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The Effect of Manual Forestripping on Milking Performance of Holstein Dairy Cows

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ABSTRACT

The objective of this study was to evaluate the effects of forestripping as a premilking stimulation technique on milk yield, milking unit attachment time, and milk flow rates in Holstein dairy cattle. Multiparous Holstein cows (n = 24) were divided into two groups (HPE, high producing, early lactation; LPL, low producing, late lactation) based on prestudy milk yield and stage of lactation. Within the production group, cows were randomly assigned into treatment (n = 6) and control groups (n = 6) in a switchback design. Cows were milked twice daily and treatments were switched after 20 milkings. Premilking udder preparation for the treatment group was as follows: forestripping, predipping with 0.5% iodine, and drying with paper towels followed by unit attachment. Udder preparation for the control group was identical except forestripping was not performed. Data were analyzed by using the PROC Means and PROC Mixed models described by SAS. During the study, cows in the HPE group produced significantly more milk and had longer milking unit attachment times compared with cows in the LPL group. The milk flow rate was 0.36 kg/min faster for the HPE cows compared with the LPL cows. There was no significant effect of order of treatment administration on any outcome variable. There were no significant differences in milk yield, milk unit attachment time, or milk flow for animals that were forestripped compared with animals that were not forestripped. In this study, the addition of forestripping to an otherwise acceptable premilking udder preparation routine did not increase milking performance of multiparous Holstein dairy cows.
(**Key words:** udder stimulation, milk yield, milk flow rate, milking routine)

Abbreviation key: HPE = high producing, early lactation, **LPL** = low producing, late lactation, **MY** = milk yield.

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INTRODUCTION

Proper premilking udder preparation is essential for the production of high quality milk. Premilking udder preparation includes the process of both teat end sanitation and premilking stimulation. Premilking stimulation is recommended to initiate milk ejection (Ely and Petersen, 1941). The mechanism of milk ejection includes both the release of oxytocin from the posterior pituitary gland and local autonomic reflexes (Ely and Petersen, 1941; Lefcourt, 1982). The "milk letdown" response occurs when oxytocin is released from the pituitary, it travels through the blood stream to the udder, and it causes contraction of the myoepithelial cells that surround secretory alveoli. The simultaneous triggering of the local autonomic reflex results in a decrease in the tension of the smooth muscle surrounding the mammary ducts and teat sphincters. Coordination of milk letdown with milking unit attachment has been shown to result in high milk flow rates and a reduction of milking unit attachment time (Gorewit and Gassman, 1985; Sagi et al., 1980a,b). A prolonged delay between stimulation and attachment (30 min) increased milking unit attachment time by 0.4 min and reduced average milk flow rates from 2.5 to 2.2 kg/min (Sagi et al., 1980a).

Many management decisions influence the effectiveness of premilking stimulation and a variety of premilking udder preparation techniques are used by dairy producers. The period between stimulation and unit attachment and the consistency and duration of udder preparation are critical factors in milking efficiency (Rasmussen et al., 1990, 1992). In one study, cows that received 31 s of premilking stimulation and had a consistent time interval (1.22 ± 0.25 min) between stimulation and unit attachment produced a higher FCM yield compared with cows that received a variable milking routine (Rasmussen et al., 1990).

The amount of stimulation required for effective milk ejection is affected by breed, stage of lactation, and production level. Both American and Danish Jersey cattle have been shown to require more stimulation than comparable Holstein cattle (Rasmussen et al., 1992). Rasmussen et al. (1992) also found that an increased number of DIM extended the time required to reach steady milk flow. Production level influences the amount of stimulation required to achieve maximum milking efficiency. Most premilking stimulation research has been performed on relatively low producing cows. Reneau and Chastain (1995) summarized milk yield (**MY**) for six studies that compared stimulation techniques. The average MY per milking for cows involved in those studies was 10.4 and 10.8 kg for nonstimulated and stimulated, respectively. In another study, Michanek and Ekelund (1994) reported that MY decreased for high producing cows and increased for low producing cows when the stimulation was increased from 15 to 35 s.

Premilking teat stimulation of 10 to 20 s and an interval of 60 to 90 s between stimulation and unit attachment is generally considered adequate to achieve efficient milk letdown and removal (Reneau and Chastain, 1995). Forestripping is an example of a strong stimulus for milk letdown. Forestripping consists of the removal of several streams of milk per quarter through manual compression of the teat. Forestripping is recommended to check for clinical mastitis and as a means of premilking stimulation (Rasmussen et al., 2000). Cows in later lactation have been reported to have higher stimulatory requirements because of lower amounts of milk being stored in the udder (Bruckmaier and Blum, 1998). The objective of this study was to evaluate the effects of forestripping as a premilking udder stimulation technique on milk yield, milking unit attachment time, and milk flow rates in low and high producing Holstein dairy cattle.

