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Behavioural risk factors associated with abnormal health in dairy cattle: A review

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ABSTRACT

Changes in living organisms' internal environment are generally expressed by behavioural signs, which reflect the health status of animals and considered as true indicator of illness. In traditional animal husbandry system, the simple way to recognize the illness in animals only when they become depressed or off fed. Changes of feeding, drinking/suckling, lying, standing, social and rumination behaviour can be helpful for early prediction or identification of abnormal health in dairy cattle. Tail raising, pawing, restlessness, looking back to abdomen, hunching of back, rubbing against wall and urination behaviour can predict the incidence of dystocia in dairy cows. In addition, walking/stepping, turning head against udder and self grooming behaviour also alter in cows and can be helpful for early prediction or identification of abnormal health. Validation of disease specific behavioural risk factors using automatic electronic monitoring system in a particular farm with defined housing design and management practices can improve the accuracy of prediction or identification of cows that are going to develop ill health. Therefore, managemental interventions at proper time based on behaviour change can be utilized as effective means to reduce the subsequent abnormal health in dairy cattle.

Key words: Behavioural risk factors, Dairy cattle, Disease, Management intervention

Behaviour is defined as "the internally coordinated responses (actions or inactions) of whole living organisms (individuals or groups) to internal and/ or external stimuli, excluding responses more easily understood as developmental changes"[40]. Any change in internal environment of living organisms is reflected by behaviour to maintain the homeostasis mechanism of body. Sick animals can be identified based on depression or off feed condition in conventional system. The father of modern medicine, Hippocrates also reported in his book "The Book of Prognostics" that keen observation of behavioural signs expressed by the animal could be helpful for identification of disease[67]. The behavioural signs of animals are not only altered during disease condition but also much earlier prior to its onset because all diseases undergo through an incubation period during which the deviation of body physiology from normal state occurred. Recent development of automatic electronic behaviour monitoring system further increases the accuracy of behaviour monitoring, generates error free and repeatable behavioural information and further improves the reliability of prediction or identification of diseased animals in advance. Therefore, it is one of the important aspects to review critically the association between behaviour and health in dairy cows.

DAIRY COW'S DAILY TIME BUDGET

Before discussing the behavioural alteration in dairy cows one should have knowledge regarding their daily time budget. The daily time budget of a cow is presented by ethogram which is defined as "the detailed description of 24 hours behavioural patterns in a day", reflects her net response to surrounding environment[8]. The daily time budget of

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a dairy cow includes the duration of activities like feeding, lying/resting, rumination, drinking, milking, social interaction and travel time along with milking[26] (Table 1).

Table 1. Daily time budget of lactating cow

Types of activities	Time spent in each activities per day
Feeding	3-5 hours (9-14 meals/day)
Lying/resting	12-14 hours
Rumination	7-10 hours
Social interactions	2-3 hours
Drinking	0.5 hours
Milking and travel time	2.5-3.5 hours

(Source[9, 26])

Lactating dairy cows spend more time in lying/resting followed by rumination, feeding and social interaction. In high yielder cows, the lying or resting period is close to 14 hours but low yielder it is approximately 10-12 hours[26]. After long term deprivation of lying if opportunity is given for both feeding and lying then cow prefers for lying[29]. In any herd deviations from the routine behaviour represent alteration from natural behaviour and can serve as a basis for estimating the health and welfare of the dairy cows. In addition to these behaviours, there are certain behaviours like tail raising, frequent micturition, pawing or scrapping on floor, rubbing against wall, transitioning from lying to standing behaviour are exhibited frequently and can be helpful for early prediction or identification of calving time and calving difficulty [44, 45]. Walking/stepping activity indicates the restlessness behaviour in dairy cows and deviates from the base level before a cow develope to abnormal health[19]. Self grooming behaviour and turning head against udder alter markedly in cows with udder infection which are adaptive response to cope with the disease and further helpful for early identification of udder infection[21].

FEEDING BEHAVIOUR AND HEALTH

Empirical research regarding association between feeding behaviour and health has been initiated in feedlot steers. Healthy steer spends 30% more time in feeding and 10% more number of feeding visits to the feed manger compared to unhealthy steers[62, 63]. Sick steers reduce their feeding time approximately 4 day prior to clinical diagnosis[56]. Though the research has been initially focussed on feed lot steers but gradually shifted to dairy cows for identification of infectious and metabolic diseases as well as calving difficulties based on behavioural changes from normal bench mark as early as possible before actual onset of disease. Post-partum metritic Holstein cows spend approximately 21-27%[65] and 8-19%[33] less time in feeding during the precalving period depending on severity of infections compared to normal cows. The risk of metritis development also increases by 1.57-1.72 times for every 10 min decrease in daily feeding time during pre-partum period[33, 65]. Dairy cows associated with ensuing dystocia decrease their daily feeding time by 34 min (24.28%) during 24 h prior to calving than cows without calving difficulty[52].

Like uterine infections, the feeding behaviour of dairy cows also alters in metabolic diseases. The ketotic cows reduce their feeding time and number of daily visit to manger by 45.5 min and 11 visits/day, respectively before 3-5 days of diagnosis[25]. The feeding behaviour not only changes in clinical ketosis condition, but also in sub-clinical ketosis (SCK). Goldhawk *et al.*[24], observed lower daily feeding time and less number of feeding visits to manger in SCK cows one week prior to calving and reported increased risk of development of SCK by approximately 2 times for every 10 min decreased in pre-partum feeding time. Similar to feeding time, the reduction of 10 visits to manger per day increases risk of development of SCK by 3.5 times in dairy cows[24].

