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Relationship between milk yield of cows and their 24-hour walking activity

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Despite many genetic and environmental factors, the level of physical activity may be a very good indicator of the physiological (e.g. estrus, approaching parturition) or health status of cows. The aim of this study was to analyse the 24-hour walking activity of lactating cows as related to the milk yielded in particular milkings over two stages of lactation. Used were 41 cows in early lactation (group G1) and 54 cows in late lactation undergoing a gradual decline in milk production (group G2). Activity of animals was measured with activity meters and expressed in Alpro units (AU), version 6.5 by DeLaval. The cows were kept in a loose system in one common building and milked three times a day in a milking parlour. Two hours before morning and evening milking the G2 cows occurred more active than cows G1 (43 and 45 *vs*. 26 and 31 AU, respectively). From morning to noon milking the G1 cows showed significantly lower activity (33 AU) than G2 cows (40 AU). The highest positive significant correlation coefficients *(r)* were estimated for G1 cows between milk yield at noon and mean 24-hour activity, mean activity between morning and noon milking, and mean activity associated with partial mixed rations (PMR) intake between evening milking and first (morning) PMR feeding (r = 0.47-0.48). The r coefficients between investigated indicators were generally lower in G2 than in G1 cows.

KEY WORDS: cows / lactation / milking / milk yield / walking activity

Twenty-four hour walking activity patterns in cattle are one of the principal indicators of the interaction between animal and environment. Regular recording and

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interpretation of these patterns enable breeders to assess the physiological and health status of animals [Kiddy 1977, Roriea *et al*. 2002, Juarez *et al*. 2003, Edwards and Tozer 2004] and their overall welfare [Capdeville and Veissier 2001].

The activity of cattle is determined by a number of factors resulting from inborn and acquired traits as well as from environmental conditions. The first group includes animal type, its genotype and sex [Arave 1981, Mullan *et al*. 2001, Schutz and Pajor 2001]. Of the environmental factors, the main role is played by photoperiod length with consideration of artificial lighting, animal housing system, hygienic conditions, and duration of production activities, especially those that are regularly repeated (e.g. milking, feeding) – Jezierski [1987], Dahl *et al*. [2000], Haley *et al*. [2001], Phillips [2002], Wagner-Storch and Palmer [2003], Raussi [2005]. Variation in the frequency of these factors leads to differences in cattle behaviour and especially cattle activity, although being herd animals they perform most of their activities (lying, moving, ingestion of feed, *etc*) together in a group [Kristensen and Rasmussen 2002, Phillips 2002].

The interaction animal x environment results in a specific body response, which can be observed and interpreted by humans. For this reason, long-term research has been conducted on cattle at identifying the animals behaviour and the relationship between behaviour and meat productive and reproductive traits [Jezierski 1987, Yániz *et al*. 2003, Meola *et al*. 2004, Cozzi and Gottardo 2005, Evans *et al*. 2005, Nkrumah *et al*. 2007, Olmos and Turner 2008].

However, the relations between milk production traits and cattle behaviour are the subject of considerable debate because different studies often lead to different conclusions [Wieckert 1971, Rathore 1982, Bouissou *et al.* 2001, Schutz and Pajor 2001, Phillips 2002]. Relevant research is gaining importance while technological advances (e.g. the use of pedometers and activity meters in practice) made it possible to monitor cattle activity on a regular basis. The new permanent monitoring systems will give even better insight into cattle behaviour and its relationship with productive traits [Moallem *et al*. 2002, Lipiński 2009].

The aim of this study was to analyse 24-hour walking activity of lactating cows and its relationship with milk yield, as affected by the stage of lactation.

Material and methods

The study was conducted on 95 Holstein-Friesian cows in second lactation. Two groups of cows were established based on existing technological groups:

- group 1 (G1) – 41 early lactation cows (average duration of the current cows' lactation = 169 days, mean daily milk yield = 43 kg milk per cow[1]) with standard deviation of 7.2 kg);

[1] The mean milk yield was calculated on the basis of data from three milkings performed during the analysed period. First, the milk yield from each milking was summed for each cow, and then obtained values were averaged within the experimental groups.

