Vet Res Commun (2017) 41:107–112
DOI 10.1007/s11259-017-9678-9

ORIGINAL ARTICLE

Effects of neonatal diarrhea and other conditions on subsequent productive and reproductive performance of heifer calves

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Received: 26 July 2016 / Accepted: 29 January 2017 / Published online: 3 February 2017

Abstract Diarrhea is one of the most frequent diseases of neonatal calves in dairy herds. The aim of this study was to evaluate the effects of neonatal diarrhea and other conditions on subsequent first lactation milk production and reproductive performance of heifer calves up to the first calving. Seven hundred heifer calves (350 with and 350 without the history of diarrhea in first month of life) were monitored from birth until a year after calving. For each heifer, birth season, birth weight, ease of birth and occurrence of diseases from birth to the end of first lactation were recorded as independent variables. Interval from birth to first service, interval from birth to conception, interval from birth to first calving and 305-days milk yield in the first lactation were recorded as dependent variables. Effects of explanatory variables on productive and reproductive indices were evaluated by survival analysis and general linear model. Heifers with the history of diarrhea during the first month of their lives showed lower daily hazard of conception [Hazard ratio: 0.85 (95%CI: 0.73–0.99)] and calving [Hazard ratio: 0.84 (95%CI: 0.72–0.98)] than those of healthy heifers. Subsequent reproductive performance of heifer calves was also associated with birth season and ease of birth. Further, heifer calves born with birth weight of below 35 kg produced an average of 518 and 506 l less milk in their first lactation compared to calves with a birth weight 40–45 ($p = 0.013$) and greater than 45 kg ($P = 0.033$), respectively. These findings showed that occurrence of neonatal diarrhea and other neonatal parameters are associated with harmful effects on subsequent production and reproductive performance.

Keywords Diarrhea · Heifer calf · Reproduction · Milk production

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Introduction

The main goal in dairy farms is more milk sold and the rearing of heifer for replacement and sale, all of which affect herd profitability (Grohn and Rajala-Schultz 2000). So, farmers try to optimise production and reproductive performance. Raising dairy heifers is one of the most important aspects of whole farm management that can affect these issues. Rearing dairy heifers is characterized as a long-duration, high-cost period that creates a gap in capturing a return on investment. The total cost of rearing young dairy cattle was estimated as 1019$ to 1567€ per successfully reared heifer in different conutries (Gabler et al. 2000; Mourits et al. 2000; Nor et al. 2012). Several management strategies have been proposed and tested to minimize costs associated with raising dairy heifers and to reduce the duration before first calving (Zanton and Heinrichs 2005). Events happening during rearing period can affect growth rate, maturity and subsequent production and reproduction performance. Identification of these events is important for appropriate production and reproduction. Also, it can be used to make more logical decisions about the selection of young stock for replacement (Mourits et al. 2000). Calfhood diseases are an example of problematic events that have a major impact on the economic efficacy of dairy farms, due to the direct costs of calf losses, treatment and the long term effects on performance (Correa et al. 1988; Heinrichs and Heinrichs 2011; Lorenz et al. 2011). Pneumonia and diarrhea especially during

the first months of life are the most frequent and important health issues, which affect growth rate of rearing calves and potentially later productive and reproductive performance (Virtala et al. 1996; Donovan et al. 1998; Van der Fels-Klerx et al. 2002). It has been shown that heifers with a calfhood history of being treated for diseases like diarrhea were more likely to calve later than healthy heifers (Waltner-Toews et al. 1986). Also, heifers with the history of mild diarrhea during their first 3 months of life produced 344 kg lower 305-days milk than those with no history of diarrhea (Svensson and Hultgren 2008).

In many countries neonatal calf diarrhea is one of the most prevalent diseases during the early months after birth (Cho and Yoon 2014; Wymann et al. 2006; Azizzadeh et al. 2012). Incidence risk of calf diarrhea is about 22 cases per 100 animal-months at risk in Iranian dairy herds (Azizzadeh 2012). Information on the effects of neonatal calf diarrhea on later productivity of dairy heifers is scarce. Controlling for the effects of birth season, birth weight, ease of birth and occurrence of other diseases, the objective of this study was to determine the effect of calf diarrhea during the first month of life on subsequent first lactation milk production and reproductive performance of dairy heifers up to the first calving.

