Increase in average scrotal circumference of Canadian beef bulls

Albert Barth
Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK, Canada

The basis for scrotal circumference measurement

In temperate climates, short growing seasons and long winter-feeding periods impose seasonal cattle management patterns upon producers. Efficient and economical herd management depends a great deal on maintaining short, well-defined, calving seasons. The advantages of short breeding seasons are applicable to tropical and subtropical regions as well as in temperate regions.[1] Short calving periods result in a uniform calf crops that can be managed in groups for vaccination, castration, weaning, weighing for performance records, and for calf sales. It also allows cow herds to be managed in groups for maintaining vaccination programs, observation of breeding activity, synchronization of estrus and artificial insemination, pregnancy testing, culling for non-pregnancy and poor performance, and good nutritional management.

In essence, the length of the calving period is dictated by the length of the breeding season. In well-managed herds, it is normal to expect beef cows to produce a calf every 12 months, and for >90% of the herd to be pregnant and due to calve within about a 65-day period. Short breeding seasons require highly fertile females. Good record keeping, nutritional management, vaccination and pregnancy testing, heifer selection and development, are some of the components of maintaining a highly fertile female population.

Early puberty in heifers is necessary in order for heifers to cycle in synchrony with the cows. In well-managed herds breeding seasons will begin three weeks after the normal end of the calving period. Since heifers are usually selected from last year's calving period, it is clear that heifers must already be cycling when they are 13 to 15 months old; preferably, heifers would have completed two or three estrous cycles by the beginning of breeding to ensure optimum fertility.[2] Beef heifers that conceive early and calve as two-year-olds have a greater probability of becoming pregnant as first calf females the following year[3] and tend to calve earlier in subsequent years.[4] However, the average age of puberty (first estrus) in well-managed, early-maturing breeds and in crossbred heifers is about 12 months of age, i.e., 50% of heifers have cycled once.[5-8] By 13-14 months of age, about 90% should have cycled once. In purebred herds with later maturing breeds, such as Hereford and Limousin,[5] having sufficient numbers of cycling replacement heifers at the start of the breeding season may be difficult. Selection for increased scrotal circumference (SC) is an essential practice since scrotal circumference of sires is highly correlated with age at onset of puberty in female and male offspring.[9-12] In two studies, correlations of 0.66 and 0.97 were found between breed means for scrotal circumference and fertility of female offspring.[13,14]

For producers that sell purebred bulls and purchase bulls for genetic improvement and for frozen semen sales, early bull puberty is immensely important. In order to capture the genetics of high-priced yearling bulls and return on investment, i.e., to have semen for sale in mid-winter, useful semen must be produced by the time a bull is 12 months old. However, only 30 to 41% of *Bos taurus* bulls produced satisfactory semen at 12 months of age and only 51-75% by 14 months of age(Barth AD, unpublished data).[15,16] Early puberty is also very important in bulls intended for natural service in commercial beef herds. In the past 20 years, it has become common to use yearling *Bos taurus* bulls as primary breeders. The use of bulls at an early age reduces production costs, shortens the generation interval and may increase genetic gains. However, the variability of onset of puberty, among and within breeds, has resulted in great variability in reproductive performance of young bulls among producer herds. Poor reproductive performance by yearling bulls may be due partly to inadequacy in mating ability; however, semen quality is a more important factor. Age of puberty, and subsequently maturity, is the main factor involved in semen quality of yearling bulls. Therefore, the successful use of yearling bulls will depend on production systems that hasten maturity.

Testis size is highly correlated with age at onset of puberty in male and female progeny.[9,17] Although the benefits of larger testes include a greater capacity to produce sperm and good quality semen,[18-20] the most important reason for selection for larger SC measurement is to promote early puberty

in male and female offspring. Fortunately, testis size is quite highly heritable with estimates of heritability ranging from 0.44 to 0.69.[19] Therefore, rapid progress can be made in selection based on SC.

