

The Relationship between Body Conformation, Testicular Traits and Serum Testosterone Levels in Pre-pubertal Male Boer Goat Crosses

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ABSTRACT

In the present study, the relationship among body conformation traits, scrotal circumference and serum testosterone concentrations were investigated in pre-pubertal male Boer goat crosses at the Caprine Research and Education Unit, Tuskegee University, Tuskegee, AL. Body conformation traits (chest girth -CG, height at withers-HTW, body length -BL, body condition scores -BCS, body weight -BW, shoulder width -SW), and scrotal circumference -SC were monitored at 3 week intervals for 12 weeks. Also, blood samples were collected and a calibrated IMMULITE 1000 assay system was used for the quantitative measurement of total serum testosterone. Although, results show a non-significant relationship between serum testosterone levels and many body conformation traits, serum testosterone levels were lowly and positively correlated to BL ($r = 0.19$), BW ($r = 0.19$), CG ($r = 0.13$), HTW ($r = 0.11$) and SC ($r = 0.18$). Scrotal circumference was moderately correlated to BL ($r = 0.30$; $P = 0.001$) and SW ($r = 0.33$; $P < .001$) and strongly correlated with BW ($r = 0.61$), CG ($r = 0.53$), HTW ($r = 0.41$) respectively. In addition, scrotal circumference and body weight increased ($P < .01$) linearly from week 6 through week 12 ($23.22 \pm 0.86\text{cm}$, $31.95 \pm 2.64\text{kg}$, $24.53 \pm 1.43\text{cm}$, $34.72 \pm 2.98\text{kg}$, $26.05 \pm 1.35\text{cm}$, and $37.46 \pm 3.44\text{kg}$), respectively. Testosterone levels increased from week 0 to week 3, after which there was a decline into week 6 before peaking at week 9. It is speculated that the week 9 peak of serum testosterone levels obtained in this study represents the attainment of sexual maturity (puberty) in Boer goat male crosses. Based on the results of this study, we hypothesized that scrotal circumference measurements, when used in conjunction with serum testosterone levels and body conformation traits can be a valuable breeding soundness evaluation tool for selecting or culling breeding Boer goat sires at an early age by limited resource producers.

Keywords: Boer goats, body conformation, testicular traits, serum testosterone

1. INTRODUCTION

Meat goat breeds available for production in the U.S include: South African Boer, New Zealand Kiko, Myotonic, Savannah, and Spanish goats [1]. The Boer goat from South Africa is a breed developed for meat production that evolved from

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21 selection pressures placed on indigenous goats of the region by farmers [2]. To
22 make genetic gain in the meat goat industry, there is a requirement to determine
23 superior Boer meat goat sires within the population and increase their use. The
24 most accurate way to test a sire's genetic worth is to perform breeding soundness
25 evaluation (BSE) and also generate progeny from the animal [3]. BSE predicts the
26 potential fertility of a buck. It is based on an examination that includes tests for
27 physical soundness, scrotal circumference, semen quality, and in some cases,
28 serum testosterone profiles, and libido/mating ability.

29 The age and weight at which puberty occurs vary greatly among breeds of
30 goats and the level of nutrition during development; however, research with various
31 breeds [4, 5] suggests that a practical indication of imminent puberty is when scrotal
32 circumference is between 25 and 27 cm. In bulls, there is a positive genetic
33 correlation between a sire's scrotal circumference, the scrotal circumference of his
34 sons, and the pregnancy rate of his daughters [6]. This indicates that bulls with a
35 larger scrotal circumference are likely to sire sons with larger scrotal circumference,
36 and daughters likely to reach puberty at younger ages.

37 Testosterone is a steroid hormone produced by cells of the testes, and is
38 considered to be the primary circulating androgen that regulates testicular function.
39 Testosterone levels are useful in selection of young sires, and in characterizing
40 sexual maturity in different breeds of meat animals [7]. It is important to
41 evaluate testosterone levels to determine the development of the reproductive
42 system [8].

43 The relationship between body measurements and serum testosterone in
44 10-12 month old Dorper rams was reported by Fourie et al. (2005). Serum
45 testosterone did not have a significant correlation with most of the body parameters
46 measured [9]. However, serum testosterone concentration in rams was positively
47 correlated to masculinity and scrotal circumference. Scrotal circumference was
48 positively and significantly correlated with body weight, body length, chest depth,
49 shoulder height, shoulder width, hindquarter width, cannon bone length, masculinity
50 (muscle score), wedge shape, selection index and age. Rams with a wedge shape
51 scores between five and seven were significantly heavier than those with type
52 scores between two and four. Collectively, Fourie et al. (2005) concluded that there

is a significant and positive relationship between scrotal circumference and serum testosterone, but no significant correlation between linear shape type score and serum testosterone levels.