Materials and methods

This was a retrospective cohort study. Data for this study were derived from a dairy farm located in Tehran province, Iran. The farm was a large commercial herd that housed about 1200 adult dairy cows and 500 young stock. The herd was comprised of Holstein-Friesian cattle that calve throughout the year and re-bred using artificial insemination. Cows were housed in open-shed barns and milked three times daily. Animals were fed on a total mixed ration. Diets were based primarily on corn silage, alfalfa hay and some concentrates. In the study herd mean parity was 2.5 and average 305-day milk production was 9500 l per cow. Estrus detection was carried out by farm staff according to a planned observation schedule. Cull cows were replaced by homebred replacement reared heifers. Diagnosis of pregnancy was carried out using ultrasonography between 30 and 35 days after breeding.

Calves which were born in the herd were separated from the cow immediately after birth and housed in a single pen for the first three months of life. Pasteurized milk, water and milk replacer were provided from the first day of their life.

The farm was equipped with a computerised system to record herd and individual animal event details. Recording of the health problems, production and reproduction indices were supervised by a full time on-staff veterinarian and a part time reproduction specialist.

From 1360 dairy calves which were born during March 2010 to March 2012, 350 calves diagnosed as diarrheic by the veterinarian during the first month of their life and treated (fluid therapy and antimicrobial and anti-inflammatory therapy) for 3 days or more. All of these heifer calves categorised as exposed group. Among other dairy calves with no record of treatment for diarrhea during the first month of their life, 350 matched calves selected as control group. The two groups were matched on calendar month and year of birth.

Heifer calves were monitored from birth until a year after calving. For each heifer, birth season, birth weight, ease of birth, occurrence of diseases (diarrhea, pneumonia and other diseases which were diagnosed by veterinarian) during the first month of their lives and from the first month to the end of following period were recorded as independent variables. Interval from birth to first service (days), interval from birth to conception (days), interval from birth to first calving (days) and 305-day milk yield in the first lactation were considered as dependant variables. Birth season was coded as a categorical variable with four categories: autumn (September to November); winter (December to February); spring (March to May); and summer (June to August). Birth weight was coded as a categorical variable with three categories: under 35, 35–40, 40–45 and more than 45 Kg. Ease of birth was coded as a categorical variable with three categories: normal (delivery of calf requiring no assistance), mild dystocia (calving event that required intervention by one person without the use of mechanical assistance) and severe dystocia (calving event that required the assistance of 2 or more people or when mechanical extraction was used or surgical procedures were assigned).

Disease occurrence during the first month of their lives and from the first month to the end of following period (based on veterinarian reports) was categorised into two levels: absent and present.

Statistical analysis

To evaluate the effects of independent variables on interval from birth to first service (days), interval from birth to conception (days) and interval from birth to first calving (days), survival (time-event) analysis was used. The association between each explanatory variable and time intervals was tested using the log rank test. Kaplan-Meier survival curves for each level of an explanatory variable were plotted and the homogeneity of the curves between levels tested using the log rank statistic. Explanatory variables that showed an association with dependent variables at $p < 0.20$, were selected for inclusion in the multivariate analysis. A Cox proportional hazard model was used to quantify the effect of each of the prescribed explanatory variables on intervals. To select those explanatory variables that best explained the intervals a backward stepwise approach was used. The significance of each explanatory

variable in the model was tested using the Wald test. Explanatory variables that were not statistically significant were removed from the model one at a time, beginning with the least significant, until the estimated regression coefficients for all retained variables were significant at an alpha level of <0.05.

The effects of explanatory variables on first lactation 305-days milk yield were evaluated by a general linear model. A backward stepwise approach as mentioned in the cox model was performed to select the explanatory variables that were significantly correlated with milk yield.

All analyses were carried out using Stata Statistical Software, release 10.0 (Stata Corporation, College Station, Texas, USA).

Results

Interval from birth to first service, birth to first conception and birth to first calving in 700 dairy heifers with respect to different levels of independent variables are presented as median, first and third quartile in Table 1. Cox proportional hazard model showed that heifers with history of diarrhea at the first month of their lives had on average lower daily hazard of conception [Hazard ratio: 0.85 (95% CI: 0.73–0.99)] and calving [Hazard ratio: 0.84 (95% CI: 0.72–0.98)] than those without the history of diarrhea, resulted in 7 days longer interval of birth to conception and 10 days longer birth to first calving for heifers with history of diarrhea at the first month of their lives ($P < 0.05$; Table 1).

Subsequent reproductive performance of heifer calves was also associated with birth season and ease of birth. Heifers that were born in the summer had a median of 25 days less interval from birth to first service, 20 days less birth to conception and 20 days less birth to first calving compared to heifers that were born in the spring. Also, on average, interval of birth to first service, birth to conception and birth to first calving for cows born with dystocia were shorter than those born normally. Heifers calves that were born with severe dystocia had a median of 7 days less interval from birth to first service, 19 days less birth to conception and 20 days less birth to first calving compared to heifers that were born normally ($P < 0.05$; Table 1).