Keywords: Scrotal circumference, puberty, selective breeding, genetic improvement

Availability of scrotal circumference data

It would seem that SC data should be accessible through records of breeding soundness evaluations in veterinary practices and veterinary institutions throughout North America and many other countries of the world; however, in order to be useful SC measurements must be reliable and the age of bulls must be accurately recorded, especially in yearling bulls. In yearling bulls testis size increases a great deal in a short period of time; a few weeks in age makes a big difference in SC. Therefore, for yearlings, birth dates must be recorded, or at the very least, bull age must be known to be accurate within two weeks. Unfortunately, very few clinicians record birth dates and often do not record age in months. In order to ensure the reliability of SC measurements, those doing the measurements must be well experienced and this may not be the case among all clinicians that evaluate bulls. The use of spring-tension SC measuring tapes to ensure application of similar tensions among users should improve repeatability of measurements, however, simple tapes without springs are widely used. Therefore the procurement of reliable SC data by breed and age is difficult. However, over the years a few researchers have produced useful data. The following table shows SC measurements from several such studies.[21]

Table 1. Scrotal circumference data (means, numbers in parenthesis) corrected to 365 ± 14 days of age for bulls from various times and locations.

	Cates 1972-81 SK	Lunstra 1988 NE	Barth 1995-98 MB	Coulter 1981 AB	Schumann 1990-92 SK	Arteaga 1998 AB, SK, MB	n	Weighted mean of all bulls	Mean of research group means
Simmental	34.8 (376)	33.7 (238)	33.3 (174)	36.0 (401)	33.4 (29)	35.7 (28)	1246	34.7	34.5
Br Swiss		33.8 (245)				34.1 (15)	260	33.8	33.8
Gelbvieh		33.9 (233)	33.7 (13)	32.5 (-)		34.5 (15)	261	33.9	33.6
Pinzgauer		33.7 (144)					144	33.7	33.7
Charolais	32.0 (576)	31.7 (197)	32.3 (330)	33.1(607)	32.0 (76)	34.7 (101)	1887	32.5	32.6
Limousin		29.1 (222)	29.6 (61)	30.3 (276)	30.2 (1)	30.9 (7)	345	29.8	30.0
Blonde d'Aquit			27.2 (7)			31.9 (8)	15	29.7	29.5
Salers			30.2 (40)	29.4 (758)	30.4 (5)		45	29.5	30.0
Tarentais			32.0 (14)				14	32.0	32.0
Maine Anjou	32.1(60)			32.1 (-)	33.7 (4)		64	32.2	32.6
Hereford	31.2 (551)	30.4 (256)	32.9 (46)	32.6 (946)	30.5 (24)	(33.9) (8)	1567	31.9	31.9
Angus	33.1 (703)	32.2 (449)	33.6 (29)	33.9 (260)	32.8 (59)	34.4 (297)	1051	33.2	33.3
Shorthorn	31.2 (138)			32.5 (147)	32.8 (20)		167	31.9	32.2
Red Poll		32.5 (222)	32.9 (28)				250	32.5	32.7
Galloway	30.6 (132)						132	30.6	30.6

It would appear from examination of the data in Table 1 that the ranking of SC by breed was quite similar between studies and did not change between the 1970's and the early 1990's. The latest work shown in Table 1[16] seems to indicate that average SC began to increase in the last half of the 1990's. A possible explanation for this is that for the decades leading up to 1994, the Society for Theriogenology system for bull breeding soundness evaluation (BSE) was used throughout North America and evidently it did not exert much pressure on breeders to select for SC. In Canada, in 1994, a switch was made to the bull BSE system of the Western Canadian Association of Bovine Practitioners (WCABP).[21] The WCABP system introduced selection for SC based on age and breed. The back of BSE forms provided data on SC and information for producers which encouraged selection for increased SC. Furthermore, on the front of bull BSE forms, SC was recorded as 'Above Average', 'Average', 'Below Average' or 'Below

Minimum'. Most breeders likely would not want to purchase bulls that were 'Below Average' in SC. Perhaps for these reasons, there was a fairly rapid response to selection for increased SC in Canada in the later part of the 1990's and beyond. This supposition would imply that there would not have been a corresponding increase in SC in bulls in the USA. However, there is some sharing of cross-border genetics, particularly in terms of frozen semen sales among purebred breeders and breeders are not bound by BSE systems in selection for increased testis size.