MATERIALS AND METHODS

The experiment was performed on multiparous Holstein cows (n = 24). Study cows were divided into two groups (**HPE**, high producing, early lactation; **LPL**, low producing, late lactation) based on prestudy MY and stage of lactation. Treatments were administered during two observation periods lasting 20 d (40 milkings) each. Treatments were administered to HPE during the first observation period. Treatments were administered to LPL during the second observation period, which occurred approximately 1 mo later. The cows were housed in a tie-stall barn at the University of Wisconsin-Madison and managed according to normal herd operating procedures.

Cows were milked in a double-six herringbone parlor equipped with automatic detachers and standard narrow-bore liners that were changed according to manufacturer's instructions. The Boumatic (Dairy Equipment Company, Madison, WI) milking system was calibrated to meet industry standards (Mein and Reid, 1996). The detachers removed units when milk flow reached 0.455 kg/min. There was a 5-s delay before unit removal. The vacuum level was 46.1 and 44.4 kPa for HPE and LPL, respectively. The vacuum was changed between production groups because of changes in the management of the milking facility. The pulsation ratio for both production groups was 60:40 and the pulsation rate for both production groups was 60 pulsations per minute (1 Hz). Within the production group, cows were randomly assigned to treatment (n = 6) and control groups (n = 6) in a switchback experimental design. Cows were milked twice daily and treatments were switched after 20 milkings. Premilking udder preparation for the treatment group was similar to existing herd operating procedures and consisted of 1) forestripping three streams of milk per quarter (time of stimulation was 10 to 15 s per cow), 2) predipping with 0.5% iodine using a teat dip applicator cup, 3) drying with paper towels, and 4) unit attachment. Udder preparation for the control group was identical except forestripping was not performed. Cows entered the milking parlor randomly and cows in the treatment group were identified by colored legbands. Cows were prepared in groups of three by using the following sequence (forestripping was omitted if the animal was in the control group): six cows entered one side of the milking parlor; the milking technician would forestrip the first cow and apply predip, then repeat the process on the next two cows; the technician then returned to the first cow to dry the teats and attach the milking unit; this process was continued for the next two cows. The time between stimulation and attachment was approximately 60 to 80 s. The sequence was then repeated for the next group of three cows on the same side of the parlor.

Premilking cow preparation and unit attachment was performed by the investigators [76 milkings were performed by A.M.W., and 4 milkings (HPE) were performed by P.L.R.]. The HPE cows were milked at 0400 and 1530 h for the first 7 d of the study and then at 0400 and 0500 h for the remainder of the study. The change of time was because of changes in the management of the milking facility. The LPL group was milked at 0345 and 1445 h throughout the study period.

The data collected consisted of MY and unit attachment time. MY and unit attachment time were collected from the computer monitors for each machine, and, the average milk flow rate for each milking was calculated by using the MY and unit attachment time data. Data from cows with multiple unit attachments during a single milking and data from cows that experienced milking machine problems were discarded. Statistical analysis was performed by using the PROC Means and PROC Mixed models described by SAS (1999). Data were analyzed in a model that included effects of subject (cow nested within treatment), treatment (forestrip and

Table 1. Pretrial descriptive data for study animals.

	High producing, early lactation cows (n = 12)		Low producing, late lactation cows (n = 12)		
	Mean	SE	Mean	SE	*P*
Parity	3.08	0.42	3.58	0.48	0.44
Days in lactation	124.17	4.80	266.08	12.67	<0.0001
Daily milk yield (kg)	46.00	1.33	26.00	1.67	<0.0001

control), production group (HPE and LPL), milking (a.m. and p.m.), order of treatment administration (control preceding treatment or vice versa), and first-order interactions with group. Milking by date was used as a repeated measure with first-order autoregressive covariance matrix.

RESULTS

Data for 913 (95.1%) of a potential 960 milkings were included in the analysis. Of potential milkings, 3.96% of the treatment group and 5.2% of the control group were excluded because of multiple attachments or problems with determination of data from the meters. In the HPE group, six cows contributed data from all 40 milkings. Three of the cows contributed data from 38 milkings, and two cows contributed data from 37 milkings. One cow contributed data from only 30 milkings because of multiple machine kick-offs. In the LPL group, two cows each contributed data from 40 and 38 milkings, three cows each contributed data from 39 and 37 milkings, and one cow each contributed data from 36 and 35 milkings.

