COSTS FOR HEALTH CARE OF HOLSTEIN COWS SELECTED FOR LARGE VERSUS SMALL BODY SIZE

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ABSTRACT

The objective of the study was to compare Holstein cows selected for large versus small body size for health care cost. All health treatments were recorded for cows from 1983 to 2005, and treatments were assigned to one of 11 categories of health disorders. Actual cost for veterinary treatments, health supplies, and drugs, as well as the value of labor required by animal attendants, was recorded. Data were for 1,035 lactations of 486 cows, of which 199 cows were from the large line and 287 cows were from the small line. Large-line cows had significantly greater total health cost than small-line cows during first lactation and tended to have greater total health cost for the first 3 lactations of cows. During first lactation, large-line cows had total health cost of $62.41, and small-line cows had total health cost of $41.41. Cows in the large line had significantly greater health cost for the individual categories of displaced abomasum and pneumonia than small-line cows during first lactation. Across the first 3 lactations, large-line cows had a total health cost per lactation of $54.15 and small-line cows had a total cost of $38.09. Cows in the large line had significantly greater health cost for the categories of locomotion and displaced abomasum across the first 3 lactations than small-line cows. Cost for displaced abomasum accounted for a majority of the difference of health cost between the body size lines for both first lactation and for the first 3 lactations of cows.

(**Keywords:** body size, health cost, type)

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INTRODUCTION

North American Holsteins have been selected for increased body size for many years (Tsuruta et al., 2004; VanRaden and Tooker, 2005; VanRaden et al., 2010), partially because selection indices in many countries have placed a positive weight on body size (Miglior et al., 2005). Furthermore, scores for conformation by the Holstein Association USA (Brattleboro, VT) continue to place more favorable ratings on cows with larger body size through the use of its body size composite, which is calculated from the 4 linear traits of stature, strength, body depth, and rump width (Holstein Association USA Inc., 2011).

Impact of increased body size

Berry et al. (2003a) and Berry et al. (2003b) reported body weight (**BW**) consistently exhibited negative genetic correlations throughout lactation with interval to first service, pregnancy to first service, and pregnancy at 63 days after the start of breeding season, while positive genetic correlations were evident between BW and both interval from first service to conception and number of services. Field data in the United Kingdom was used by Pryce et al. (2000), and they found genetic correlations of calving interval (**CI**) with stature and body depth were moderate (0.26 to 0.33), indicating that taller, deeper cows had longer CI. Rogers et al. (1999) reported body depth, stature, and strength each had negative correlations with reproductive diseases. Lengthened CI may result in reduced lifetime milk yield and increased replacement cost (Pryce et al., 2000). Conversely, from a single British research herd, Brotherstone et al. (2007) reported cows that were heavier at calving suffered fewer reproductive problems during first lactation. Clearly, many studies in the literature suggest increases for BW in the Holstein breed will lead to reduced overall fertility. With reduced fertility, Holstein cows are more likely to be culled (Sewalem et al., 2008), which, in turn, could be detrimental to the profitability of dairying.

Reproductive culls accounted for 8.6% of culls on Swedish dairy farms (Löf et al., 2007), and Pinedo et al. (2010) reported 17.7% of culls on United States (**US**) herds enrolled in Dairy Herd Improvement (**DHI**). Also, Dechow and Goodling (2008) found comparable percentage of culls (20.1%) for fertility in Pennsylvania dairy herds. Hansen et al. (1999) reported cows selected for large body size had a culling rate of 33.0% for infertility.

Productive life of US Holsteins declined by 3.5 months for cows born in 2009 compared with cows born in 1980 (AIPL, 2012). Hansen et al. (1999) found cows selected for large body size had a 2.9 month disadvantage for productive life compared to cows selected for small body size and the difference for productive life between the two body size lines suggested a substantial increase in replacement cost for females in Holstein cows selected for larger body size compared to smaller body size.

Body weight of first lactation cows had no correlation with milk yield for Berry et al. (2003a) or for Veerkamp et al. (2000); however, body weight was positively correlated with dry matter intake (**DMI**) (Veerkamp et al., 2000). Conversely, Veerkamp and Brotherstone (1997) found an antagonistic correlation between BW and milk yield of -0.09. However, Hansen et al. (1999) reported production of cows selected for large versus small body size were not statistically different in a long term selection project. Veerkamp and Brotherstone (1997) reported DMI and average BW had a moderate but positive correlation of 0.31, and DMI was positively correlated with stature (0.13), chest width (0.28), body depth (0.34), and rump width (0.24). Their results suggests BW had a negligible effect on milk yield, but larger cows consume more feed to produce milk and, thereby, increased the maintenance costs of cows.

Replacement costs are one of the largest input costs for dairying (USDA, 2012). Also, survivability of calves is an important factor for success of dairy producers because calf death can negatively affect replacement costs and overall profitability (Linden et al., 2009). Holstein cows selected for large versus small body size in a long-term selection project gave birth to 2.5 kg heavier calves (Hansen et al., 1999), but the body size lines didn't differ for calving ease. Conversely, difficult deliveries were considerably more frequent for large and medium size calves versus small calves (53.04%, 41.45%, and 5.52%, respectively) for first-lactation cows in a Canadian field data (Sewalem et al., 2008). Similarly, Linden et al. (2009) concluded that assistance during parturition was associated with higher birth weight of calves. Sewalem et al. (2008) also found large calves had poorer survival than small or medium size calves for Canadian Holsteins. Cows delivering large calves were 1.04 times more likely to be culled than cows delivering a medium-sized calf (Sewalem et al., 2008). Hansen et al. (1999) found cows selected for large body size were culled 7.6% of the time for calving complications. Also, increased birth weight of calves was predictive of a higher incidence of lameness in the subsequent lactations of cows (Linden et al., 2009). Therefore, larger calves can be associated with a plethora of complications ranging from calving difficulty at parturition, decreased survivability of the calf, and increased disease incidence in later lactations.

Health data

Health disorders are of increasing interest for commercial dairies over time; however, data on health disorders are difficult to measure and expensive to record. Producer-recorded data is often unreliable and poorly documented on dairies (Koeck et al., 2012). With unreliable data, culling decisions based on disease incidence and disease treatment are difficult. Reasons for culling based on disease ranged from 3.0% to 6.9% (Dechow and Goodling, 2008; Hadley et al., 2006; Pinedo et al., 2010), which potentially indicates dairy producers are not culling effectively for disease or else diseases aren't being recorded routinely and reliably to be utilized for effective culling decisions. From examining herd removals, Wenz and Giebel (2012) found only 56% of dairies using Dairy Comp 305 consistently provided a condition affecting record (**CAR**) code when a sold event was recorded. Lack of use of CAR codes on dairies makes it difficult to accurately evaluate health management decisions.

Most on-farm software report lower incidence rates for health disorders than anticipated on most dairies, which suggests underreporting by dairy farmers, who may record health disorders only when treatment is required (Parker Gaddis et al., 2012). The ability to differentiate between new and recurrent clinical episodes of a health problem can aid in the investigation into the cause of unacceptably high incidence rates for health (Wenz and Giebel, 2012), which may help minimize unwarranted health treatments for individual cows. Summarizing and evaluating health data that is consistently and accurately recorded should facilitate increased knowledge of health management outcomes, which are critical for rational and cost-effective decision-making for dairies in regard to 1) disease incidence rates, 2) retreatment rates, 3) recurrence rates, 4) removal rates (sold or died), and 5) lost quarter rates for mastitis (Wenz and Giebel, 2012). Too frequently, this type of information is unavailable for dairy producers to utilize. Protocols for recording health data on dairies should be held to more rigorous standards so the health data to be more effectively used by dairy producers and researchers alike.