Increase in average testis size of Canadian beef bulls in recent years

Recently (2006-11), SC data were obtained from bulls evaluated for breeding soundness by 41 veterinary practices in western Canada and from record of performance test stations from 16 regions of Quebec.[22] Bull age ranged from one to 11 years, however, the majority of bulls were aged one to two years since this is the most common group evaluated for breeding soundness. Data were available for 10,968 bulls, 8361 from western Canada and 2607 from Quebec. Twenty-one beef breeds were represented. The mean SC for black and red Angus bulls did not differ at any age, thus data were combined under the Angus breed. Similarly, SC data for polled- and horned Hereford bulls did not differ at any age and data were combined under the Hereford breed. Fewer than ten animals were present in each age group for ten breeds including Belgian Blue, Brown Swiss, Dexter, Fleckvieh, Maine Anjou, Piedmontese, Red Poll, Shaver, Tarantaise and Texas Longhorn breeds. Therefore, these breeds were not included in any data analysis. Scrotal circumference measurements for steel tapes, Reliabull tapes and Coulter tapes did not differ ($P<0.05$), but measurements for 'other' (homemade tapes) did differ, therefore, data for 'other' tapes were not used. Scrotal circumference data did not differ between different practices or regions of Canada. Thus, useful data were available for 10,579 bulls for 11 beef breeds including Angus, Hereford, Simmental, Charolais, Gelbvieh, Limousin, Shorthorn, Speckle Park, Blonde d'Aquitaine, Salers and Galloway.

Testis growth is very rapid from the time of weaning at about seven months of age until maturity at about 15 mo of age. Thereafter, testis growth rates decrease quickly and by two years of age about 90% of final testis size is achieved; growth ceases at about four years of age.[23] The change in SC per day of age was determined from data reported previously[24,25] and from unpublished data (Barth). The rate of change in SC does not differ between breeds,[26] but rather those breeds that have larger testes at a year of age start out with larger testes at the time of weaning. For example, the SC of Limousin bulls averaged 4 cm less at eight months of age than Simmental bulls and this difference carried through to 12 months of age.[25] The rate of increase in SC (SC/d) between 240 and 365 d of age for seven breeds of beef bulls appeared not to have changed between 1981 (0.0670 cm/day[15]) and 2000 (0.0647 cm/day[25]). Two studies from 1986-1989[27,28] showed that the increase in SC between 330 and 430 days was 0.024 to 0.026 cm/day. A subset of data from 2006-2011 study[22] for yearling Angus bulls, in which age was available in days, indicated that testis growth rate for a similar age group (SC =0.024 cm/day) was in agreement with the earlier data. This gave us some confidence in using the older data for the rate of change in SC in young bulls. Table 2 shows the rate of change in SC that was used to correct SC data to 365 days of age (Table 3) in yearling bulls for ten beef breeds, Angus, Hereford, Shorthorn, Galloway, Red Poll, Charolais, Simmental, Maine Anjou, Limousin, and Salers.[22]

Table 2. Estimated increase in scrotal circumference (SC) per month of age for ten breeds of beef bulls.

	Increase in SC	
Age in months	Daily (cm)	Monthly (cm)
10-11	0.062	1.86
11-12	0.050	1.50
12-13	0.038	1.14
13-14	0.026	0.78
14-15	0.014	0.42

Simmental yearling bulls had a significantly larger average SC than any other breed (Table 3). There was no significant difference between Angus, Charolais and Gelbvieh breeds. Although, not different than Gelbvieh, Herefords had a significantly smaller SC than Angus and Charolais. Speckle Park, Salers, Limousin and Blonde d'Aquitaine had a significantly lower SC than previously mentioned breeds, but were not different from each other.