– group 2 (G2) – 54 cows undergoing a gradual decline in production (average duration of the current cows' lactation = 254 days, mean daily milk yield = 33 kg milk per cow with standard deviation of 4.7 kg).

Cows were kept in a straw-bedded loose barn, milked three times daily and fed partial mixed rations (PMR) twice daily as a basal diet. Feeding stations were used and cows had free access to water and outdoor area. All cows were milked three times per day in DeLaval herringbone milking parlour 2x12.

During the study over the same 24-hours period for G1 and G2 no estrus or health problems were observed which could have a significant effect on the change in animal activity or production. No handling or veterinary procedures were performed other than feeding, manure removal and bedding, which were carried out during milking. Artificial fluorescent steady light of low intensity was left on in the barn from dusk until dawn to monitor cows periodically.

The following individual data were recorded:

– morning milk yield (MMY, kg);
– noon milk yield (NMY, kg);
– evening milk yield (EMY, kg) and
– daily milk yield (DMY, kg);
– duration of morning milking (MD, s);
– duration of noon milking (ND, s);
– duration of evening milking (ED, s), and
– average daily milking duration (AMD, s).

The calculations accounted for mean activity of the cows in the following time periods:

– from evening milking to morning milking (AEM);
– directly (2 h) before morning milking (AbM),
– from morning milking to noon milking (AMN),
– directly (2 h) before noon milking (AbN),
– from noon milking to evening milking (ANE) and directly (2 h) before evening milking (AbE).

Walking activity of animals was measured using activity meters and was expressed in units of the Alpro version 6.5 by DeLaval (Alpro Units – AU) – [Instruction Book Alpro 2005]. General activity meter rule is the following: transponder, counting the number of animal movements (NAM), is located on the cow's neck. Every hour information about NAM is transmitted by antennas to the central processor and software of Alpro system.

Moreover, measured and recorded was the mean 24-hour activity of cows (AA) and their mean activity associated with PMR feeding from evening milking to first PMR feeding (PMR1), from first to second PMR feeding (PMR2) and from second PMR feeding to evening milking (PMR3).

The data were collected during the same 24-hour period for animals of both groups. Milking time, PMR feeding time, and sunrise and sunset times were also recorded (Tab. 1).

Table 1. Milking time, PMR feeding time, and sunrise and sunset times during the experiment

Group	Time (h)						
	morning milking	noon milking	evening milking	first PMR feeding	second PMR feeding	sunrise	sunset
G1	4:47 to 5:41	12:24 to 13:13	19:28 to 20:17	8:34	16:37	5:11	18:50
G2	3:40 to 4:36	11:04 to 11:57	18:26 to 19:20	6:27	15:01		

[1]G1 – early lactation cows (n = 41); G2 – late lactation cows (undergoing a gradual decline in daily milk production, n = 54).

The numerical data were assessed statistically by analysis of variance according to the following model:

$$Y_{ij} = \mu + LP_i + \epsilon_{ij}$$

where:

Y_{ij} – observation of j-th trait (AA, AEM, AbM, AMN, AbN, ANE, AbE, PMR1, PMR2, PMR3) for i-th stage of lactation;

μ – overall mean;

LP_i – fixed effect of i-th stage of lactation;

ϵ_{ij} – random error.

Pearson's simple correlation coefficients with Bonferroni correction were computed between cow activity and milk production traits.

Results and discussion

It is apparent from Figures 1 and 2 that 24-hour activity of cows from both groups was strictly related to time of day and most important management routines (milking and PMR feeding). As expected, cows were calmest during the night, *i.e.* between evening and morning milking. Although mean animal activity clearly decreased during this period, it was not paralleled by lack of movement in all animals from the group, as evidenced by the minimum mean activity of G1 (16 AU) and G2 cows (14 AU). The 21:00 to 00:00 h period was the time cows were the least active. It can be assumed that most cows rested and slept over that period. During the day, cows' activity mainly resulted from milking and PMR feeding. Most often, these activities were preceded by peak activity and followed by decreased activity. The only exception was the morning milking, which took place during the time when cow activity gradually increased after the night rest and only reached a local peak before first PMR feeding (51 AU in G1 and 50 AU in G2 cows). These were the times of peak activity of cows.