Koeck et al. (2012) reported direct herd life of cows was positively associated with all heath traits, and this suggested selection for disease resistance should improve longevity of cows. Data recording is useful for dairy producers and researchers; however, many herds do not use health-recording software, and a large proportion of data is lost after data validation (Koeck et al., 2012; Parker Gaddis et al., 2012; Zwald et al., 2004). Appuhamy et al. (2007) stated direct selection for disease resistance requires accurate records of disease incidence and severity, and many producers do not record diseases in a manner useful for that purpose. Continued education of dairy producers on the benefits of accurately and consistently recorded health data is especially important for the future.

Incidence rates of, and correlations among health disorders

Minimizing the health care needs of dairy cows is important from both economical and animal welfare points of view. Appuhamy et al. (2009) examined incidence rates of common health disorders of Holstein cows in the US and found, across lactations, cows had incidence rates of 11.2% mastitis, 3.9% for displaced abomasum, 5.6% for ketosis, and 15.3% for lameness. Similarly, Parker Gaddis et al. (2012) examined incidence rates of dairy cows from the use of on-farm computer programs in the US and found incidence of 12.3% for mastitis, 2.2% for DA, and 5.2% for ketosis; however, lameness was substantially lower at 6.4% compared to Appuhamy et al. (2009). Zwald et al. (2004a) reported incidence rates in the US from field data of 20.0% for mastitis, 3.0% for DA, and 10.0% for lameness. From field data on Canadian Holsteins, Koeck et al. (2012) found incidence rates of 12.6% for mastitis, 3.7% for DA, 4.5% for ketosis, and 9.2% for lameness. Thompson-Crispi et al. (2012) reported incidence rates of 23.6% for mastitis, 6.9% for metritis, and 3.0% for DA. In German contract herds, Gernand et al. (2012) found a substantially higher incidence rate for mastitis at 38.0%, and a lameness incidence of 7.3% for Holsteins.

Across studies, mastitis had the highest incidence rate, and mastitis is the major disease of dairy cows. The majority of all health disorder of dairy cows occur within the first 60 days in milk (**DIM**) (Appuhamy et al., 2009; Harder et al., 2006; Parker Gaddis et al., 2012). However, mastitis can be a direct result of dystocia, and mastitis occurs approximately at 82 DIM after a cow has calving complications. Cows with an incidence of an early health disorder have an increased risk of a later health disorder (Parker Gaddis et al., 2012).

Lyons et al. (1991) reported cows with a mammary disorder had a genetic correlation of 0.52 and 0.84 with digestive and locomotive disorders, respectively. Koeck et al. (2012) found mastitis incidence had genetic correlations of 0.20, 0.36, and 0.49 with DA, ketosis, and lameness incidence, respectively. Zwald et al. (2004b) found lower genetic correlations among health disorders than other studies; however, they had positive genetic correlations between mastitis and DA (0.08), ketosis (0.17), and lameness (0.20). Hansen et al. (2002) and Lassen et al. (2003) looked at the genetic correlations between clinical mastitis and any disease other than mastitis and found correlations of 0.24 and 0.32, respectively. Zwald et al. (2004b) reported antagonistic relationships of stature, strength, and body depth with metabolic disorders such as DA. Rogers et al. (1999) reported selection for wider rumps, deeper bodies, more strength, and taller cows would likely have little, if any, positive impact on disease resistance. Frigo et al. (2010) reported cows at 10 DIM had a genetic correlation of 0.15 between BW and mastitis. Abdel-Azim et al. (2005) examined the correlations among sire transmitting abilities for disease traits and found a strong correlation between DA and infectious diseases (0.28) and udder health (0.20), which suggests cows that have one type of health problem are predisposed to another type of health problem during lactation.

Cost of health disorders

The impact of health disorders on cost of production have two components: 1) expenditures for veterinary services and drug supplies and 2) reduced milk output (Wells et al., 1998). Most dairies do not keep on-farm records on the cost of diseases. Vast improvement is needed to assess whether inputs of time, drugs, and labor will reduce the initial cost of treatment and return a profit.

Diseases such as mastitis, DA, ketosis, cystic ovaries, metritis, and lameness severely affect the profitability of dairying through increased veterinary treatments, additional labor, lost milk sales, and involuntary culling (Zwald et al., 2004a). Cows with clinical mastitis have reduced milk production and incur treatment cost (Shim et al., 2004), and Ettema and Santos (2004) reported treatment cost of $50.80 for each case of clinical mastitis. Guard (2009) found somewhat lower cost for a single case of clinical mastitis (veterinary cost, drugs/supplies, and labor), $30.00; however, the cost of mastitis was $209.00 when factoring in losses from discarded milk, lost production, delayed conception, death, and culls. Consequently, considering all cost and lost revenue from dairy cattle diseases has huge implications for dairy profitability.

According to the USDA (2012), cost of milk production for veterinary and medicine costs ranged from $0.48 to $1.42 per hundred pounds in the US. When averaged across all US states, veterinary and medicine costs alone were 4% of milk value sold per hundred pounds (USDA, 2012), and this estimate likely was conservative due to underreporting of disease treatments or to culling of sick animals.

Jones et al. (1994) analyzed health care costs of a Minnesota experimental herd of Holsteins selected for milk production versus a 1964 control line of Holsteins. Cows in the milk selection line had higher health care costs than the control line during first lactation of $28.22, mostly attributed to more mastitis (43% of total health cost). Similarly, Kaneene and Hurd (1990) found mastitis was the highest cost of disease in dairy cattle at $35.54. Mahoney et al. (1986) analyzed health care cost of Holstein cows bred experimentally for large versus small body size and found cows in the large body-size line incurred significantly ($P < 0.05$) higher treatment cost than cows in the small body-size line during first lactation ($12.10 versus $6.57). These costs are much lower than those reported by Zwald et al. (2004b), who reported cost of health problems during first lactation ranged from $128 to $169.

When multiple lactations were analyzed, Jones et al. (1994) found the milk selection line of Holsteins had more mastitis (63% of total health cost) compared to the control-line cows. When examining multiple parities of the milk selection versus control-line Holstein cows, both lines had increased total health cost with successive lactation; however, the milk selection line had a greater increase in total health cost than the control line. When all lactations were examined, Mahoney et al. (1986) again found the digestive category to be significantly ($P < 0.01$) for the cows selected for large body size compared to cows selected for small body size, and this difference accounted for 26% of the total difference for health care cost. The large-line cows also had significantly ($P < 0.01$) higher total health costs than the small-line cows, $12.82 versus $8.39, respectively.

Holstein cows have steadily increased for body size over time. Economic indicators show few, if any, advantages of larger Holstein cows. Overall, continued selection for larger body size will likely have negative impact on fitness and health traits of Holstein cows. Dairy herds today may be able to minimize health-related costs more effectively if the impact of size of cow on these costs was better understood. Taller and larger Holstein cows may be more desirable from a show-ring (hobby) perspective; however, they appear to be undesirable from a commercial standpoint.

