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Prediction of pathologic disorders of the reproductive system based on the time of occurrence of the first estrus after calving.

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Abstract

Reasons for performing this study: Cows becoming pregnant in an efficient manner and at a profitable interval after calving is the goal of reproduction management in dairy cattle. Post-partum bacterial infections of the genital tract and post-partum ovarian cysts can lead to a prolonged interval calving-first ovulation. Being able to predict pathologic disorders of the reproductive system, based on the time of occurrence of first heat after calving, detected with a sensor, could make it possible to intervene early. The early diagnosis and treatment of reproductive problems after calving is very important, because it influences herd profitability and is, therefore, of great economic importance.

Objective: Determine if the moment, at which the first estrus after calving, detected with a sensor, occurs, could predict whether the cow has problems in the reproductive tract or not.

Materials & methods: Leg movement activity was obtained of 3107 mostly Holstein-Friesian cows with a pedometer between day 12-30 post-partum. A heat-attention was given if the number of steps for three consecutive 2 h time period exceeded a threshold, i.e. the mean plus 1.4 (x-factor) times the standard deviation of the preceding 4 days. Data of disease registration was available for every cow. Cows were housed in 18 farms, spread over the Netherlands. A bivariate Pearson Correlation in SPSS 24 was applied for statistical analysis.

Results: 59,6 % of all cows received a heat-attention between day 12-30 after calving and 4,2 % of all cows had reproductive problems, mainly located in the uterus. 4 % of the cows who showed no heat-attention, had reproductive problems. Of the cows who showed a heat-attention, 4,3 % had reproductive problems. 59,6 % of the cows who had no reproductive problems, showed a heat-attention. Of the cows who had reproductive problems, 61,5 % showed a heat-attention. 59,5 % of the cows who had no uterine problem, showed a heat-attention. 62,7 % of the cows who had a uterine problem, showed a heat-attention. 59,7 % of the cows who had no ovarian problem, showed a heat-attention. 20 % of the cows who had a uterine problem, showed a heat-attention. Heat-attention versus reproduction problem (P=0.652), heat-attention versus uterine problem (P=0.475) and heat-attention versus ovarian problem (P=0.071) were not significant.

Conclusion: The moment of occurrence of first heat after calving, as detected with the sensor, did not predict whether the cow had problems post partum in the reproductive tract or not.

Keywords: dairy cattle, heat-detection, pedometer, first estrus post-partum, reproduction problem, uterine infection, ovarian cysts

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Introduction

Many papers have been published on the most common uterine diseases. These uterine diseases mainly occur after calving and have a great effect on the fertility of dairy cows [Ghanem et al., 2015; Sheldon et al., 2006]. Cows must attain adequate uterine involution and return to ovarian cyclicity before the end of the voluntary waiting period to become pregnant in a timely manner [LeBlanc, 2008]. So bovine uterine diseases are very important in reproduction management.

Uterine infection

In normal situations, the uterine lumen is sterile before parturition. The cervix, vagina and vulva form a barrier against the entry of bacteria. During parturition, there is an opportunity for bacteria to enter the genital tract, because these barriers are compromised [Sheldon & Dobson, 2004]. There is also a suppression of the immune function from 1 to 2 weeks pre-partum until 2 to 3 weeks postpartum [LeBlanc, 2008]. This is a normal process in cows. In the first 2 weeks following calving 90 % of the cows have microorganisms in their uterus, between days 16 and 30, 78 % of the cows have bacteria in their uterus, between days 31 and 45, 50 % have bacteria in their uterus and between days 45 and 60, 9 % have bacteria in their uterus [Ghanem et al., 2015]. The balance between host immunity and bacteria pathogenicity determines the development of clinical disease. Retained placenta, dystocia, twins, and stillbirth are risk factors for the development of clinical disease [Sheldon et al., 2009].

After parturition, the placenta should be expelled within a few hours [Sheldon et al., 2009]. In the first week post-partum, the uterus contracts rapidly. Physical shrinkage, necrosis and sloughing of caruncles and the regeneration of the endometrium is a normal process in uterine involution. The caruncles are usually sloughed by 12 days after parturition, as result of loss of the allantochorion and necrosis of caruncles. Because the caruncles count for over half of the weight of the uterus, sloughing of the caruncles gives a rapid reduction in weight of the involuting postpartum uterus. The lochial discharge is caused by the sloughed caruncles and the remains of fetal fluids and blood from the ruptured umbilicus. Regeneration of the endometrium first occurs in the inter-caruncular areas and then by centripetal growth of the cells over the caruncle. 25 days after parturition the epithelial regeneration is complete. The deep layers of tissues, however, are not completely regenerated until 6–8 weeks post-partum [Sheldon et al., 2008].

The environment of the uterine lumen after parturition, stimulates the growth of aerobic and anaerobic bacteria. Almost all of these bacteria are contaminants in the uterine lumen. These bacteria can cause an infection of the uterus. Infection implies bacterial adherence to the mucosa, colonization or penetration of the epithelium, and/or release of bacterial toxins that lead to establishment of uterine disease [Azawi, 2008]. Several bacteria can be isolated from the infected uterus. *Escherichia coli*, *Arcanobacterium pyogenes*, *Fusobacterium necrophorum*, *Prevotella melaninogenica* and *Proteus* species are often isolated [Williams et al., 2007; Azawi, 2008; Sheldon et al., 2008]. A. pyogenes, F. necrophorum and Prevotella species can increase the chance of uterine disease and the risk of clinical endometritis and its severity because they have been shown to act synergistically [Sheldon et al., 2008].