One cow in the LPL group was replaced after the third milking when she developed clinical mastitis. The data from her first three milkings were discarded.

There was no significant difference in parity between cows included in the HPE group compared with the LPL group (Table 1). As defined by the protocol, at the beginning of the study, cows in the HPE group were earlier in lactation and had a significantly higher prestudy MY compared with cows in the LPL group (Table 1).

During the study, cows in the HPE group produced significantly more milk and had longer milking unit attachment times compared with cows in the LPL group (Table 2). The milk flow rate was 0.36 kg/min faster for the HPE cows compared with the LPL cows (Table 2). Morning MY was higher and milking unit attachment times were longer compared with p.m. values (Table 2). There was no significant difference in milk flow rates between a.m. and p.m. milkings (Table 2). There was no significant effect of order of treatment administration on MY (P = 0.14), machine attachment time (P = 0.38), or milk flow rate (P = 0.99).

There were no significant differences in MY, milking unit attachment time, or milk flow for animals that were forestripped compared with animals that were not forestripped (Table 3). Significant differences in milking performance were not observed for animals included in either the HPE or the LPL group (Table 3).

DISCUSSION

Our study is distinct from previous studies of premilking stimulation because of the comparatively high MY of the animals in both the HPE and the LPL groups and because the study compared two milking routines that differed only in the application of forestripping. The animals included in our study were selected to represent animals typical of a modern, high producing dairy herd. The MY of cows included in this study were considerably higher than MY of animals included in previous studies. Sagi et al. (1980a) compared no stimulation to 60 s of massage plus forestripping and various machine stimulation techniques. The MY of the 12 cows included in that study was about 11.5 kg per milking. Sagi et al. (1980b) used 12 multiparous cows to examine the effect of delaying attachment time after cows were manually stimulated and forestripped. The average MY of the cows that were manually stimulated was 10.4 kg per milking. The effect of varying duration of massage without using forestripping was reported by Gorewit and Gassman (1985). The MY of the five multiparous animals in the study was 12.2 to 13.4 kg per milking depending on the time of premilking stimulation. Twelve Holstein cows were used in an experiment in which the authors of the study examined the combined effect of duration of premilking teat stimulation and attachment delay (Rasmussen et al., 1992). The animals in that study produced about 11.0 kg per milking. The kilograms of milk per milking of the cows included in both groups of our study exceeded daily MY of animals included in all previous experiments. The production level of animals included in our study probably influenced the outcome of our experiment. Milking per-

Table 2. Least-square mean values for production, unit attachment time, and flow rate by production group and milking time.

	Milk yield (kg)	*P*	Attachment time (min)	*P*	Flow rate (kg/min)	*P*
Production group						
HPE	20.85		6.76		3.22	
LPL	14.27	<0.0001	4.96	<0.0001	2.87	0.0101
Milking time						
a.m.	18.64		6.13		3.09	
p.m.	16.48	<0.0001	5.58	0.0104	3.00	0.3909

formance was significantly different between production groups. Animals included in the HPE group produced more milk, had longer attachment times, and had faster average milk flow compared with animals included in the LPL group. Earlier researchers have suggested that the amount of milk in the udder before milking may influence milking performance (Williams and Mein, 1978). Unfortunately, the unintended change in vacuum level of the milking system between production groups makes it difficult to separate effects of production level from potential effects that could be attributed to differences in vacuum level. Potential errors associated with changes in vacuum level would have been equally distributed between treatment and control groups and there should not have been any confounding associated with this issue. Both groups of cattle included in our study are typical of high producing Holsteins used in commercial dairy herds in the United States and our results should be applicable to these herds.

The results of our study are consistent with previous reports of the relationship between premilking udder stimulation and MY. The process of forestripping did not significantly influence MY for either production group we examined (Table 3). Sagi et al. (1980b) performed two different experiments involving the effect of premilking stimulation on MY. The stimulation procedures used in the first experiment included 1) no stimulation, 2) intravenous oxytocin (0.75 IU), 3) forestrip followed by 30 s of manual massage and unit attachment 30 s later, and 4) forestrip followed by 30 s of manual massage and delayed unit attachment (30 m). Twelve Holstein cows were included in the experiment. A second experiment with four Holstein cows looked at no stimulation versus manual udder massage for 30 s followed by unit attachment. There was no significant effect of premilking stimulation on MY in either experiment.

