.4.1. Socio-economic characterizations

Pre-tested structured questionnaire was administered to 15 dairy personnel by interview; and 80% (12/15) were males and 20% (3/15) of them were females. Age structure has showed that 4 (26.67%) of them were at an age range of 15-24 years (early working age), 8 (53.33%) were at an age range 25-54 years (Prime working age), 1 (6.67) was at an age range of 55-64 years (mature working age) and 2 (13.33%) of them were at an age range of 65 years and over (elderly). Academic back grounds of the respondents' were also interviewed. From the 15 respondents' of the study area, 33.3% (5/15) were illiterates, 6.7% (1/15) were at an academic status of 5 up to 8 classes, 40% (6/15) were at an academic status of 9 up 12 classes (joined high school) and 20% (3/15) were graduates of diploma and above; and the majority (80 %) of the respondents were married.

4.4.2. Knowledge, attitude and practices (KAP) of the dairy personnel's on lameness

Information about the problem status, owner's attitude and awareness was also recorded by the interviewer. Thus, 66.7 % (10/15) of the respondents did observe abnormal gait in

any one of their animals on their farms and 33.3% (5/15) did not observe any of abnormal gaits (altered locomotion), respectively. Out of the five respondents that did not observe any gait problem, only 20% (1/5 or 6.7% out of 15) of the respondents did not observe any altered locomotion although regularly visits of their animals while 80% (4/5) did not observe any altered locomotion because of information gap even if one or more animals were lame, respectively.

Although, none of the respondents had regular locomotion scoring practice for lameness detection and prevention of the problem in their herds, they had responded that altered locomotion was observed during their visits while milking and feeding. Out of 10 respondents that observed lameness, 80% (8/10) (or 53.3% of the total) of them recognized that altered locomotion and lesions were observed more in hind limbs which is in consistence with present findings in observation (77.42%) while 20 % (or 13.7 % of the total)) of them recognized that altered locomotion and lesions were observed more in for limbs, respectively. However, 33% (5/15) of the total respondents didn't observed altered locomotion in any one of the legs. In consistence with the present findings (63.33%), 66.7% (10/15) of the respondents who observed any abnormal gait respond that abnormal gait was more observed in lactating dairy cattle while 33.3% (5/15) didn't observe any of the legs were affected with such problems. None of the respondents had come across gait problem in young animals' especially in calves which was different from the present study findings (one case). In addition, 66.7% (10/15) of the respondents respond that limping legs, 13.3% (2/15) of the respondents respond that abduction/adduction of legs, 20% (3/15) of the respondents respond that nodding movement (head bobbing) and 26% (4/15) of the respondents respond that arching back could be clinically observed in lame cows after interpretation of the problem's signs, respectively.

Based on the questionnaire survey, management practices between dairy farms were different. For example, 26.7% (4/15) of the respondents respond that they had regular hoof trimming practices while the remaining 73.33 % of them didn't demonstrate any hoof trimming practice. In addition, 20% (3/15) % of the farms had ration formulation

practice based on the ration formulation criteria while 80 % (12/15) of the farms did not have ration formulation criteria but formulate dairy ration by guessing up on their previous experiences. Another management practices observed was that only 3(20%) farms had beddings practices of straw to their cattle in the night time. However, none of the farms had any foot bath practices to their cattle. Moreover, only 40% (6/15) of the farms let their cattle for exercise for at least four to six hours. However, the remaining 9 farms confine their cattle on tie stall for 24 hours as the information obtained from the respondents.

Although altered locomotion was observed by dairy personnel prior to this study in 10 of the farms, 60 % (6/10) did not take any preventive measures. Whereas, 40 % (4/10) used mitigation measures like topical antibiotic treatment and hoof trimming; and among this 6.7% (1/10) responded that one or more lame cows were culled because of reduced milk production. Similarly, out of six (6) farms that did not take any mitigation and control measures, one farm (16.7%) has culled 4 dairy cows considering that they were aged and thus produced low milk but did not guess that it is due to lameness even if they were lame.

4.4.3. Major diseases and problems of dairy cattle in the study area

Investigation on major dairy herd health problems was also made during questionnaire. Major diseases of dairy cattle in the study area were summarized based on the information obtained from the respondents (Table 8). Although table 8 summarizes major disease and health problems that respondents had complained in the area, only foot rot, mastitis, calf mortality and bloat were clinically diagnosed during the study period.

