Productive Life and Reasons for Disposal of Holstein Cows Selected for Large Versus Small Body Size

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ABSTRACT

Holstein cows were compared for direct and correlated responses to selection for large versus small body size. The divergent selection lines differed for body weight, body dimensions, and birth weight of calves but did not differ for production or calving ease. Also, cows in the small line required fewer services to conception during first lactation than did cows in the large line. Cows in the body size lines differed for three reasons for disposal: udder conformation, which favored cows in the large line; problems with legs and feet, which favored cows in the small line; and a miscellaneous category, which included internal infections and favored cows in the small line. Productive life to a maximum of 6 yr was 87.7 d (15.4%) longer for cows in the small line than for cows in the large line. Continued selection for larger Holstein cows in North America might not be economically justifiable.
(**Key words**: body size, productive life, genetics, longevity)

Abbreviation key: **PL** = productive life, **PL72** = PL to 72 mo of age, **PL84** = PL to 84 mo of age.

INTRODUCTION

Holsteins in North America have been selected for increased body size for many years (4). Consequently, dairy producers in North America are milking dairy cows of larger size than were milked during the 1960s (1). Likely reasons for selection for larger body size are numerous and include 1) scores for conformation traits by Holstein Association USA (Brattleboro, VT) and the Holstein Association of Canada (Brantford, Ontario, Canada) continue to place more favorable ratings on cows with larger body size, 2) some dairy producers believe that larger cows have more body capacity to consume more feed, which in turn might allow cows to produce greater volumes of milk, and 3) some dairy producers are unsatisfied with body size of heifers at first calving because of poor heifer growth, and these dairy producers may attempt to compensate for substandard heifer management by selecting for increased genetic potential for mature body size (2).

Despite the emphasis on larger body size in selection programs, especially by registered breeders, no research has documented that large cows have functional or economic advantages over small cows within breed. Previous studies have indicated that small cows are more feed efficient than are large cows (8) and that small cows have fewer health problems, especially for digestive disorders, than do large cows (4). The major justification for including conformation traits in selection programs is to improve the productive life (**PL**) of cows. Research (6) has documented the importance of conformation traits of the udder to lengthen PL; however, no evidence exists to support continued selection for larger body size of dairy cows.

The objectives of this study were to access the direct response to divergent selection for large versus small body size of Holstein cows; to determine the correlated responses for number of services, calf size, and calving ease; and to compare the divergent lines for PL and reasons for disposal.

MATERIALS AND METHODS

Experimental Design

An experimental herd of Holstein cows at the Northwest Experiment Station, Crookston, of the University of Minnesota has been selected since 1966 for large versus small body size. During 1966, 60 Holstein cows in an existing herd were paired by sire and were randomly assigned to one of two genetic lines, large or small. Cows not fitting into pairs by sire were paired by predicted producing ability for milk production. Progeny were assigned to the same genetic line as their dams. Except for sire selection, both heifers and cows were managed together and

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identically. Lactating cows were housed in a tie-stall barn.

Service sires were selected from among the top 50% of active AI sires available in the US for PTA for production. The production criterion changed over the years of the study and, in chronological order, was 1) milk (kilograms), 2) milk-fat dollar value, 3) fat (kilograms) plus protein (kilograms), and 4) protein (kilograms). All other selection was based on the body size of daughters, either large or small. Sires were selected for standardized PTA for stature, strength, and body depth with the body size index of 0.5(stature) + 0.25(strength) + 0.25(body depth). The three most extreme sires for transmitting large and small body size were selected once each year from the summer genetic evaluations of the USDA for production and from the Holstein Association USA for body size. Reliability of PTA was required to be at least 70%. Cows within line were randomly mated to sires, except inbreeding coefficients were not allowed to surpass 6.25%, and calving difficulty was avoided for virgin heifers.

Cows and heifers were periodically added to the herd, especially to facilitate an expansion in the capacity of the barn to 106 stalls during 1987. These cows were considered to be new foundation animals for the selection project for body size and were assigned to one of the two genetic lines; however, cows in the present study were required to have at least three generations of prescribed large or small sires.