In dairy cows with acute locomotory disorder, the feeding time and frequency of visit to feeder starts declining 3 to 15 days (average 7.7) from day of onset till its clinical diagnosis by 19 min/d and 10 visits/day, respectively; however to compensate daily requirement feeding rate increases[25]. The variation in feeding behaviour in lame cows may be attributed to pain experience by cows when getting up and lying down, moving to and from the feeder and standing to feed.

In a study at ICAR-National Dairy Research Institute, Karnal, it has been observed that metritic Karan Fries (KF) cows significantly reduced their daily feeding time and number of feeding visit to manger during 2 weeks before calving[49] (Table 2). Further, while considering feeding time one week pre-partum we could predict the ensuing metritis with 86% accuracy and cows with lower feeding time were 3 - 9 times more likely to develop post-partum metritis[49, 50]. Feeding time is positively associated with dry matter intake (DMI) in dairy cows[24, 33], so reduction in feeding time may decreases DMI and thereby increases negative energy balance (NEB), which increases the circulating non-esterified fatty acids (NEFA) and β-hydroxy butyric acid (BHBA), reduces functional activity of neutrophils and further predispose the dairy cows to metabolic and infectious diseases[30, 48]. Recently, Sepúlveda-Varas *et al.*[59], reported that mobilization of fay from adipose tissue to enhance the circulating energetic substance to liver for oxidation owing to NEB is a homeorhetic adaptation in cows during peripartum period. But incomplete oxidation at liver produces ketone bodies like BHBA and makes the cows more susceptible to metabolic and infectious diseases. The change in feeding behaviour particularly feeding time before parturition in cows with dystocia may be associated with pain due to larger size or malposition of calf[52]. Pain also reduces the frequency (number of visit to manger) and magnitude (daily feeding time and visit duration) of highly motivated feeding behaviour[68], and may increase the dystocia condition in dairy cows.

Fogsgaard *et al.*[21], observed significantly (P<0.02) lower feeding time on the day of infusion of *E. coli* into udder quarter of dairy cows fed with total mixed ration than the days before (d -2 and d -1) infusion and after recovery (d +2 and d +1). The lower feeding time may be associated with fever and an adaptive response which reduces availability of micronutrients like zinc and iron to micro-organism, thereby suppress their growth[59]. On the contrary experimentally induced mastitic cows (infusing *E. coli* lipopolysaccharide *i.e.*, LPS into the udder quarter) spent 13.83% longer time in feeding silage on the day of infusion compared to the day before infusion[60]. The reason of higher feeding time on silage is not clear; hence further more studies are needed to associate feeding time and acute udder infection. Moreover, owing to variation in the degree of infections and types of pathogens, all types of mastitis do not reduce feed intake and daily feeding time[25], so feeding time is less reliable for identification of mastitis.

Table 2. Pre-partum feeding and inactive standing behaviour of metritic and normal cows

Behavioural parameters	Metritic	Normal	P value
	Mean ± SE (Median)	Mean ± SE (Median)	
Feeding time (minutes/day)			
Week-2	378.68 ± 10.56 (376)	410.03 ± 9.21 (401)	0.041
Week-1	276.72 ± 07.43 (284)	328.41 ± 6.47 (324)	<0.001
Feeding visit (numbers/day)			
Week-2	17.57 ± 0.51 (17)	19.57 ± 0.51 (19)	0.01
Week-1	12.93 ± 0.29 (13)	14.98 ± 0.35 (15)	<0.001
Inactive standing time (minutes/d)			
Week-2	515.15 ± 11.34 (514.5)	474.65 ± 11.09 (476.0)	0.016
Week-1	665.85 ± 15.45 (689.0)	602.09 ± 10.52 (599.5)	<0.001

(Source[49])

DRINKING BEHAVIOUR AND HEALTH

Most of the research regarding association of drinking (suckling in young calves) behaviour and health disorders has been studied in feed lot steer and suckling dairy calves; however, little work has been reported in dairy cows. The morbid steer spends 23.7% less time at the water trough 3-4 days prior to diagnosis compared to healthy steer and can be detected with 81.5% accuracy[5]. The pre-weaned unhealthy dairy calves significantly ($P<0.05$) reduce their number of non-nutritive visits (received no milk) to an automatic milk feeder compared to healthy calves which is most sensitive behaviour to identify clinical diseases[64]. In another study, Borderas *et al.*[7], observed that sick calves reduced their number of daily visit by 2.43 visits/day but visit duration in diseased calves increased by 1.66 min/visit during last 2 days prior to its diagnosis in an automatic milk feeder with high milk or milk replacer supply (12 lit/d); however, in restricted supply (4 lit/d) calves only reduced visit duration by 1.35 min/visit compared to healthy caves. Previous studies also reported higher non-nutritive visits to automatic milk feeder with restricted milk allowance compared to the feeder with high milk allowance which may be a sign of hunger in calves[35, 37, 46, 66], so the difference in visit to the feeder was observed in high and low allowance of milk. Hence, in modern calf management practices the non-nutritive visits can be reduced by increasing the milk allowance[35, 66] and the sick animal can be identified well in advance for effective management decision.

In case of dairy cows, health status is not directly associated with drinking behaviour rather associated with rate and amount of water intake. The lower rate and amount of water intake during transition period is associated with post-partum metritis[33]. Proudfoot *et al.*[52], reported that dystotic cows 24 hours before calving took 13.8 kg (61%) less water than cows with normal calving and could also predict dystocia with 68.2% accuracy. The total daily water intake is also reduced by 22.19% in SCK cows during one week preceding calving[24]. As such no strong association of drinking behaviour and health status has been observed in dairy cows, so drinking behaviour is less reliable to predict the ensuing health disorders in dairy cow, rather water intake can fairly predict the health disorders. However, drinking behaviour of suckling calves may be helpful for early identification of health disorder.

