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Prevalence and risk factors of lameness in dairy cattle in Alexandria, Egypt

Amr M. A. Rashad[1,2], Ahmed A. Kohla[1], Mahmoud A. Aziz[1], and Dalia K. A. EL-Hedainy[1]

[1] *Animal Production Department, Faculty of Agriculture (El-Shatby), Alexandria University, Alexandria 22545, Egypt*

[2] *Current address: Faculty of Agriculture, Alexandria University, Alexandria El-Shatby, Egypt*

Abstract

Aim of study: Providing further information on the prevalence of lameness in four dairy cattle herds and gain insights into the risk factors associated with the frequency of lameness incidence including farm, frequency of mastitis, and number of lactations.

Area of study: Alexandria, Egypt.

Material and methods: Four dairy Holstein cattle farms near Alexandria Governorate in Egypt were involved in a retrospective investigation of lameness episodes between the years 1987 and 2011. The association between the frequency of lameness injury and the explanatory variables was tested by the maximum likelihood analysis of variance, adopting a loglinear model. The explanatory variables included in the model were farm, frequency of mastitis injury and number of lactations as well as their one-way interactions.

Main results: The prevalence of lameness ranged between zero and 19% in the four farms and the frequency of lameness events (from 0 to 4 times) increased with lactation number and mastitis incidence with correlation coefficients of 0.15 and 0.12, respectively.

Research highlights: Lameness is present in Egyptian dairy cow herds with highly variable prevalence and the risk increases with lactation number and mastitis.

Additional key words: dairy cows; Kaplan-Meier; performance.

Abbreviations used: ALM (El-Alamia); DIM (Dima); FAR (Farm Key); TAL (Talaat Mostafa)

Authors' contributions: AMAR, AAK suggested the work idea and collected the data. AMAR and MAA analyzed the data and prepared the tables. DKAELH prepared the figures. AMAR, DKAELH and MAA wrote the manuscript. MAA revised the final manuscript. All authors approved the final article.

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Correspondence should be addressed to Amr M. A. Rashad: amr_rashad43@yahoo.com

Introduction

Lameness is one of the most important welfare, health, and productivity problems in intensive dairy cattle farming worldwide. The disorder is considered the third major health problem (after mastitis and reproductive problems), and is the third most important reason for culling (Huxley, 2013). Nowadays, this issue is considered a high research priority (Bauman *et al.*, 2016). Lameness is a debilitating condition, associated with pain (Rushen *et al.*, 2007), and it is the most visible animal welfare concern (von Keyserlingk *et al.*, 2012). It causes substantial economic losses (Ettema & Ostergaard, 2006) due to reductions in milk production (Green *et al.*, 2002) and reproductive performance (Garbarino *et al.*, 2004), in addition to treatment costs. Also, it is a multifactorial condition, predisposed by environmental, management and genetic factors (Van Nuffel *et al.*, 2015). Several factors have been found to contribute to lameness disorder (Newsome *et al.*, 2017). It is accepted that early detection, prompt and effective treatment of lameness reduces severity, increases response rates to treatment (Thomas *et al.*, 2015), and decreases direct and indirect costs (Bruijnis *et al.*, 2010).

Lameness prevalence was estimated in several studies carried out worldwide. For example, lameness prevalence estimates in the USA oscillated from 11% in 1996 to 14% in 2007 to 10% in 2014 (USDA, 2007). Similarly, in the United Kingdom lameness prevalence was higher at 20% in 1991 to 22% in 2001 (Whay, 2002). A uniform and standardized system for lameness data collection and analysis at herd and national levels can provide baseline information on type, frequency, distribution and risk factors associated with this disorder, and are greatly needed. Furthermore, these large-scale data can be used for disease surveillance, genetic improvement and benchmarking, and consequently, increasing awareness about the lameness problem.