Abbreviation key: **BW** = Body Weight; **CAR** = Condition Affecting Record; **CI** = Calving Interval; **DIM** = Days in Milk; **DHI** = Dairy Herd Improvement; **DMI** = Dry Matter Intake; **US** = United States

REFERENCES

Abdel-Azim, G. A., A. E. Freeman, M. E. Kehrli, Jr., S. C. Kelm, J. L. Burton, A. L. Kuck, and S. Schnell. Genetic basis and risk factors for infectious and noninfectious diseases in US Holsteins. I. estimation of genetic parameters for single diseases and general health. 2005. J. Dairy Sci. 88:1199-1207.

AIPL (Animal Improvement Programs Laboratory). 2012. Genetic and phenotypic trends. http://aipl.arsusda.gov/eval/summary/trend.cfm?R_Menu=HO.h#StartBody. Accessed Oct. 25, 2012.

Appuhamy, J. A. D. R. N., B. G. Cassell, and J. B. Cole. 2009. Phenotypic and genetic relationships of common health disorders with milk and fat yield persistencies from producer-recorded health data and test-day yields. J. Dairy Sci. 92:1785-1795.

Appuhamy, J. A. D. R. N., B. G. Cassell, C. D. Dechow, and J. B. Cole. 2007. Phenotypic relationships of common health disorders in dairy cows to lactation persistency estimated from daily milk weights. J. Dairy Sci. 90:4424-4434.

Berry, D. P., F. Buckley, P. Dillon, R. D. Evans, M. Rath, and R. F. Veerkamp. 2003a. Genetic relationships among body condition score, body weight, milk yield, and fertility in dairy cows. J. Dairy Sci. 86:2193-2204.

Berry, D. P., F. Buckley, P. Dillon, R. D. Evans, M. Rath, and R. F. Veerkamp. 2003b. Genetic parameters for body condition score, body weight, milk yield, and fertility estimated using random regression models. J. Dairy Sci. 86:3704-3717.

Brotherstone, S., M. P. Coffey, and G. Banos. 2007. Genetic parameters of growth in dairy cattle and associations between growth and health traits. J. Dairy Sci. 90:444-450.

Dechow, C. D. and R. C. Goodling. 2008. Mortality, culling by sixty days in milk, and productive profiles in high- and low-survival Pennsylvania herds. J. Dairy Sci. 91:4630-4639.

Ettema, J. F., and J. E. P. Santos. 2004. Impact of age at calving on lactation, reproduction, health, and income in first-parity Holsteins on commercial farms. J. Dairy Sci. 87:2730-2742.

Frigo, E., C. D. Dechow, O. Pedron, and B. G. Cassell. 2010. The genetic relationship of body weight and early-lactation health disorders in two experimental herds. J. Dairy Sci. 93:1184-1192.

Gernand, E., P. Rehbein, U. U. von Borstel, and S. König. 2012. Incidences of and genetic parameters for mastitis, claw disorders, and common health traits recorded in dairy cattle contract herds. J. Dairy Sci. 95:2144-2156.

Guard, C. 2009. The costs of common diseases of dairy cattle (Proceedings). Accessed July 23, 2012. http://veterinarycalendar.dvm360.com/avhc/Veterinary+Food+Animal/The-costs-of-common-diseases-of-dairy-cattle-Proce/ArticleStandard/Article/detail/586496.

Hadley, G. L., C. A. Wolf, and S. B. Harsh. 2006. Dairy cattle culling patterns, explanations, and implications. J. Dairy Sci. 89:2286-2296.

Hansen, L. B., J. B. Cole, G. D. Marx, and A. J. Seykora. 1999. Productive life and reasons for disposal of Holstein cows selected for large versus small body size. J. Dairy Sci. 82:795-801.

Hansen, M., M. S. Lund, M .K. Sørensen, and L. G. Christensen. 2002. Genetic parameters of dairy character, protein yield, clinical mastitis, and other diseases in the Danish Holstein cattle. J. Dairy Sci. 85:445-452.

Harder, B., J. Bennewitz, D. Hinrichs, and E. Klam. 2006. Genetic parameters for health traits and their relationship to different persistency traits in German Holstein dairy cattle. J. Dairy Sci. 89:3202-3212.

Holstein Type-Production Sire Summaries. July 2011. Holstein Association USA, Brattleboro, VT.

Jones, W. P., L. B. Hansen, and H. Chester-Jones. 1994. Response of health care to selection for milk yield of dairy cattle. J. Dairy Sci. 77:3137-3152.

Kaneene, J. B., and H. S. Hurd. The national animal health monitoring system in Michigan. III. cost estimates of selected dairy cattle diseases. 1990. Prev. Vet. Med. 8:127-140.

Koeck, A., F. Miglior, D. F. Kelton, and F. S. Schenkel. 2012. Health recording in Canadian Holsteins: data and genetic parameters. J. Dairy Sci. 95:4099-4108.

Lassen, J., M. Hansen, M. K. Sørensen, G. P. Aamand, L. G. Christensen, and P. Madsen. 2003. Genetic relationship between body condition score, dairy character, mastitis, and diseases other than mastitis in first-parity Danish Holstein cows. J. Dairy Sci. 86:3730-3735.

Linden, T. C., R. C. Bicalho, and D. V. Nydam. 2009. Calf birth weight and its association with calf and cow survivability, disease incidence, reproductive performance, and milk production. J. Dairy Sci. 92:2580-2588.

Löf, E., H. Gustafsson, and U. Emanuelson. 2007. Associations between herd characteristics and reproductive efficiency in dairy herds. J. Dairy Sci. 90:4897-4907.

Lyons, D. T., and A. E. Freeman. 1991. Genetics of health traits in Holstein cattle. J. Dairy Sci. 74:1092-1100.

Mahoney, C. B., L. B. Hansen, C. W. Young, G. D. Marx, and J. K. Reneau. 1986. Health care of Holsteins selected for large or small body size. J. Dairy Sci. 69:3131-3139.

Miglior, F., B. L. Muir, and B. J. Van Doormaal. 2005. Selection indices in Holstein cattle of various countries. J. Dairy Sci. 88:1255-1263.

Parker Gaddis, K. L., J. B. Cole, J. S. Clay, and C. Maltecca. 2012. Incidence validation and relationship analysis of producer-recorded health event data from on-farm computer systems in the United States. J. Dairy Sci. 95:5422-5572.

Pinedo, P. J., A. De Vries, and D. W. Webb. 2010. Dynamics of culling risk with disposal codes reported by Dairy Herd Improvement dairy herds. J. Dairy Sci. 93:2250-2261.

Pryce, J. E., M. P. Coffey, and S. Brotherstone. 2000. The genetic relationship between calving interval, body condition score and linear type and management traits in registered Holsteins. J. Dairy Sci. 83:2664-2671.

Rogers, G. W., G. Banos, and U. Sander-Nielsen. 1998. Genetic correlations among protein yield, productive life, and type traits from the United States and diseases other than mastitis from Denmark and Sweden. J. Dairy Sci. 82:1331-1338.

Sewalem, A., F. Miglior, G. J. Kistemaker, P. Sullivan, and B. J. Van Doormaal. 2008. Relationship between reproduction traits and functional longevity in Canadian dairy cattle. J. Dairy Sci. 91:1660-1668.

Shim, E. H., R. D. Shanks, and D. E. Morin. 2004. Milk loss and treatment costs associated with two treatment protocols for clinical mastitis in dairy cows. J. Dairy Sci. 87:2702-2708.