Table 8: Status of major diseases and problems of dairy cattle in the study area

Scientific name	Local name	Rank
Mastitis	Dhibee muchaa	1 st
Bloat	Bokoksa	2 nd
Black leg	Abba gorbaa	3 rd
Foot rot	Cooki	4 th
Calf mortality	Du'a jabbii	5 th
Lumpy skin disease	Gurubrubeta (kintarot)	6 th
Delayed pregnancy	Rimaa qabachuu dhabuu	7 th
Foot and mouth disease	Qabenecha	8 th

5. DISCUSSION

In this repeated cross-sectional study, the overall animal level prevalence of lameness was found to be 8.98% (95% CI, 5.39 – 12.56). This finding is therefore higher than the report made by Sulayeman and Fromsa (2012) reported that prevalence of lameness in dairy farms of Hawassa town was 3.5%. However, lower than the report made by Abunna *et al.* (2017) who reported 13.9% prevalence of lameness in intensive dairy farms of Bishoftu town. The present study is in agreement with the findings of Lobago *et al.* (2001) in that 73 (7.7%) animals out of 964 animals examined clinically exhibited clear signs of lameness in dairy cattle under urban and peri-urban production systems in Addis Ababa milk shed. Similarly, one or more cases of lameness was observed in eight of the dairy farms where herd level prevalence of lameness was found to be 53.3% (8/15) which is lower than the report made by Abunna *et al.* (2017) who reported one or more cases of lameness in 16 farms (94%) out of 17 farms under intensive and extensive production systems in Bishoftu town. Therefore, the lower prevalence of lameness in the study area as compared to the findings of Abunna *et al.* (2017) might be due to the difference in management and environmental condition. In this study, the prevalence of lameness is nil in half of dairy farms because of exercise and letting them out on pasture as compared to those farms that confine animals for the whole day. Thus, the higher prevalence reported by Abunna *et al.* (2017) might be due to confinement of dairy cattle in tie stall and high concentrate feeding which could be associated with laminitis.

Animal level prevalence of lameness in this study was found to be higher than the prevalence in some other parts of the world. For example, Manske *et al.* (2002) found that the prevalence of lameness was 5.1% in 4899 Swedish dairy cows on 101 Swedish dairy farms. However, lower than animal level prevalence of lameness in some other countries. For example, Espejo *et al.* (1996) reported that the mean prevalence of clinical lameness was 24.6% in 5,626 high-producing Holstein cows housed in free stall barns in Minnesota. The higher prevalence estimated in this study as compared to Manske *et al.* (2002) might be due to small number of dairy cattle surveyed. Whereas the lower

prevalence estimated in this study as compared to Espejo *et al.* (1996) was supposed to be due to house type in that higher prevalence of lameness could be estimated in loose house design with deep bedded packs (Shearer, 1997; Cramer *et al.*, 2008; Popescu *et al.*, 2010; Popescu *et al.*, 2013).

Moreover, the lameness prevalence varied extensively among the farms, ranging from 0 % to 42.86%, with a mean within-herd level prevalence of 20.96 % in those farms where one or more cases of lameness was detected. The difference in the prevalence of lameness between the farms might be due to the differences in awareness and management practices. For example, among the respondents who observed lameness, 60 % (6/10) of them did not take any preventive measures when interviewed. What needs special attention is that in half (4/8) of the dairy farms that one or more lameness cases were observed, lameness prevalence exceeded 15% of the herd; and thus it is important to differentiate the cause (Weaver, 1985; Nordlund *et al.*, 2004). It should be noted, however, that other targets might be appropriate for herds in different management systems, such as grazing or barn type (Nordlund *et al.*, 2004). Again in two of the dairy farms that were listed as lameness was detected, at least one animal was presented with severe lameness (LS = 5). Thus, it is a good indicator of the lameness problems and needs especial attention of hypothesized risk factors especially claw trimming and floor type (Von Keyserlingk *et al.*, 2012). Compared to other parts of the world, this result agrees with the report made by Solano *et al.* (2015) who found that herd-level prevalence of lameness ranged from 0 to 69% (mean = 21%) in Canadian Holstein-Friesian cows housed in free stall barns. The dairy cows observed in Canada by Solano *et al.* (2015) were found to be kept in free stall house design; and thus the higher prevalence observed in Canada in line to this result might be due to the free stall design. Whereas the higher mean within-herd level prevalence of lameness detected in line to Solano *et al.* (2015) in this study might be due to small number of dairy farms sampled; and poor management systems like no hoof trimmings. Moreover, lameness prevalence exceeded 15% of the herd in some of the farms surveyed, thus it is important to differentiate the cause (Weaver, 1985; Nordlund *et al.*, 2004). Although incidence in this study was not calculated, Clarkson *et al.* (1996) reviewed that annual incidence of lameness can be

estimated from the prevalence at one point in time. As a result emphasis has to be given for the prevalence of lameness in the study. Generally, herd level prevalence (0% to 79%) of lameness varied widely between herds in different parts of the world (Barker *et al.*, 2010).