Understanding the multifactorial nature and interconnected risk factors for lameness is fundamental for disease prevention (LeBlanc *et al.*, 2006). Economic losses and animal welfare concerns related to lameness should motivate farmers and the dairy industry to focus on prevention rather than treatment. Therefore, there should be nationwide strategies for monitoring lameness, locomotion, routine hoof trimming, and providing a comfortable and hygienic housing. Prevention programs need to be tailored to control both infectious and noninfectious lameness. Despite the importance and increased awareness of lameness, prevalence studies in dairy herds in Egypt are scarce (Refaai, 2014). The present study aimed at providing further information on the prevalence of lameness in four dairy cattle herds in Egypt and gain insights into the risk factors associated with the frequency of lameness incidence including farm, frequency of mastitis, and number of lactations.

Material and methods

Four dairy farms with Holstein Friesian cows near Alexandria Governorate were involved in this study, namely El-Alamia (ALM), Dima (DIM), Farm Key (FAR) and Talaat Mostafa (TAL) farms. Lameness records collected covered the period from 1987 to 2011 and they did not include information regarding the cause and duration of lameness or time of the year when it occurred.

Animal management and lameness detection

In all farms, cows were loose-housed indoors all year round on sandy flooring, except FAR which had concrete flooring. Cows included in the study were in their first to 12 lactations. They were kept under different feeding regimes and management practices for the whole study period and were milked twice daily. Standard data describing the dairy herd include frequency of lameness injury, frequency of mastitis injury, number of lactations, life-time milk production, longevity, means of days open, dry period and calving interval along the productive life of the cow, as well as cow, sire and dam identifications.

Traditionally, lameness detection relied on visual assessment when the cows were walking to or from the milking parlor. Lameness was defined as any degree of limping on one or more legs, ranging from slightly putting off weight from one leg up to walking on three legs only and resulting in the cow having an arched back. Cows that were not affected with lameness were classified as healthy. Occurrence of clinical mastitis (CM) was detected by dairymen upon observing a hard-swollen warm udder and changes in milk consistency (watery or blood-tinged secretions and clots in milk). A cow was considered to have subclinical mastitis based on altered milk electric conductivity (EC) using sensors incorporated in the milking unit. Animals with chronic mastitis were promptly eliminated from the herds and were not included in the study.

Statistical analysis

Before undertaking statistical analysis, data were screened for unlikely or missing values, errors and outliers. After this screening, the final data sets available for the analyses of were 1332, 101, 257 and 158 cows in ALM, DIM, FAR and TAL farms, respectively.

Prevalence of lameness and the association between the frequency of lameness injury and the explanatory variables

Prevalence of lameness on each farm was expressed as the proportion of lame cows. Data were classified by farm (4 farms); frequency of lameness (classified into two groups: healthy cows (0), and lame cows (1), which are those cows injured one or more times): frequency of mastitis (healthy cows (0), and cows with one or more episodes (1)); and number of lactations (classified into two groups: first lactation and second lactation or more).

Walds chi-square statistics were used to compare lameness prevalence according to explanatory variables using CATMOD procedure of SAS (2009). The procedure computes generalized Wald (1943) statistics, which are approximately chi-square distributed if the sample sizes are sufficiently large and the null hypotheses are true. Further, the association between the frequency of lameness and the explanatory variables was tested by the maximum likelihood analysis of variance, adopting a loglinear model which typified by the Bishop *et al.* (1977) using R version 3.6.1 (2019-07-05). The explanatory variables included in the model were farm, frequency of mastitis injury and number of lactations as well as their one-way interaction.

Adoption of survival functions for analyzing lameness data

Survival analysis is a statistical method used to examine changes over time to a specified event. Analysis and modeling of 'time-to-event' data is the primary objective of survival analysis. The time starting from a specified point to the occurrence of a given event, for example injury is called the survival time and hence, the analysis of group data is referred to the survival analysis (Goel *et al.*, 2010). The technique of survival analysis was used in this study to compare survival of either healthy or lame cows between the four farms, and to assess the association or relationship of explanatory variables with survival time, which is the number of lactations in this study. Survival analysis considers time (the time until a particular event of interest occurs).