Thompson-Crispi, K. A., B. Hine, M. Quinton, F. Miglior, and B. A. Mallard. 2012. *Short communication:* Association of disease incidence and adaptive immune response in Holstein dairy cows. J. Dairy Sci. 95:3888-3893.

Tsurata, S., I. Misztal, and T. J. Lawlor. 2004. Genetic correlations among production, body size, udder, and productive life traits over time in Holsteins. J. Dairy Sci. 87:1457-1468.

USDA (United States Department of Agriculture). 2012. Milk cost of production estimates. http://www.ers.usda.gov/data-products/milk-cost-of-production-estimates.aspx. Accessed Oct. 27, 2012.

VanRaden, P. M., J. B. Cole, M. E. Tooker, and T. A. Cooper. 2010. Genetic base changes for January 2010. Accessed Aug. 15, 2011. http://aipl.arsusda.gov/reference/base2010.htm.

VanRaden, P. M., and M. E. Tooker. 2005. Genetic base changes for February 2005. Accessed Aug. 15, 2011. http://aipl.arsusda.gov/reference/arch/base2005.htm.

Veerkamp, R.F., and S. Brotherstone. Genetic correlations between linear type traits, food intake, live weight and condition score in Holstein Friesian dairy cattle. 1997. Anim. Sci. 64:385–392.

Veerkamp, R. F., J. K. Oldenbroek, H. J. Van Der Gaast, and J. H. J. Van Der Werf. 2000. Genetic correlation between days until start of luteal activity and milk yield, energy balance, and live weights. J. Dairy Sci. 83:577-583.

Wells, S. J., S. L. Ott, and A. Hillberg Seitzinger. 1998. Key health issues for dairy cattle – new and old. J. Dairy Sci. 81:3029-3035.

Wenz, J. R. and S. K. Giebel. 2012. Retrospective evaluation of health event data recording on 50 dairies using Dairy Comp 305. J. Dairy Sci. 95:4699-4706.

Zwald, N.R., K. A. Weigel, Y. M. Chang, R. D. Welper, and J. S. Clay. 2004a. Genetic selection for health traits using producer-recorded data. I. Incidence rates, heritability estimates, and sire breeding values. J. Dairy Sci. 87:4287-4294.

Zwald, N.R., K. A. Weigel, Y. M. Chang, R. D. Welper, and J. S. Clay. 2004b. Genetic selection for health traits using producer-recorded data. II. Genetic correlations, disease probabilities, and relationships with existing traits. J. Dairy Sci. 87:4295-4302.

Zwald, N.R., K. A. Weigel, Y. M. Chang, R. D. Welper, and J. S. Clay. 2004b. Genetic selection for health traits using producer-recorded data. II. Genetic correlations, disease probabilities, and relationships with existing traits. J. Dairy Sci. 87:4295-4302.

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Costs for health care of Holstein cows selected for large versus small body size.

INTERPRETIVE SUMMARY

Holstein cows selected for large body size had significantly higher total health cost in first ($62.41 versus $41.41) and tended to have higher total health cost across the first 3 lactations ($54.15 versus $38.09) compared to Holstein cows selected for small body size in a long-term selection project. Among 11 categories of health care, large-line cows had higher cost for displaced abomasum and pneumonia than small-line cows during first lactation. Across the first 3 lactations, large-line cows had significantly higher health care cost for locomotion and displaced abomasum than small-line cows. Continued selection for large body size in Holsteins may not be economically justifiable.

INTRODUCTION

North American Holsteins have been selected for increased body size for many years (Tsurata et al., 2004; VanRaden et al., 2010; VanRaden and Tooker, 2005). Scores for conformation by the Holstein Association USA, Brattleboro, VT, continue to place more favorable ratings on cows with larger body size through the use of body size composite, which is calculated from the four linear traits of stature, strength, body depth, and rump width (Holstein Association, USA, 2011). Contrary to selections goals of the Holstein Association USA, the USDA places a negative weight on body size composite within its selection index called Lifetime Net Merit.

Minimizing the health care needs of dairy cows is important from both economical and animal welfare points of view. Diseases such as mastitis, displaced abomasum (**DA**), ketosis, cystic ovaries, metritis, and lameness severely affect the profitability of dairying through increased veterinary treatments, additional labor, lost milk sales, and involuntary culling (Zwald et al., 2004a). Appuhamy et al. (2009) examined incidence rates of common health disorders of United States Holstein cows and found first-lactation cows had incidence rates of 5.2% for ketosis and 4.1% for DA, whereas multiparous cows had incidence rates of 5.9% for ketosis and 3.7% for DA.

Cows with clinical mastitis have reduced milk production and incur treatment cost (Shim et al., 2004), and Ettema and Santos (2004) reported treatment cost of $50.80 for each case of clinical mastitis. Jones et al. (1994) analyzed health care costs of a Minnesota experimental herd of Holsteins selected for milk production versus a 1964 control line of Holsteins. Cows in the milk selection line had higher health care costs during first lactation of $28.22, mostly attributed to more mastitis (43% of total health cost) than the control-line cows.

Furthermore, Mahoney et al. (1986) reported cows selected to be large had significantly greater health costs than did cows selected to be small. Hansen et al. (1999) reported cows selected to be large were not significantly different than cows selected to be small for production; however, cows selected to be large had shortened productive life and reduced reproductive capabilities than cows selected to be small. The objective of this phenotypic study was to compare health care costs of Holstein cows selected for large versus small body size from the same long-term selection project analyzed by Mahoney et al. (1986) and Hansen et al. (1999).

MATERIALS AND METHODS

Design of Long-Term Selection Project

Holstein cows in a long-term selection project at the Northwest Research and Outreach Center, Crookston, of the University of Minnesota were selected for large versus small body size beginning in 1966. During 1966, 60 Holstein cows were paired by sire and were randomly assigned to one of two groups – large or small – for body size. Cows not fitting into pairs by sire were paired by predicted producing ability for milk production. Progeny were assigned to the same body size line as their dams. Except for service sire selection, both heifers and cows were managed together and identically in a tie-stall barn that had relatively large stall sizes and grates over the gutters. The long-term selection project using divergent sire selection continued for more than 40 years.

Throughout the years of the study, service sires were required to be in the top 50% of bulls for production among the active AI bulls available in the United States at the time of selection. Criteria for selection for production changed over the course of the selection project, and chronologically were 1) milk (kg), 2) fat (kg) plus protein (kg), and 3) protein (kg). All AI bulls were required to have a reliability of PTA at least 70% for both production and type traits prior to 1988, and the reliability requirement was increased to 80% in 1988.

Other than the minimum culling level for PTA for production, the AI bulls were selected solely based on a body size index [0.5 (stature) + 0.25 (strength) + 0.25 (body depth)], which was calculated from PTA for stature, strength, and body depth. The 3 most extreme bulls 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. Selection of an AI bull for one year did not eliminate the bull from consideration for subsequent years. Cows within each body size line were randomly mated to AI bulls, except inbreeding coefficients were not allowed to exceed 6.25%, and calving difficulty was avoided on heifers.

Heifers and cows were periodically added to the herd to expand herd size, especially to facilitate an expansion in the capacity of the tie-stall barn from 60 to 106 stalls in 1987. These additional cows were regarded as new foundation cattle for the selection project for body size and were assigned to one of the two body size lines. However, cows were required to have at least 3 generations of prescribed large-line or small-line AI bulls beyond the foundation generation to be included in the data for this study.