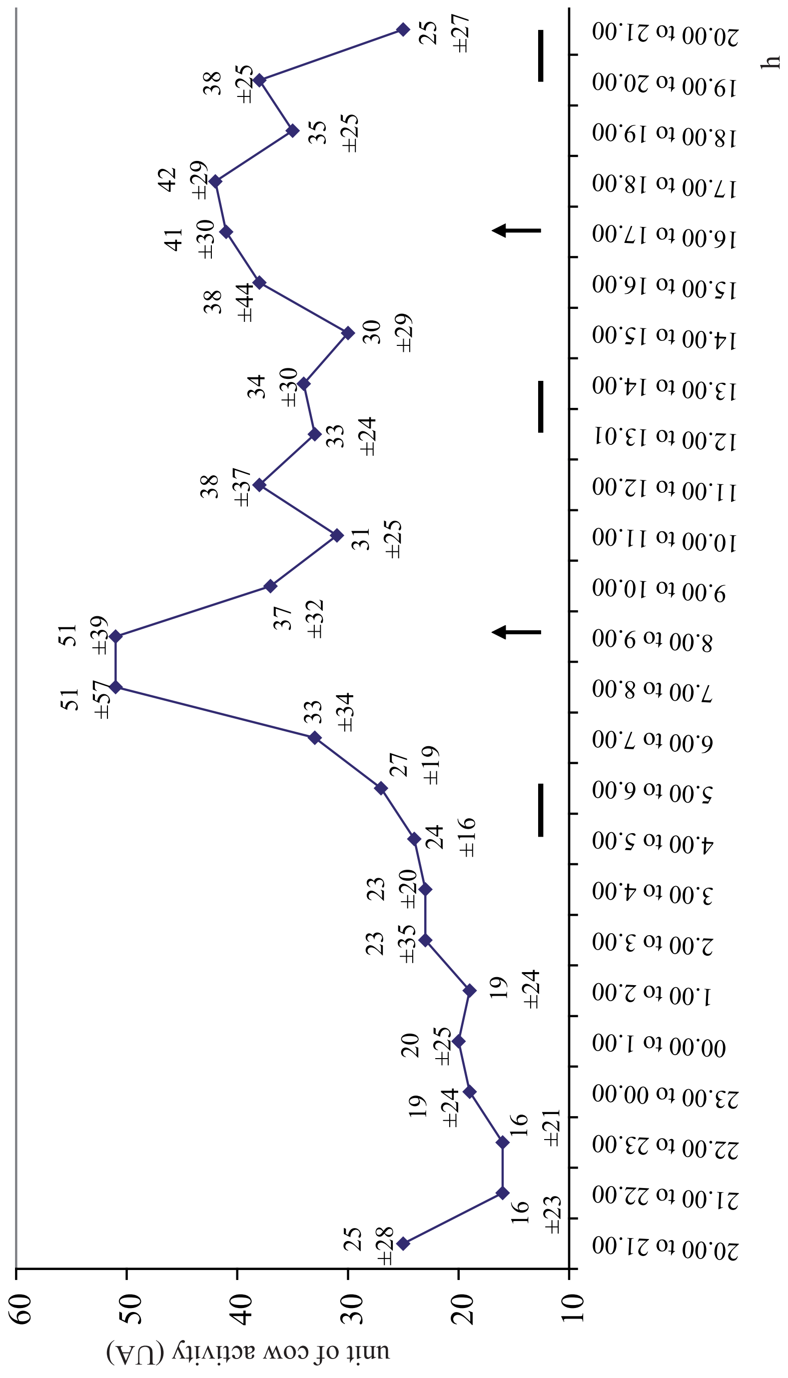

Fig. 1. Mean 24-hour walking activity of early lactation cows (n=41).
Notes: except average values standard deviation values were given, bold continuous line – approximate milking time, vertical arrow – approximate PMR feeding time.

