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Research Article

Effect of Short-distance Walking Activity on Milk Production and Metabolic Status of Lactating Dairy Cows

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ABSTRACT

In this study, the effect of daily short-distance walking exercise on milk production and metabolic status of the lactating dairy cows was investigated. The experiment was conducted with 10 lactating dairy cows comprising 2 groups (5 dairy cows/group), which were walking activity and non-walking activity. The walking activity (WA) group lactating dairy cows walked outdoors for 1 km/d, and the non-walking activity (non-WA) lactating dairy cows were maintained within a cowshed from 18thApril to30th May. The activity volume of the neck was not significantly different between the groups, but the activity volume of the leg was higher in WA group compared with non-WA (p<0.05). The rectal temperature was higher in the WA group (38.6 ℃) compared with non-WA (38.2 ℃) (p<0.05). No significant differences in dietary NE intake, milk production and milk composition were found between the groups. The plasma cortisol concentration was higher in WA group (2.14 ㎍/dl) compared to non-WA (0.95 ㎍/dl) (p<0.05). However, plasma cortisol level of WA dairy cows was significantly decreased as compared with non-WA cows. On the contrary, the level of plasma melatonin was increased in WA cows than that of non-WA dairy cows. It may be interpreted as a change in physical fitness. From this study, we suggest that walking activity can be improved energy balance. Further investigation is needed to determine whether different combinations of distance, rate or doing in morning or afternoon will stimulate energy balance.

(**Key words**: Dairy cow, Walking activity, Milk production, Metabolic status)

Ⅰ. INTRODUCTION

Cows are reserved in many different indoor management systems. However, current dairy systems limited these series of walking activity to do cows especially, when housed indoors except for dairy farm, which has sufficient size of pasture or outdoor yard. Dairy farmers who apply the feeding management system through grazing in South Korea are very limited. Lack of access to pasture can be a threat to welfare and health of dairy cows because of documented positive effects of grazing such as improved leg health, lower prevalence of mastitis and a decrease of stereotypes and aggression in the herd (Kilgour, 2012). Walking activity is essential to sustain life-supporting actions such as feed searching, to eat, to be milked, avoidance of aggressive herd mates, seeking shelter, reproductive behavior and so on. However there is known that walking constitutes a major activity for cows that increases nutritional requirements and reduces milk yield (Ribiero et al., 1977; Lawrence & Stibbards, 1990; Matthewman et al., 1993; Mendez et al., 1996). A number of studies have reported on observations concerning the reproduction and health (like lameness, metabolic disorders) that are attributed to lack of exercise (Anderson et al., 1979; Miettinen et al., 1991). There is a problem that preparations for daily movement or walking activity of cows have a contrary tendency with farmer's economic or labour-saving management, although most farmers know and admit that cows are good to walking exercise steadily.

A number of studies have performed to estimate the effect of walking activity on milk production and energy status under the dairy farms that cows housed in the tie-stall. Most of those studies have examined cow that walked long distances (3 to 12 km) (D'Hour et al., 1994; Coulon & Pradel, 1997; Coulon et al., 1998). In South Korea, there are limitations to applying the previous studies to dairy farms that dairy cows were housed only in a tie-stall barn without grazing. Therefore, this study was aimed to investigate the effect of short-distance walking activity on milk production and metabolic status in lactating dairy cow.

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Ⅱ. MATERIALS AND METHODS

1. Animals and experimental design

All lactating dairy cows were housed, and the study was conducted at Department of Animal Resources Development, National Institute of Animal Science (NIAS), Cheonan, South Korea. The experimental protocol was evaluated and approved by the Animal Testing Ethics Committee of the NIAS (Jeonju, South Korea). A total of 10 multiparous Holstein dairy cows (average 2.6 of lactation number; average 34.2 kg/d of milk yield; an average 126 days in milk) were included in an experiment carried out from 18th April - 30th May 2017. All lactating dairy cows were subjected to the same management procedures and housed in the tie-stall barn. Also, the cows were milked in a herringbone milking parlour twice daily (06:00 and 17:00). All dairy cows fed total mixed rations (TMR, NE_l 1.7 Mcal/kg, and TDN 68.7%) with concentrate *ad libitum*. The dry matter intake (DMI, kg/day), was estimated daily as the difference between the amount of feed intake and feed refusal. The chemical composition of the rations based on the realized TMR and concentrate are presented in Table 1.

2. Walking activity and rectal temperature measurement

All lactating dairy cows were randomly selected and assigned to the non-walking activity group (non-WA) and walking activity (WA) group. During the experiment, we measured the activity volume of neck and thurl part in a cow from 09:00 to 18:00 daily when cows were induced to walk at the speed of 3 km/h for 1 km/d and the other group (non-WA) of lactating dairy cows remained at the barn. The rectal temperature of all dairy cows was measured with using stanchion once a week before and after walking activity. Neck and leg activity of cows were measured using the pedometer (YAMASA Corporation, Tokyo, Japan) around between 09:00 and 18:00.