Data and Methods of Analysis

Cows used for this study were born after January 1, 1983. Data file 1 included 217 cows born from January 1, 1983 to December 31, 1989, and all cows in data file 1 had the opportunity to be in the herd for 7 yr (84 mo) and had been culled from the herd. Data file 2 included all cows in data file 1 plus 59 cows (n = 276) born from January 1, 1990 to April 30, 1991, and all cows in data file 2 had the opportunity to be in the herd for 6 yr (72 mo). Data file 3 included all cows in data file 2 plus 121 cows (n = 397) born from May 1, 1991 to November 30, 1994, and many of these cows were still alive at the time of analysis for this study.

Data file 1 was used for the analysis of reasons for disposal and PL to 84 mo of age (**PL84**). Measures of PL for this study were reported in days, and PL84 was essentially the same trait as that used by the Animal Improvement Programs Laboratory of USDA for the genetic evaluations for PL released in the US. Days in milk were summed across lactations, but individual lactations were allowed a maximum of 305 d. Data file 2 was used for the analysis of PL to 72 mo of age (**PL72**), which was similar to PL84 except that days in milk were summed only to 72 mo of age. Data file 3 was used for the analysis of all other traits in this study, and data was specific to parities of cows. Lactations initiated by abortions were eliminated from data file 3.

All cows were weighed immediately postpartum, as were their calves. Body weight and four body dimensions were recorded 1 mo postpartum (provided cows remained in the herd): height at the withers, length of body from withers to pin bones, depth of chest, and circumference of chest. For lactations initiated with twin births of calves, body weight immediately postpartum was excluded from the data, but body weight and body dimensions 1 mo postpartum were included in the data. Calving ease was coded on a linear scale from 1 to 5, where 1 = no assistance and 5 = use of a mechanical puller. Production of milk, fat, and protein was actual production (kilograms) from routine DHI. Production records were required to have at least 90 d in milk and were projected to 305 d. Also, for both heifers and cows that conceived, number of services to conception was recorded.

Reasons for disposal of the 217 cows in data file 1 were assigned to 12 categories: low production, reproduction, calving complications, abortion, mastitis, udder conformation, udder injury, legs and feet, metabolism, digestion, respiration, and miscellaneous. Miscellaneous reasons included kidney infection, bladder infection, peritonitis, twisted intestine, split pelvis, slow milking, and less than four functional quarters. Cows were allowed to be culled for one (coded as 1), two (each coded as 0.5), or three (each coded as 0.33) reasons for disposal.

Because numbers of observations for parities beyond 3 were very limited, results from analysis of only parities one, two, and three are reported. The general linear model for single parities included effects of genetic line (for all traits), age of calving (for body weights and dimensions, calving ease, calf weight, and production traits), and sex of calf (for calf weight). Genetic line was the only effect in the model for analysis of number of services, reasons for disposal, PL84, and PL72. Because of the small sample size for this single-herd study, neither year nor season was included in the linear model. To determine whether increases with parity for differences in body weight of body size lines were significant, an additional model combined data from parities 1, 2, and 3 of cows. The model, fitted with cow nested within line as a random variable, was analyzed with PROC MIXED of SAS (7).

TABLE 1. Number and ranges of observations for direct responses to selection for body size.

Trait	Parity	Small line n	Small line Minimum	Small line Maximum	Large line n	Large line Minimum	Large line Maximum
			(kg)			(kg)	
Postpartum							
Body weight	1	217	416	720	159	450	822
	2	126	488	731	93	514	834
	3	70	515	784	53	580	885
1 mo Postpartum							
Body weight	1	210	398	683	145	434	722
	2	135	429	667	93	503	748
	3	80	499	694	51	553	780
			(cm)			(cm)	
Height at withers	1	210	120	142	145	127	147
	2	135	121	141	93	128	146
	3	80	123	138	51	130	150
Length of body	1	210	125	153	145	129	152
	2	135	129	151	93	138	159
	3	80	134	156	51	141	163
Depth of chest	1	210	61	78	145	64	79
	2	135	61	75	93	66	80
	3	80	64	74	51	67	79
Circumference of chest	1	210	169	206	145	175	224
	2	135	174	201	93	187	221
	3	80	180	215	51	193	219

RESULTS AND DISCUSSION

Direct Response to Selection for Body Size

Table 1 has the numbers and ranges of observations, and Table 2 has the least squares means and standard errors for body weights and dimensions, which were regarded as the direct responses to selection for body size. As expected, the least squares means (Table 2) were different ($P < 0.01$) for all body weights and dimensions across parities. The ranges of observations for body weights and dimensions (Table 1) indicate that there was a tremendous overlap of phenotypic body sizes across the two genetic lines. Despite high estimates of heritability for traits related to body size, the cows in the two genetic lines had little difference for body size during the early generations of the selection experiment. Linear methods of scoring measures of body size (stature, strength, and body depth) coupled with more sophisticated methods of estimating PTA for sires successfully resulted in genetic lines that differed significantly for phenotypes of body weight and dimensions. However, the distributions of phenotypes for the two lines continue to have considerable overlap following more than 30 yr of intensive selection for body size.