Table 3. The mean (± SD) scrotal circumference corrected to 365 days of age for yearling bulls of 10 common beef breeds in Canada.

Breed	N	Mean ± SD
Simmental	1050	36.06 ± 2.50^{A}
Angus	3004	34.62 ± 2.21^{B}
Charolais	1469	34.55 ± 2.82^{B}
Gelbvieh	190	34.41 ± 2.63^{BC}
Hereford	272	33.93 ± 2.41^{CD}
Shorthorn	55	33.03 ± 1.60^{DE}
Speckle Park	55	32.04 ± 1.77^{EF}
Salers	31	31.84 ± 2.84^{EF}
Limousin	290	31.52 ± 2.22^{F}
Blonde d'Aquitaine	16	31.24 ± 2.13^{F}

^{A,B} Different superscripts indicate significant differences ($P<0.05$).

Scrotal circumference data for bulls ≥2years of age were not corrected, however, for bulls recorded as two years old, age was known to be accurate within ± 2 months of two years. At two years of age, Gelbvieh, Charolais and Simmental had a significantly larger SC than all other breeds with the exception of Herefords (Table 4). The mean SC for Angus, Hereford, Galloway and Shorthorn did not differ. Limousin and Speckle Park bulls had significantly smaller SC than most breeds except for Galloway and Shorthorn.

Table 4. The mean (± SD) scrotal circumference for 2-year-old bulls (± 2 months) of 9 common beef breeds in Canada.

Breed	N	Mean ± SD
Gelbvieh	43	40.17 ± 2.53[A]
Charolais	271	39.28 ± 2.83[A]
Simmental	223	39.19 ± 2.58[A]
Hereford	268	39.15 ± 2.69[AB]
Angus	1031	38.55 ± 2.45[B]
Galloway	23	38.39 ± 2.97[BC]
Shorthorn	40	37.86 ± 2.15[BC]
Limousin	80	35.72 ± 2.05[C]
Speckle Park	21	35.43 ± 2.52[C]

[A,B] Different superscripts indicate significant differences (P<0.05).

Tables 5 and 6 provide data for three-year-old bulls and for bulls ≥4 years of age. The differences in mean SC among breeds are not very large and therefore, breed rankings based on SC in these tables may be due small sample sizes and other population differences within regions from year to year.

Table 5. The mean (± SD) scrotal circumference for three-year-old bulls of six common beef breeds in Canada.

Breed	N	Mean ± SD
Charolais	114	41.09 ± 2.47[A]
Gelbvieh	28	40.48 ± 2.72[A]
Simmental	193	40.30 ± 3.06[A]
Angus	489	39.91 ± 2.67[AB]
Hereford	49	39.48 ± 2.55[B]
Limousin	56	36.67 ± 2.53[C]

[A,B]Different superscripts indicate significant differences (P<0.05).

Table 6. The mean (± SD) scrotal circumference for • 4-year-old bulls of six common beef breeds in Canada.

Breed	N	Mean ± SD
Simmental	249	43.05 ± 2.50[A]
Charolais	150	42.29 ± 2.56[AB]
Angus	624	41.78 ± 2.68[B]
Gelbvieh	44	41.48 ± 2.83[B]
Hereford	89	41.12 ± 2.41[B]

[A,B]Different superscripts indicate significant differences (P<0.05).

The means for SC for one- and two-year-old bulls from 1972-1998 was determined from published reports[21] and compared to data from 2006-2011[22] in Tables 7 and 8. There has been a significant increase in SC over time for all breeds shown in yearling and two-year-old bulls. The largest increase in yearling bulls was seen for the Hereford and Charolais breeds, and the smallest increase was seen in the Shorthorn and Gelbvieh breeds. This might be because the Gelbvieh breed was uncommon in the earlier decades, but became very common in the last two decades, whereas, the Shorthorn breed was common in the early decades and very uncommon in the last two decades. Thus differences in SC based on large amounts of data may not be comparable between the earlier decades and the last two decades in these two breeds. The Hereford and Charolais breeds have been in common use for the past four decades, thus the results of selection pressure for SC would be easily detectable. At two years of age, the increase in average SC was greatest in the Limousin breed which has also been in common use for the past four decades.