In up to 40 % of the dairy cows, uterine disease is present within a week of parturition (metritis). 15 % - 20 % have clinical disease that persists beyond 3 weeks postpartum (endometritis) and 30 % have chronic inflammation of the uterus without clinical signs of uterine disease (subclinical endometritis) [Sheldon et al., 2009]. Metritis occurs within 21 days after calving but is most common within 10 days after parturition. Metritis involves the endometrium, the underlying glandular tissues and the muscular layer [Azawi, 2008; Sheldon et al., 2006; Sheldon et al., 2009]. Metritis is characterized by an enlarged uterus and the uterine discharge is a watery red-brown fluid to viscous off-white purulent material, which often has a fetid odor. Metritis can be present with fever (>39,5°C), decreased milk production and dullness. Metritis without signs of systemic illness is also possible. Clinical endometritis is characterized by the presence of purulent or mucopurulent discharge detectable in the vagina, 21 days or more postpartum. Subclinical endometritis is defined as inflammation of the endometrium in the absence of purulent material in the vagina [Sheldon et al., 2006; Sheldon et al., 2009; McGavin & Zachary, 2012]. Pyometra is characterized by the accumulation of purulent material within the uterine lumen in the presence of a persistent corpus luteum and a closed cervix [Sheldon et al., 2008].

Ovarian cysts

Ovarian cysts are generally defined as follicular structures of at least 2.5 cm in diameter that persist for at least 10 days in the absence of a corpus luteum. Ovarian cysts are often classified into two groups: 1) follicular cysts and 2) luteal cysts [Kesler & Garverick, 1982]. Follicular cysts may be single or multiple on one or both ovaries, are usually thin-walled and secrete small amounts of progesterone; luteal cysts are usually single structures on one ovary, generally have thicker walls and secrete varying amounts of progesterone. Follicular cysts are more common than luteal cysts [Garverick, 1997; Kesler & Garverick, 1982]. Luteal cysts are likely follicular cysts in later stages. In luteal cysts, thecal or granulosa cells, or both, of the follicular cysts luteinize spontaneously and secrete progesterone. However, many follicular cysts do not luteinize spontaneously and remain follicular cysts until subsequent regression and turnover or until treatment. The occurrence of ovarian follicular cysts is a common finding during early post-partum period in dairy cattle. Ovarian follicular cysts have been reported to be one of the main causes of infertility in dairy cattle [Garverick, 1997]. The primary physiological defect leading to the formation of ovarian follicular cysts is a failure of the hypothalamus to trigger the preovulatory surge of luteinizing hormone (LH) in response to GnRH. The factor responsible for this hypothalamic defect may be progesterone. Intermediate levels of progesterone have been shown to prevent ovulation and promote persistence of dominant follicles in normal cycling cows [Silvia et al., 2002]. The disease usually leads to an increased calving interval and is, therefore, considered an important cause of economic loss for the dairy industry. Highest cyst incidence rates have been reported for the intervals before 60 days lactation [Erb & White, 1981] and peaking between 14 and 40 days postpartum [Morrow et al., 1969].

Consequences of bacterial infections of the reproductive system

Cows becoming pregnant in an efficient manner and at a profitable interval after calving is the goal of reproduction management in dairy cattle [LeBlanc et al., 2002]. Post-partum bacterial infections of the genital tract have a great effect on the fertility of dairy cows. Infection can lead to delayed uterine involution and perturbed embryo survival. In addition, pituitary LH secretion is suppressed by uterine bacterial infection, bacterial products or the associated inflammation and perturbs postpartum ovarian follicular growth and function, which disrupts ovulation in dairy cattle [Azawi, 2008]. The growth of dominant follicles in the ovary of cows with uterine bacterial infections is slower and the peripheral plasma estradiol concentrations are lower. If cows with uterine infections ovulate, the peripheral plasma concentrations of progesterone are lower than those in normal fertile animals, and luteal phases are often extended [Williams et al., 2007; Sheldon et al., 2009]. The most important effects of pathologic disorders of the reproductive system are therefore the increased numbers of days to conception, the increased numbers of services needed for conception and an increased risk of culling. The precise economic consequences of these bacterial infections remains largely unknown, but it is speculated up to billions of dollars annually for the global dairy industry [Ghanem et al., 2015].

Estrous cycle

An estrous cycle begins at estrus, consists of a series of predictable reproductive events and ends at the subsequent estrus. The period of sexual receptivity is called estrus. Estrus is commonly referred to as heat. The two major phases in the estrous cycle are the follicular phase and the luteal phase [Senger, 2012]. GnRH is a key neuropeptide controlling reproductive functions and plays also an important role in the regulation of receptive female behavior in cattle [van Eerdenburg, 2008]. Before the article of van Eerdenburg (2008) was published it was assumed that estradiol was the most important regulatory factor for estrous behavior in cattle [Senger, 2012]. Estradiol causes major physiological changes in the genital tract [Senger, 2012]. These changes lead to an environment in the uterus that allows sperm to fertilize the oocyte [Roelofs et al., 2010].