LYING AND INACTIVE STANDING BEHAVIOUR AND HEALTH

Research on lying and standing behaviour has mostly been conducted to associate it with lameness and calving difficulty in dairy cows. It has been observed that higher standing time along with rapid decrease in lying time during peri-partum period is associated with higher incidence of sole ulcer[9]. The increase in total standing time in milch cows housed in a loose cubicle building increases incidence of ensuing lameness in Holstein cows[22]. The increase in standing time during 2 weeks pre-partum and within 24 hours post-partum increases lameness incidence significantly ($P=0.02$) by 1.48 and 1.25 times, respectively in mid lactation[54]. In addition, when cows face more competitive environment (0.3 meter manger space), their inactive standing time (standing without eating) increases for access to feed during transition period[53] which is a key risk factor for development of lameness in dairy cows[54]. Moreover, it has also been observed that cows that spend more time perching half way in the stall (only 2 front feet inside the stall) or standing more time with their front feet in the cubicle are more prone to higher haemorrhage scores in feet or lameness while spending same time in standing in all other parts of the pen compared to healthy cows[16, 23, 54]. These results reflect that dairy barns should be designed in such a way to minimize the time a cow spends more in standing partially with its two front feet inside the stalls or cubicles to reduce the risk of hoof injuries. Thus altered standing behaviour not only reflects hoof health of cows but also the housing design and managemental fault that compromise normal behavioural pattern in dairy cows[12].

The standing time not only associated with lameness in dairy cows but also with calving difficulties, sub-clinical hypocalcemia and uterine health. The cumulative standing bouts (frequency of transitioning from lying to standing) increased by 2.6 bouts during 24 hours prior to calving in cows with dystocia than cows without dystocia and dystocia could be predicted with 77.8% accuracy[52]. It has been observed that lying frequency increases 2 hours before calving in cows with dystocia; whereas, 6 hours before in normal calving cows[45]. The dystocic cows also spent more time in lying on lateral side with the head in resting position during 2-4 hours preceding calving[3]. The laterality of lying may be due to pain associated straining and discomfort of the calf present in birth canal and this position also help for better expulsion of fetus[3]. It has been observed that cows with sub-clinical hypocalcemia had 3 hours more standing time during 24 hours period before calving compared to the healthy counter parts[34]. Circulating calcium plays important role in myometrial contraction and positively associated with rate of contraction. The higher standing time in sub-clinical hypocalcemic cows may be explained by the discomfort associated with increased duration of labour owing to lower rate of myometrial contraction[34]. Further, higher daily inactive standing time (standing without eating) has been observed in metritic crossbred cows prior to parturition compared to normal cows[49] (Table 2), may decreases feeding time and intake in dairy cows, which results in NEB and increases susceptibility to infectious and metabolic diseases. Therefore, altered lying and inactive standing behaviour can be helpful for early prediction of diseases and proper feeding management can prevent the ensuing abnormal health in advance. Further, Petersson-Wolfe *et al.*[51], observed significant activity changes in SCK cows and reported that SCK cows had higher number of resting or lying bouts compared to healthy counter parts (16 vs. 12 bouts) prior to one day before diagnosis. The lying and standing behaviour not only predict the health status of cows but also the calving time in dairy animals as frequency of transitioning from laying to standing and number of lying bouts increases consistently during 4-6 hours prior to calving[3, 36, 44, 45].

In addition, change of lying and standing behaviour has also been associated with udder health. Siivonen *et al.*[60], induced mastitis in dairy cows by infusing *E. coli* LPS into the udder and observed that cows with mastitis had overall less total lying time (16.25%), less lying time on the side of the inflamed udder quarter (15.61%) and more standing time on the induction day (18.94%) compared to the day before induction. Interestingly, the experimentally induced mastitic cows spend less time in lying down during the first 12 hour after infusion compared with the period of 12-24 hour after infusion[70]. Fogsgaard *et al.*[21], artificially induced *E. coli* mastitis in dairy cows and observed significantly increased ($P<0.001$) idle standing time in the initial 24 hour after induction compared to the days before induction (d -2 and d -1) and after recovery (d +2 and d +1). Similarly, Cyples *et al.*[11], experimentally induced the *E. coli* mastitis in dairy cows and reported that during the 4-7 hours following LPS infusion, cows spent 10.42% less time lying down ($P=0.005$) on the day of the challenge compared with the baseline (2 days before infusion). Yeiser *et al.*[69], also observed significantly ($P<0.05$) lower lying and higher standing time in mastitic cows (induced mastitis using *E. coli* LPS) within 6-9 hours following infusion compared to cows without infusion. In experimentally induced mastitic cows, the diurnal pattern of lying also deviated during 4-7 hour following infusion compared to 2 days before and after induction[11]. Hänninen *et al.*[31], recorded hourly resting or lying time and reported that cows took longer resting time immediately during 2 hours following endotoxin infusion into udder and then resting time shortened significantly ($P<0.05$) compared to the cows day before induction. The cows with mastitis also spend 35 min (4.71%, $P=0.04$) less time in lying on day 2 following the treatment of antibiotic compared to control cows[43]. The mastitic cows due to pain and discomfort may reduce their lying time and spend more time in standing which is an indicator of adaptive behaviour to facilitate recovery of mastitis[11]. The infected swollen udder coming in contact with the hard floor while lying may produce pain, so the cow prefers more time in standing and less time in lying. Further, Kikkers *et al.*[38], reported that cows that lay down more time on their left side had higher risk of having mastitis in the right side quarter but due to higher data variation and less time (four times only) recording of lying position they did not get any difference statistically. However, if electronic data logger can be used for continuous recording of lying position, then it can be helpful for early detection of disease[38].