Data

Cows were born from January 1, 1983 to December 31, 1997, and health care was recorded on an incidence basis from March 28, 1985, to June 17, 2002. Therefore, the data for this study follows, chronologically, the data of Mahoney et al. (1986) and reflects continued divergence for body size of cows in the two lines. All cows were required to have calved the first time on or after January 1, 1985.

Eleven categories of health treatment are described in Table 1. Health treatments were recorded by category, and actual cost for 188 veterinary treatments, health supplies, and drugs were assigned at 2010 values. Also, the amount of labor in minutes required by animal attendants for each health treatment was recorded. Fixed costs for veterinary supplies and drugs were the means from 7 vendors serving Minnesota during the summer of 2010. Costs of veterinary procedures were the means of costs across 3 veterinary clinics in Minnesota. Veterinarian labor was valued at $115/hour, and animal attendant labor was valued at $10/hour. Those health treatments administered routinely to cows in both body size lines, such as vaccinations, deworming, and dry cow therapy, were not included in the data. Health care cost including the value of labor was summed for individual categories of health treatment for lactations of cows. Lactation number was coded as first, second, or third, and the lactations of cows beyond third lactation were discarded because these cows were subject to severe culling bias from health problems.

Lactations totaled 1,035 for 486 daughters of 84 AI bulls, and data were for 486 first lactations, 331 second lactations, and 218 third lactations. Cows in the large line were 199 daughters of 45 bulls with 412 lactations (2.07/cow), and cows in the small line were 287 daughters of 39 bulls with 623 lactations (2.17/cow). Cows were required to have a recorded BW immediately postpartum to be included in the analysis, and 34 lactations of cows were discarded because BW was missing. Additionally, body dimensions at 1 month postpartum for some, but not all, of the 1,035 lactations of 486 cows. The 4 body dimensions were height at withers, length of body, depth of chest, and circumference of chest. Body dimensions were available for 960 of 1,035 lactations (93%), including 441 of 486 first lactations (91%) of cows. The BCS of cows was not routinely recorded throughout the years of the study. Over time, the small line grew in cow number relative to the large line, because the cows in the small line remained in the herd longer, calved more frequently, and left more female offspring in the herd (Hansen et al., 1999).

Incidence rates for health treatments were calculated as the number of cows with a treatment for a health category within each body size line divided by the total number of cows in the respective body size line during the lactation. A chi-squared test was used to assess the statistical significance of difference of body size lines for incidence rates during first, second, and third lactations.

Years of calving for all lactations were 1985 to 2002; however, the 20 cows that calved with first lactation during 1985 were pooled for analysis with cows that calved during 1986. Also, 13 cows calved for the second or third time after December 31, 2000, and they were pooled for analysis with cows that calved during 2000. Year-block was then defined as successive 5-year blocks for year of calving (1986 to 1990, 1991 to 1995, and 1996 to 2000).

Dependent variables for the statistical analysis were health care cost by individual category, as well as summed across all categories, for lactations of cows. Independent variables were the fixed effects of body size line, year-block nested within body size line, lactation number nested within body size line, and the linear, quadratic, and cubic effects of BW at calving nested within body size line as covariables. Additionally, the model fitted cow nested within body size line as a random variable. The BW was regarded as the best descriptor of body size and superior to the individual or combined effects of the 4 recorded body dimensions. Furthermore, BW was recorded for more of the cows than were the body dimensions. The MIXED procedure of SAS (SAS Institute, 2004) was used to obtain solutions and conduct the ANOVA. An alternative fixed effect was a linear covariables for age at calving (mo); however, preliminary analysis revealed this effect did not explain variation ($P > 0.05$) of health care. Effect of sire of cows was not investigated because of the small number of daughters per sire (mean of 5.8 daughters/sire).

RESULTS AND DISCUSSION

Response for Body Size

The means and ranges of observations for BW and the 4 body dimensions (Table 2) indicate a tremendous overlap of the phenotypes for two body size lines. Although selected to be large versus small, cows in the two body size lines were greatly impacted, quite obviously, by environmental and random factors to arrive at realized phenotypic body size. As examples, severe pneumonia as a calf may reduce the eventual body size of a lactating cow and delayed age at first calving may increase the body size of a lactating cow. Therefore, the experimental units in this selection project represent the consequences of long-term selection for or against body size rather than phenotypic classifications for body size without regard to underlying genetics for body size. The previous study of cows in the same selection project from 1969 to 1983 (Mahoney et al., 1986) reported cows selected for large body size averaged 514 kg and cows selected for small body size averaged 464 kg after first calving. In the present study, cows in the large and small lines averaged 615 kg and 556 kg, respectively, after first calving. Therefore, cows in both body size lines continued to become heavier for BW between the time of the study by Mahoney et al. (1986) and the present study. Cows in the small line were expected to become lighter for BW with time; however, the pervasive selection emphasis for larger body size in the Holstein breed resulted in increased BW of cows in both body size lines in this study. Stated another way, steadfast selection for smaller body size of cows resulted in small-line cows that were divergent from large-line cows for BW; however, small-line cows also became heavier with time.

Cows in the large line had mean BW of 672 kg immediately after second calving, whereas cows in the small line had mean BW of 595 kg (Table 2). Cows in both body size lines increased in BW from first to second lactation; however, the large-line cows gained more weight from first lactation to second lactation than small-line cows. The BW in third lactation was 726 kg and 631 kg, respectively, for large-line and small-line cows. Therefore, during third lactation, small-line cows likely would not be regarded as very small cows by most dairy producers. On the other hand, the large-line cows would be regarded as extremely large cows during third lactation by most dairy producers. The large-line cows had greater mean BW at calving of 11% at first calving, 13% at second calving, and 15% for third calving than the small-line cows.

Large-line cows were approximately 7.3 cm taller than small-line cows at 1 mo postpartum after first, second, and third calving (Table 2). However, for the other 3 body dimensions, large-line cows increased their differences from lactation to lactation in a similar fashion to BW. Phenotypic correlations of BW with the body dimensions across body size lines ranged from 0.65 to 0.72 for height at withers, length of body, and depth of chest within each of the 3 lactations. However, BW had a higher phenotypic correlation with circumference of chest of 0.80 for both first and second lactation and 0.79 for third lactation. Historically, circumference of chest has often been used to approximate BW, and the results from this study of cow size support the substantial positive relationship between these 2 traits. Within the body size lines, all phenotypic correlation of BW with body dimensions were smaller than those across body size lines; however, the strongest correlations (0.61 to 0.75) were once again for BW with circumference of chest.

Although sire selection for the body size lines was based only on production (top 50% of active AI bulls) and the body size index, the cows in the body size lines were expected to reflect changes for traits genetically correlated with body size. Mean PTA for cows from the April 2012 genetic evaluation of USDA for the large line and small lines, respectively, were: milk (-660 kg, -501 kg), fat (-21 kg, -16 kg), protein (-21 kg, -17 kg), SCS (2.91, 2.97), productive life (-1.3 mo, +0.6 mo), and daughter pregnancy rate as a measure of cow fertility (+0.6%, +1.2%). Differences of mean PTA of the body size lines for production and SCS were small and likely due to chance. However, differences for productive life and cow fertility probably were more meaningful and were likely a consequence of the genetic antagonism of body size with these two traits.