In another experiment, Sagi et al. (1980a) looked at the effect of four premilking stimulation treatments on MY. Treatments included 1) no stimulation, 2) manual stimulation for 60 s (including forestripping and massage), 3) positive pressure pulsation for 60 s, and 4) fast pulsation for 60 s. The mechanical stimulation took place during the first 60 s that the unit was attached. Positive pressure pulsation was achieved by increasing the pressure in the pulsation chamber of the milking unit. Fast pressure pulsation was achieved by increasing pulsation rates. No significant effect of premilking stimulation on MY was observed in this experiment.

In a study by Gorewit and Gassman (1985), the effects of duration of premilking udder preparation on MY in five multiparous Holstein cows were examined. Premilking stimulation in this experiment included 1) no stimulation, 2) manual udder massage for 15 s, 3) manual udder massage for 30 s, 4) manual udder massage for 60 s, and 5) manual udder massage for 120 s. In all cases, unit attachment was performed immediately

Table 3. Least-square mean values for production, unit attachment time, and flow rate by treatment and production group.

	Milk yield (kg)	*P*	Attachment time (min)	*P*	Flow rate (kg/min)	*P*
Combined data						
Forestrip	17.90		5.85		3.09	
Control	17.22	0.3098	5.86	0.9550	3.01	0.5483
HPE						
Forestrip	20.94		6.74		3.26	
Control	20.76	0.8047	6.78	1.000	3.19	1.000
LPL						
Forestrip	14.86		4.96		2.92	
Control	13.68	0.2963	4.95	1.0000	2.82	1.0000

after massage was complete. There was no significant effect of the duration of premilking udder preparation on MY.

One study presents conflicting data about the relationship between premilking stimulation technique and MY (Merrill et al., 1987). In this study, 33 Holsteins were divided into two groups and treatments were applied for a full lactation. The premilking routines both included forestripping, but the "full stimulation" group also received 40 s of udder stimulation and had milking units attached 60 s after beginning udder preparation. The "minimal stimulation" group did not receive udder massage and had units attached immediately after teats were dried. In this report, cows that received full stimulation had slightly lower unadjusted average lactation MY compared with cows in the minimal stimulation group. However, when MY was examined by using lactation curve models, a slight increase in MY was noted for cows that received full stimulation. In any case, cows in both groups of this study were forestripped, and any effects would probably be caused by the duration between stimulation and unit attachment rather than incomplete stimulation.

The effect of duration of premilking teat preparation, attachment delay, and the number of forestripping squirts was examined by Rasmussen et al. (1992). Longer premilking preparation (30 vs. 10 s) significantly increased MY for Danish Jersey cows but had no influence on MY of American Holstein cows.

The milking unit attachment times that we observed (Table 2) were within the range of what others have reported for animals that have been adequately stimulated (Mein and Reid, 1996). It is well accepted that adequate premilking stimulation results in higher average milk flow rates and reduced unit attachment time (Gorewit and Gassman, 1985; Sagi et al., 1980a,b). Gorewit and Gassman (1985) suggested that 30 s of premilking udder massage would be adequate premilking preparation. Rasmussen et al. (1992) evaluated the effect of forestripping in combination with variable duration of teat wiping. Forestripping five streams of milk, compared with forestripping one stream of milk, decreased unit attachment time and increased average milk flow rates when the duration of teat wiping was 5 s but not when the duration of teat wiping was 20 s. In our study, the control group was predipped with a dip cup, but the teats were not handled until they were dried immediately before unit attachment. The average flow rates observed in both groups of animals in our study were higher than others have reported and animals included in the LPL group were in late lactation. In a review of milk ejection in ruminants, Bruckmaier and Blum (1998) concluded that adequate premilking stimulation was more important at the end of lactation because of the lower amount of milk stored in the udder and the small size of the cisternal fraction. Whereas some researchers have suggested that late lactation cows require more stimulation, we did not observe a beneficial effect of forestripping on attachment time or average flow rate in either production group. The high average flow rates that we observed are an indication that stimulation in both the forestripped and the control group was sufficient for adequate milk letdown. It is difficult to make direct comparisons of average flow rates between this study and previous experiments because of differences in detacher settings. The detachers in previously published reports were calibrated to remove units (or in some cases activate end of milking indicator lights to signal milking technicians to manually remove the units) when the milk flow reached 0.2 kg/min. Under those conditions, attachment times would be prolonged and average flow rates would be reduced compared with the milking performance that we observed.