This prevalence of lameness could be invariably associated with some of risk factors in epidemiological investigation of lameness. Therefore, putative risk factors (intrinsic and extrinsic) supposed both at herd and animal level were floor type, herd size, animal confinement for 24 hours in tie stall, bedding practices, foot bath practices, hoof trimming practices, age, sex and parity of animals. However, although 39 male animals of almost all calves were sampled in order to see the associations with the prevalence of lameness and sex, none of them were observed as having $LS \geq 3$; and the majority of animals reared in dairy farms of the study area were female while male animals especially calves will stay up to one year's only; and almost all animals found to be lame were females. In addition, although lameness incidence increases with age and older cows tend to have increased levels of hoof damage (Raber *et al.* (2004), some authors (Konig, 2009) recommended that the age of cattle cannot be altered but age can be managed carefully, either through appreciation that older cows may be more likely to become lame. Moreover, only one (0.41% of the total sample) animal with an age range of ≤ 36 months (young) was found to be clinically lame in this study; and more likely almost all young aged animals (calves, heifers and bulls) were removed from the data in order to avoid bias as there were no chances of having parity. Similarly, no dairy farms in the study area practiced foot bath practices. Thus, age and sex of study animals and foot bathing practices were not statistically analyzed as putative risk factors associated with lameness. However, putative risk factors statistically analyzed for their significant associations using Fisher's exact test and univariate logistic regression models were floor type, herd size, bedding practices, animal confinement for 24 hours in tie stall, hoof trimming practices and parity of animals. Except herd size and bedding practices, all the remaining variables have statistically significant association with the prevalence of lameness based on Fisher's exact test. Since random effect of clustering of farms was suspected and mixed model was used. However, the intra-cluster correlation was

extremely low and less than one ($2.94e-07$); and because of stratification the precision of overall estimates might be greater there by the gain in precision resulted from the fact that the between-stratum variation is explicitly removed from the overall estimate of variance (Dohoo *et al.*, 2003). Thus, clustering effect was ignored and univariate logistic regression model was used.

Univariable logistic regression analysis result showed that herd size, bedding practices and parity of animals had no statistically significant association in the prediction of lameness ($p > 0.05$). However, floor type (categorized as wet & crackly and clean & dry), hoof trimming practices (yes or no) and animal confinement (indoor keeping only or not) were found to be statistically significant ($p < 0.05$) in the prediction of lameness. Moreover, multivariable logistic regression analysis result of hypothesized risk factors revealed that except hoof trimming practices none of the predictor variables were statistically significant ($p > 0.05$). This might be due to confounding of some variables. In addition, the effect of some variables may exist when other variables are there (interaction term). Similarly some of management practices may vary from herd to herd. Thus, interactions were made between the variables. However, none of the interaction terms was statistically significant and no confounding effects were observed between variables; and thus the full model was considered as it was. But the model was simplified by removing non-significant variables by “stepwise” function. The likelihood-ratio test in the removal of non-significant variables from the full model in multivariable logistic regression showed that the p-value was not statistically significant ($p = 0.0749$). This means removal of non-significant variables from the model did not bring any significant changes in the model. Thus simplified model showed that only floor type and hoof trimming practices were the only predictors of lameness. Based on the obtained univariate logistic regression analytical outputs each putative risk factor will be discussed for the significant association with the prevalence of lameness accordingly.

Firstly, intrinsic risk factor supposed to be associated with the prevalence of lameness was parity of animals. As a result the dairy cattle in the study area were grouped as primiparous and multiparous based on the information obtained from the dairy personnel

and farm records. In order to avoid bias dairy cattle of 108 (calves, bulls and heifers) were removed from the data as there were no chances of having parity as discussed earlier. Univariate logistic regression (both univariable and multivariable) analysis result indicated that parity of animals was not found to be significantly associated with the prevalence of lameness. This finding therefore agrees to the report made by Sadiq *et al.* (2017) who reported that the prevalence of lameness was not associated with parity ($P > 0.05$) whereas cows in early lactation were significantly associated (OR = 3.3; 95% CI, 2–7) in dairy farms in Selangor, Malaysia. Though statistically not significant, univariable logistic regression analysis result indicated that the odds of lameness was 7.3 times higher in multiparous animals as compared to primiparous animals (OR = 7.3, $p = 0.057$). This result supports the report made by Solano *et al.* (2015). However, Solano *et al.* (2015) significantly found that compared with first parity, cows in parity 2, 3, and ≥ 4 had 1.6, 3.3, and 4 times, respectively, higher odds of being lame in Canadian Holstein-Friesian cows housed in free stall barns. Furthermore, in terms of lesion type Solano *et al.* (2016) also discussed that parity of animals was associated with digital dermatitis, sole ulcers and white line as the most frequently observed lesions in dairy cattle in Alberta, Canada. Possible explanations we might consider in this study is the higher prevalence of lameness estimated in multiparous dairy cows in this study area was supposed to be due to the longer period of stay in uncomfortable barn type and management systems. Special thing we might also have to consider in this study area is believes of dairy personnel's in that when dairy caws especially lactating ones are left out for exercise milk production will be low. So that some of the dairy personnel in the study area were not willing to let their cattle out. Thus the more the parity of animals the more they will be confined. This could lead to physical damage of hooves in multiparous animals because of longer standing time and thus more heel and sole cracks were observed. In contrast to this Bicalho *et al.* (2009) recommended that lameness in dairy cows can occur anytime throughout the lactation, as is true for many other diseases.