Normally, the estrus approximately lasts 11.8 ± 4.4 hours. The average interval between onset of estrus and ovulation is 30.6 ±4.4 h. Ovulation occurs 18.8 ± 4.4 h after the end of estrus [Roelofs et al., 2005a]. The beginning of the estrus period was determined as the observation period in which the first estrous symptom was seen. The end of estrus was considered as the period in which the last symptom was observed [van Eerdenburg et al., 1996].

After regression of the corpus luteum of pregnancy, there is a variable anovulatory period before first ovulation takes place [Savio et al., 1990]. The calving-to-first ovulation interval is affected by nutrition, body condition, suckling, parity, and uterine disease [Heppelman et al., 2013]. The return to normal cyclic ovarian activity occurs by 10-20 days post-partum [Opsomer et al., 1996] and the interval calving-to-first ovulation lasts from 21 to 30 days in healthy cows. Therefore, the first heat-attention post-partum can be expected within 30 days after calving in healthy cows [Heppelman et al., 2013]. Puerperal uterine diseases may prolong the anovulatory interval by up to 10 days [Zain et al., 1995].

Silent estrus

The first post-partum ovulation in lactating dairy cows is often a so called ‘silent’ estrus [Roelofs et al., 2010]. A silent heat means that there’s a lack of evident signs of estrous behavior, although there is normal follicular development [Zduńczyk et al., 2005; Senger, 2012]. Only through rectal palpation, ultrasound of the ovaries or by measuring progesterone in milk or plasma, silent heats may be detected [Opsomer et al., 1996; van Eerdenburg et al., 1996]. Among different herds, the incidence of silent heat varies from 10 % to 40 % [Zduńczyk et al., 2005]. The progesterone that is released from the corpus luteum after the silent ovulation stimulates estrus expression during the next ovulatory cycle. So, the second and following estrous periods are most of the time accompanied with a better expression of estrous behavior [Roelofs et al., 2010]. However, the modern cow has a much lower level of expression than before [van Eerdenburg et al., 1996; Roelofs et al., 2010]. This leads to the fact that many estruses are missed.

Estrus detection

As mentioned before, cows becoming pregnant in an efficient manner and at a profitable interval after calving is the goal of reproduction management in dairy cattle [LeBlanc et al., 2002]. A good detection of estrus and successfully inseminating cows is critically important to achieve this goal [Roelofs et al., 2010]. The missing of estrous periods influences the herd profitability. There are longer calving intervals, the conception rates decrease and there is more wasted semen. These parameters lead to economic losses [Ghanem et al., 2015; Roelofs et al., 2010].

There are several methods to detect estrus: visual observation, changes in body temperature, changes in vaginal mucus resistance, recording of mounting activity and also increase in number of steps around estrus [Roelofs et al., 2005b]. In the early 1950s of the last century, activity (measured by pedometers) of dairy cows during estrus was first studied [Farris, 1954]. Farris (1954) showed that the estrous period in dairy cows is characterized by an increased number of steps. The increase in number of steps is a tool for accurate detection of estrus. Reported detection rates of pedometers are often above 80 % [Firk et al., 2002; Lehrer et al., 1992]. Detection rates of 100 % are also reported [Schofield et al., 1991; Arney et al., 1994]. The threshold that is used to define an increase in activity as an estrous period and the time period that is used to record the number of steps affect detection rates [Roelofs et al., 2005b]

Detection of estrus with pedometers can be performed by utilisation of different threshold values. Most common are thresholds of relative increases compared to earlier measurements [Firk et al., 2002]. Roelofs et al. (2005b) described two different methods to calculate an increase in the number of steps (measured by a pedometer): one based on the median number of steps and the other based on the standard deviation of the average number of steps. In both methods, the number of steps recorded in a 2 h time period is compared with the number of steps made in the same time period during the 10 preceding days. Comparisons are done per 2 h time period, because of the presence of a diurnal pattern in number of steps during diestrus [Koelsch et al., 1994; Arney et al., 1994] and therefore it is more precise to record the number of steps in small time periods [Roelofs et al., 2005b; Moore & Spahr, 1991; Liu & Spahr, 1993].

In the median method, the number of steps taken in a particular 2 h time period is divided by the median number of steps of the 10 preceding days. For every 2 h time period, a ratio is calculated. If this ratio exceeds a threshold, for example, 10.0 for one period (MED10) or 5.0 for two consecutive periods (MED5), this is defined as an actual increase in number of steps and designated as an estrus alert based on pedometer readings. In the method based on the standard deviation, the mean and standard deviation of the number of steps is calculated for the 10 preceding days. If the number of steps for a particular 2 h time period exceeds a threshold, i.e. the mean plus, for example, 2 (called x-factor) or 2.5 times the standard deviation of the preceding 10 days, this is defined as an actual increase in number of steps. If this increase occurs, for example, for two consecutive periods, this is defined as a pedometer estrus alert. If one period with increased activity would be considered a pedometer estrus, the percentage of correct pedometer estrus alerts would increase, however, the number of false pedometer estrus alerts would increase tremendously [Roelofs et al., 2005b]. Therefore, it appeared to be better to take 2 or 3 consecutive periods of increase to define a pedometer estrus alert.

