Relationships of Scrotal Circumference to Puberty and Subsequent Reproductive Performance in Male and Female Offspring

J.S. Brinks

Colorado State University, Fort Collins

Reproductive efficiency, obtained through cost-effective measures, is the most important factor affecting profitability of the cow-calf enterprise. The reproductive efficiency of bulls and females both contribute to expressed reproductive performance of the cow herd. It is quite possible that although females are culled for low expressed reproduction, sires with only average reproductive potential are subsequently used resulting in female offspring that again need to be culled based on low reproductive performance. This culling process, although repeated every generation, would improve reproductive potential of the herd very little as long as sires with average reproductive potential are used.

Since nearly 90% of the genetic change over time is due to sires, heritable reproductive measures in bulls need to be identified and used to genetically improve reproductive potential in male and female offspring. This discussion reviews some of the literature relating to scrotal circumference (SC) and its possible use in improving overall reproductive efficiency of the cow herd.

Breeding Soundness Examination - The breeding soundness exam (BSE) recommended by the Society of Theriogenology is widely used for both yearling and older bulls and especially for yearling bulls at the conclusion of performance tests. I believe there are two primary uses for the BSE: 1) to cull bulls classified as unsatisfactory and possibly retest bulls (especially yearlings) which are classified questionable and 2) to select yearling bulls to genetically improve both bull and their heifer offspring reproductive efficiency. Both uses should improve immediate bull performance while the second use should also aid in improving long-term herd reproductive potential. This discussion will concentrate on the second use and on yearling bull information since this is when selection would be most effective. A portion of the present BSE information for yearling bulls (12 to 14 mo) is shown in table 1.

The BSE includes information on SC, semen morphology and motility, and an internal and external physical examination. Bulls receiving 60 or more points are usually classified as satisfactory breeders if they pass the physical exam and have at least 30 cm SC. Scrotal circumference is an important component of the BSE accounting for up to 40 of the possible 100 points.

SC Adjustment Factors - If SC in yearling bulls is to be used as a selection criterion, some attention should be given to adjustments to account for differences in age and age of dam among bulls. Results from several major studies relating to adjustment factors for SC are listed in table 2.

The formula for mature dam equivalent 365 d scrotal circumference

= actual scrotal circumference (cm)
+ age adjustment value x (365 - actual age in d) + age of dam adjustment

Heritability Estimates - There are several reports in the literature relating to the heritability of SC in yearling beef bulls on both an age and weight adjusted basis (table 3).

These studies indicate that SC in yearling bulls is a moderate to highly heritable trait (approximately 50%) and that selection should be very effective in changing SC. It is somewhat surprising that SC adjusted for weight differences appears to be as highly heritable as age adjusted

SC. This indicates considerable additive genetic variance for relative scrotal size.

Relationship of SC to Seminal Traits - Several studies have found moderate but favorable phenotypic relationships between SC and measures of semen quantity and quality. A few estimates of genetic correlations are listed in table 4.

Knights et al. (1984) also reported favorable genetic relationships of SC with measures of semen quality and quantity. In general, as SC increases in yearling bulls, motility, percent normal sperm, semen volume, sperm concentration and total sperm output increase and percent abnormalities decrease.

Relationship of SC to Age at Puberty - Results from the Roman L. Hruska Meat Animal Research Center (Lunstra, 1982) indicated that SC was a more accurate predictor of when a bull reached puberty than either age or weight regardless of breed or breed cross. Bulls reached puberty (50×10^6 sperm with a minimum of 10% motility) at an average SC of 27.9 cm. Lunstra (1982) reported a correlation of .98 among breed means (eight breeds) for SC of bulls with age at puberty in heifers (table 5).

Genetic correlation estimates between SC in yearling bulls and age at puberty in half-sib heifers of -.71 and -1.07 (favorable) have been reported by Brinks et al. (1978) and King et al. (1983). These very strong genetic relationships coupled with Lunstra's (1982) data indicate that age at puberty and SC are essentially the same trait. Toelle and Robinson (1985) also reported that SC was favorably related genetically to several measures of female reproductive traits.

Relationship of SC with Growth - The genetic and phenotypic correlations of SC with measures of growth reported in the literature are generally favorable. A partial listing of these genetic correlations are presented in table 6.