More recently, it has also been observed a non-linear association between post-milking standing time and subsequent intramammary infection (IMI) in dairy cows[14, 15]. DeVries *et al.*[15], reported lower chance (odds ratio=1.4) of development of ensuing environmental IMI in cows lying down for the first time between 40-60 min after milking compared to those cows lying within 40 min following milking in tie stall herds. Moreover, environmental IMI incidence increases significantly (P<0.05) when post-milking standing time increases beyond 60 min compared to cows with post-milking standing time between 0-40 min[15]. In another study, DeVries *et al.*[14], reported that cow with longer post-milking standing time (>2.5 hours) in free stall barn had 2.7 times higher (odds ratio = 2.7) chance to develop environmental IMI. This variation in association between environmental IMI and post milking standing time may be due to increase in teat canal diameter within 30 min following milking and again 2-4 hours after milking[42, 58]. Moreover, inconsistent results by different studies may be attributed to other managemental factors like housing management and floor hygiene. Hence, lying and standing behaviour may be useful for the identification of udder health. The post-milking lying and standing time can be managed by feed manipulation near milking[14, 15], and incidences of environmental IMI can be reduced. However, further more studies are required regarding association between post-milking lying and standing time with environmental IMI in dairy cows.

RUMINATION BEHAVIOUR AND HEALTH

Generally, cows ruminate approximately 35-40% of a day and rumination time (RT) is positively associated with rumen pH (R^2=0.91) in dairy cows[13], so alteration of rumination time from normal state will be helpful for early prediction or identification of diseases. In a retrospective study, Soriani *et al.*[61], reported that lower rumination time (RT) before calving was associated with higher incidence of post-partum diseases (mastitis, retained placenta, metritis, ketosis, displacement abomasum and lameness) than higher RT in dairy cows. The dairy cows with mastitis decreases their daily RT by 63 minutes compared to normal cows (Bar and Solomon, 2010). Dairy cows with endotoxin challenge decrease their cud chewing time between 3 to 9 hours after infusion[20, 70]. Similarly, Hänninen *et al.* [31], and Siivonen *et al.*[60], reported that cows spent less time in rumination (P<0.05) after 4-8 hours of artificially induction of acute clinical mastitis by infusing *E. coli* LPS into udder quarters. Recently, Fogsgaard *et al.*[21], induced mastitis artificially in dairy cows by infusing *E. coli* isolates into healthy front quarter and observed significantly lower duration of rumination time on the day of induction (P<0.03) than before infusion (d -2 and d -1) and after recovery (d +2), and 4.8% lower rumination time on day 1 post infusion (P=0.01) compared to day 2 after infusion. However, the endotoxin effect was observed more on rumination behaviour during 12-20 hours after infusion[21]. The disparity in the effect on rumination behaviour after challenge may be because of infected materials used; as the systemic effects of infection commences much earlier when infused with *E. coli* LPS compared to actual *E. coli* isolate[6, 20]. Although, both rumination activity and fever are associated with higher energy expense but cow fails to avoid fever by self, so she may reduce RT to conserve energy. The lower RT in cows during high fever (associated with higher energy expense) may be an adaptive response to minimise energy expenses[31, 60]. Lower rumination time in acute mastitic cows may be due to pain or stress[1, 20]. Therefore, health status of dairy animal can be predicted in advance by monitoring rumination behaviour.

The lower RT during post-calving period elevates the circulating BHBA (r= -0.35) and decrease the glucose (r= 0.21) concentration in dairy cows[61]. Further, studies have been reported reduced neutrophil functions in cows with elevated BHBA and associated with higher risk of uterine infections and clinical ketosis[17, 30, 48]. So in dairy cows, lower RT may enhance the chances of metabolic and infectious diseases during early lactation by altering energy metabolites and therefore, proper nutritional management can reduce the health disorders in dairy cows by improving energy balance in such conditions. In addition, in a healthy herd at least 40% of cows must ruminate at any time point, indicator of healthy rumen function and can be a good indicator of change in rumen pH[12, 18]. However, DeVries *et al.*[13], observed 10% fewer cows ruminating at the peak time of rumination in sub-acute ruminal acidosis (SARA) condition (pH<5.8); moreover, for herd level accurate identification of SARA more numbers of observations were needed. Electronic monitoring of rumination behaviour using data logger can be helpful for accurate monitoring of RT in large dairy herds easily and it will be helpful for accurate identification of SARA. Furthermore, development of herd specific standard can be helpful for assessment of welfare as well as health status of dairy herd.

SOCIAL BEHAVIOUR AND HEALTH

In loose housing system as competitive situation always prevails more or less extent, socially sub-ordinate dairy cows are displaced more from the feed manger[47]. The social environment of cows is disturbed more during transition period as dairy animals are shifted from one group to another for better management[10]. Recent studies have been reported that sub-ordinate cows (low displacement index) were most susceptible to ensuing diseases may be due to inadequate feeding[22, 23, 49].

$$\text{Displacement Index} = \frac{x}{x+y}$$

Where,
x is number of times the individual displaced any cow
y is number of times the individual has been displaced

The chances in development of ensuing lameness are more in cows with lower social ranks i.e. lower displacement index. In a study, Galindo *et al.*[23], reported that cows with lameness had low index of displacement than normal cows (0.51 vs. 0.56). Galindo and Broom[22] grouped the cows based on displacement index into low (<0.4), medium (0.4-0.6) and high (>0.6) rank groups and observed that 60% low ranking cows developed lameness; whereas only 33% in medium and 18% in high rank group. The higher incidence of lameness in low ranking cows may be due to more standing and less lying time that increases hoof lesions[23].