Table 1. Composition of total mixed rations and concentrates fed to lactating dairy cows

Item	Diet	
	TMR	Concentrate
Dry matter intake (%)	47.03	88.64
Crude protein (%)	11.59	21.43
Ether extract (%)	5.16	4.03
Crude fiber (%)	22.24	9.58
Crude ash (%)	6.18	7.21
Neutral detergent fiber (%)	44.98	28.85
Acid detergent fiber (%)	25.14	14.29
Net energy of lactation (NE_l)(Mcal/kg)	1.42	1.76

TMR and concentrates comprised 47.03% and 88.64% of total dry matter (DM), respectively.

Table 2. Rectal temperature and activity volume in lactating dairy cows before and after walking

Item	NWA[1]	WA[2]	SEM	*p*-value
Rectal temperature, ℃				
Before walking	38.2	38.2	0.245	0.634
After walking	38.2	38.6	0.318	< 0.05
Activity volume[3]				
Neck part	1,420	1,929	620.5	0.082
Thurl part	389	1,501	680.9	< 0.05

[1] NWA, non-walking activity group.
[2] WA, walking activity group.
[3] Activity volume was counted using pedometer from 09:00 to 18:00 daily.

3. Blood sampling

Blood samples were collected from each lactating dairy cows in the week before starting the experiment. Blood samples were collected from the jugular vein of each lactating dairy cows just after walking activity on 3 and 6 weeks over the duration of the experiment by vacutainers containing heparin. Collected blood samples were chilled on ice immediately, and then centrifuged at 1500 x *g* for 15 min at 4 ℃ within 1 h of collection. The supernatants were separated and stored at -80 ℃ until further use.

4. Milk sampling

Milk samples were collected from each lactating dairy cow in both groups using in-line milk meters. On each milk-sampling, samples were collected at four consecutive milkings (i.e. am + pm). Milk samples were collected before starting the experiment day, 3rd and 6th week of the experimental period. Following, each raw milk sample was immediately determined chemical compositions (fat, protein, lactose contents and so on) by milk composition analyzer (CombiScope FTIR 300 HP, Delta Instruments, JB Drachten, Netherlands).

5. Sample Analysis

All plasma samples were assayed for glucose, urea nitrogen, non-esterified fatty acids (NEFA) and β-hydroxybutyrate (BHBA) level by using Clinical Analyzer (Hitachi 7180, Japan). Analysis of cortisol in plasma samples was performed using the enzyme immunoassay for direct determination and quantification (AE59031BO; Abebio, China). Intra- and inter-assay CV was 8.0% and 12.0%, respectively.

6. Statistical Analysis

The obtained data were analyzed statistically using SAS software package (9.2). Analysis of variance was evaluated using analyses of variance (ANOVA) test by presenting least squares means. The differences between treatment means were performed by Tukey Kramer test. The *P* values less than 0.05 were considered to be significant.

Table 3. Feed intake and energy balance in lactating dairy cows

Item	NWA[1]	WA[2]	SEM	*p*-value
Dry matter intake (DMI) (kg)	23.93	24.36	3.234	0.441
Feed efficiency, Milk yield/DMI	1.42	1.32	0.267	< 0.05
Net energy intake (NE_l)(Mcal/d)	35.95	36.39	4.702	0.595
Energy balance (Mcal/d)	1.44	6.40	4.281	0.199

[1] NWA was non-walking activity group.
[2] WA was walking activity group.

Table 4. Milk production and milk composition in lactating dairy cows

Item	NWA[1]	WA[2]	SEM	*p*-value
Milk yield (kg/d)	33.65	32.06	7.097	0.204
FPCM[3] (kg/d)	34.47	33.81	4.778	0.472
Milk fat (%)	3.94	3.86	0.504	0.591
Milk protein (%)	3.22	3.30	0.275	0.292
Lactose (%)	4.83	4.74	0.237	0.164
Total solids (%)	12.7	12.6	0.719	0.674

[1] NWA: non-walking activity group.
[2] WA: walking activity group.
[3] Fat and protein corrected milk (FPCM) was calculated by milk yield x (0.337 + 0.116 x Fat % + 0.06 x Protein %).

Ⅲ. RESULTS AND DISCUSSION

1. Rectal temperature and activity volume

The rectal temperatures of cows were similar in two groups before walking, but higher in WA group (38.6 ℃) compared with non-WA group (38.2 ℃) ($p<0.05$) after walking. Spies et al. (1965) reported that the rectal temperatures and respiration rates of the exercised ewes were significantly increased by exercise. Walking activity increases the action of the muscles of the hind limbs comparatively more than those of the forelimbs when compared with standing (Gustafson, 1994). In this study, the activity volume of neck part was not significantly different between the groups, but the activity volume of thurl part was higher in WA group cows compared with non-WA group cows ($p<0.05$). Coulon & Pradel (1997) reported that cows having walked spent 13 min longer feeding than those having remained in the stable. As observed by Coulon & Pradel (1997), the quantities of feed intake were increased 0.43 kg DM/day for cows having walked than for cows at rest. In the present study, the activity volume of neck part for dairy cows having walked was higher than that for cows remained in the barn (1,420 and 1,929 units for cows at rest and those having walked, respectively). The results of the present study showed that if walking in cows was not directly reflected in the movement of the neck, the increase in neck movement of groups with walking might be associated with increasing some feed intake.