A pedometer estrus alert can, for example, be defined as correct, when it is accompanied by behavioral estrus or when ovulation is confirmed by ultrasound of the ovaries or progesterone in the milk. A pedometer estrus alert can, for example, be defined as false, when it is not accompanied by a behavioral estrus and be defined as missed, when behavioral estrus (followed by ovulation) is not accompanied by a pedometer estrus alert [Roelofs et al., 2005b].

Roelofs et al. (2005b) showed in their study that the method based on the standard deviation (threshold of S.D. 2 and S.D. 2.5) resulted in the highest percentage of correct pedometer estrus alerts (87 %). The methods that use the median (MED10 and MED5) resulted in poor percentages of correct pedometer estrus alerts (51 % and 52 %, respectively).

A previous study in this large research project, Sense of sensors in transition management, showed that comparing the number of steps taken in a 2 h time period with the number of steps taken in the same time period during the 10 preceding days was not sufficient to detect the first estrus after calving [de Groot et al., 2016]. From previous results in the Sense of sensors in transition management project it appeared that the first few days after parturition the number of steps is higher than normal [de Groot et al., 2016]. It is, therefore, likely that the first estrus is missed, because of the fact that the days with a high number of steps after parturition are included in the algorithm. It could be better to use only 4 days in the moving average to compare the actual number of steps with.

Purpose of this study

The objective of this study was to investigate if the moment, at which the first (silent) estrus after calving occurs, is a prediction whether the cow has problems in the reproductive tract or not. If the moment of first estrus is a good prediction, every cow with an extended interval between calving and the moment of first estrus have to be examined for reproductive problems. If there are, for example, problems like metritis or cystic follicles present they should be treated. The early diagnosis and treatment of reproductive problems is very important because it influences herd profitability and is therefore of great economic importance. We make use of sensors to identify cows with an extended interval between calving and the first heat. The sensor registers the activity of the cows and gives an alert if a cow is in heat. If no alert occurs within 12-30 days (first ovulation post-partum can be expected within 12-30 days in healthy cows [Heppelman et al., 2013; Opsomer et al., 1996] after calving we have to examine the cow for reproductive problems. So clinically, the challenge is to identify those cows that are truly at risk of impaired fertility, expecting that treatment can be administered early to correct the problem.

Hypotheses

H0: Dairy cows that do not receive an estrus attention between 12-30 post-partum, detected with activity sensors, do not show specific pathologic disorders of the reproduction system after calving.

H1: Dairy cows that do not receive an estrus attention between 12-30 post-partum, detected with activity sensors, show specific pathologic disorders of the reproduction system after calving.

Material & Methods

Sensors and heat detection

In this study, we used a G-sensor. This sensor is able to measure movement in three directions and is equipped with active radiofrequency identification (RFID) for identification of the animals.

The G-sensor is made by Nedap (Groenlo, the Netherlands) and is called SmartTag Leg (fixed on a leg). Walking behavior (number of steps) is measured by the SmartTag Leg in periods of two hours. The number of steps taken in a 2 h time period was compared with the number of steps taken in the same time period during the 4 preceding days. The mean and standard deviation of the number of steps was calculated for the 4 preceding days. If the number of steps for a particular 2 h time period exceeded a threshold, i.e. the mean plus 1.4 (called x-factor, see below) times the standard deviation of the preceding 4 days, this was defined as an actual increase in number of steps. If this increase occurred for three consecutive 2h periods, this was defined as a pedometer estrus alert. A pedometer estrus alert was defined as correct, when there was only one continuous period of alerts between day 12-30. A pedometer estrus alert was defined as false positive, when there was more than one period of alerts between day 12-30 (one of these periods of alerts was probably correct, but the others were false positive), and as missing, when there was no alert.

The estrus attentions were available from 10 days pre-partum to 70 days post-partum. For this study, we only took the period 12-30 days post-partum in consideration.

X-factor

In order to determine which x-factor was optimal, the number of cows with a heat-attention (total heat-attentions, false pos. heat-attentions included), the number of cows with a false positive heat-attention (false pos. heat-attention is a part of the total heat-attentions), the percentage of false positive heat-attentions and the difference in percentage false positive heat-attentions for the consecutive x-factors were calculated for the x-factors 1.0 - 2.0 (1.0, 1.1, etc.) (Table 2). The optimal x-factor is the x-factor with a high number of heat-attentions and a low number of false positive heat-attentions.

Animals

Mainly Holstein-Frisian breed cows from 18 different dairy farms, located in the East and South of the Netherlands participated in this study. Cows of different parity were equipped with the SmartTag Leg. Heat-attention information between day 12-30 post-partum was available for 3107 cows (a cow could have calved several times, but at each new calving, the cow was considered as a new cow). The disease registration after parturition of these cows was available. The cows were monitored from 42 days pre-partum until 28 days post-partum.