The genetic correlation between SC and birth weight appears to be relatively low whereas the correlation between SC and yearling weight is relatively high. This suggests that larger SC (earlier puberty) and faster growth rate is compatible in young bulls. Selection for increased SC should result in increased growth from birth to yearling ages while holding birth weights relatively constant. These relationships suggest a favorable growth curve, i.e., reaching a higher percent of mature weight at earlier ages while maintaining or increasing early growth rate and possibly holding mature weight in check.

Selection Example - If one selects bulls with larger SC, what changes in SC and age at puberty (AP) are expected in the male and female offspring?

Assume the following values:

Heritability of SC = .50
Genetic correlations of SC with AP = -.9
Genetic standard deviation of SC = 1.4 cm
Genetic standard deviation of AP = 24 d
Selection differential for sires = 1 cm
Then:

Response in male offspring = heritability x selection differential

$$R = .5\left(\frac{1.0\ cm + 0\ cm}{2}\right) = .25\ cm$$

Correlated response in AP of female offspring = R x genetic regression

$$CR = (.25)(-.9) \times \left(\frac{24}{1.4}\right) = 3.86d$$

Thus, for each centimeter superiority of sires above the population mean, one would expect a .25 cm increase in SC of male offspring and 3.86 d earlier in puberty of female offspring. Since age at puberty in females appears to be favorably related to measures of subsequent reproduction (Werre and Brinks, 1986), the cow herd should also improve in reproductive potential.

Smith et al. (1989b) reported that for each 1 cm increase in a sire's SC there was a .31 cm increase in the sons' SC, or very close to expectations. In addition, they reported an associated -.796 d change in age at puberty, a -.667 d change in day of first calving and a -.826 d change in age at first calving of female offspring per cm of SC of sire. The change in age at puberty is less than expected from the example above. Possibly there is a greater change in inherent age at puberty than expressed age at puberty due to seasonal or climatic effects. In either case, expected progeny difference values should aid greatly in selecting for inherent fertility.

Relationship of AP to Subsequent Productivity - Correlations of AP with reproductive and productivity traits by line of sire means through four lactations are presented in table 7. The correlations among line of sire means may indicate a genetic relationship. These correlations indicate that heifers from lines with early puberty also tended to conceive earlier each year through four lactations, except for the third lactation. Also, they weaned heavier calves and had high accumulative most probale producing ability (MPPA) values, presumably through higher milk production.

This favorable relationship of earlier age at puberty with higher milk production and reproduction has also been observed from correlations among breed means from other studies. Laster et al. (1979) reported the following correlations among breed means: AP with percent calving the first 25 d, -.75; AP with pregnancy percent, -.42; and AP with milk production, -.88; indicating that earlier age at puberty resulted in earlier and more pregnancies and greater milk production on a between breed basis. Doornbos et al. (1983) reported a residual correlation of -.40 between AP and percent pregnant.

Discussion

Fertility is a complex trait made up of several component traits and is greatly affected by differences or changes in the environment, especially nutritional environment. Fertility might be considered as two traits, inherent fertility and expressed fertility. Inherent fertility refers to the genetic potential for reproductive performance and is not directly measurable. Genes that affect overall physiological and endocrine functions may control inherent fertility and account for the generally favorable genetic relationships of measures of early reproductive fitness with growth, milk and overall productivity. On the other hand, expressed fertility can be measured by age at puberty, quality and quantity of spermatozoa, and conception rate. Expressed fertility is dependent upon the external environment and the environment (additional stress) created by the animal's potential for growth, size or milk production. Under environments of nutritional stress the relationship of productivity with expressed fertility may be antagonistic even though the relationship between inherent fertility and productivity may be favorable. Thus, the observed genetic improvement in fertility traits may be less than expected even though expected genetic progress is being made in inherent fertility.

One might think of improved inherent fertility as an insurance policy. Under low stress conditions there may be little difference in expressed fertility between herds of moderate vs superior inherent fertility. However, under stress conditions (drought and high price feed) herds with superior inherent fertility may have acceptable expressed fertility whereas those with lower potential may falter badly. Herds with superior inherent fertility offer more flexibility in a given environment to increase growth and(or) milk without sacrificing expressed fertility.