It has been proposed that the timing of oxytocin release and the duration between stimulation and unit attachment is a more important determinant of milk letdown than achieving maximum blood oxytocin levels (Gorewit and Gassman, 1985; Sagi et al., 1980b). Reneau and Chastain (1995) suggested that 10 to 20 s of stimulation is adequate for milk letdown given that units are attached within 60 to 90 s from the start of stimulation. In our study, we compared two milking routines that are in common use in commercial dairy herds in the United States. If the process of applying teat dip to the cows was an effective premilking stimulus or if cows were preconditioned by entry into the milking parlor, then the duration between stimulation and attachment in both groups we studied would have met the guidelines. Teats were vigorously dried with a paper towel in both groups, but the process of drying did not exceed 10 to 15 s per cow and only teats (not the base of the udder) were handled. Unit attachment proceeded immediately after drying the teats and was usually completed within an additional 5 to 8 s. Under the conditions described in this report, the addition of forestripping to this routine did not enhance milking performance. Forestripping is performed primarily to detect clinical mastitis and is considered the single most effective method to reduce bulk milk cell count in problem herds (Rasmussen et al., 2000). Forestripping is an important part of many premilking routines and should continue to be recommended because it is the only way that farmers can detect mild clinical mastitis and divert abnormal milk.

CONCLUSIONS

Animals included in this study were higher producing and had higher average milk flow rates than animals included in previous studies of premilking stimulation techniques. The use of forestripping as a premilking udder stimulation procedure did not significantly affect MY, unit attachment time, or average milk flow rates in this study. Other studies have demonstrated differences between primiparous and multiparous animals in response to premilking stimulation (Rasmussen et al., 1992). This study included only multiparous animals and the results should not be extrapolated to primiparous animals.

REFERENCES

Bruckmaier, R. M., and J. W. Blum. 1998. Oxytocin release and milk removal in ruminants. J. Dairy Sci. 81:939–949.

Ely, F., and W. E. Petersen. 1941. Factors involved in the ejection of milk. J. Dairy Sci. 24:211–223.

Gorewit, R. C., and K. B. Gassman. 1985. Effects of duration of udder stimulation on milking dynamics and oxytocin release. J. Dairy Sci. 68:1813–1818.

Lefcourt, A. 1982. Effect of teat stimulation on sympathetic tone in bovine mammary gland. J. Dairy Sci. 65:2317–2322.

Mein, G. A., and D. A. Reid. 1996. Milking-time tests and guidelines for milking units. Pages 235–243 in Natl. Mastitis Counc. Ann Mtg. Proc., Nashville, TN. Natl. Mastitis Counc., Madison, WI.

Merrill, W. G., R. Sagi, L. G. Petersson, T. V. Bui, H. N. Erb, D. M. Galton, and R. Gates. 1987. Effects of premilking stimulation on complete lactation milk yield and milking performance. J. Dairy Sci. 70:1676–1684.

Michanek, P., and K. Ekelund. 1994. Influence of milking-routines on milking-time and yield. Pages 153–155 in Natl. Mastitis Counc. Ann. Mtg. Proc., Orlando, FL. Natl. Mastitis Counc., Madison, WI.

Rasmussen, M. D. 2000. A review of milking preparation: The science. Pages 104–110 in Natl. Mastitis Counc. Ann. Mtg. Proc., Atlanta, GA. Natl. Mastitis Counc., Madison, WI.

Rasmussen, M. D., E. S. Frimer, D. M. Galton, and L. G. Petersson. 1992. The influence of premilking teat preparation and attachment delay on milk yield and milking performance. J. Dairy Sci. 75:2131–2141.

Rasmussen, M. D., E. S. Frimer, Z. Horvath, and N. E. Jensen. 1990. Comparison of a standardized and variable milking routine. J. Dairy Sci. 73:3472–3480.

Reneau, J. K., and J. P. Chastain. 1995. Premilking Cow Prep: Adapting to your system. Pages 46–63 *in* Natl. Mastitis Counc. Reg. Mtg. Proc., Harrisburg, PA. Natl. Mastitis Counc., Madison, WI.

Sagi, R., R. C. Gorewit, W. G. Merrill, and D. B. Wilson. 1980a. Premilking stimulation effects on milking performance and oxytocin and prolactin release in cows. J. Dairy Sci. 63:800–806.

Sagi, R., R. C. Gorewit, and S. A. Zinn. 1980b. Milk ejection in cows mechanically stimulated during late lactation. J. Dairy Sci. 63:1957–1960.

SAS. 1999. SAS User's Guide: Statistics, Version 8. SAS Inst., Inc., Cary, NC.

Williams, D. M., and G. A. Mein. 1978. Physiological and physical responses of the supported teat during milking. Pages 96–106 *in* Proc. Int. Symp. Machine Milking, Louisville, KY. Natl. Mast. Counc. Inc., Washington, DC.