The social behaviour is not only associated with hoof lesion but also with other reproductive and metabolic disorders. Dairy cows with metritis displace other cows 18.91-26.19% less frequently one to two weeks prior to calving and are displaced by other cow 22.58% more frequently from the feed manger compared to normal cows[33, 49] with low displacement index[49] (0.43 vs. 0.55, Fig. 1). Further, it has been observed that the feeding related displacement one week before calving could predict post-partum metritis with 78-79% accuracy and the cows that had displaced more by other cows or displaced less to other cows at the manger during prepartum period were 2.25-3.0 times more likely to develop ensuing metritis[49]. Similar to metritic cows, the sub-clinical ketotic cows also displace other less frequently (29.17%) from the feed manger compared to normal cows (10.2 vs. 14.4 displacements/day) one week before calving[24]. The association of displacement from manger with illness may be explained by two coping strategies i.e. proactive and reactive coping strategies[55, 67]. Low hypothalamic-pituitary-adrenal (HPA) axis reflects proactive coping strategy with more aggressive behavioural response to stressors and lower production of circulating cortisol, where as reactive coping strategy is associated with high HPA activity and more production of circulating cortisol, and reflects a cow with behavioural inhibition and low-aggression[55, 67]. Furthermore, the over activation of HPA axis produces more circulating cortisol

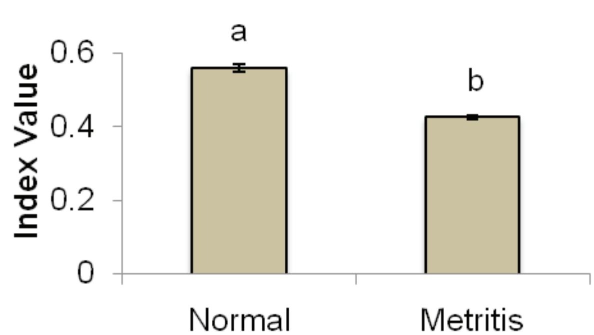

Fig. 1. Displacement index (P<0.001)

and suppresses the immunity of animals and may predisposes more towards infectious agents[59, 67]. Under competitive situation during transition period when manger space reduces from 0.6 to 0.3 meter/cow, then cow are displaced more frequently from the manger[53] and may increase incidences of abnormal health. Therefore, reducing number of displacements by proper grouping or providing optimum manger space for free access to feed or by increasing frequency of fresh feed delivery to increase feeding time can improve the health status of cows[59].

In dairy animals, in addition to the above behaviours there are also certain behaviours (walking activity) which frequently reflect change in physiology or health status. In case of metabolic or digestive disorder, sick cows walk 13-15 steps less compared to healthy cows 1-2 days before diagnosis[19]. However, cows with ketosis, left displaced abomasum and other digestive disorders can be identified 5-6 days earlier than the clinical diagnosis by monitoring steps or walking activity along with milk yield[19]. The reduction of activity before clinical diagnosis in sick cows may be due to restriction of movement by reduction of appetite reflected as less attendance at feed manger and increase lying time[57]. The stepping or walking activity also associated with udder infections. In dairy cows, higher stepping behaviour is associated with more somatic cell counts[28], reflects that during udder infection stepping or walking activity increases. Siivonen *et al.*[60], observed 21.81% more steps in dairy cows on the day of infusion of *E. coli* LPS into the udder quarter compared to the day before induction. Recently, Medrano-Galarza *et al.*[43], reported higher restless behaviour during milking (frequency of stepping, lifting and kicking) in mastitic cows on the day of treatment of antibiotic and the day following treatment, then restlessness behaviour gradually decreased. Thus, such changes in behaviour may be used to assess the recovery of udder infection. The swollen udder produces pain and may increase restlessness behaviour due to discomfort[39]. During artificially induced *E. coli* mastitis, dairy cows significantly reduced the frequency ($P<0.04$) of turning head against udder per undisturbed hours on the day of induction and day 1 after induction compared to d -2 and d -1 before induction and day 2 after induction[21]. Similarly, during 24 hours post-infection, the dairy cows showed significantly ($P<0.005$) lower frequency of self-grooming behaviour per hour compared to the day before infection (d -2 and d -1) and day 2 after infection[21]. The lower head turning and grooming behaviour in mastitic cows may be an adaptive response to reserve energy to cope with metabolic expense of fever as well as sickness[2, 32]. The self grooming behaviour is also a good indicator of pain[4], so due to severe pain may be reduced in experimentally induced mastitic cows.

The frequency and duration of tail raising before 2-4 hours of normal calving increases in dairy heifer and cows[3, 44, 45]. Further, when dystocia condition is associated with mal-presentation of fetus the tail raising behaviour increased markedly (60.23%) compared to normal counter parts during 6 hours before calving[3]. The tail raising behaviour is considered as good indicator of pain[27, 41] and may be triggered by the acute pain at the perineal region of cows during parturition[27]. Restlessness behaviour as assessed by increased standing bouts, walking, change in lying position and position of legs increases during 4 hours prior to calving in dystocia condition as well as there is consistent increase in restlessness behaviour in cows during 4-6 hours prior to calving[3]. Head turning and kicking behaviour are considered as indicator of pain and increase significantly ($P<0.05$) during the pre-calving period in dystotic cows compared to the cows that deliver the calves easily[41]. Hence, in animal husbandry practices keen observation of behaviour can be helpful for early prediction of calving time and calving difficulty.

CONCLUSION

Behavioural alteration in dairy cattle is strongly associated with ensuing abnormal health. However, a single behaviour is not always associated with all diseases rather related to a specific disease. Further, the disease specific behavioural markers should be studied with more refinement, so that it can be helpful for prevention of diseases or health problems in dairy animals in non-invasive way. Moreover, automatic electronic behaviour monitoring system can increase the accuracy of recording of a particular behaviour and can enhance the reliability of early identification of diseased cattle. Therefore, identification of disease specific behaviour and immediate management interventions can reduce occurrence of abnormal health and helpful for further improvement of animal welfare.