Summary

Most genetic improvement results from sire selection. Therefore, some selection criterion in young bulls is needed to improve reproductive potential in both bulls and female offspring. Scrotal circumference appears to be a key indicator trait and should be useful when combined with other measures of fertility. Scrotal circumference is easy to obtain, is highly repeatable and highly heritable. It is favorably related to seminal characteristics. It is a good indicator of age at puberty in bulls and in related females. The high estimated genetic correlation between scrotal circumference and age at puberty in females indicates that sires with above average scrotal circumference should produce female progeny with earlier ages at puberty and improved subsequent reproduction potential. Scrotal circumference is favorably related to growth from birth to yearling ages but lowly related to birth weight, thus indicating a favorable growth curve.

Expected progeny difference values for scrotal circumference or other reproductive indexes need to be developed and reported by breed associations in their sire summaries.

Literature Cited

Bourdon, R.M. and J.S. Brinks. 1985. Scrotal circumference in yearling Hereford bulls: Adjustment factors, heritabilities and genetic environmental and phenotypic relationships with growth traits. J. Anim. Sci. 62:958.

Brinks, J.S., M.J. McInerney and P.J. Chenoweth. 1978. Relationship of age at puberty in heifers to reproductive traits in young bulls. Proc. West. Sect. Am. Soc. Anim. Sci. 29:28.

Coulter, G.H. and R.H. Foote. 1979. Bovine testicular measurements as indicators of reproductive performance and their relationship to productive traits in cattle: A review. Theriogenology 11:297.

Doornbos, D.E., C.A. Steffan, D.D. Kress and D.C. Anderson. 1983. Beef heifers differing in milk production. III. Relationship of age at puberty, percent pregnant and day pregnant. Proc. West. Sect. Am. Soc. Anim. Sci. 34:8.

Hughes, S.T. 1987. Breeding soundness traits in beef bulls. Ph.D. Dissertation. Colorado State Univ., Fort Collins.

King, R.G., D.D. Kress, D.C. Anderson, D.E. Doornbos and P.J. Burfening. 1983. Genetic parameters in Herefords for puberty in heifers and scrotal circumference in bulls. Proc. West. Sect. Am. Soc. Anim. Sci. 34:11.

Knights, S.A., R.L. Baker, D. Gianola and J.B. Gibb. 1984. Estimates of heritabilities and of genetic and phenotypic correlations among growth and reproductive traits in yearling Angus bulls. J. Anim. Sci. 58:887.

Laster, D.B., G.M. Smith, L.V. Cundiff and K.E. Gregory. 1979. Characterization of biological types of cattle (Cycle II). II. Postweaning growth and puberty of heifers. J. Anim. Sci. 48:500.

Latimer, F.G., L.L. Wilson, M.F. Cain and W.R. Stricklin. 1982. Scrotal measurements in beef bulls: Heritability estimates, breed and test station effects. J. Anim. Sci. 54:473.

Lunstra, D.D. 1982. Testicular development and onset of puberty in beef bulls. In Beef Research Program Progress Report No. 1. U.S. Meat Animal Research Center ARM-NC-21. p. 26.

Lunstra, D.D., K.E. Gregory and L.V. Cundiff. 1988. Heritability estimates and adjustment factors for the effects of bull age and age of dam on yearling testicular size in breeds of beef bulls. Theriogenology 30:127.

Neely, J.D., R.H. Johnson, E.U. Dillard and D.W. Robinson. 1982. Genetic parameters for testes size and sperm number in Hereford bulls. J. Anim. Sci. 55:1033.

Smith, B. A. 1986. The relationship of sire scrotal circumference on offspring reproduction and subsequent productivity. M.S. Thesis. Colorado State Univ., Fort Collins.

Smith, B.A., J.S. Brinks and G.V. Richardson. 1989a. Estimation of genetic parameters among breeding soundness examination components and growth traits in yearling bulls. J. Anim. Sci. 67:2892.

Smith, B.A., J.S. Brinks and G.V. Richardson. 1989b. Relationships of sire scrotal circumference to offspring reproduction and growth. J. Anim. Sci. 67:2281.

Toelle, V.D. and O.W. Robinson. 1985. Estimation of genetic correlations between testicular measurements and female reproductive traits in beef cattle. J. Anim. Sci. 60:89.

Werre, J.F. and J.S. Brinks. 1986. Relationships of age at puberty with growth and subsequent productivity in beef heifers. Proc. West. Sect. Am. Soc. Anim. Sci. 37:300.