Incidence Rates of Health Disorders

Table 3 has incidence rates for health disorders during first lactation and the large-line cows had a highly significant ($P < 0.01$) and greater incidence rate for the categories of other udder (non-mastitis, 5.5% versus 1.1%), DA (14.6% versus 5.6), and pneumonia (7.0% versus 1.4%) than the small-line cows. Large-line cows also had a significantly ($P < 0.05$) higher incidence rate of treatments for locomotion (41.2% versus 32.4%). Other digestion (9.6% versus 5.6%) and the total across categories (80.4% versus 73.2%) tended ($P < 0.10$) to have higher incidence for large-line cows than small-line cows. For comparison, Appuhamy et al. (2007) found an incidence rate of 7.9% for DA analyzing health treatments from two institutional herds, and Appuhamy et al. (2009) reported an incidence rate of 4.1% for DA using field data.

During second lactation (Table 4), large-line cows had a highly significant ($P < 0.01$) and greater incidence rate of DA (10.2% versus 2.5%) than small-line cows. Large-line cows also had a significantly ($P < 0.05$) higher incidence rate of treatments for other digestion (8.6% versus

3.5%). During third lactation (Table 5), large-line cows tended to have a significantly ($P < 0.10$) higher incidence rate of treatments for locomotion (34.1% versus 23.3%). Importantly, cows with severe health problems in one lactation may be culled or die prior to a subsequent lactation. For multiparous cows, Appuhamy et al. (2007) found an incidence rate of 27.0% for lameness of cows in two institutional herds, and Appuhamy et al. (2009) reported an incidence rate of 17.3% for lameness from field data. Appuhamy et al. (2007) also found an incidence rate of 13.5% for metabolic diseases for multiparous cows.

Tests of Significance for Fixed Effects

The *P*-values from the ANOVA for cost of individual health categories and total health cost are in Table 6. Effect of body size line was highly significant ($P < 0.01$) for other udder (non-mastitis) and locomotion across the first 3 lactations. Body size line was also significant ($P < 0.05$) for DA and approached significance ($P < 0.10$) for total health cost. In each case, the large-line cows had greater health cost than the small-line cows. The effect of lactation number nested within body size line was highly significant ($P < 0.01$) for locomotion, milk fever, and reproduction and was significant ($P < 0.05$) for other udder (non-mastitis). For the other udder (non-mastitis) category, least squares means were highest during first lactation for large-line cows and during second lactation for small-line cows. For locomotion, greatest health cost was during first lactation for both body size lines. For the categories of milk fever and reproduction, cows in third lactation had greatest cost for both body size lines.

Effect of year-block nested within body size line was highly significant ($P < 0.01$) for mastitis, other udder (non-mastitis), locomotion, ketosis, pneumonia, and total health cost. The linear, quadratic, and cubic effects of BW nested within body size line were significant ($P < 0.05$) for only the categories of other udder (non-mastitis), locomotion, and DA, as well as for total health cost. For all regression coefficients that were statistically significant, the linear coefficient was positive, the quadratic coefficient was negative, and the cubic coefficient was again positive.

Health Cost during First Lactation

Results for only first lactations from the multi-lactation analysis are reported separately, because results from later lactations are likely biased due to culling or death of cows with the most severe health problems. Least squares means for total health cost for first lactation were $62.41 and $41.41, respectively, for large-line and small-line cows (Table 7), and the difference was highly significant ($P < 0.01$). Therefore, health care costs were 34% higher (difference of $21.00 divided by the mean for the large line) for large-line cows than small-line cows. The previous study from this selection project by Mahoney et al. (1986) with cows from 1969 to 1983 found the large-line cows had nearly twice the health cost ($12.10 versus $6.57) of small-line cows during first lactation. When the 1984 health costs were adjusted for inflation to 2010 health costs (U.S. Bureau of Labor Statistics), cows in the study of Mahoney et al. (1986) had health cost of $25.39 and $13.79 for large-line and small-line cows, respectively. Therefore, the health costs increased dramatically for both body size lines of cows from the previous study (data from 1969 to 1983) to the present study (data from 1985 to 2002). However, the health care cost during first lactation in this study was less than that found by Jones et al. (1994) for a milk selection line versus a 1964 control line of Holsteins ($97.65 versus $59.14, respectively) when costs were adjusted for inflation (U.S. Bureau of Labor Statistics). However, the health care cost during first lactation in the present study was less than Zwald et al. (2004b), who reported cost of health problems during first lactation ranged from $128 to $169.

Table 7 also has least squares means of health care cost for individual categories during first lactation for the body size lines. Much of the difference between body size lines (60%) was because of the significant ($P < 0.05$) difference for DA. However, the pneumonia category also contributed significantly ($P < 0.01$) to the difference for health cost of large-line and small-line cows. Furthermore, the cost for other udder (non-mastitis) treatments tended ($P < 0.10$) to be greater for the large-line cows than small-line cows. However, the health cost for other udder (non-mastitis) was considerably less than the health cost of mastitis, which did not differ significantly for the body size lines. Just three of the categories – other udder (non-mastitis), DA, and pneumonia – accounted for 79% of the difference of total cost for health care between the large-line and small-line cows during first lactation.

The line difference for DA may potentially be attributed to the large-line cows having larger calves (2.5 kg heavier, Hansen et al., 1999), larger body cavities and, consequently, a greater internal void after calves were born compared to small-line cows, and these differences may have, in turn, predisposed the large-line cows to DA (Hansen et al., 1999). Zwald et al. (2004b) reported correlations between PTA for probability of disease occurrence and PTA for type traits, and found the correlation of occurrence of DA with stature was 0.08, with strength was 0.11, and with body depth was 0.11.

Treatment cost for pneumonia was more than 5 times greater ($P < 0.01$) for the large-line cows than the small-line cows during first lactation. Lyons et al. (1991) reported cows with incidence of pneumonia treatment had a genetic correlation of 0.76 with digestion incidence and a correlation of 0.52 with mammary incidence. These genetic correlations suggest cows that have one type of health problem are predisposed to another type of health problem.

Health Costs for the First 3 Lactations

Analyzing health cost for successive lactations of cows within the same statistical model may result in biased solutions, especially for later lactations, because cows with extreme health care costs were more likely to have been culled or die on the farm prior to subsequent lactations. The use of a mixed model with cow as a random variable may account for some, but perhaps not all, of this culling bias.

Across the first 3 lactations of cows, the body size lines tended to differ significantly ($P < 0.10$) for health care cost (Table 8). Least squares means for total cost of health care across lactations were $54.15 and $38.09, respectively, for the large-line and small-line cows, and the health costs were 30% higher (difference of $16.06 divided by the mean for the large line) for large-line cows than the small-line cows. The previous report (Mahoney et al., 1986) of health care costs from this long-term selection project found cows selected for large body size had significantly ($P < 0.01$) greater health cost ($12.82 versus $8.39) across lactations than cows selected for small body size. Adjusted for inflation (U.S. Bureau of Labor Statistics), the cows selected for large and small body size had health care cost of $26.91 and $17.61, respectively; therefore; the health costs increased substantially for both body size lines since the previous study (Mahoney et al., 1986).

Most of the difference (83%) of total health cost for the body size lines across the lactations was because of the significant ($P < 0.05$) difference for DA. Zwald et al. (2004b) reported an antagonistic relationship of stature, strength, and body depth with metabolic disorders such as DA.