Although the above intrinsic factor was considered in this study, most lameness could be related to housing through the effect of the floor surface (Lau *et al.*, 1997) and management practice of hoof care and others. It is, therefore, possible to moderate the

extrinsic risks from the environment and herd management to better suit the dairy cow's requirements. Among those extrinsic risk factors barn type and management systems in the study area were regularly visited and interviewed. Therefore, special emphasis on herd size, animal confinement, floor type, bedding practices and hoof trimming practices was given as extrinsic risk factors association with the prevalence of lameness; and will be discussed in detail.

Herd size was supposed to be extrinsic risk factor associated with the prevalence of lameness in that in large and medium scale farms dairy cattle will be confined more as compared to small scale farms (Cook *et al.*, 2016). Similarly, Shearer (1997) intuded that large herds and herds with corral housing in winter (muddy conditions) were risk factors cited in California by recent surveys. But the difference in animal level prevalence of lameness between the herd sizes was not statistically significant in this study ($p > 0.05$). Though statistically not significant, the odds of lameness were lower by 0.63 in medium scale farms as compared to small scale farms by univariable logistic regression analysis. This could be due to small samples size of small scale dairy farms as compared to medium scales. However, the majorities of farms that one or more cases of lameness observed were medium scale farms 55.5% (5/9) as compared to small scale farms 50 % (3/6); and thus herd level prevalence of lameness was higher in medium scale farms than small scale farms. Nevertheless, herd size was not included in multivariable logistic regression analysis as it was not found to be important predictor of lameness in univariable logistic regression analysis with a p-value of > 0.25 .

Besides herd size, animal confinement was also investigated in this study supposed to be extrinsic risk factor associated with the prevalence of lameness in dairy cattle. As a result, out of 137 dairy cows considered in statistical analysis, 82 of them were found to be kept under confined management systems for the whole day and 55 of them were under no confinement systems where dairy cattle could be let for at least four to six hours in a day out of the barn for exercise and cleaning purpose. Univariable logistic regression analysis result showed that the odds of lameness was 17.4 times more likely to occur in dairy farms where cattle are confined for 24 hours as compared to those who let their cattle for

exercise in a day (OR=17.4; $p = 0.006$). This is therefore in line to the manual made by Shearer (1997) in that confinement on hard surfaces is sufficient alone to cause a mechanical form of laminitis, that with subsequent claw overloading could lead to claw disease. Similarly, Barker *et al.* (2010) discussed that cows being housed for 61 days or longer at the time they were locomotion scored by the visiting researcher was found to be important risk factor associated with the prevalence of lameness in dairy herds in England and Wales. This is because overstocking and animal confinement on hard surface will lead to physical damage of hooves (Shearer and van Amstel, 2011; Bicalho and Oikonomou, 2013). Nevertheless, in simplified multivariable logistic regression analysis, animal confinement was not significantly associated with the prevalence of lameness and thus removed by ‘stepwise’ function test ($p > 0.05$).

Another environmental risk factor that could be invariably associated with the prevalence of lameness was housing systems in the area. Shearer (1997), Cramer *et al.* (2008) and Popescu *et al.* (2013) found that lameness prevalence was significantly higher in the loose dairy farms than in those with tie stalls. For example, Cramer *et al.* (2008) reported that 46.4% of cows had a foot lesion in free-stall housing systems while 25.7% of cows in tie-stall barns had a foot lesion in Ontario. In addition, Solano *et al.* (2016) found that the odds of sole ulcers and white line disease were ≥ 2 times higher in cows housed in free stalls than those housed in deep-bedded packs. However, housing types were not compared in this study because all of the dairy farms in study area use tie stall design with stanchion than free stall design. But floor type was categorized as wet & crackly (slipperiness, damp and cracks together) and clean & dry; and bedding practice were considered as putative risk factors of housing effect on lameness.

Some authors (Lau *et al.*, 1997) discussed that most lameness is related to housing through the effect of the floor surface. Therefore, floor type of each farm was regularly visited and categorized as wet & crackly and clean & dry. A total of 69 dairy cows were kept under wet and crackly floor type while 68 dairy cows were found to be kept in clean and dry floor type. Higher prevalence (26.09%) was observed in wet and crackly as well as slippery floor type than clean and dries ones (4.41%) suggested that wet hoof is softer