Housing and management

On 15 farms, there are 100-150 cows (including dry cows) and 3 farms have more than 300 cows (including dry cows). On 8 farms milking was done with an automatic milking system (AMS) and there were 10 farms who milked with a milking parlor. The farms used different types of bedding. 9 farms had matrasses, 7 farms deep litter bedding and 2 farms had a combination of matrasses and deep litter bedding. Almost all farms (16) had slatted floors, 2 farms had a solid floor. On some farms, the cows calved on a slatted floor, other farms kept their cows on straw from 10 days before calving and let them calf on straw. Manure is scraped on most farms by an automatic robot scraper (10), 6 farms have a manure scraper and on 2 farms the manure was scraped by hand or with a tractor.

Feeding was done by different management strategies. The cows were fed corn- and grass silage and some farmers also fed byproducts like soy, pulp and brewers grain. The concentrates were fed separately by some farmers and others fed via a TMR system. The dry cows were fed with lesser quality grass silage, the same feeding as the milking cows, structure rich products (straw of grass-seed hay) or with residues of the milking cows. On some farms, the cows were kept inside throughout the year. On other farms, the cows had access to pasture during the lactation, dry period, or both, in summer.

Disease registration

Data of disease registration was available for every cow. For each cow in this study there was a form. On this form, the farmer recorded the date of parturition, time of parturition, progression of parturition (no help, light traction, moderate traction, severe traction, cesarean section), at which time the calf was separated from the mother (immediately after birth, within 1h, 4h, 12h, 24 h, >24h), when the placenta is expelled (within 6h, 6-12h, 12-24h, >24h), if there was a treatment for retained placenta and disease registration. For the disease registration, the farmer could tick or circle various diseases and their treatment. These diseases were: mastitis, lameness, left abomasal displacement, ketosis, and milk fever and there was also space available to record other diseases (like cystic ovaries, metritis, endometritis) and treatments.

Data arrangement/analyzes

The analyzed data from Nedap database was processed in Excel (Table 1).

Farm no.	Cow no.	Lifeno.	Calving date	Heat-attention	Reproduction problem	Uterus problem	Ovarian problem
3	93	NL 768066450	1-11-2014	1	1	0	1
3	129	NL 485420094	10-7-2015	0	1	1	0

Table 1. Example of the analyzed data. (The reproduction problems are divided in uterine problems and ovarian problems. Number 1 means a heat-attention/reproduction problem/uterus problem/ovarian problem. Number 0 means no heat-attention/reproduction problem/uterus problem/ovarian problem).

Statistical analysis

For this study a bivariate Pearson Correlation in SPSS 24 (International Business Machines (IBM), New York) was applied. Relations were considered significant when P <0.05.

Different bivariate Pearson Correlations were performed: total heat-attentions (including false pos. heat-attentions) versus reproduction problem, total heat-attentions versus uterine problem and total heat-attentions versus ovarian problem.

Results

X-factor

The number of cows with a heat-attention (total heat-attentions, false pos. heat-attentions included), the number of cows with a false positive heat-attention (false pos. heat-attention is a part of the total heat-attentions), the percentage of false positive heat-attentions and the difference in percentage false positive heat-attentions for the consecutive x-factors are calculated for the x-factors 1.0 - 2.0 (1.0, 1.1 etc.) (Table 2). The optimal x-factor is the x-factor with a high number of heat-attentions and a low number of false positive heat-attentions. X-factor 1.4 is used in this study because of the big drop in percentage false positive heat-attentions (3.6 %) between x-factor 1.3 and 1.4. The drop in percentage false positive heat-attentions between x-factor 1.0 and 1.1 is bigger, but the percentage false positive heat-attentions is also higher for x-factor 1.1 (70.8 %).

Heat-attentions

The outcome of the bivariate Pearson Correlation was not significant for total heat-attentions versus reproduction problem (R=0.08, P=0.652), total heat-attentions versus uterine problem (R=0.013, P=0.475) and total heat-attentions versus ovarian problem (R=-0.032, P=0.071). Individual farms also showed no significance between these parameters.

Heat-attention information was available for 3107 cows. 59,6 % of these cows showed a heat-attention between day 12-30 post-partum and 40,4 % showed no heat-attention. 130 cows (4,2 %) showed reproduction problems (Table 3 and Graph 1). 125 problems were located in the uterus, 4 problems were located in the ovarium and 1 problem was located in both uterus and ovarium.

Of the 1254 cows that showed no heat-attention, 4,0 % (n=50) had reproduction problems. 46 of these problems were located in the uterus, 3 problems in the ovaria and 1 problem in both uterus and ovaria. Of the 1853 cows that showed a heat-attention, 4,3 % (n=80) had reproduction problems. 79 problems were located in the uterus and 1 problem was located in the ovaria (Table 4 (numbers with green color) and Graph 2).

Of the 2977 cows that had no reproduction problem, 59,6 % (n=1773) showed a heat-attention and 40,4 % (n=1204) showed no heat-attention. Of the 130 cows that had a reproduction problem, 61,5 % (n=80) showed a heat-attention and 38,5 % (n=50) showed no heat-attention (Table 4 (numbers with blue color) and Graph 3).

Of the 2981 cows that had no uterine problem, 59,5 % (n=1774) showed a heat-attention and 40,5 % (n=1207) showed no heat-attention. Of the 126 cows that had a uterine problem, 62,7 % (n=79) showed a heat-attention and 37,3 % (n=47) showed no heat-attention.