The Kaplan-Meier statistic was used to estimate survival functions of lame and healthy cows and elaborate the corresponding plots (Kaplan & Meier, 1958). The graph for the survival function takes stepwise shape with each step representing the probability that an individual cow will not be injured past a particular time "t". At "t=0", the Kaplan-Meier estimator is one and with "t" going to infinity, the estimator tends to zero. Right censoring was considered for cows not becoming lame by the end of the study or prior to abandoning the study before its completion.

The log-rank test was used to test the null hypothesis that the survival probability for lame and healthy cows did not differ significantly and the chi-squared distribution was used to derive a *p*-value. The analysis was performed using R vers. 3.6.1.

Results

Prevalence of lameness injury

Table 1 shows the number and percentage of cows according to number of lameness events in the dairy farms under study. As indicated from the table, no lame cows were observed in DIM farm. In ALM the frequency of lameness episodes ranged between zero (62% of cows) and eight episodes (2 cows) and was highest among first lactation animals.

Risk factors associated with lameness recurrence

Maximum likelihood analysis

Chi-square values for the relationship between the frequency of lameness and farm, frequency of mastitis and number of lactations and their interactions, resulting from the Maximum Likelihood Analysis of Variance are presented in Table 2. Chi square values for the differences among farms, frequencies of mastitis injury, number of lactations and frequencies of lameness injury were significant ($p<0.01$). The interactions between the frequency of lameness injury and each of farm, and number of lactations were also significant ($p<0.01$); however, the interaction between frequency of lameness and frequency of mastitis was not significant. The likelihood ratio measuring the combined effect of terms included in the model was also significant with a chi-squared value of 312.73 ($p<0.01$).

Table 3 shows chi square values for the relationship between frequency of lameness injury and farm and frequency of mastitis injury as classified by frequency of lameness injury along the time frame, which is the number of lactations along the whole life of dairy cows in this case. Differences among healthy or lame cows within the subclasses of farm and frequency of mastitis injury interaction up to the fourth incidence of lameness were significant as indicated from the values of chi square. Differences among cows injured five times or more were not significant. Thus, it is concluded that there was a

Table 1. Frequency of lame cows by farm during the period from 1987 to 2011 in four farms in Alexandria Governorate in Egypt.

Frequency of lameness injury	ALM		DIM		FAR		TAL	
	No.	%	No.	%	No.	%	No.	%
0	826	0.620	101	1.000	207	0.805	138	0.873
1	258	0.194	0	0.000	29	0.113	14	0.089
2	128	0.096	0	0.000	6	0.023	4	0.025
3	61	0.046	0	0.000	8	0.031	1	0.006
4	38	0.029	0	0.000	4	0.016	1	0.006
5	10	0.008	0	0.000	1	0.004	0	0.000
6	2	0.002	0	0.000	1	0.004	0	0.000
7	7	0.005	0	0.000	0	0.000	0	0.000
8	2	0.002	0	0.000	0	0.000	0	0.000
9	0	0.000	0	0.000	1	0.004	0	0.000

ALM=Alamia. DIM=Dima. FAR=Farm Key. Tal=Talaat Mostafa.

Table 2. Chi-square values for the relationship between frequency of lameness and farm, frequency of mastitis injury and number of lactations and their interactions resulted from the maximum likelihood analysis of variance

Source [a]	Degrees of freedom	Chi-square[b]
Farm	3	832.74**
MAST	1	391.44**
CLN	1	51.27**
LAME	1	44.30**
Farm*LAME	2	63.72**
MAST*LAME	1	0.30
CLN*LAME	1	22.08**
Likelihood Ratio	8	312.73**

[a] MAST=mastitis, CLN=number of lactations, LAME=lameness. [b] **Significant at p<0.01

relationship between the frequency of lameness incidence and each of farm and the mastitis incidence, up to four injuries. Such relationship was absent among lame cows injured five times or more up to nine. The correlation (r) between lameness (from 0 to 4 times) and lactation number was significant positive (0.15*) and r between lameness (from 0 to 4 times) and mastitis was also significant positive (0.12*) as shown in Table 3.