Three hundred and five-day milk yield with respect to different levels of independent variables are described by mean ± standard deviation in Table 2. Evaluation of factors influencing milk yield in the first lactation period using general linear model showed that higher birth weight resulted in successively higher 305-days milk production at first lactation; calves which were born with a low birth weight (under 35 kg) gave 518 and 506 kg lower 305-days milk than those born with birth weight of 40–45 ($P = 0.013$) and more than 45 kg ($p = 0.033$), respectively (Table 2).

Discussion

Our data originated from only one herd and therefore results might be not representative for a larger population of herds, but it provided useful insights into factors influencing subsequent productive and reproductive performance of heifer calves. The results of the present study showed that neonatal calf diarrhea and some characteristics of heifer calves like ease of birth, birth season and birth weight can influence their future productive and reproductive performance, in the first lactation. Effects of neonatal diarrhea on birth to conception and birth to first calving was in agreement with findings of Waltner-Toews et al. (1986) who reported that heifers with a calfhood history of being treated for diarrhea were 2.86 times more likely to calve after 900 days of age than other calves. Also, slight effects of calfhood occurrences of respiratory and digestive disease on age at first calving reported by Rossini (2004). Increase in time from birth to conception and age at first calving in heifer calves that experience neonatal diarrhea might be due to their lower growth during the rearing period. Neonatal health affects weight and height gain (Wittum et al. 1994; Virtala et al. 1996; Van der Fels-Klerx et al. 2002). Wittum et al. (1994) found that diarrhea during the neonatal period resulted in a 10.7 kg reduction in weaning weight. Moreover, Donovan et al. (1998) predicted a depression in 180 days weight gain of 9.1 kg for heifer calves which were treated for neonatal diarrhea. Poorly grown animals require more services to conceive, calve later and subsequently perform less effectively (Wathes et al. 2008).

Results of the present study showed that heifers that were born in the spring had longer birth to first service, birth to conception and birth to first calving intervals compared to those born in other seasons especially the summer. In the study herd, 13–15 months heifers are prepared for their first service of breeding. So, the first service of breeding for calves born in spring is likely in summer. Mean (minimum, maximum) temperature in our study area was 26.5 °C (14, 43) associated with summer (Iran Meteorological Organization 2014) and it is established that hot weather suppresses the behavioural signs and duration of estrus (Bearden et al. 2004).

Calves that experience dystocia at birth showed better reproductive performance than those born normally. Calves born with dystocia were heavier. The average birth weight for calves born with severe dystocia, mild dystocia and those born normally were 43.5, 42 and 40.6 Kg, respectively. Heavier calves have potential for more weight gain during the prepubertal period (Martin et al. 1962; Mioc et al. 2011), so, they will be eligible for breeding earlier.

We did not find any significant relationship between the occurrence of diarrhea during first month of life and milk production in the first lactation. Our finding is in agreement with Rossini (2004) and Warnick et al. (1995), while it contrasts to results obtained by Svensson and Hultgren (2008) who reported that animals that contracted mild diarrhea during

Table 1 Median and interquartile range of Birth to first service, Birth to conception and Birth to first calving in 700 dairy cows with respect to different levels of independent variables and the results of final cox proportional hazard model

Independent variables	Levels	N	**Birth to first service (days)**			**Birth to conception (days)**			**Birth to first calving (days)**		
			Median(IQR[1])	HR[2*]	P[*]	Median(IQR)	HR	P	Median(IQR)	HR	P
Birth season											
	Spring	71	487(471–510)	Ref		505(480–536)	Ref		780(753–820)	Ref	
	Summer	229	462(450–478)	2.51	<0.001	485(463–513)	1.32	0.040	760(740–790)	1.35	0.030
	Fall	276	466(455–477)	2.27	<0.001	483(463–523)	1.25	0.099	760(735–795)	1.25	0.093
	Winter	120	470(455–492)	1.82	<0.001	500(468–538)	0.98	0.885	770(740–820)	0.96	0.801
Birth weight											
	Under35	73	464(455–485)	-	-	495(464–529)	-	-	770(740–800)	-	-
	35–40	245	468(455–482)	-	-	486(467–523)	-	-	760(740–790)	-	-
	40–45	263	466(452–481)	-	-	490(464–529)	-	-	760(740–800)	-	-
	More than 45	115	470(455–485)	-	-	485(460–525)	-	-	760(740–805)	-	-
Ease of birth											
	Normal	352	470(455–485)	Ref		495(468–528)	Ref		770(745–805)	Ref	
	Mild dystocia	280	466(452–480)	1.19	0.033	483(463–521)	1.19	0.034	760(740–795)	1.16	0.069
	Severe dystocia	64	463(450–473)	1.48	0.005	476(461–504)	1.32	0.045	750(730–780)	1.67	<0.001
Diarrhea during the first month											
	Absent	349	466(452–480)	-	-	485(463–515)	Ref		760(735–790)	Ref	
	Present	347	469(455–485)	-	-	493(467–530)	0.85[a]	0.041	770(744–805)	0.84	0.03
Pneumonia during the first month											
	Absent	682	468(455–483)	-	-	488(465–525)	-	-	760(740–800)	-	-
	Present	14	470(453–480)	-	-	475(460–521)	-	-	750(730–805)	-	-
Other disease during the first month											
	Absent	609	467(453–480)	-	-	487(464–526)	-	-	760(740–800)	-	-
	Present	87	477(465–491)	-	-	492(468–517)	-	-	768(745–790)	-	-
Disease from first month to end of following periods											
	Absent	399	467(451–480)	-	-	486(463–524)	-	-	760(739–797)	-	-
	Present	297	468(455–485)	-	-	491(466–528)	-	-	764(742–800)	-	-