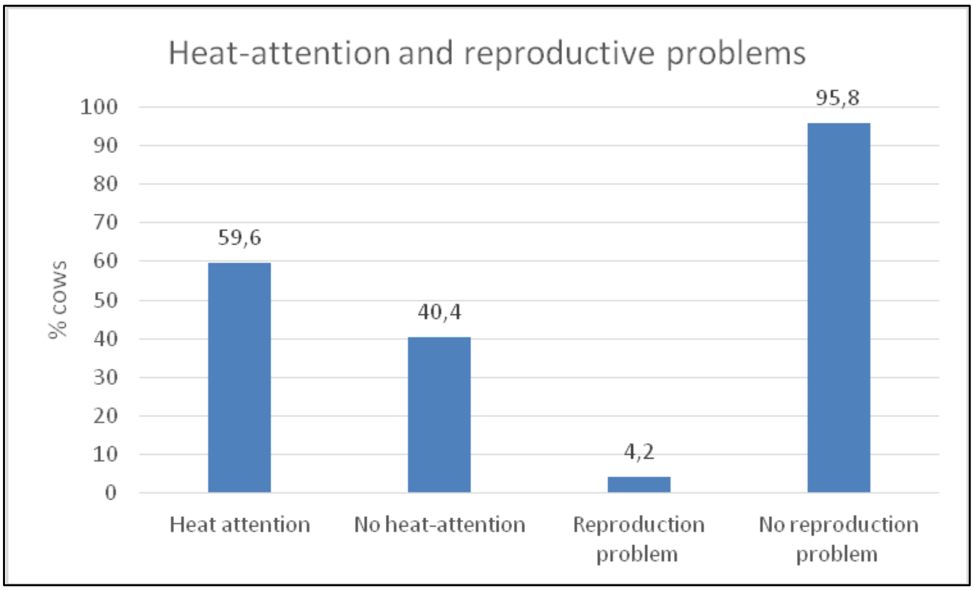
Of the 3102 cows that had no ovarian problem, 59,7 % (n=1852) showed a heat-attention and 40,3 % (n=1205) showed no heat-attention. Of the 5 cows that had a uterine problem, 20 % (n=1) showed a heat-attention and 80 % (n=4) showed no heat-attention.

X-factor	Total heat-attentions	False pos. heat-attentions	% false pos. heat-attentions	Difference in % false pos. heat-attentions
1	2349	1777	75.6	
1.1	2227	1577	70.8	4.8
1.2	2086	1409	67.5	3.3
1.3	1965	1259	64.1	3.5
1.4	1853	1120	60.4	3.6
1.5	1735	998	57.5	2.9
1.6	1622	897	55.3	2.2
1.7	1525	814	53.4	1.9
1.8	1444	749	51.9	1.5
1.9	1379	686	49.7	2.1
2	1307	638	48.8	0.9

Table 2. Calculated heat-attention data for x-factors 1.0 - 2.0.

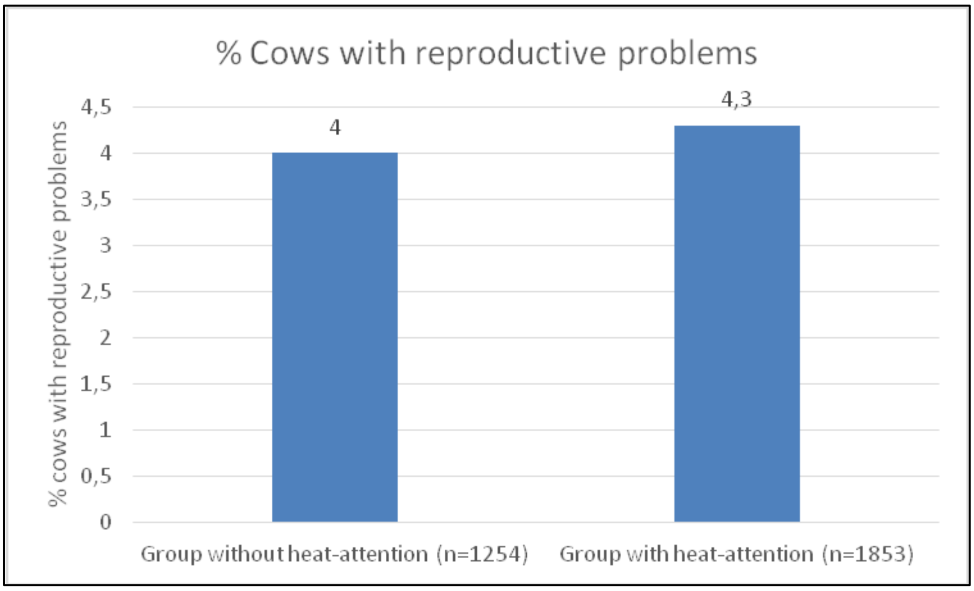
	Reproduction problem	**No reproduction problem**	**Total**
Heat-attention	80 (2,6 %)	1773 (57,0 %)	1853 (59,6 %)
No heat-attention	50 (1,6 %)	1204 (38,8 %)	1254 (40,4 %)
Total	130 (4,2 %)	2977 (95,8 %)	**3107**

Table 3. Results of the analyzed data.