Kaplan Meier (K-M) survival analysis

The estimated survival probability, standard errors and 95% confidence intervals according to lactation number for healthy cows and lame cows injured once to nine times are presented in Table S1 [suppl]. The results were further graphically depicted in Fig. 1, offering a visual representation of the predicted survival curves. Survival curves show, for each time plotted on the X axis, the portion of all individuals surviving as of that time. The term "survival" in this case is a bit misleading; however, we use survival curves to study times required to reach an endpoint, whether culling the cow while she was healthy or otherwise, getting injured and hence became lame. The number of events of healthy cows increased up to the third lactation; then it declined up to the eleventh lactation. Similar trend was observed for lame cows injured once. No certain trend was observed for lame cows injured more than two times, except those injured six, eight or nine times which it was unity. All cows, either healthy or lame start at the top (1.0 or 100%) of the y-axis. The curves took a step down similar to the survival percentages shown in Table S1 [suppl]. The observed events resulted in a left to right descending pattern. The K-M plot looks like a

Table 3. Chi square values and correlation coefficients for the relationship between frequency of lameness injury, farm and frequency of mastitis injury and number of lactations.

Frequency of lameness injury	Degrees of freedom	Chi-square value	Correlation coefficient
0	**27**	**153.00****	
1	**27**	143.00**	
2	27	95.30 **	0.15* [a]
3	27	44.20**	0.12* [b]
4	27	42.80**	
5	27	10.60	
6	27	23.50	
7	27	12.30	
8	23	5.30	
9	17	36.00**	

* Significant at p<0.05, ** Significant at p<0.01. [a] Correlation (r) between lameness (from 0 to 4 times) and lactation number. [b] Correlation (r) between lameness (from 0 to 4 times) and mastitis