Cows in the small line had a mean body weight of 558 kg immediately after first calving. Most dairy producers probably would not regard this mean weight as excessively small. However, cows in the large line had a mean body weight of 609 kg after first calving, which would be regarded as quite large by most dairy producers, especially when the mean age of first calving of only 25.5 mo is considered. Cows in both lines increased in body weight with parity; however, the difference of body size lines for body weight (both postpartum and 1 mo postpartum) became more pronounced with increased parity ($P < 0.01$). Thus, the cows that were bred to be large continued to grow more after first calving than did the cows that were bred to be small. Immediately after third calving, cows in the small line had a mean body weight of 641 kg, which is a large cow. In comparison, cows in the large line had a mean body weight of 720 kg after the third calving. At the time of dry-off, cows in both size lines weighed much more than they did immediately postpartum; in fact, some cows in the large line surpassed 900 kg at the time of dry-off. Once dairy cows reach an acceptable body size, continued growth beyond that body size might not be desirable economically.

The magnitude of differences (kilograms and centimeters) in mean body size in Table 2 might seem fairly small. However, the greater body weight of cows in the large line at 1 mo postpartum—10% for

TABLE 2. Least squares means and standard errors for direct responses to selection for body size.

Trait	Parity	Small line		Large line		Difference
		$\overline{X}$	SE	$\overline{X}$	SE	
		(kg)				
Postpartum						
Body weight	1	558	3.2	609	3.7	51**
	2	596	4.6	664	5.4	68**
	3	641	7.2	720	8.3	79**
1 mo Postpartum						
Body weight	1	507	3.2	559	3.8	52**
	2	555	4.2	625	5.1	70**
	3	584	5.4	672	6.8	88**
		(cm)				
Height at withers	1	129.0	0.2	136.1	0.3	7.1**
	2	130.4	0.3	137.4	0.4	7.0**
	3	130.9	0.4	138.6	0.5	7.7**
Length of body	1	136.0	0.3	141.6	0.3	5.6**
	2	141.3	0.4	147.6	0.4	6.3**
	3	145.0	0.5	151.4	0.7	6.4**
Depth of chest	1	67.1	0.2	70.9	0.2	3.8**
	2	68.2	0.2	72.6	0.3	4.4**
	3	69.5	0.3	74.2	0.3	4.7**
Circumference of chest	1	186.2	0.5	195.1	0.6	8.9**
	2	190.1	0.5	200.5	0.6	10.4**
	3	194.0	0.7	205.7	0.9	11.7**

**$P < 0.01$.

parity 1, 13% for parity 2, and 15% for parity 3—seemed considerable based on visual inspection. Although the increase in stature (height at the withers) was less pronounced than was body weight on a percentage basis (5 to 6% across parity), the difference of 7.0 to 7.7 cm also seemed to be greater upon casual observation. Thus, published PTA for stature, strength, and body depth might lead dairy producers to believe that bulls with extreme PTA for these traits will uniformly transmit extremely small or extremely large size to their daughters. Actually, the differences in phenotypes for body size of daughters of bulls with extreme PTA will likely to be much more modest than anticipated. The Holstein Association USA reported that sires with PTA differing by 6 standard deviations for stature (height at hips) will have daughters that will have a mean difference of only 5.1 cm when those sires are mated to cows that are breed average for stature (3). For this study, consistent use for over 30 yr of the most extreme sires for transmitting small size resulted in cows that would be considered to be of adequate size by most North American and, especially, international standards.