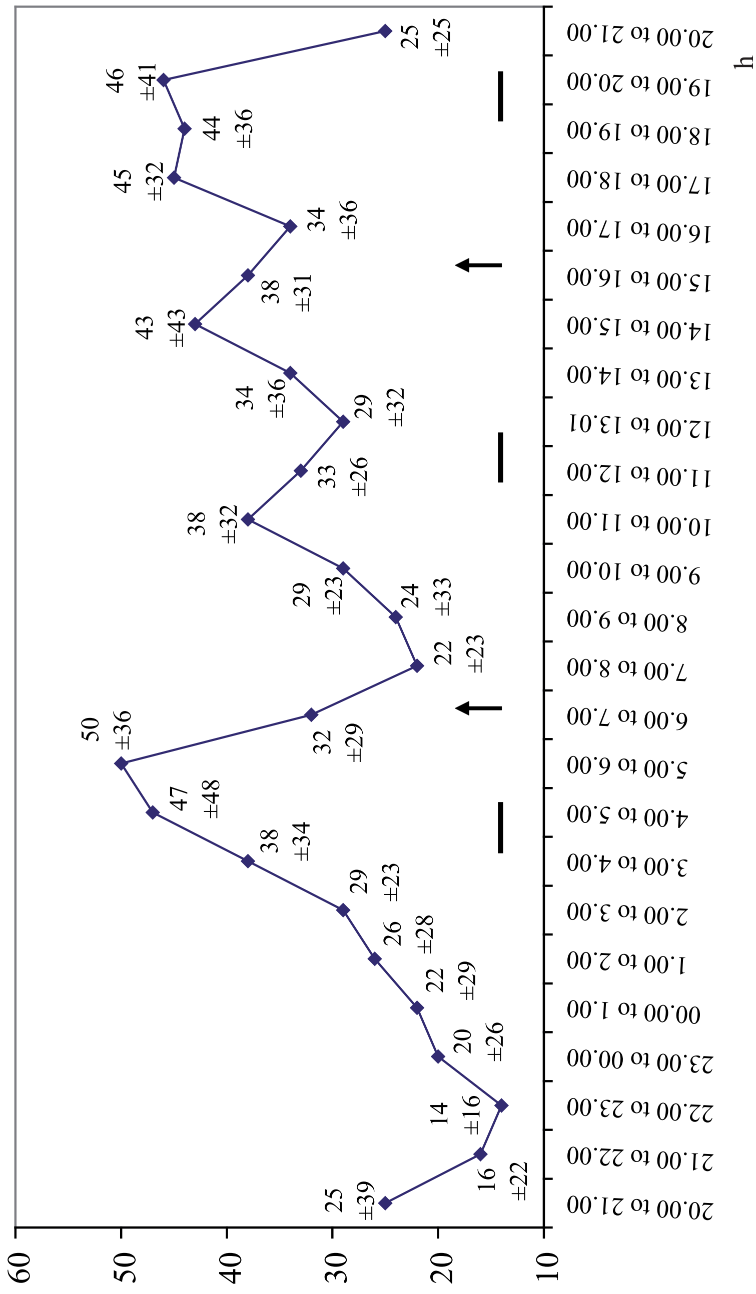

Fig. 2. Mean 24-hour walking activity of cows (n=54) undergoing a gradual decline in daily milk production .
For explanations, see Figure 1.

Table 2. Twenty-four hours walking activity (AU) of the cows

Activity period	Statistical parameter	Group G1	Group G2	Intergroup difference
	n (df=94)	41	54	
AA	mean	31	33	ns
	SD	11.5	14.3	
AEM	mean	20	22	ns
	SD	11.1	12.8	
AbM	mean	26	43	**
	SD	10.6	28.4	
AMN	mean	40	33	*
	SD	18.0	17.8	
AbN	mean	34	33	ns
	SD	18.4	25.6	
ANE	mean	37	37	ns
	SD	20.3	17.9	
AbE	mean	31	45	*
	SD	19.9	32.5	
PMR1	mean	27	30	ns
	SD	10.9	14.9	
PMR2	mean	35	32	ns
	SD	13.4	13.5	
PMR3	mean	35	39	ns
	SD	16.5	19.2	

AA – mean 24-hour activity; AEM – mean activity from evening milking to morning milking; AbM – mean activity directly (2 h) before morning milking; AMN – mean activity from morning milking to noon milking; AbN – mean activity directly (2 h) before noon milking; ANE – mean activity from noon milking to evening milking; AbE – mean activity directly (2 h) before evening milking; PMR1 – mean activity from evening milking to first PMR feeding; PMR2 – mean activity from first to second PMR feeding; PMR3 – mean activity from second PMR feeding to evening milking; G1 – early lactation cows (mean daily milk yield of 43 kg with SD of 7.2 kg); G2 – cows undergoing a gradual decline in daily milk production (mean daily milk yield of 33 kg with standard deviation of 4.7 kg).
Means in rows: *P<0.05, **P<0.01, ns – not significant.