Testicular development in relation to age, body weight, semen characteristics and testosterone was reported in Kivircik ram lambs [10]. All measurements of testis, body weight, and serum testosterone concentrations were positively correlated with each other. A significant positive correlation was found at seven to eight months of age [10] between all testicular measurements, semen volume and motility. Scrotal circumference could provide useful estimate of testicular growth, as its correlations with other testicular measurements were the highest, and this information could be used as selection criteria for ram lambs at an early age.

A procedure that would link external body conformation and testicular traits with serum testosterone or semen quality may provide a good guide to breeding soundness evaluation in meat goat sires [11]. Since limited resource producers may not be in a position to test libido and/or ejaculate qualities of males before using them for breeding, a procedure that would link external testicular measurements with serum testosterone may provide a good guide to breeding soundness evaluation, especially, where bucks are reputed to have exceptionally high libido [12, 13].

There is no evidence in literature to suggest that this approach has been used in selecting potential Boer meat goat sires for superior breeding. Therefore, the aim of this study is to identify the relationship between certain body conformation, testicular traits and serum testosterone levels of pre-pubertal male Boer crosses.

2. MATERIAL AND METHODS

2.1. Animal Management:

Twenty five pre-pubertal male Boer goat (Boer x Kiko) crosses (110.1 ± 20.1 days old), and singled sourced from a local meat goat producer were used in this study. The Tuskegee University Animal Care and Use Committee approved animal care, handling and sampling procedures. Upon arrival the animals were given an overall health check by an attending veterinarian at Tuskegee University's School of Veterinary Medicine. The animals were treated with Panacur (*fenbendazole*) to

control the development and reproduction of internal parasites and quarantined for three weeks at the Tuskegee University's Caprine Research Facility. Each animal was housed for the entire experimental period in individual 1.8 x 2.1m indoor pens after the quarantine period. Throughout the experimental period, animals were maintained on a daily diet that consisted of a high energy concentrate that was given at 2lbs/day. The animals were also allowed *ad libitum* access to hay, water and mineralized salt blocks.

2.2. Body Conformation Measurements

The body conformation measurements recorded at 3-week intervals for 12 weeks (wk 0-131 d, wk 3- 152 d, wk 6- 173 d, week 9- 194 d, and wk 12-213 d of age) included: body weight, BW, kg (recorded using a MTIAHS-100 Sheep and Hog Scale System and, body condition score, BCS, scored subjectively on scale of 1 = emaciated to 5 = obese). A measuring tape was used to determine shoulder width (the horizontal distance between the processes on the left shoulder to those on the right shoulder blade), chest girth (the width around the chest just behind the front legs), body length (the distance from the sternum to the aitch bone), hip width (the distance between the left and right femur bones). The height at wither (determined with the aid of a metric ruler as the vertical length from the thoracic vertebrae to the ground).

2.3. Testicular Measurements

The scrotal circumference was determined from each animal by pulling the testicles firmly into the lower part of the scrotum, grasping the neck of the scrotum with one hand, squeezing and pulling down. Thereafter, the circumference was measured with the aid of a measuring tape and recorded every 3 weeks for 12 weeks as the largest diameter of the scrotum.

2.4. Blood Collection

Blood samples were collected at intervals of three weeks for 12 weeks for each animal. The blood was collected via jugular venipuncture into 10ml heparinized vacutainer tubes, and placed on ice immediately after collection. The serum was separated by centrifugation at 3000 rpm at 4°C for 10 minutes and aliquoted into separate vials which were kept frozen at -4° C until testosterone assay.

119 2.5. Serum Testosterone Assay

120 A calibrated IMMULITE 1000 system (developed at Meharry Medical
121 College, Nashville, Tennessee) was used for the quantitative measurement of total
122 serum testosterone. IMMULITE 1000 Total Testosterone is a solid-phase, enzyme-
123 labeled, competitive chemiluminescent immunoassay. The solid-phase, a
124 polystyrene bead enclosed within an IMMULITE Test Unit, is coated with a
125 polyclonal rabbit antibody specific for testosterone. Serum samples and alkaline
126 phosphatase-labeled testosterone were simultaneously introduced into the Test
127 Unit, and incubated for approximately 60 minutes at 37°C with intermittent agitation.
128 During this time, testosterone in the sample competed with alkaline phosphatase
129 labeled testosterone for antibody-binding sites on the bead. Unbound material was
130 then removed by a centrifugal wash. Substrate is then added, and the Test Unit is
131 incubated for another 10 minutes.