Across years of this study (births from 1983 to 1994), body weights did not change with year for the small line but had a significant increase with year for the large line. These results conform with our observation that, because of the continued emphasis on larger body size of Holsteins in North America, our small line has not changed for body size; however, the large line has continued to diverge for body size from the small line over time. The continued emphasis on larger cow size in North America began in the late 1960s. The ideal model cow of the Holstein Association USA was altered markedly in 1977, especially by increasing its body size (5). The small genetic line in this study might reflect the body size of the previous ideal Holstein cow, which was developed in 1922 (5). The mean PTA for the proven and available AI sires (in standard deviation units) summarized by the Holstein Association USA in February 1998 were 0.91, 0.68, and 0.78, for stature, strength, and body depth, respectively, on a 1990 fixed genetic base (3). Consequently, cows sired by AI bulls in US should continue to become larger in the future.

Production Response

The two body size lines did not differ ($P > 0.10$) for any of the three production traits across parity (Table 3). Rolling herd averages from DHI for the two body size lines have almost always favored the small line, but these differences were not likely to have been significant. Most feed consumed by lactating cows is

TABLE 3. Least squares means and standard errors for production traits.

Trait	Parity	Small line[1]		Large line[2]		Difference[3]
		$\overline{X}$	SE	$\overline{X}$	SE	
		(kg)				
Milk	1	8535	97	8492	117	–43
	2	9820	145	9578	176	–242
	3	9687	204	9954	261	267
Fat	1	308	3	300	4	–8
	2	337	6	325	7	–12
	3	332	9	331	12	–1
Protein	1	276	3	275	4	–1
	2	315	4	307	5	–8
	3	301	7	320	9	19

[1]Number of observations for small line: 191 (parity 1), 127 (parity 2), and 75 (parity 3).

[2]Number of observations for large line: 130 (parity 1), 87 (parity 2), and 46 (parity 3).

[3]$P > 0.10$.

for milk production rather than for body maintenance. In a previous study of cows in this selection project (8), however, income over feed cost was higher for cows in the small line.

Response for Number of Services, Calving Ease, and Calf Weight

Table 4 has least squares means and standard errors for number of services, calving ease, and calf weight. Although differences were significant ($P < 0.05$) only for reproduction during first lactations, all differences in line means for number of services favored the small line. No explanation for the difference in reproductive performance for the body size lines was obvious. The body size lines did not differ ($P > 0.50$) for calving ease. However, both lines had high levels of calving difficulty at first calving with a mean score of approximately 3.1 on a 1 to 5 scale. Whether this was a management related problem or was a function of the divergent selection for body size is unknown.

Mean calf weight at birth differed significantly for all three parities, and the mean difference was 2.6, 2.3, and 2.5 kg for parities 1, 2, and 3, respectively. The large line had calf weights that were approxi-

TABLE 4. Least squares means and standard errors for number of services, calving ease, and calf weight.

Trait and parity	Small line			Large line			Difference
	n	$\overline{X}$	SE	n	$\overline{X}$	SE	
Services, no							
Virgin heifers	233	1.54	0.07	164	1.67	0.08	0.13
1	141	1.79	0.10	98	2.08	0.12	0.29*
2	88	1.91	0.14	59	2.08	0.17	0.17
3	48	2.02	0.18	25	2.24	0.25	0.22
Calving ease							
1	228	3.16	0.10	163	3.08	0.12	–0.08
2	130	1.51	0.10	96	1.43	0.11	–0.08
3	77	1.36	0.11	56	1.45	0.13	0.09
		(kg)			(kg)		
Calf weight							
1	222	39.4	0.31	163	42.0	0.36	2.6**
2	126	42.4	0.45	95	44.7	0.52	2.3**
3	73	43.0	0.75	54	45.5	0.87	2.5*

*$P < 0.05$.

**$P < 0.01$.

TABLE 5. Least squares means for reasons for disposal.

Reason	Small line	Large line	Difference
	(%)		
Low production	4.9	6.2	1.3
Reproduction	34.5	33.0	–1.5
Calving complications	8.8	7.6	–1.2
Abortion	8.0	4.3	–3.7
Mastitis	15.3	16.3	1.0
Udder conformation	11.9	5.3	–6.6*
Udder injury	0.9	2.2	1.3
Legs and feet	2.8	7.4	4.6†
Metabolism	4.0	5.4	1.4
Digestion	5.6	3.6	–2.0
Respiration	0.4	0.0	–0.4
Miscellaneous	2.8	8.7	5.9*

†$P < 0.10$.