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REFERENCES

1. Anderson, D. E. and Muir, W. W. 2005. Pain management in cattle. *Vet. Clin. Food Anim.* **21**: 623-635.
2. Aubert, A. 1999. Sickness and behaviour in animals: A motivational perspective. *Neurosci. Biobehav. Rev*. **23**: 1029-1036.
3. Barrier, A. C., Haskell, M. J., Macrae, A. I. and Dwyer, C. M. 2012a. Parturition progress and behaviours in dairy cows with calving difficulty. *Appl. Anim. Behav. Sci.* **139**: 209-217.
4. Barrier, A. C., Ruelle, E., Haskell, M. J. and Dwyer, C. M. 2012b. Effect of a difficult calving on the vigour of the dairy calf, the onset of maternal behaviour and some behavioural indicators of pain in the dam. *Prev. Vet. Med.* **103**: 248-256.
5. Basarab, J. A., Milligan, D., Hand, R. and Huisma, C. 1996. Automatic monitoring of watering behaviour in feedlot steers: potential use in early detection of respiratory disease and in predicting growth performance. *Proc. Can. Soc. Anim. Sci.* 46th Annu. Conf., July 7-11, Lethbridge, Alberta, pp. 28.
6. Borderas, T. F., de Passillé, A. M. and Rushen, J. 2008. Behaviour of dairy calves after allow dose of bacterial endotoxin. *J. Anim. Sci.* **86**: 2920-2927.
7. Borderas, T. F., Rushen, J., Von Keyserlingk, M. A. G. and De Passillé, A. M. B. 2009. Automated measurement of changes in feeding behaviour of milk-fed calves associated with illness. *J. Dairy Sci.* **92**: 4549-4554.
8. Broom, D. M. and Fraser, A. F. 2007. Describing, recording and measuring behaviour. *In: Domestic animal behaviour and welfare*, 4th Ed. CAB International, Wallingford, Cambridge University press, UK, pp. 17-24.
9. Chapinal, N., De Passille, A. M., Weary, D. M., Von Keyserlingk, M. A. G. and Rushen, J. 2009. Using gait score, walking speed and lying behaviour to detect hoof lesions in dairy cows. *J. Dairy Sci.* **92**: 4365-4374.
10. Cook, N. B. and Nordlund, K. V. 2004. Behavioural needs of the transition cow and considerations for special needs facility design. *Vet. Clin. North Am. Food Anim. Pract.* **20**: 495-520.
11. Cyples, J. A., Fitzpatrick, C. E., Leslie, K. E., DeVries, T. J., Haley, D. B. and Chapinal, N., 2012. The effects of experimentally induced Escherichia coli clinical mastitis on lying behaviour of dairy cows. *J. Dairy Sci.* **95**: 2571-2575.
12. Devries, T. and Von Keyserlingk, M. A. G. 2011. Predicting and identifying illness through changes in dairy cow behaviour. *Proc. Four-state dairy nutrition and management conference*, June 8-9, Dubuque, Iowa. pp. 108-110.
13. DeVries, T. J., Beauchemin, K. A., Dohme, F. and Schwartzkopf-Genswein, K. S. 2009. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: Feeding, ruminating, and lying behaviour. *J. Dairy Sci.* **92**: 5067-5078.
14. DeVries, T. J., Deming, J. A., Rodenburg, J., Seguin, G., Leslie, K. E. and Barkema, H. W. 2011. Association of standing and lying behaviour patterns and incidence of intramammary infection in dairy cows milked with an automatic milking system. *J. Dairy Sci.* **94**: 3845-3855.

15. DeVries, T. J., Dufour, S. and Scholl, D. T. 2010. Relationship between feeding strategy, lying behaviour patterns, and incidence of intramammary infection in dairy cows. *J. Dairy Sci.* **93**: 1987-1997.

16. Dippel, S., Tucker, C. B., Winckler, C. and Weary, D. M. 2011. Effects of behaviour on the development of claw lesions in early lactation dairy cows. *Appl. Anim. Behav. Sci*. **134**: 16-22.

17. Duffield, T. F., Lissemore, K., McBride, B. W. and Leslie, K. E. 2009. Impact of hyperketonemia in early dairy cows on health and production. *J. Dairy Sci.* **92**: 571-580.

18. Eastridge, M. L. 2000. Walking the rumen health tightrope. *Hoard's Dairyman* **145**: 626.

19. Edwards J. L. and Tozer, P. R. 2004. Using activity and milk yield as predictors of fresh cow disorders. *J. Dairy Sci*. **87**: 524-531.

20. Fitzpatrick, C. E., Chapinal, N., Petersson-Wolfe, C. S., DeVries, T. J., Kelton, D. F., Duffield, T. F. and Leslie, K. E. 2013. The effect of meloxicam on pain sensitivity, rumination time, and clinical signs in dairy cows with endotoxin-induced clinical mastitis. *J. Dairy Sci.* **96**: 2847-2856.

21. Fogsgaard, K. K., Røntved, C. M., Sørensen, P. and Herskin, M. S. 2012. Sickness behaviour in dairy cows during Escherichia coli mastitis. *J. Dairy Sci*. **95**: 630-638.

22. Galindo, F. and Broom, D. M. 2000. The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. *Res. Vet. Sci.* **69**: 75-79.

23. Galindo, F., Broom, D. M. and Jackson, P. G. G., 2000. A note on possible link between behaviour and the occurrence of lameness in dairy cows. *Appl. Anim. Behav. Sci*. **67**: 335-341.

24. Goldhawk, C., Chapinal, N., Veira, D. M., Weary, D. M. and Von Keyserlingk, M. A. G., 2009. Prepartum feeding behaviour is an early indicator of subclinical ketosis. *J. Dairy Sci.* **92**: 4971-4977.