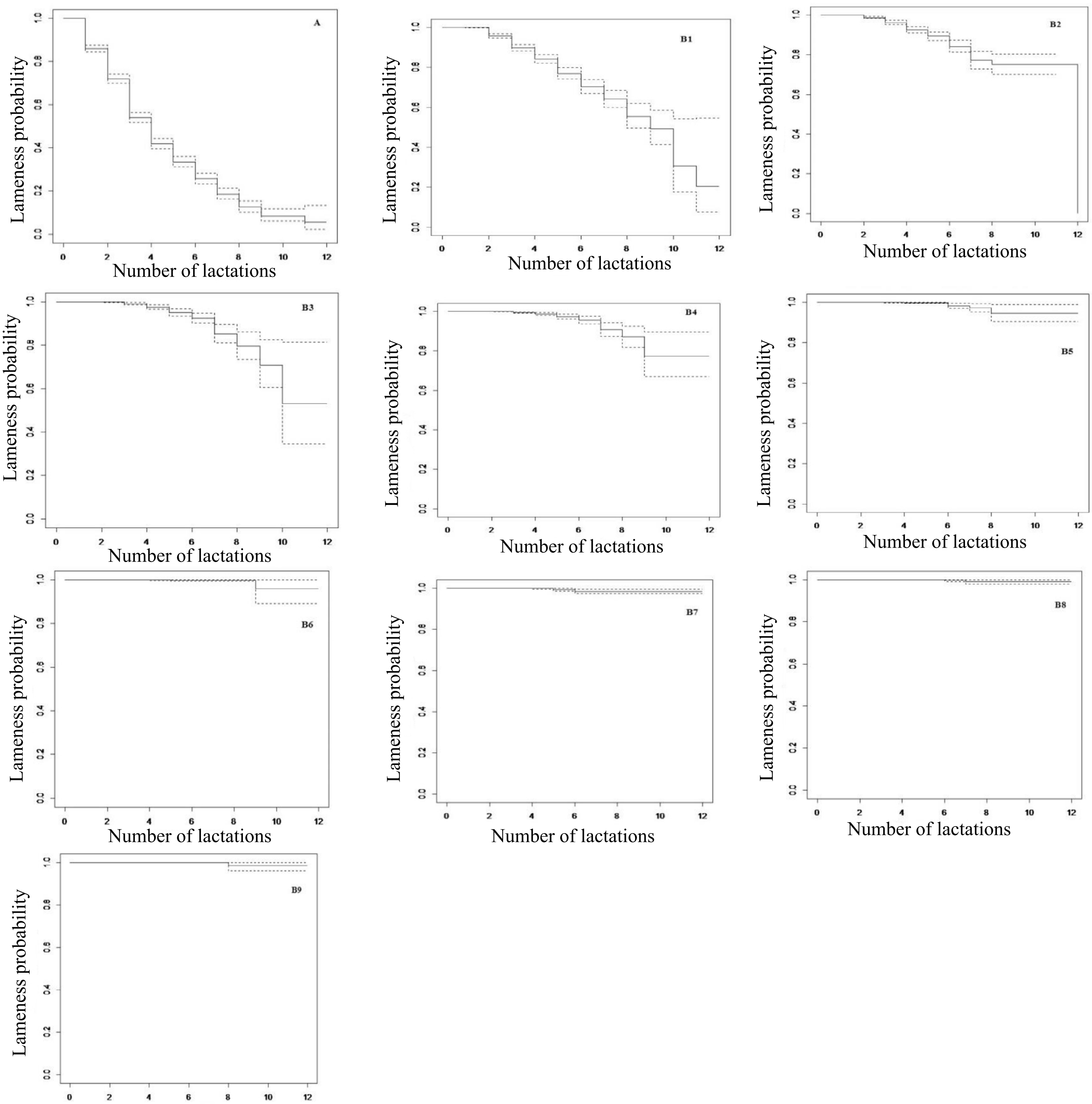

Figure 1. Kaplan-Meier plot for healthy cows (A) and for cows injured once to nine times (B1 to B9)

series of downward steps. The probability of surviving an interval is related to the number of cows, either healthy or lame, in that interval. Each interval is assumed to be independent, and each affects the subsequent interval.

Discussion

This study aimed at identifying the risk factors for lameness incidence of dairy cows in four farms. The prevalence of lameness ranged between zero and 19% in the four farms. The highest percentage of lameness incidence was observed in ALM farm, followed by FAR farm. The observed variation in the incidence of lameness between farms might be attributed to the different management systems, different housing systems and other unmeasured variables. Farm-specific risk factors, such as stall size, have a greater influence on lameness prevalence than outside factors such as climate and facilities such as dietary management, degree of exercise, stocking density, and differences in hoof care programs (Cook, 2003). According to Cook (2003), bedding influences lameness prevalence. In his study, the percentage of lameness in farms on sand bedding was 21.2% compared 33.7% in farms using rubber. Our results indicated that ALM farm with sand bedding had lameness prevalence in the first lactation of 19%, followed by 10% in the second lactation. This result is approximately similar to the findings of Cook (2003) in farms with sand bedding. Prevalence of lameness in FAR where cows were kept on concrete floor was lower than in ALM farm. However, this result should be taken with care because the recording system in this farm was questionable. Overall, the prevalence of lameness in the present study was lower than that reported in two dairy farms in the UK by Mahendran & Bell (2015), which were 23% and 49% ($p<0.001$). In Canada, Solano *et al.* (2015) found that herd-level lameness prevalence ranged from 0 to 69%, with a mean of 21%. Lameness prevalence increased with increasing parity. They suggested that lameness prevalence was higher in herds with less than 100 cows and lower in barns with a sand or dirt stall base. They attributed the wide range of lameness prevalence to the great variability in facilities and management practices among farms (Solano *et al.*, 2015). They concluded that the prevalence of lameness could be decreased by improving management of multiparous, thin, or injured cows and by adopting management practices intended to improve cow comfort, namely the floor's slip resistance and the stall's lying surface (Solano *et al.*, 2015). In the USA, Cook (2003) showed that the prevalence of lameness was seasonal and varied between farms from 21.1% to 23.9%. In Canada, Englebert (2015) found that lameness prevalence was 19% in 2011 and 27% in 2015 ($p<0.05$). A similar prevalence of lameness was also reported by Solano *et al.* (2015) who reported an average prevalence of lameness ranging between 19 to 24% in three Canadian provinces. In Australian dairy herds at pasture, Ranjbar *et al.* (2016) estimated prevalence of cows with lameness to be 18.9%. The prevalence of lameness in a UK study was 39% in in zero-grazing herds (39%) compared to 15% in herds that allowed cows to graze during warmer months (Haskell *et al.*, 2006).