than dry hoof and therefore the sole is more likely to become penetrated or the corium bruised if the feet are damp (Nordlund *et al.*, 2004; Blowey, 2011). Even though it was not free stall design, this may result in heel and sole cracks allowing ulcers, abscesses, or infections to occur because of wet feet standing in manure and urine (Bicalho and Oikonomou, 2013). Therefore, univariable logistic regression analysis result indicated that the odds of lameness was 7.64 times more likely to occur in wet and crackly barn type as compared to clean and dry type (OR=7.64; $p = 0.002$). Remarkably, simplified model of multivariable logistic regression analysis has also showed that floor type together with hoof trimming practices were the most potential predictors of lameness. Thus, simplified model of multivariable logistic regression analysis showed that the odds of lameness was 4.32 times more likely to occur in animals of wet and crackly barn type as compared to animals in clean and dry floor type (OR= 4.32; $p = 0.033$). Some of the floors of the farms in the study area were wet, slippery and crackly that could also be associated with physical damage to dairy cattle there by increased prevalence of lameness in the farms as compared to clean and dry type. This is in line to the discussion made by Barker *et al.* (2010) who discussed that one of the risk factors for increased lameness of dairy herds in England and Wales was the presence of damaged concrete in yards. In addition, poor hygiene of barn was considered in a floor category of wet and crackly could be a risk factor associated with lameness prevalence in tied dairy cattle (Popescu *et al.*, 2010; Bicalho and Oikonomou, 2013). Ninety percent (20/22) or more of lameness in dairy cattle involved was due to the foot (claw) lesions (25/27). This pattern of lameness suggested that floor type could be responsible for lameness disorders more than just other management errors (Shearer, 1997).

Besides floor type, another extrinsic management risk factor of housing effect that should not be missed was bedding practices. The effect of flooring quality in the emergence of foot problems of the cows can be minimized by the resting bed (Phillips and Schofield, 1994). Moreover, reduced lying time due to bedding materials was reported as factor associated with lameness (Shearer and van Amstel, 2011; Bicalho and Oikonomou, 2013). Therefore, in this study only three (20%) small scale dairy farms had demonstrated beddings of straw to their cattle during the night time while the remaining

12 farms did not demonstrate significant bedding practices. Though statistically not significant, the odds of lameness was 1.5 times more likely to occur in animals of dairy farms with no beddings as compared to animals in dairy farms with bedding practice based on univariable logistic regression analysis (OR = 1.48; $p = 0.718$). This is therefore agrees with the report made by Cook *et al.* (2004) and Espejo *et al.* (2006). However, Cook *et al.* (2004) and Espejo *et al.* (2006) found statistically significant association; and discussed that the use of deep, loose bedding has long been associated with beneficial effects on lameness. Somers *et al.*(2003) also found that herd-level prevalence of digital dermatitis ranged from 92 to 100% when cows were housed on concrete flooring, whereas when cows were housed in deep-bedded straw yards, 65% of herds were free of digital dermatitis. In line to this, majority of infectious causes of foot problems were recorded in those houses with no bedding practices where floor type was considered as damp and slippery. Nevertheless, bedding practices was not included in multivariable logistic regression analysis as it was not found to be important predictor of lameness in univariable logistic regression analysis with a p-value of > 0.25 . Under normal conditions, the cows spent ~13-14 hours lying and 2.5 hours standing per 24 hours (Wierenga and Hopster, 1990). Leonard *et al.* (1994) also discussed that heifers which spent 10 or more hours per day lying down had significantly better claw health than those that spent 5 hours or less lying down per day. However, in uncomfortable barn type and no beddings dairy cattle had reduced lying time (Phillips and Schofield, 1994); and cows were spending longer standing that feet were wetter and dirtier, and the risk of infectious conditions such as foul was increased in this study (Wierenga and Hopster, 1990). Moreover, dairy cattle in the study area were found to be more stressed and supposed to lie below this range because of milking activities and no beddings where extended milking time was reported as factor associated with lameness (Bicalho and Oikonomou, 2013). On the other hand lame cows were found to be more restless at milking, spend more time lying down and eat more slowly (O'Callaghan, 2002; Callaghan *et al.*, 2003).

Remarkably, what deserves special attention regarding to management risk factors associated with the prevalence of lameness in this study was absence of regular and

trained claw trimming practices across the majority of the dairy farms surveyed. Therefore, the effect of hoof trimming practices on the prevalence of lameness was investigated in 137 dairy cattle of which 66 were kept under dairy farms with hoof trimming practices and 77 were kept under dairy farms with no hoof trimming practice. Higher prevalence of lameness (27.27% (18/66)) was scored in dairy cattle under the farms that did not demonstrate hoof trimmings than farms that demonstrated hoof trimming practices (4.23% (3/71). In this study absence of hoof trimming practices was found to be important risk factor that significantly associated with the prevalence of lameness both in univariable and multivariable logistic regression analysis. Univariable logistic regression analysis result implied that the odds of lameness was 8.5 times more likely to occur in dairy cattle when farms do not demonstrate claw (hoof) trimmings as compared to those with hoof trimming practices (OR=8.58; CI, 2.37 - 30.47). Moreover, simplified model of multivariable logistic regression analysis result has also indicated that the odds of lameness was 5.13 times more likely to occur in dairy cattle under no hoof trimming management systems as compared to those with hoof trimming practices (OR = 5.13; 95% CI, 1.34 – 19.57). In line to this Sadiq *et al.* (2017) reported that for cows with claw lesions, prevalence of lameness was associated with overgrown claw (OR = 2.7; 95% CI, 1.4-5.3) in dairy farms in Selangor, Malaysia. However, Sadiq *et al.* (2017) also reported that despite the higher prevalence of lameness in cows with overgrown claw (31.9%), the association tends not to be significant in dairy farms in Selangor, Malaysia ($P > 0.05$). According to the guideline made by Shearer (1997), increased hoof growth (particularly of the outside claw of rear feet) leads to overgrowth and eventually overloading of the affected claws. The end result is a greater likelihood of developing claw disease. Nevertheless, majority of dairy farms in this study area did not demonstrate significant attention to hoof care as a result 40% (11/27) of foot and leg problems in dairy cattle with $LS \geq 3$ was due to excessive hoof growths associated with vertical and horizontal fissures that we can appreciate in appendix IV, E. In comparison, on other parts of the world hoof trimming tasks were found to be primary concern of farmers. For example, Cook *et al.* (2016) reported that 87.9% of herds operating a hoof-trimming schedule for adult cows, and 65.5% of trimming herds doing so at least twice per lactation in Wisconsin. As the preventive approach Blowey (2011) recommended that