25. Gonzalez, L. A., Tolkamp, B. J., Coffey, M. P., Ferret, A. and Kyriazakis, I. 2008. Changes in feeding behaviour as possible indicators for the automatic monitoring of health disorders in dairy cows. *J. Dairy Sci.* **91**: 1017-1028.

26. Grant, R. 2009. Stocking density and time budgets. *Proc. Western dairy management conference,* March 11-13. Reno, NV, Unites State, pp. 7-17.

27. Gregory, N. G. 2004. Pain. *In: Physiology and Behaviour of Animal Suffering*. UFAW Animal Welfare Series. Blackwell Science, Oxford, pp. 94-130.

28. Gygax, L., Neuffer, I., Kaufmann, C., Hauser, R. and Wechsler, B. 2008. Restlessness behaviour, heart rate and heart-rate variability of dairy cows milked in two types of automatic milking systems and auto-tandem milking parlours. *Appl. Anim. Behav. Sci.* **109**: 167-179.

29. Haley, D. B., Rushen, J. and de Passillé, A. M. 2001. Assessing cow comfort: effects of two floor types and two tie stall designs on the behaviour of lactating dairy cows. *Appl. Anim. Behav. Sci.* **71**: 105-117.

30. Hammon, D. S., Evjen, I. M., Dhiman, T. R., Goff, J. P. and Walters, J. L. 2006. Neutrophil function and energy status in Holstein cows with uterine health disorders. *Vet. Immunol. Immunopathol*. **113**: 21-29.

31. Hänninen, L., Kaihilahti, J., Taponen, S., Hovinen, M., Pastell, M. and Pyörälä, S. 2007. How behaviour predicts acute endotoxin mastitis in dairy cows? *Proc. "Animal health, animal welfare and biosecurity"*, Estonian University of Life Sciences, Jogeva Plant Breeding Institute, Estonian Research Institute of Agriculture, Tartu, Estonia. pp. 157-161.

32. Hart, B. L. 1988. Biological basis of the behaviour of sick animals. *Neurosci. Biobehav. Rev*. **12**: 123-137.

33. Huzzey, J. M., Veira, D. M., Weary, D. M., and Von Keyserlingk, M. A. G. 2007. Prepartum behaviour and dry matter intake identify dairy cows at risk for metritis. *J. Dairy Sci.* **90**: 3220-3233.

34. Jawor, P. E., Huzzey, J. M., Le Blanc, S. J. and Von Keyserlingk, M. A. G. 2012. Associations

of subclinical hypocalcemia at calving with milk yield, and feeding, drinking, and standing behaviours around parturition in Holstein cows. *J. Dairy Sci.* **95**, 1240-1248.

35. Jensen, M. B. 2006. Computer-controlled milk feeding of group-housed calves: the effect of milk allowance and weaning type. *J. Dairy Sci.* **89**: 201-206.

36. Jensen, M. B. 2012. Behaviour around the time of calving in dairy cows. *Appl. Anim. Behav. Sci.* **139**, 195-202.

37. Jensen, M. B. and Holm, L. 2003. The effect of milk flow rate and milk allowance on feeding behaviour in dairy calves fed by computer controlled milk feeders. *Appl. Anim. Behav. Sci.* **82**: 87-100.

38. Kikkers, B. H., Ozsvari, L., Van Eerdenburg, F. J., Bajcsy, A. C. and Szenci, O. 2006. The influence of laterality on mastitis incidence in dairy cattle-preliminary study. *Acta Vet. Hung.* **54**: 161-171.

39. Leslie, K. E. and Petersson-Wolfe, C. S. 2012. Assessment and management of pain in dairy cows with clinical mastitis. *Vet. Clin. Food Anim*. **28**: 289-305.

40. Levitis, D. A., Lidicker Jr, W. Z. and Freund, G. 2009. Behavioural biologists don't agree on what constitutes behaviour. *Anim. Behav.* **78**: 103-110.

41. Mainau, E., Cuevas, A., Ruiz-De-La-Torre, J. L. and Manteca, X. 2010. Effect of time and parity on the behaviour of dairy cows during the puerperal period. *Proc. of the 44th Int. Congr. of the ISAE*, Uppsala, Sweden, 4-7 August, p. 46.

42. McDonald, J. S. 1975. Radiographic method for anatomic study of the teat canal: Changes between milking periods. *Am. J. Vet. Res.* **36**: 1241-1242.

43. Medrano-Galarza, C., Gibbons, J., Wagner, S., de Passillé, A.M. and Rushen, J. 2012. Behavioural changes in dairy cows with mastitis. *J. Dairy Sci.* **95**: 6994-7002.

44. Miedema, H. M., Cockram, M. S., Dwyer, C. M. and Macrae, A. I. 2011a. Behavioural predictors of the start of normal and dystocic calving in dairy cows and heifers. *Appl. Anim. Behav. Sci.* **132**: 14-19.

45. Miedema, H. M., Cockram, M. S., Dwyer, C. M. and Macrae, A. I. 2011b. Changes in the behaviour of dairy cows during the 24 h before normal calving compared with behaviour during late pregnancy. *Appl. Anim. Behav. Sci*. **131**: 8-14.

46. Nielsen, P. P., Jensen, M. B. and Lidfors, L. 2008. Milk allowance and weaning method affect the use of computer controlled milk feeder and the development of cross-sucking. *Appl. Anim. Behav. Sci*. **109**: 222-236.

47. Olofsson, J. 1999. Competition for total mixed diets fed for ad libitum intake using one or four cows per feeding station. *J. Dairy Sci.* **82**: 69-79.

48. Ospina, P. A. Nydam, D. V. Stokol, T. and Overton, T. R. 2010. Evaluation of nonesterified fatty acids and β-hydroxybutyrate in transition dairy cattle in the North-eastern United States: Critical thresholds for prediction of clinical diseases. *J. Dairy Sci.* **93**: 546-554.