Also, locomotion (8%) contributed significantly ($P < 0.01$) to the difference for total health cost across the lactations. The feet and legs of large-line cows supported more BW than did the feet and legs of small-line cows; consequently, the large-line cows would be expected to have feet and legs that were more prone to injury than the small-line cows. Furthermore, Hansen et al. (1999) reported the large-line cows in this selection project had mean wither height of 139 cm during third lactation compared to 131 cm for small-line cows. The higher center of gravity of large-line cows compared to small-line cows may have caused the large-line cows to be more prone to slipping and falling, which could impact locomotion.

Least squares means of total health cost by lactation number are in Table 9. Health care costs decreased for both large-line and small-line cows from first lactation to second lactation, but then increased during third lactation for small-line cows. Consequently, the difference for health care cost was highly significant ($P < 0.01$) during first lactation and significant ($P < 0.05$) during second lactation for large-line cows compared to small-line cows. However, the body size lines did not differ for health care cost during third lactation.

Table 10 has least squares means of total health cost for the 3 year-blocks. The difference of body sizes line for total health cost was $5.69 for the first year-block, and the difference increased to $18.65 and $23.85 during second and third year-blocks, respectively. From first to second year-block, the large line increased 41%, whereas the small line increased 28%, for total health cost. Apparently, the continued divergence of BW for the body size lines with time (across year-blocks) resulted in a corresponding increase in health care cost.

CONCLUSIONS

Greater cost for health care was incurred for cows selected for large versus small body size in this study. The difference of the body size lines for total health cost was mostly attributed to an increase in cost of treatment for DA, with 60% of differences of health costs during first lactation and 83% of differences across the first 3 lactations due to DA. This is in agreement with the previous study of health care costs from an earlier period of time for cows in this selection project. Consequently, the Holstein cows in the large line were economically disadvantaged compared to those in the small line for health care cost, which is an important contributor to profitability of dairying. Cows that require less health care are also preferable from an animal welfare point of view. Continued selection for larger body size of cows may not be justifiable.

REFERENCES

Appuhamy, J. A. D. R. N., B. G. Cassell, and J. B. Cole. 2009. Phenotypic and genetic relationships of common health disorders with milk and fat yield persistencies from producer-recorded health data and test-day yields. J. Dairy Sci. 92:1785-1795.

Appuhamy, J. A. D. R. N., B. G. Cassell, C. D. Dechow, and J. B. Cole. 2007. Phenotypic relationships of common health disorders in dairy cows to lactation persistency estimated from daily milk weights. J. Dairy Sci. 90:4424-4434.

Ettema, J. F., and J. E. P. Santos. 2004. Impact of age at calving on lactation, reproduction, health, and income in first-parity Holsteins on commercial farms. J. Dairy Sci. 87:2730-2742.

Hansen, L. B., J. B. Cole, G. D. Marx, and A. J. Seykora. 1999. Productive life and reasons for disposal of Holstein cows selected for large versus small body size. J. Dairy Sci. 82:795-801.

Holstein Type-Production Sire Summaries. July 2011. Holstein Association USA, Brattleboro, VT.

Jones, W. P., L. B. Hansen, and H. Chester-Jones. 1994. Response of health care to selection for milk yield of dairy cattle. J. Dairy Sci. 77:3137-3152.

Lyons, D. T., and A. E. Freeman. 1991. Genetics of health traits in Holstein cattle. J. Dairy Sci. 74:1092-1100.

Mahoney, C. B., L. B. Hansen, C. W. Young, G. D. Marx, and J. K. Reneau. 1986. Health care of Holsteins selected for large or small body size. J. Dairy Sci. 69:3131-3139.

SAS® Institute SAS/STAT Software, Release 9.2. 2008. SAS Inst., Inc. Cary, NC.

Shim, E. H., R. D. Shanks, and D. E. Morin. 2004. Milk loss and treatment costs associated with two treatment protocols for clinical mastitis in dairy cows. J. Dairy Sci. 87:2702-2708.

Tsurata, S., I. Misztal, and T. J. Lawlor. 2004. Genetic correlations among production, body size, udder, and productive life traits over time in Holsteins. J. Dairy Sci. 87:1457-1468.

U.S. Bureau of Labor Statistics. 2011. Inflation Calculator. Accessed Feb. 16, 2012. http://www.bls.gov/data/inflation_calculator.htm.

VanRaden, P. M., J. B. Cole, M. E. Tooker, and T. A. Cooper. 2010. Genetic base changes for January 2010. Accessed Aug. 15, 2011. http://aipl.arsusda.gov/reference/base2010.htm.

VanRaden, P. M., and M. E. Tooker. 2005. Genetic base changes for February 2005. Accessed Aug. 15, 2011. http://aipl.arsusda.gov/reference/arch/base2005.htm.

Zwald, N.R., K. A. Weigel, Y. M. Chang, R. D. Welper, and J. S. Clay. 2004a. Genetic selection for health traits using producer-recorded data. I. Incidence rates, heritability estimates, and sire breeding values. J. Dairy Sci. 87:4287-4294.

Zwald, N.R., K. A. Weigel, Y. M. Chang, R. D. Welper, and J. S. Clay. 2004b. Genetic selection for health traits using producer-recorded data. II. Genetic correlations, disease probabilities, and relationships with existing traits. J. Dairy Sci. 87:4295-4302.

Table 1. Categories of health care treatment.

Category	Description
Mastitis	Clinical mastitis
Other udder	Physical injury to teats and udder, edema, treatments not for clinical mastitis
Locomotion	Hoof trimming, joint injury, foot rot
Displaced abomasum	Displaced abomasum
Other digestion	Hardware, upset stomach, off feed, indigestion, bloat
Ketosis	Ketosis
Milk fever	Milk fever
Pneumonia	Pneumonia, labored breathing, coughing, influenza
Reproduction	Post-calving reproductive complications up to 40 DIM; retained placenta, cystic ovaries, metritis, prolapse uterus
Fertility	Reproductive treatments after 40 DIM; heat synchronization shots, follicular cysts, inducing to calve
Other	Kidney or bladder infection, peritonitis, split pelvis, not categorized elsewhere

Table 2. Number of cows, unadjusted means, standard deviations, and ranges of observations resulting from selection for body size.

		Large line					Small line				
Trait	Parity	n	$\bar{X}$	SD	Minimum	Maximum	n	$\bar{X}$	SD	Minimum	Maximum
			------------------------ (kg) ------------------------					------------------------ (kg) ------------------------			
Postpartum body weight	1	199	615	62.9	441	822	287	556	54.6	416	795
	2	128	672	64.6	503	834	203	595	55.8	471	777
	3	85	726	69.1	534	885	133	631	56.7	490	784
			------------------------ (cm) -----------------------					------------------------ (cm) -----------------------			
Height at withers	1	179	136.3	4.1	126.5	146.6	262	129.0	3.7	119.0	142.0
	2	123	137.5	3.7	127.5	145.6	196	130.3	3.5	120.5	141.4
	3	77	139.2	4.2	129.9	149.8	123	131.8	3.5	122.4	141.3
Length of body	1	179	142.0	4.7	129.2	155.8	262	136.1	4.2	125.4	152.8
	2	123	147.8	4.1	136.6	159.4	196	141.4	4.4	128.5	154.8
	3	77	152.3	5.2	141.0	164.1	123	145.4	4.6	133.7	155.5
Depth of chest	1	179	71.4	3.1	63.7	80.2	262	67.3	2.6	60.8	78.4
	2	123	73.1	2.8	66.2	80.4	196	68.4	2.7	60.7	75.3
	3	77	75.1	3.0	67.1	82.3	123	69.6	2.1	64.3	76.0
Circumference of chest	1	179	196.1	8.8	175.0	224.0	262	186.4	7.2	168.0	206.0
	2	123	201.6	7.2	182.0	221.0	196	189.6	6.5	174.0	205.0
	3	77	207.7	7.4	193.0	229.0	123	193.2	6.5	179.0	215.0

Table 3. Incidence rates of health treatments by category for body size lines during first lactation.