routine foot trimming at drying off period than parturition (which predisposes to coriosis), has an important influence on the development of lameness.

Descriptive statistics on foot and leg problems indicated that lesions prevalence was higher in rear feet than in front feet among all types of foot lesions similar to the findings of Sulayeman and Fromsa (2012), Abunna *et al.* (2016) and Solano *et al.* (2016). In 77.42% (24/31) of the dairy cattle with $LS \geq 2$, foot and leg problems were observed in rear feet. A total of 39 foot and leg problems; 33 (84.6 %) claw lesions and 6 (15.4%) joint and/or leg problem were recorded in the study time. Possible explanation to this is outside claw of the cow's rear legs bear the burden of continuously changing weight load and this may be the reason why they are often damaged (Shearer and van Amstel, 2011). Another thing we shall consider is that hygiene of the barn. This means hind legs are more prone to infectious causes of lameness because of manure contaminations. Therefore, this result is the reflection of wet and crackly floor type as discussed before. In addition, 14 % of foot and leg problems that resulted lameness was due to systemic infections. This is therefore in agreement with the review made by some authors (Winckler and Willen, 2001) reviewed that only 15% of cases are caused by other disorders of the limb. Greenough (2007), Konig (2009) and Refaai *et al.* (2013) also reviewed that systemic infections may cause animals to have problems to move in a natural way although Lau *et al.*(1997) discussed that most lameness is related to housing through the effect of the floor surface.

Moreover, lameness in this study area was found to be underestimated herd health problem in terms of milk loss. However, simple linear regression analysis result showed that the average daily milk yield/cow was significantly declined by 4.22 liters with the case of lameness ($p = 0.000$) which was higher than the report made by Sulayeman and Fromsa (2012) where a mean loss in milk yield was 1.63 liter per cow per day in Hawassa dairy cattle. This is therefore warning issue in terms of milk production and economic loss since the ultimate goal of dairy industry is milk production and heifers. On the other parts of the world, studies by Rajala-Schultz *et al.* (1999), Warnick *et al.* (2001), and Hernandez *et al.* (2005) indicated a linear relationship between increasing degree of lameness and decreasing milk yield among cows in their second or later

lactations. For example, Warnick *et al.* (2001) and Green *et al.* (2002) estimated the loss of milk production due to lameness ranged from 0.8 kg to 2 kg/day; depending on time since hoof trimming and herd effects. Similarly questionnaire survey result revealed that only one farm had culled one or more cows because of lameness and one lame cow was found to produce only two liters of milk/day.

Finally, questionnaire survey result on Knowledge, attitude and practices (KAP) of the dairy owners and/or attendants on lameness in the study area revealed that although the problem was detected under no regular visits in the majority of the farms (66.7%), lameness was underestimated dairy cattle health problem. As a result the prevalence of lameness of was extensively varied among the farms. Moreover, only 40% out of 10 farms that had detected lameness cases had some mitigation measures especially to infectious cases of lameness but the remaining did not. Thus, locomotion scoring system in the study area was not found to be routine task of dairy personnel.

6. CONCLUSION AND RECOMMENDATIONS

Based on the results from locomotion score system and questionnaire survey the present study indicated that the prevalence of lameness varied extensively among the farms ranging from 0 to 42.86%. The overall animal level prevalence was found to be 8.98 %. Whereas, an averaged within-herd level prevalence of lameness was found to be 20.96% in those farms with one or more cases of lameness. No claw trimmings and floor type of wet and crackly were the most important management risk factors associated with the prevalence of lameness. Questionnaire survey result also revealed that hoof trimming practices had not been demonstrated in the majority of dairy farms surveyed. Moreover, the impact of lameness on milk yield in this study area was higher than other's findings in the country. Nevertheless, no farms had considered that reduction in milk production per cow/day in lame cows was due to lameness rather seemed to them due to aging. Thus, it can be concluded that the obtained prevalence of lameness was beyond the expected level and deserves attention concerning to the prevention of the problem rather than clinical management of individual lameness cases; and lameness was found to be underestimated dairy cattle health problem in the study area. Based on this conclusion, the following recommendations were forwarded:-

- ❖ One key area where knowledge is lacking is how well farmers perceive lameness. Thus, awareness creation on the impact of lameness in dairy industry is needed.
- ❖ Trainings to farmers and animal health professionals about locomotion scoring should be given.
- ❖ Claw/hoof trimmings should be exercised.
- ❖ Attention to the hygiene of dairy cattle and flooring quality of the barn should be given. So crackly and slippery flooring types should be avoided.