49. Patbandha, T. K., Mohanty, T. K., Layek, S. S., Kumaresan, A. and Behera, K. 2012. Application of pre-partum feeding and social behaviour in predicting risk of developing metritis in crossbred cows. *Appl. Anim. Behav. Sci.* **139**: 10-17.

50. Patbandha, T. K., Mohanty, T. K., Layek, S. S., Kumaresan, A., Kantwa, S. C., Malhotra, R., Ruhil A. P. and Prasad, S. 2013. ROC analysis of pre-partum feeding time can accurately predict post-partum metritis development in Holstein Friesian (HF) crossbred cows. *J. Vet. Behav.: Clin. Appl. Res.* **8**: 362-366.

51. Petersson-Wolfe, C. S., Tholen, A. R., Currin, J., Leslie, K. E. 2013. Practical Methods for Mastitis Control. *WCDS Advances in Dairy Technology* **25**: 341-358.

52. Proudfoot, K. L., Huzzey, J. M., Von Keyserlingk, M. A. G. 2009a. The effect of dystocia on the dry matter intake and behaviour of Holstein cows. *J. Dairy Sci.* **92**: 4937-4944.

53. Proudfoot, K. L., Veira, D. M., Weary, D. M. and Von Keyserlingk, M. A. G. 2009b. Competition at the feed bunk changes the feeding, standing and social behaviour of transition dairy cows. *J. Dairy Sci.* **92**: 3116-3123.
54. Proudfoot, K. L., Weary, D. M. and Von Keyserlingk, M. A. G. 2010. Behaviour during transition differs for cows diagnosed with claw horn lesions in mid lactation. *J. Dairy Sci.* **93**: 3970-3978.
55. Proudfoot, K. L., Weary, D. M. and Von Keyserlingk, M. A. G. 2012. Linking the social environment to illness in farm animals. *Appl. Anim. Behav. Sci*. **139**: 203-215.
56. Quimby, W. F., Sowell, B. F., Bowman, J. G. P., Branine, M. E., Hubbert, M. E. and Sherwood, H. W. 2001. Application of feeding behaviour to predict morbidity of newly received calves in a commercial feedlot. *Can. J. Anim. Sci*. **81**: 315-320.
57. Schultz, L. H. 1988. Milk fever, ketosis, and the fat cow syndrome. In: Church, D.C. (Eds.), *The ruminant animal: Digestive physiology and nutrition*. Prentice-Hall, Inc., Englewood Cliffs, NJ. pp. 493-509.
58. Schultze, W. D. and Bright, S. C. 1983. Changes in penetrability of bovine papillary duct to endotoxin after milking. *Am. J. Vet. Res.* **44**: 2373-2375.
59. Sepúlveda-Varas, P., Huzzey, J. M., Weary, D. M. and Von Keyserlingk, M. A. G. 2013. Behaviour, illness and management during the periparturient period in dairy cows. *Anim. Prod. Sci.* **53**: 988-999.
60. Siivonen, J., Taponen, S., Hovinen, M., Pastell, M., Lensink, B. J., Pyörälä, S. and Hänninen, L. 2011. Impact of acute clinical mastitis on cow behaviour. *Appl. Anim. Behav. Sci.* **132**: 101-106.
61. Soriani, N., Trevisi, E. and Calamari, L. 2012. Relationships between rumination time, metabolic conditions and health status in dairy cows during the transition period. *J. Anim. Sci.* **90**: 4544-4554.
62. Sowell, B. F., Bowman, J. G. P., Branine, M. E. and Hubbert, M. E. 1998. Radio frequency technology to measure feeding behaviour and health of feedlot steers. *Appl. Anim. Behav. Sci.* **59**: 277-284.
63. Sowell, B. F., Branine, M. E., Bowman, J. G. P., Hubbert, M. E., Sherwood, H. W. and Quimby, W. F. 1999. Feeding and watering behaviour of healthy and morbid steers in a commercial feedlot. *J. Anim. Sci.* **77**: 1105-1112.
64. Svensson, C. and Jensen, M. B. 2007. Identification of diseased calves by use of data from automatic milk feeders. *J. Dairy Sci.* **90**: 994-997.
65. Urton, G., Von Keyserlingk, M. A. G. and Weary, D. M. 2005. Feeding behaviour identifies dairy cows at risk for metritis. *J. Dairy Sci.* **88**: 2843-2849.
66. Vieira, A. D., Guesdon, V., de Passillé, A. M., von Keyserlingk, M. A. G. and Weary, D. M. 2008. Behavioural indicators of hunger in dairy calves. *Appl. Anim. Behav. Sci*. **109**: 180-189.
67. Weary, D. M., Huzzey, J. M. and Von Keyserlingk, M. A. G. 2009. Using behaviour to predict and identify ill health in animals. *J. Anim. Sci.* **87**: 770-777.
68. Weary, D. M., Niel, L., Flower, F. C. and Fraser, D. 2006. Identifying and preventing pain in animals. *Appl. Anim. Behav. Sci*. **100**: 64-76.
69. Yeiser, E. E., Leslie, K. E., McGilliard, M. L. and Petersson-Wolfe, C. S. 2012. The effects of experimentally induced Escherichia coli mastitis and flunixin meglumine administration on activity measures, feed intake, and milk parameters. *J. Dairy Sci.* **95**: 4939-4949.
70. Zimov, J. L., Botheras, N. A., Weiss, W. P. and Hogan, J. S. 2011. Associations among behavioural and acute physiologic responses to lipopolysaccharide induced clinical mastitis in lactating dairy cows. *Am. J. Vet. Res*. **72**: 620-627.