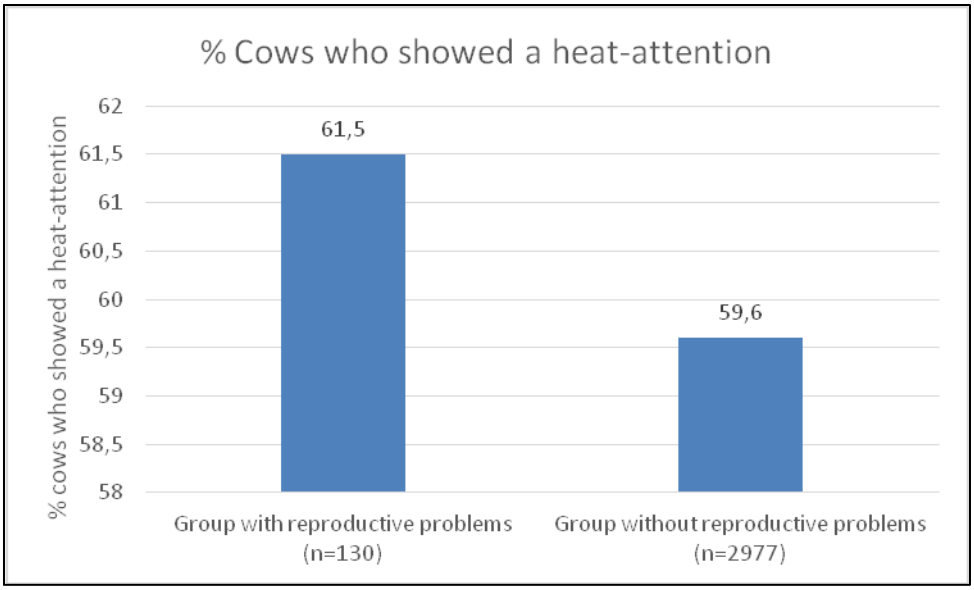


Graph 1. Percentage of cows with heat-attentions and reproductive problems.

Prediction of pathologic disorders of the reproductive system based on the time of occurrence of the first estrus after calving.



Graph 2. Percentage of cows with reproductive problems within the group of cows with and without a heat-attention.



Graph 3. Percentage of cows who showed a heat-detection within the group of cows with and without reproductive problems.

	Reproduction problem	**No reproduction problem**	**Total**
Heat-attention	80 (4,3 %) (61,5 %)	1773 (95,7 %) (59,6 %)	1853 (100 %)
No heat-attention	50 (4,0 %) (38,5 %)	1204 (96,0 %) (40,4)	1254 (100 %)
Total	130 (100 %)	2977 (100 %)	**3107**

Table 4. Results of the analyzed data. (The green colors are percentages of the total number of 'heat-attentions' (n=1853) and total number of 'no heat-attentions' (n=1254). The blue colors are percentages of the total number of 'reproduction problem' (n=130) and total number of 'no reproduction problem' (n=2977)).

Discussion

Silent estrus

The results of this study showed that 59,6 % of the cows had a heat-attention within 30 days after calving, detected with pedometers. In contrast to the leading opinion that the first estrus is often a silent estrus and is therefore not detected [Roelofs et al., 2010], our results indicate that a substantial number of cows do show their first heat after calving. They show an increase in number of steps. Two major requirements are needed for good estrus detection: a skilled observer must spend sufficient time on the observations and cows have to show overt signs of estrus during those observations [van Eerdenburg et al., 1996]. Standing heat is the most discriminative sign of estrus, but not all cows express this behavioral sign [van Eerdenburg et al., 1996; Roelofs et al., 2005b; Roelofs et al., 2005a]. When, in practice, estruses are detected only using this behavioral sign, many estruses will be missed [Roelofs et al., 2005b]. It becomes clear that signs other than standing heat are important to detect cows in estrus. Behaviors that are more displayed during estrus, compared to non-estrus, are resting with the chin on the rump of another cow, being mounted but not standing, (disorientated) mounting, sniffing the vulva of another cow, restlessness, also licking, rubbing, and aggressive behavior like head butting. The above-mentioned changes in behavior can be observed by the herdsman [Roelofs et al., 2010]. With the inclusion of these signs in an estrus detection protocol, a cow can be detected in heat without showing standing heat (van Eerdenburg et al., 1996). When observations were performed twice a day for half an hour on standing heat alone, 19 % of the cows were detected in heat. When observations were done 3 times per day for 30 min, this percentage increased to 30 %. The percentage of heat detection even increased to 90 %, when all the behaviors mentioned above were included 3 times per day for half an hour [Roelofs et al., 2005a]. Another study found a detection rate of 12 % with three observations of half an hour daily only observing standing heat and a rate of 74 % was found when all the behaviors were included [van Eerdenburg et al., 1996]. Besides the ability of the farmer to recognize and interpret several behaviors that indicate if a cow is in estrus, estrus detection depends also on the time that is invested in estrus detection. Timing of observation on the day, time spent on estrus detection, and frequency have a large effect on estrus detection rates [Roelofs et al., 2010].