Health Category	Large line	Small line	Difference
	(%)		
Mastitis	24.6	26.3	-1.7
Other udder	5.5	1.1	4.4**
Locomotion	41.2	32.4	8.8*
Displaced abomasum	14.6	5.6	9.0**
Other digestion	9.6	5.6	4.0†
Ketosis	6.0	5.2	0.8
Milk fever	0.5	0.7	-0.2
Pneumonia	7.0	1.4	5.6**
Reproduction	23.6	18.5	5.1
Fertility	18.1	19.2	-1.1
Other	13.1	9.1	4.0
Total	80.4	73.2	7.2†

** $P < 0.01$
* $P < 0.05$
† $P < 0.10$

Table 4. Incidence rates of health treatments by category for body size lines during second lactation.

Health Category	Large line	Small line	Difference
	----------------------------	(%) ----------------------------	
Mastitis	21.1	27.1	-6.0
Other udder	2.3	1.5	0.8
Locomotion	24.2	20.2	4.0
Displaced abomasum	10.2	2.5	7.7**
Other digestion	8.6	3.5	5.1*
Ketosis	6.3	4.9	1.4
Milk fever	5.5	2.5	3.0
Pneumonia	3.1	1.0	2.1
Reproduction	10.9	14.8	-3.9
Fertility	26.6	27.1	-0.5
Other	5.5	3.5	2.0
Total	70.3	69.0	1.3

** $P < 0.01$
* $P < 0.05$

Table 5. Incidence rates of health treatments by category for body size lines during third lactation.

Health Category	Large line	Small line	Difference
	------------------------------- (%)		-------------------------------
Mastitis	30.6	24.8	5.8
Other udder	1.2	3.0	-1.8
Locomotion	34.1	23.3	10.8†
Displaced abomasum	8.2	6.8	1.4
Other digestion	10.6	8.3	2.3
Ketosis	10.6	15.0	-4.4
Milk fever	16.5	18.1	-1.6
Pneumonia	2.4	3.0	-0.6
Reproduction	22.4	25.6	-3.2
Fertility	32.9	31.6	1.3
Other	5.9	7.5	-1.6
Total	85.9	83.5	2.4

† $P < 0.10$

Table 6. *P*-values from tests of significance for cost of individual health categories and total health cost.

Category	Line	Lactation no. within line	Year-block within line	BW within line	BW^2 within line	BW^3 within line
df	1	4	4	2	2	2
Mastitis	0.41	0.62	<0.01**	0.55	0.58	0.60
Other udder	<0.01**	0.02*	<0.01**	0.02*	0.02*	0.02*
Locomotion	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**	<0.01**
Displaced abomasum	0.03*	0.48	0.60	<0.01**	<0.01**	<0.01**
Other digestion	0.22	0.71	0.39	0.45	0.47	0.49
Ketosis	0.88	0.36	<0.01**	0.99	0.99	0.97
Milk fever	0.97	<0.01**	0.92	0.99	0.96	0.93
Pneumonia	0.63	0.46	<0.01**	0.62	0.64	0.67
Reproduction	0.98	<0.01**	0.12	0.99	0.99	0.99
Fertility	0.96	0.20	0.23	0.55	0.53	0.53
Other	0.38	0.87	0.27	0.66	0.66	0.66
Total	0.07†	0.13	<0.01**	0.02*	0.02*	0.01*

** $P < 0.01$
* $P < 0.05$
† $P < 0.10$

Table 7. Least squares means and percentage of total health costs by category for body size lines during first lactation.

Health category	Large line			Small line			Difference of means	Difference of percentage
	$\overline{X}$	SE	Percentage of total	$\overline{X}$	SE	Percentage of total		
	------------- ($) -------------			------------- ($) -------------			---- ($) ----	
Mastitis	3.95	0.99	6	4.74	1.01	11	-0.79	-4
Other udder	1.68	0.41	3	0.66	0.41	2	1.02†	5
Locomotion	10.95	1.42	18	8.00	1.41	19	2.95	14
Displaced abomasum	28.65	4.10	46	16.06	4.16	39	12.59*	60
Other digestion	2.69	0.95	4	2.00	0.96	5	0.69	3
Ketosis	2.66	1.43	4	3.84	1.45	9	-1.18	-6
Milk fever	0.09	0.27	0	0.00	0.27	0	0.09	1
Pneumonia	3.67	0.77	6	0.71	0.78	2	2.96**	14
Reproduction	3.31	1.07	5	1.83	1.10	4	1.48	7
Fertility	1.63	0.62	3	1.13	0.62	3	0.50	2
Other	3.29	0.98	5	2.36	0.99	6	0.93	4
Total	62.41	5.33	100	41.41	5.40	100	21.00**	100

** $P < 0.01$
* $P < 0.05$
† $P < 0.10$

Table 8. Least squares means and percentage of total health costs by category for body size lines across lactations.

Health category	Large line			Small line			Difference of means	Difference of percentage
	$\overline{X}$	SE	Percentage of total	$\overline{X}$	SE	Percentage of total		
	-------------- ($) --------------			-------------- ($) --------------			---- ($) ----	
Mastitis	5.69	0.98	10	4.73	0.70	12	0.96	5
Other udder	0.16	0.39	0	0.66	0.28	1	-0.50†	-3
Locomotion	7.43	1.55	13	6.13	1.15	16	1.30**	8
Displaced abomasum	25.25	3.95	46	11.78	2.82	30	13.47*	83
Other digestion	1.75	0.92	3	1.26	0.65	3	0.49	3
Ketosis	1.39	1.38	2	4.92	0.98	12	-3.53	-22
Milk fever	1.14	0.26	2	0.91	0.18	2	0.23	1
Pneumonia	3.68	0.83	6	1.01	0.60	2	2.67	16
Reproduction	4.72	1.12	8	4.93	0.81	13	-0.21	-1
Fertility	1.97	0.59	3	1.70	0.42	4	0.27	1
Other	3.87	1.07	7	1.92	0.78	5	1.95	12
Total	54.15	5.14	100	38.09	3.67	100	16.06†	100

** $P < 0.01$
* $P < 0.05$
† $P < 0.10$

Table 9. Least squares means of total health cost for body size lines by lactation number.

	Large line		Small line		
Parity	$\bar{X}$	SE	$\bar{X}$	SE	Difference of means
	($)				
1	62.41	5.33	41.41	5.40	21.00**
2	50.85	7.52	28.33	5.64	22.52*
3	49.20	10.22	44.54	6.71	4.66

** $P < 0.01$
* $P < 0.05$

Table 10. Least squares means of total health cost for body size lines by year-block.

Year-block	Large line $\bar{X}$	Large line SE	Small line $\bar{X}$	Small line SE	Difference of means
	($)				
1986-1990	35.58	6.79	29.89	5.72	5.69
1991-1995	60.24	7.17	41.59	5.43	18.65*
1996-2000	66.64	7.94	42.79	5.52	23.85*

* $P < 0.05$