*$P < 0.05$.

mately 6% greater than the small line, which is much less than the 10 to 15% difference in postpartum body weight of their dams in the two body size lines.

Reasons for Disposal

Reproduction has been an ongoing management problem of the herd of cows comprised of the two body size lines, which is reflected in the approximately one-third of cows in both lines that were culled because of reproductive problems (Table 5). Mastitis was the only other reason for disposal that surpassed 15%, and the two lines did not differ for this reason for disposal.

Least squares means for body size lines differed for only three reasons for disposal. Two reasons for disposal were different at the 0.05 level: udder conformation and miscellaneous reasons. Legs and feet differed at the 0.10 level. The differences for both udder conformation and legs and feet were easy to explain. Because cows in the small line had shorter legs, udders were closer to the ground and, therefore, were more likely to have functional problems for milk removal. Likewise, the legs and feet of large cows supported more body weight than did the legs and feet of small cows and, consequently, could be expected to be under more stress and more prone to injury. Also, larger cows have a higher center of gravity than do small cows and might be more likely to slip and fall. The greater disposal of cows in the large line for miscellaneous reasons is not as easily explained; however, the cows in the large line seemed more predisposed to infections.

PL

Table 6 has the least squares means for the 217 cows (PL84) or 376 cows (PL72) in the body size lines. For each measure of PL, the difference between lines was approximately 88 d (2.9 mo) and favored cows in the small line. The line difference for PL was significant ($P < 0.05$) for PL72; however, probably because data file 1 was substantially smaller than data file 2, the P value for difference of body size lines for PL84 was only 0.125. The 87.7 d difference for PL72 represents a 15.4% advantage for cows in the small line.

The substantial difference in PL for the body size lines clarifies the greater need for replacement females for the large line versus the small line. Almost all new foundation females entering the herd after the 1966 initiation of the selection project were placed in the large line (again, to be included in the present study of cows, all cows had at least three generations of project sires). Yet, cows in the small line have continued to outnumber cows in the large line.

Typically, advocates for placing emphasis on conformation traits in genetic improvement programs have argued that conformation traits are important for increasing the PL of cows. The results of this study suggest that increased body size of Holsteins results in decreased PL rather than increased PL.

CONCLUSIONS

Emphasis on increased body size of cows continues in North America. Therefore, the small line for this

TABLE 6. Least squares means and standard errors for productive life.

Measure	Small line n	Small line $\overline{X}$ (d)	Small line SE (d)	Large line n	Large line $\overline{X}$ (d)	Large line SE (d)	Difference	P
84 mo	125	712.5	37.4	92	624.0	43.6	88.5	0.125
72 mo	157	658.3	28.9	119	570.6	33.2	87.7	0.047

selection project has become, essentially, a control line of cows for constant body weight across time, and cows in the large line have continued to become larger with time. Smaller cows have less maintenance cost and, at least for this study, had longer PL and perhaps enhanced reproductive capabilities. Of course, large cows have greater salvage value than do small cows. Furthermore, a difference of approximately 2.5 kg for calf weight at birth is probably of some economic value, especially for those calves grown for veal or beef production. Yet, small cows almost certainly have economic advantages over large cows within breed.

Results from this study should raise the question of whether Holstein cows should continue to be bred to become larger. A deficiency of this study, however, was the single management system for cows. Tie-stall barns might eliminate some of the social and physical stress on cows that exists for cows housed in groups or in free-stall barns.

Dairy producers should not attempt to overcome deficiencies in heifer rearing that result in inadequately grown heifers by selecting for larger body size. If most heifers grown by an individual dairy producer lack adequate body size, factors other than genetics are almost certainly the cause. Cows that are bred to be larger continue to grow more after first calving than do cows that are bred to be less large. Once an acceptable size of cows is reached, continued growth of cows beyond that size likely is not economically desirable.

If larger cows are needed to accommodate the demands of increased production, then selection for production should result in cows becoming larger as a correlated response. Seemingly, only traits that are documented to increase productivity and efficiency of productivity should be included in selection goals. Udder depth, disease resistance, and reproduction are examples of traits known to affect efficiency of production. Some might argue that a negative weight should be placed on body size in selection indices; however, for environments with ready access to relatively inexpensive feed, the sacrifice of selection intensity to decrease body size might not be justifiable. Over the long term, selection for economically important traits other than those related to body size should result in cows of near optimum size.

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