Table 7. Difference in mean SC in one-year-old bulls of seven beef breeds determined from data of six researchers from 1972 to 1998[21] and data from 2006-2011.[22]

Breed	Mean SC (cm) 1972-1998	Mean SC (cm) 2006-2011	Difference (cm)
Angus	33.3	34.6	1.3*
Charolais	32.6	34.6	2.0*
Gelbvieh	33.6	34.4	0.8*
Hereford	31.9	33.9	2.0*
Limousin	30.0	31.5	1.5*
Shorthorn	32.2	33.0	0.8*
Simmental	34.5	36.1	1.6*

*Mean from the present study differs from previously reported means (P<0.05).

Table 8. Difference in mean SC in two-year-old bulls of six beef breeds from 1987 data[29] and data from 2006-2011.[22]

Breed	Mean SC (cm) 1987	Mean SC (cm) 2006-2011	Difference
Angus	37.2	38.6	1.4*
Charolais	36.3	39.3	3.0*
Gelbvieh	-	40.2	-
Hereford	36.1	39.2	3.1*
Limousin	32.2	35.7	3.5*
Shorthorn	34.9	37.9	3.0*
Simmental	38.8	39.2	0.4*

*Mean from the present study differs from previously reported means (P<0.05).

During the period from 1994 to 2013, in the method of bull BSE of the WCABP,[21] the suggested minimums in SC for a satisfactory classification were established by disqualifying bulls that were below one standard deviation of the mean for their breed and age. In 2012, the WCABP established a committee to study the recent SC data and to make recommendations on minimum SC by age and breed for the future. The data indicated that some of the breed rankings had changed and for some of the breeds, especially the most common breeds used in the past two decades, the minimum SC should be increased. The committee felt that a great deal of progress already had been made in selection for testis size and to continue to disqualify bulls in the bottom standard deviation for SC likely placed more selection pressure than necessary. It was suggested that bulls in the bottom tenth percentile for SC should be disqualified for a satisfactory classification in the future. There were insufficient data to make recommendations for many breeds that are not present in large numbers in Canada at the present time. For these breeds the WCABP committee recommended that SC data from studies prior to the year 2000 should likely continue to be used for breeding soundness evaluations. Table 9 shows the recommended minimums for SC by age and breed adopted by the WCABP for bull BSEs going forward.

Table 9. Suggested Minimum Scrotal Circumference (cm) for 2014 and forward.

Age (mo)	Simmental, Angus, Charolais, Gelbvieh, Pinzgauer, B. Swiss/Braunvieh	Hereford, Shorthorn, Maine Anjou, Red Poll, S. Devon, Holstein	Speckle Park, Salers, Tarentais	Limousin, Blonde d'Aquitaine, Galloway	Texas Longhorn
12	32	31	30	29	28
13	33	32	31	30	29
14	34	33	32	31	30
15	34.5	33.5	32.5	31.5	30.5
16-20	35	34	33	32	31
21-≥30	35	35	34	33	32

Some have expressed their belief that the beneficial effect of SC on age at puberty has already been sufficiently achieved for many breeds and fear that continued selection for larger SC for all breeds may lead to semen quality issues in bulls with excessively large testes. These are valid questions and

going forward, research on the effect of testis size on both age of puberty and semen quality should be continued. It would appear that at least for breeds that have smaller testes, e.g., those in the last three columns of Table 9, progress in selection for increased testis size is still needed. At the present time, a small amount of data exists in which SC of Angus and Charolais bulls aged 13.5 to 15 months was grouped as 30-32.9 cm, 33-35.9 cm, and so on, up to 44.9 cm. Preliminary analysis showed that fewer bulls had satisfactory semen quality when SC was 30-32.9 cm. There were no differences in the proportions of bulls with satisfactory semen quality in the other SC groups; however, there were only four bulls in the group that had a SC of 42-44.9.

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