Confirming pedometer estrus alert

In our study, we assumed that a pedometer estrus alert meant that the cows is in estrus. The pedometer estrus alert was not confirmed by behavioral estrus signs, ultrasound of the ovaries or progesterone measurements in the milk. Changes in progesterone level have a strong correlation with estrus and can be measured in milk or blood plasma [Firk et al., 2002]. Combining activity (with pedometers) and progesterone measurements is expected to lead to improved prediction of reproductive status [O'Connell et al., 2011]. Therefore, the accuracy of heat-detection in this study would probably have been improved when we had combined the pedometer estrus alert with progesterone measurements.

Heat-attentions

A percentage of 60 % false positive heat-attentions was found in this study by using the x-factor 1.4. It is important to have a high detection percentage and a high accuracy, for pedometer readings to be useful as estrous detection as well as predictor of ovulation time [Roelofs et al., 2005b]. In our experiment, using a threshold based on the mean of the 2 h time periods during 4 days prior plus 1.4 times the standard deviation appeared to give the best results in terms of accuracy and detection. In this study, it was not important to find the exact moment of estrus, but we wanted to find out if there was an estrus alert given within 30 postpartum. The purpose was not to determine the moment of insemination, but to determine the predictive value of an estrus alert on pathologic disorders of the reproductive system. Therefore, we chose a relatively low threshold (x-factor 1.4).

The percentage of measured false pedometer estrus alerts, differs considerably in previous reports [Moore & Spahr, 1991; Peter & Bosu, 1986; Holdsworth & Markillie, 1982]. The percentages differ from 0 % [Peter & Bosu, 1986] to 205 % [Moore & Spahr, 1991] or more [Holdsworth & Markillie, 1982]. The use of different threshold definitions, different periods (e.g. 12 h instead of 2 h periods) or different management (e.g. automatic milking system, different floor surface) may explain these large differences between the different experiments. In a study of Koelsch et al. (1994), was found that a likely source of false estrous indications by pedometer readings were altered routines. So, the occurrence of pedometer estrus alerts should be interpreted with caution after alteration of the daily routine. Therefore, for pedometer readings to have a high detection percentage and a high accuracy, it is important to have a daily routine in practice. If a farmer wants to detect as many estruses as possible, the consequence is that there will be more false pedometer alerts. And if a farmer wants to know for sure that a pedometer estrus alert is correct, there will be more missed pedometer estrus alerts. So, in the end it is up to the farmer to choose a threshold that fits his wishes the best.

Reproduction problems

4,2 % of the cows in this study showed reproduction problems. This percentage is much lower than is mentioned in previous reports. Sheldon et al., (2009) stated that in up to 40 % of the dairy cows, uterine disease is present within a week of parturition (metritis). Subsequently, clinical disease that persists beyond 3 weeks postpartum (endometritis) is present in 15 % - 20 % of cattle and chronic inflammation of the uterus without clinical signs of uterine disease (subclinical endometritis) is present in 30 % of cattle [LeBlanc et al., 2002; Gilbert et al., 2005]. The lower percentages of reproduction problems within 30 days after calving in the present study could be explained by the fact that disease registration was done by the farmers. Most farmers are able to detect a clinical metritis or clinical endometritis when there is fetid discharge present, but detecting subclinical endometritis and cystic ovaries is much more difficult for farmers. Traditionally, clinical diagnosis of cysts has been based on the reproductive history of the cow and the detection of a smooth, fluid-filled structure about 2.5 cm in diameter on the ovary by palpation per rectum performed by experienced clinicians. Using ultrasound to detect cysts increases accuracy. Diagnosis and treatment usually occur following one examination [Garverick, 1997]. So, the fact that disease registration is done by farmers could explain the low numbers of uterine and ovarian problems that have been diagnosed in this study. In addition, the reporting of the reproduction problems by the farmers must be done punctually. It is possible that not all farmers have recorded the reproduction problems accurately. Therefore, it is likely that the recorded reproduction problems in this study, is an underestimation of the actual number of reproduction problems.

Conclusion

There was no relationship between the time of occurrence of first estrus after calving and the presence of problems in the reproductive tract. Distinction is made between total heat-attentions versus reproduction problems, total heat-attentions versus uterine problems and total heat-attentions versus ovarian problems. Individual farms also show no significance between heat-attentions and reproduction problems. The low number of noted reproduction problems can be explained by the ability of the farmer to detect uterine and ovarian problems and notation of the findings by the farmer. Further research, where detection of reproduction problems is done by experienced clinicians, could be worthwhile to investigate if in that situations there is a relationship present between the time of occurrence of first estrus after calving and the presence of problems in the reproductive tract.

Acknowledgments

I would like to say thanks to my supervisors F.J.C.M van Eerdenburg and P.R. Hut for guiding me in this research and linking me with the participating farms and the Nedap research. I thank the farm owners and staff for making it possible to collect data on these farms. I also would like to say thanks to the people of the faculty of University of Utrecht Department of Farm Animal Health who helped me with data analysis and for assisting writing this paper. This research was funded by Nedap (Groenlo, the Netherlands) and is part of the project, Sense of sensors in transition management.

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