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10. APPENDICES

Appendix I: Description of the five point locomotion systems published

Locomotion score	Picture	Description by Sprecher <i>et al.</i> (1997)	Description by Konig (2009)
1		<p>Normal</p> <p>Normal gait. Level back posture while walking</p>	<p>The cow does not have uneven gait at all</p> <ul style="list-style-type: none"> - No signs of uneven gait - Even weight bearing between legs - The back is flat while walking - No signs of head bob
2		<p>Mildly lame</p> <p>Normal gait. Level back posture while standing, but back arched while walking</p>	<p>The cows has a slightly uneven gait</p> <ul style="list-style-type: none"> - The cow might walk almost normally - The gait is often slightly uneven and the cow is likely to take shorter strides - But, there are no evident signs of limping or uneven weight bearing. - The back might be arched - No signs of head bob.
3		<p>Moderately lame</p>	<p>The cow has uneven gait</p>

		<p>Gait affected, short striding. Back arched while standing and walking</p>	<ul style="list-style-type: none"> - Abnormal gait pattern - Walks with short strides on 1 or more leg(s) - In most cases, a trained observer will be able to tell which leg is affected (mild signs of uneven weight bearing) - The back is usually arched - But there may or may not be signs of head
4		<p>Lame Back always arched. Only one deliberated step at a time, one or more limbs favored.</p>	<p>The cow has a very much uneven gait</p> <ul style="list-style-type: none"> - The cow is obviously limping on 1 or more leg(s) - An untrained observer will usually be able to detect the affected leg(s) - In most cases, the back is arched - Head bob will be evident
5		<p>Severely lame Additionally, extreme reluctance to bear weight one or more limbs</p>	<p>The cow has an extremely uneven gait</p> <ul style="list-style-type: none"> - The cow is unable, unwilling, or very reluctant to bear weight on the affected leg(s) - The back is arched - Head bob is evident and can be extreme

Appendix II: Questionnaire survey format for lameness

EPIDEMIOLOGICAL INVESTIGATION OF LAMENESS IN SELECTED DAIRY FARMS OF SULULTA TOWN, CENTRAL ETHIOPIA

Date of interview: Dy/Mm/Year _____/_____/_____

Enumerator's full Name _____-

Woreda (Town): _____ Kebele _____

Name of the farm _____

Farm owner's (attendant's) Full Name _____ sex _____

Age _____

Education Level: Illiterate [] 1-4 grades [] 5-8 grades [] 9-12 grades [] diploma and above []

Marital status: Single [] Married [] Widow [] Widower [] Divorced []

I Environment, Management and Housing conditions of the farm

1. What is your farm's herd size?

Calves		Heifers	Dry cows	Lactating Cows	Pregnant	Bulls	Total	
M	F	F	F	F	F	M	M	F

2. Do you have ration formulation practice based on any manual given to you by the experts?

A. Yes B. No

2.1. Did you observed any distention of rumen following grain feeding?

A. Yes B. No

3. How do you feed your cattle?

A. Tie stall Free stall C. both

3.1. How many hours do your cattle stay at tie stall in a day? _____

3.2. For how many hours do your animals get laid? _____

3.3. Do you let your animals for exercise outside the barn? A. Yes B. NO

3.4. If yes, for how many hours do your animals be out of the barn? _____

4. Do you have farm production record? A. Yes B. No

4.1. Average milk yield per Cow per day _____litter.

4.2. Average Lactation length _____ in months.

5. What kind of beddings do you use on the farm?

A. Sand [] B. Straw [] C. No beddings []

6. Do you have any footbath practices?

A. Yes B. No

7. Do you have regular hoof trimming practices?

A. Yes B. No

II. Disease status of the farm

1. What are the main diseases of dairy cattle at your farm?

No	Local name of the diseases	Scientific name	Rank

2. Is there any abnormal gaits observed before?

A. Yes B. No

2.1. If yes which animals did show such problems more?

A. Calves [] B. Pregnant [] C. Lactating [] D. Dry cow [] E. Bulls [] F. Heifers []

2.2. Do you have any locomotion scoring practice while the animals are at different positions (walking/or standing on different surfaces like concrete)?