[1] Interquartile range

[2] Hazard ratio

[*] Hazard ratio and *P*-value presented for those independent variables that retained in the final model

[a] Interpretation: Controlling for other condition, the average daily hazard of being pregnant for heifer calves with history of diarrhea in first month of life is 0.85 time of heifer without history of diarrhea in first month of life (the reference category)

Table 2 Mean and standard deviation for 305 days milk yield in 700 dairy cows with respect to different levels of independent variables and the results of final general linear model

Independent variables	Levels	N	Average of Milk yield (kg)± SD[a]	P*
Birth season				
	Spring	70	10,692 ± 1851	-
	Summer	225	10,792 ± 1668	-
	Fall	254	10,924 ± 1466	-
	Winter	119	10,702 ± 1417	-
Birth weight (Kg)				
	Under35	71	10,415 ± 1699	Ref
	35–40	236	10,762 ± 1619	0.098
	40–45	253	10,933 ± 1527	0.013
	More than 45	108	10,921 ± 1450	0.033
Ease of birth				
	Normal	340	10,712 ± 1547	-
	Mild dystocia	266	10,961 ± 1557	-
	Severe dystocia	62	10,758 ± 1734	-
Diarrhea during the first month				
	Present	332	10,828 ± 1538	-
	Absent	336	10,803 ± 1606	-
Pneumonia during the first month				
	Present	14	10,450 ± 1233	-
	Absent	654	10,824 ± 1578	-
Other disease during the first month				
	Present	83	10,946 ± 1507	-
	Absent	585	10,797 ± 1581	-
Disease from first month to end of following period				
	Present	289	10,726 ± 1509	-
	Absent	379	10,884 ± 1616	-
First calving season				
	Spring	80	10,840 ± 1458	-
	Summer	156	10,873 ± 1600	-
	Fall	284	10,887 ± 1582	-
	Winter	148	10,606 ± 1577	-
Calving type				
	Normal	359	10,889 ± 1535	-
	Mild dystocia	184	10,815 ± 1606	-
	Severe dystocia	42	11,016 ± 1694	-
	Stillbirth	58	10,782 ± 1337	-
	Abortion	25	9508 ± 1644	-

[a] Standard deviation

* *P*-value presented for those independent variables that retained in the final model

their first 3 months of life had lower 305-days milk yield than animals without diarrhea. Conflicting results in the literature might be explained by different study periods of recording diseases beside differences in management of diseases. In Iran most of larger dairy farms as well as the study herd had a full time on-staff veterinarian and relatively high numbers of farm staff relative to herd size. So, occurrence of diseases will be diagnosed and treated in early stage.

Our finding showed that birth weight is positively associated with first lactation 305-days milk yield. It might be explained by more weight gain of high birth weight calves during the prepubertal period (Martin et al. 1962; Mioc et al. 2011). Zanton and Heinrichs (2005) concluded that increasing prepubertal gains up to 799 g per day and body weight at calving within the range of 477 to 550 kg tended to increase first-lactation milk production similar to other

investigators (Heinrichs 1993; Hultgren et al. 2007; Heinrichs and Heinrichs 2011).

In summary, our study suggests that calfhood diarrhea and some individual characteristics of heifer calves is associated with lowered productive and reproductive performance during the first lactation period. It must be considered in dairy farm management and selecting replacement heifer calves.

Acknowledgements This study was supported financially by the Research Council of Ferdowsi University of Mashhad, Mashhad, Iran (grant number 3/25588). We would like to thank Prof. Dr. Jalil Mehrzad for his constructive English and scientific revision and correction.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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