In most cases, no significant differences were found in the activity between group G1 and G2 (Tab. 2). However, during the AbM and AbE periods the G2 cows were more active (43 and 45 AU, respectively) than cows G1 (26 and 31 AU, respectively) – P<0.01. This could be due to differences in the rate of milk secretion in the analysed stages of lactation and the associated lower need of G2 cows to spend time lying and ruminating. Meanwhile, G2 cows were significantly (P<0.05) calmer during the AMN period (33 AU) compared to G1 cows (40 AU).

It is also worthy of note that the activity of individual cows varied considerably in relation to the analysed period of time, especially directly before individual milkings.

No significant relationships were found between cow activity or milking parameters and PMR feeding time except the milk yield during noon milking, which – especially in G1 cows – was significantly correlated with mean daily activity of the cows (r = 0.47), mean activity of the cows from evening milking to morning milking (r = 0.48) and mean activity of the cows from morning milking to noon milking (r = 0.48) – Table 3. However, weaker relationships between investigated traits occurred in G2 cows – the strongest correlations were identified between milk yield during morning milking and mean activity of the cows directly (2 h) before evening milking as well as between milk yield during noon milking and mean activity of the cows from evening milking to morning milking (r = 0.38 and r = 0.38, respectively) – Table 4.

Table 3. Correlation coefficients (r) between walking activity of G1 cows and their milk yield and milking duration

Item	MMY	MD	NMY	ND	EMY	ED	MY	AMD
AA	0.27	0.22	0.47*	0.10	0.27	0.24	0.37	0.21
AEM	0.37	0.24	0.40	0.10	0.25	0.24	0.38	0.22
AbM	0.01	0.10	-0.22	-0.03	-0.24	-0.11	-0.15	-0.01
AMN	0.23	0.18	0.48*	0.17	0.33	0.21	0.37	0.22
AbN	0.08	0.05	0.19	-0.20	0.07	0.05	0.12	-0.04
ANE	0.08	0.04	0.31	0.04	0.14	0.13	0.19	0.08
AbE	0.26	0.34	0.30	0.10	0.22	0.32	0.29	0.29
PMR1	0.32	0.27	0.48*	0.19	0.29	0.25	0.40	0.27
PMR2	0.21	0.09	0.40	-0.03	0.28	0.20	0.32	0.09
PMR3	0.16	0.22	0.35	0.07	0.12	0.21	0.23	0.19

MD – duration of morning milking (s); NMY – milk yield (kg) during noon milking; ND – duration of noon milking (s); EMY – milk yield (kg) during evening milking; ED – duration of evening milking (s); MY – daily milk yield (kg); AMD – average daily milking duration (s).
*Significant coefficients of correlation with Bonferroni correction, P<0.0028.

Table 4. Correlation coefficients (r) between walking activity of G2 cows and their milk yield and milking duration

Item	MMY	MD	NMY	ND	EMY	ED	MY	AMD
AA	-0.07	0.11	0.26	0.19	0.09	-0.06	0.10	0.12
AEM	-0.03	0.15	0.38	0.23	0.15	-0.04	0.19	0.16
AbM	-0.20	0.09	0.06	0.18	0.05	0.05	-0.06	0.14
AMN	-0.07	-0.00	0.24	0.15	0.05	-0.08	0.07	0.04
AbN	-0.13	0.04	-0.05	0.16	-0.10	-0.08	-0.12	0.06
ANE	0.24	0.16	0.22	0.03	0.26	0.02	0.29	0.09
AbE	-0.38	0.00	0.09	0.19	-0.25	-0.18	-0.24	0.03
PMR1	-0.02	0.05	0.25	0.12	0.19	-0.07	0.16	0.06
PMR2	-0.00	0.15	0.20	0.14	0.08	-0.02	0.10	0.12
PMR3	-0.12	0.11	0.21	0.20	-0.00	-0.07	0.02	0.12

Abbreviations are explained at the bottom of Table 3.