A. Yes B. No

2.3. What were common signs of abnormal gait observed at your farm?

A. Arching Back [] B. Limping legs [] C. Abduction /Adduction of legs []

D. Nodding movement of the head in a vertical plane [] E. All []

2.4. Which legs do have gait problems predominantly?

A. Hind Legs [] B. Front legs [] C. Both []

2.5. What do you do with known lame animals at your farms?

A. Cull [] B. Leave as it with some medications [] C. Both []

2.6. Do those lame cows give similar amount of milk per day/lactation as they were healthy (not lame)?

A. Yes B. No

Appendix III: Observational data registration format

S no	Animal id	Name of the farm	Farm scale	Sex	Age(yrs)	Foot and leg problems					LS(1-5)	Leg Affected	Average daily milk yield
						S&H crac ks	Hemorrh ages and sole abs	Foot rot	Joint swelli ngs	Hoof growth			
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													

Appendix I: Selected photos of foot and leg problems observed across the dairy farms



A. Hock joint abscess and increased Hoof growth



B. Carpal joint swelling



C. Heel and sole cracks with white line disease



D. Early stage of interdigital dermatitis



E. increased hoof growths of front and hind feet



F. Hemorrhage (on the left and sole abscesses and HHE)

G. Foot rot (swelling of entire digit) and topical treatment practice

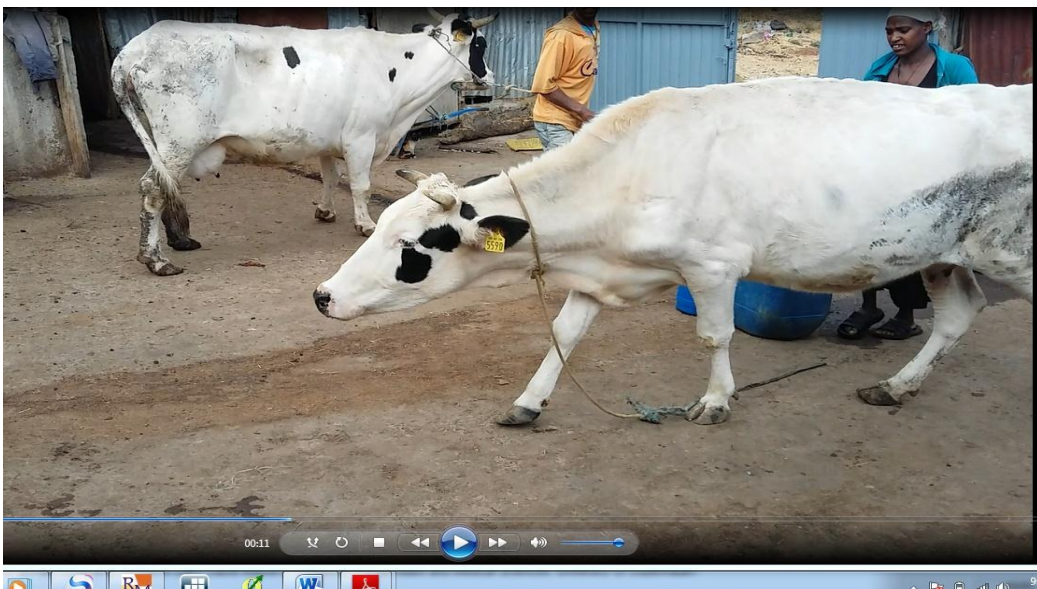


H. Foot lesion identification and management practice

Appendix II : Some of selected photos of clinical signs of lameness detected by the locomotion score system



A. Caw arching back in standing position because of lameness



B. photo taken from the video record of a caw with nodding movement while walking during locomotion scoring

Appendix III: Some of selected photos of dairy cattle management system



A. Dairy cattle on pasture



B. Dairy cattle feeding and watering on tie stall

Appendix VII: Some of selected photos of feed sources and ration formulation practice



A. Crop residue (straw) feed sources




B. Hay storage system as a source of dairy cattle feed



C. Brewery byproduct storage and ration formulation practice

Appendix VIII: Ethical Clearance Certificate

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ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu/Debre Zeit

Animal Research Ethical Review Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/09/05/10/2018

Name of Applicant: **Mulatu Woldehana (DVM, MSc fellow)**

Address: **College of Veterinary Medicine and Agriculture, Addis Ababa University**

Title of the project: *Epidemiological investigation of Lameness in selected Dairy farms of Sululta town, Central Ethiopia*

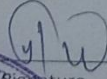
Date of application:	14/11/2017
Nature of the project:	non-invasive
Target animal species:	cattle
Number of animals involved:	245
Study area:	Sululta town, Ethiopia

Minutes No. and date of review: VM/ERC/05/10/018, 03/01/2018

The above indicated research project is acceptable from ethical perspective, relevance, originality and technical competence points of view. Hence the project is allowed to be executed provided that:

4. All procedures and conditions stipulated in the proposal are respected and any deviation or changes be reported to the committee
5. The project activities be open for occasional supervision by the committee whenever this is deemed necessary

Dr Getachew Terefe
Chairman

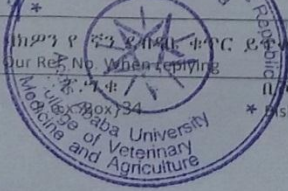


The Federal Democratic Republic
of Ethiopia

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