2. Feed intake and energy balance

Numerous of studies have reported that heavy exercise was followed by appetite suppression (Lamb et al. 1979). This author also reported that grain consumption of cows decreased by exercise at the rate of 5.5 km/h. Similarly, Henning (1987) study results showed that roughage intake of sheep decreased by the intensive exercise on a treadmill at a maximum of 3 km/h with a 10° incline for 9 km/d. In the present study, no significant differences in dry matter intake were found between WA and non-WA groups. However, feed efficiency of WA group was lower than that of non-WA group ($p<0.05$). These results showed a tendency similar to the results of previous studies of Mitchell & Hamilton (1933) reported that it was decreased feed efficiency when beef cattle were exercised. Clapperton (1964) also reported that there was a slight increase of dry matter digestibility when sheep were exercised. On the other hand, Lamb et al. (1979) reported that walking improved reproductive and feeding efficiency without affecting production of 2-year-old dairy heifers kept in confinement. Generally, values from 45 to 60 kcal/km 100 kg BW^{-1} have been accepted for unrestrained cattle walking on the open range (ARC, 1980; CSlRO, 1990). Ribeiro et al. (1977) reported that cattle walking on a treadmill between 1 and 6 km could increase energy requirement by about 4 to 24% above maintenance. Although it was lower than the results of Ribeiro et al. (1977), Mendez et al. (1996) found that cattle walking between 6 to 9 km/d at 3 km/h can increase energy expenditure by only 4 to 6%, which estimated from the carbon dioxide dilution rate technique. In this study, no significant differences in dietary NE intake and energy balance were found between WA and non-WA groups. The results of the present study suggest that the extra energy costs for walking in cows may be lower than the energy costs for the improvement of negative energy balance during the early lactation period of dairy cows.

3. Milk production and composition

No significant differences in milk yield and composition were found between WA and non-WA groups. It is known that walking might influence production because walking is an activity that requires the expenditure of energy (Osuji, 1974). Thomson & Barnes (1993) did not find an adverse effect on milk production of dairy cattle travelling 8 km day^{-1}, even though their cows walked part of that distance over a 15 m hill. Also, Gemeda et al. (1995) reported slight differences in body weight losses and milk production between walking and non-walking cows. However, Coulon & Pradel (1997) reported that a long walk (12.8 km) of cows incurred a considerable decrease in milk yield, and cows were fed above their requirements.

4. Metabolic status

Walking activity increased the plasma glucose level ($p<0.05$), but there were no significant differences in plasma urea nitrogen, NEFA and BHBA between treatments (Table 5). Radostis et al. (2000) reported that blood glucose level in mid lactating cows were within the physiological range 45.0 - 75.6 mg/dl. In this study, plasma glucose content of cows remained at the barn was lower than that reported by Radostis et al. (2000). However, all

Table 5 Metabolic status in lactating dairy cows

Item	NWA[1]	WA[2]	SEM	*p*-value
Glucose (mg/dl)	36.67	45.93	10.281	< 0.05
Urea nitrogen (mg/dl)	10.19	9.96	2.964	0.842
NEFA[3] (uEq/L)	59.73	74.07	37.282	0.318
BHBA[4] (umol/L)	95.33	81.43	26.453	0.169
Cortisol (ug/dl)	0.95	2.14	1.072	< 0.05
Melatonin (pg/ml)	18.49	19.91	6.891	0.595

[1] NWA, non-walking activity group.
[2] WA, walking activity group.
[3] NEFA, non-esterified fatty acids.
[4] BHBA, β-hydroxybutyrate.

cows did not show any clinical signs. The results of the current study showed that the plasma NEFA concentration was numerically higher (+14.34 uEq/L) in walked activity dairy cows, and plasma BHBA concentration was numerically lower (-13.9 umol/L) in WA dairy cows as compared with cows that remained at the barn. The results of the current study showed there were no significant levels of NEFA and BHBA between treatment groups. Oetzel (2004) study reported that NEFA concentrations > 400 uEq/L indicate problems with energy balance and subsequent intensive lipomobilization, and that BHBA concentrations > 1200 umol/L is associated with subclinical ketosis. Cortisol concentration was increased in WA group (2.14 μg/dl) than non-WA group (0.95 μg/dl) (p<0.05). In the previous studies about the preferred walking speed of cow, walking at 3 - 4 km/h seemed to be pleasant while rapid walking or trotting at more than 5 km/h seemed very stressful (Lamb et al., 1979; Blake et al., 1982). Based on the study result, cows were adaptable to walking because of cows are not trained for the walking as reported by Coulon et al. (1998).

Ⅳ. CONCLUSION

Results of the present study showed that the WA dairy cows were influenced to the reduction of milk yield and the increase of energy balance. These results may lead to a marked reduction of the milk price paid to dairy farmers. Also, we observed the possibility that WA of dairy cows may be improved energy balance compared with cows that remained at the barn (non-WA). Further research is warranted to understand WA as a possible means of improving the energy status and giving the welfare quality of dairy cows, which housed in the tie-stall farms

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