These correlations are considered moderate, suggesting that in cows with daily milk yield of about 40 kg, the increase in walking activity was paralleled by the increase in some milking parameters, although this only concerned noon milking. Correlations markedly weaker, or no correlations at all were found in G2 cows (Tab. 4).

Generally, no relationships were identified between milking duration and cow activity, or the correlations were weak, which was only to be expected (Tab. 3 and 4).

Under natural conditions, sunlight has the most profound impact on 24-hour activity of cattle. Animals become most active just after sunrise and remain so until dusk [Jezierski 1987]. This is because vision provides cattle with 50% of information about the surroundings, and daylight colours (yellow, orange and red) are discriminated better than nighttime colours (purple, blue) – Phillips and Lomas [2001], Phillips [2002]. Photoperiod length was also shown to have a significant impact on milk yield and composition [Dahl *et al*. 2000, Velasco *et al*. 2008]. In the loose housing of dairy cows with designated milking periods (twice to three times daily) in the milking parlour and TMR/PMR feeding at set times, mainly these activities determine the 24-hour activity of cows. This particularly concerns morning and evening milking time, as confirmed by the present results. Where milking robots are introduced, 24-hour activity of cows is less related to milking time because it is the animal which mostly decides when to enter the milking unit, both at night and during the day [Wagner-Storch and Palmer 2003].

Edwards and Tozer [2004] reported that the general trend of mean daily walking activity in Holstein-Friesian cows over the first 30 days of lactation was similar in both healthy and sick animals although healthy cows were more active than sick cows. Initially, high walking activity of cows (about 240 steps/h for sick cows and 300 steps/h for health cows) rapidly decreased and then remained stable at about 140-180 steps/h during the day at about 11 days of lactation. The present study suggests that the above stabilization of mean daily activity may last even after the cows have reached maximum daily milk yield, as no significant differences were found between the feeding groups. Edwards and Tozer [2004] also demonstrate that both healthy and sick cows (e.g. suffering from ketosis or with displaced abomasum) are characterized by specific levels of walking activity. When using real-time monitoring of cows, this may serve to identify not only healthy and sick animals but also individual diseases.

Similarly to the current findings, DeVries *et al*. [2003] showed that the activity of loose-housed dairy cows is considerably influenced by milking time and feeding time. According to the above authors, TMR feeding and feed push-up increased cow activity at the feeding table by a maximum of 40%, while this study indicates that mean activity of all cows after the morning PMR feeding most often clearly decreased by almost 40% for G1 and by 53% for G2 cows. This was probably due to the lower walking activity of the animals at the feeding table. Meanwhile, the difference between the groups could result from the fact that G2 cows were milked one hour earlier in the morning and therefore were more active, which, in turn, they probably compensated with a greater decline in activity after first PMR feeding compared to G1 cows (Fig.

1 and 2). Also worth noting is the large variation in cow activity from first to second PMR feeding (SD = 13.4-13.5), which shows that specific behaviour of individual animals played a very important role during that period.

Mean 24-hour activity of G1 and G2 cows generally remained at a similar level. Probably it was the result of ensuring proper conditions of animals' management and feeding. Nonetheless, slightly higher relationships were noted between milk yield and activity in G1 cows, which was probably due to the specific nature of the early stages of milk production and the associated feeding. It is pertinent to note the moderate and positive relationship between daily milk yield and mean 24-hour activity of G1 cows. Taking into account that technology for constant online monitoring of milk flow and cattle welfare is being introduced into practice (*i.e.* measuring of walking activity of animals), the results obtained demonstrate that the relationships shown in the present study could be of practical importance. More and more information available at an increasingly rapid rate on cow performance, health and behaviour, as well as growing insight into the relationships between them will help breeders to take better care of animals while optimizing (rather than intensifying) their performance. This course of action is increasingly seen among dairy cattle breeders around the world.

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