Several works stated that risk factors for laminitis include growth rate, age, parturition, parity, stage of lactation, milk production, feeding and nutrition, behavior, housing, season, hoof trimming practices and reproductive disorders (Greenough & Vermunt, 1991; Smilie *et al.*, 1996; Nocek, 1997; Svensson & Bergsten, 1997). Olechnowicz & Jaskowski (2011) classified factors influencing lameness in dairy cows into two groups: intrinsic factors and extrinsic factors. The most important intrinsic risk factors are season of calving, gestation and stage of lactation, breed and milk yield level, previous injury, parity and season of claw trimming (Olechnowicz & Jaskowski, 2011). The risk of lameness increases with age and milk yield level of cows and claw lesions are also genetically determined (Olechnowicz & Jaskowski, 2011). Extrinsic risk factors influencing lameness of cows are claw disorders and the housing system, including different floor surfaces (Olechnowicz & Jaskowski, 2011). In this study risk factors for lameness prevalence included farm, mastitis occurrence and number of lactations. Huang *et al.* (1995) and Offer *et al.* (2000) also considered increasing number of lactations to be associated with higher levels of lameness. Meanwhile, Kossaibati *et al.* (1999) indicated that the incidence of lameness increased significantly from the fifth lactation onwards. Offer *et al.* (2000) reported higher locomotion scores in lactation 4 when compared to lactations 1 to 3. When sole ulcers occurred in one lactation, they tended to reappear during subsequent lactations (Enevoldsen *et al.*, 1991; Hirst *et al.*, 2002). However, Bradley *et al.* (1989) reported that the incidence of acute laminitis was higher in primiparous heifers when compared to multiparous cows.

Lame cows find it harder to lie down and rise which increases the risk of teat tramps (Rajala-Schultz & Gröhn 1999), which in turn predicts clinical mastitis (Oltenacu *et al.*, 1990; Elbers *et al.*, 1998). In the USA, Hernandez *et al.* (2002) found that lactation number, clinical mastitis, and days in lactation were significantly different between lame and healthy Holstein cows. In a study performed on Holstein cows in two dairy herds, Booth *et al.* (2004) indicated that 45% of dairy cows were diagnosed lame once, 23% twice, 12% three times, and 20% were diagnosed as lame four or more times.

In summary, our results further contribute to our understanding of the importance of lameness in dairy cows in Egypt and report a significant positive association between lameness prevalence, farm features, number of lactations up to the fourth lactation and mastitis. Further studies need to be performed for a better understanding of farm-specific husbandry factors that increase the risk of lameness, to allow designing and implementing prevention and control strategies to reduce the impact of this disease which heavily impacts on dairy cows welfare and production.

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