Table 1. Yearling Bull Breeding Soundness Examination (BSE) Information

Classification	Very good	Good	Fair	Poor
Scrotal Circumference (cm)	> 34	30-34	< 30	< 30
Score	40	24	10	10
Morphology Abnormalities				
Primary (%)	< 10	10 to 19	20 to 29	> 29
Total (%)		26 to 39	40 to 59	> 59
Score	< 25	24	10	3
Motility				
Gross	Rapid swirling	Slower swirling	Generalized oscillation	Sporadic oscillation
Individual	Rapid linear	Moderate linear	Slow linear to erratic	Very slow erratic
Score	20	12	10	3
Total Score	85	60	30	16

Table 2. Age and Age of Dam Adjustment Factors for Scrotal Circumference							
			Age of dam adjustment (cm)				
Source	**No. of breeds**	**No. of bulls**	**2 yr**	**3 yr**	**4 yr**	**5+ yr**	**Age (cm/d)**
Bourdon and Brinks (1985)	Hereford	4233	.8	.2	.1	0	.026 .032[a]
Smith (1986)	4 breeds	570	.7	.3	.1	0	.025
Lunstra et al.(1988)	12 breeds	3090	1.3	.8	.4	0	.032

[a]Bulls on full feed.

Table 3. Estimates of Heritability for Scrotal Circumference in Yearling Beef Bulls		
Source	**Heritability**	**Standard error**
Age adjusted		
Bourdon and Brinks (1985)	.49	.06
Knights et al. (1984)	.36	.06
Neely et al. (1982)	.44	.24
Latimer et al. (1982)	.38	.16
Lunstra (1982)	.52	
Coulter and Foote (1979)	.68	
Lunstra et al. (1988)	.41	.06
Smith et al. (1989a)	.40	.09
Polled Hereford (1987)	.55	.21
Weight adjusted		
Bourdon and Brinks (1985)	.46	.06
Neely et al. (1982)	.44	.24
Lunstra (1982)	.69	
Lunstra et al. (1988)	.50	.06

Table 4. Genetic Correlations between Scrotal Circumference and Seminal Traits

Source	Motility	Primary abnormalities (%)	Secondary abnormalties (%)	Normal (%)
Brinks et al. (1978)	.25	-.51	-.42	.58
Hughes (1987)	.09	-.07	-.09	.08

Table 5. Breed Comparisons: Bull Testicular Size Versus Heifer Age at Puberty

Breed	Heifer age at puberty[a] (d)	Scrotal circumference of yearling bulls[b]	
		Average (cm)	Range (cm)
Gelbvieh	341 ± 9	34.8 ± 0.5	30.2 to 42.2
Brown Swiss	347 ± 8	34.3 ± 0.5	31.0 to 39.6
Red Poll	352 ± 8	33.5 ± 0.5	29.7 to 37.1
Angus	372 ± 12	32.8 ± 0.5	26.2 to 38.4
Simmental	372 ± 6	32.8 ± 0.8	26.2 to 39.1
Hereford	390 ± 13	30.7 ± 0.5	26.2 to 36.1
Charolais	398 ± 7	30.4 ± 0.8	25.4 to 37.6
Limousin	398 ± 6	30.2 ± 0.5	24.4 to 34.3
Average	368 ± 3 (723)	32.2 ± 0.3 (274)	

[a] Least-squares means ± standard error. Number of heifers measured is given in parentheses. Data from Germ Plasm Evaluation Project (Cycle I, II, and III).
[b] Data from Germ Plasm Utilization Project and adjusted to 365 d of age.

Table 6. Genetic Correlations between Scrotal Circumference and Measures of Growth

Source	Birth weight	Weaning weight	Post-weaning weight	Yearling Weight
Bourdon and Brinks (1985)	.18	.29	.35	.44
Knights et al. (1984)	.10	.00		.68
Neely et al. (1982)		.86	.22	.52
Smith et al. (1989a)	.08	.56	.59	.63
Lunstra et al. (1988)	-.02	.00	.00	.10

Table 7. Correlation of Age at Puberty with Productivity Traits[ab]

	1st lactation			2nd lactation			3rd lactation			4th lactation		
	HCC	AWWR	MPPA	HCC	AWWR	MPPA	HCC	AWWR	MPPA	HCC	AWWR	MPPA
Age at puberty	.54	-.65	-.62	.34	-.11	-.38	-.06	-.24	-.10	.47	-.11	-.25

[a] From Werre and Brinks (1986).
[b] HCC = Heat cycles of conception (1 = early, 3 = late), AWWR = adjusted 205 d weaning weight ratio, MPPA = most probable producing ability.