132 The chemiluminescent substrate, a phosphate ester of adamantyl dioxetane,
133 undergoes hydrolysis in the presence of alkaline phosphatase to yield an unstable
134 intermediate. The continuous production of these intermediate results in the
135 sustained emission of light, thus improving precision by providing a window for
136 multiple readings. The bound complex - and thus also the photon output, as
137 measured by the luminometer - is inversely proportional to the concentration of
138 testosterone in the sample.

139 2.6 Statistical Analysis

140 Descriptive statistics [14] was performed on the data to determined individual
141 buck differences in selected body conformation, testicular and serum testosterone
142 profiles. Also, data was subjected to analysis of variance using the GLM procedures
143 [14]; correlation coefficients (r) were established between various body, testicular
144 parameters and serum testosterone profiles.

145

146 3. RESULTS AND DISCUSSION

147

148 The means and standard deviations for phenotypic traits, testicular traits and
149 serum testosterone levels (TT) are shown in Tables 1. The average SC at
150 week 0 was (22.87±2.42cm), with a slight decline into week
151 (22.54±1.77cm).

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Table 1. The Effect of Week on Body Conformation, Testicular Traits,

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Serum Testosterone at week 0, 3, 6, 9, and 12)* in Pubertal Male Boer Crosses.

Parameters	Week 0 (N= 25)	Week 3 (N=23)	Week 6 (N= 23)	Week 9 (N=23)	Week 12 (N= 23)
Week 12					
Body Condition Score (BCS, 1-5)	3.40 ± 0.50 ^b	3.21± 0.51 ^{ab}	3.08± 0.41 ^{ab}	2.91± 0.59 ^a	3.13± 0.69 ^{ab}
Body Length (BL, cm)	58.62 ± 2.41 ^a	61.95± 3.21 ^b	63.72± 2.26 ^{bc}	65.25± 2.34 ^{cd}	67.13± 2.75 ^d
Body Weight (BW, kg)	27.66 ± 2.54 ^a	27.52± 2.20 ^a	31.95± 2.64 ^b	34.72± 2.98 ^c	37.46± 3.44 ^d
Chest Girth (CG, cm)	66.34± 3.22 ^{ab}	64.37± 1.95 ^a	67.82± 2.58 ^{bc}	68.91± 2.21 ^{cd}	70.79± 2.35 ^d
Height at Withers (HTW, cm)	58.01± 1.90 ^a	59.97± 2.27 ^b	61.20± 1.86 ^{bc}	62.29± 2.13 ^c	64.58± 2.39 ^d
Hip Width (HW, cm)	42.16± 3.12 ^a	41.95± 2.28 ^a	43.63± 1.65 ^{ab}	42.18± 1.68 ^a	45.06± 2.06 ^b
Scrotal Circumference (SC, cm)	22.87± 2.42 ^a	22.54± 1.77 ^a	23.22± 0.86 ^{ab}	24.53± 1.43 ^b	26.05± 1.35 ^c
Shoulder Width (SW, cm)	41.14± 2.54 ^a	40.40± 1.84 ^a	41.73± 1.52 ^a	41.29± 1.92 ^a	44.06± 2.11 ^b
Testosterone (TT, ng/ml)	5.625± 6.03 ^a (N= 20)	8.74±11.26 ^a (N= 17)	7.48±8.25 ^a (N= 23)	27.48±14.42 ^b (N= 23)	10.74±14.40 ^a (N=23)

154 *Means ± Standard Deviations

155 ^{a,b,c,d} Means in each row with the same superscript are not significantly different ($P =$
 156 .05).

157 However, SC increased linearly from week 6 through week 12 (23.22±0.86cm,
 158 24.53±1.43cm and 26.05±1.35cm), respectively. There was no significant difference
 159 for SC between weeks 0, 3, and 6; and week 6 and week 9 ($P = .15$), respectively.

160 In addition, SC and BW increased correspondingly from week 6 through week 12
 161 (23.22±0.86cm; 31.95 ±2.64kg) (24.53±1.43cm; 34.72 ±2.98kg) and (26.05±1.35cm;
 162 37.46 ±3.44kg), respectively. The average TT level at week 0 was
 163 5.625±6.03ng/ml, with a slight increase into week 3 (8.74±11.26ng/ml, $P = .09$).

164 Also, there was a decline in TT level at week 6 (7.48±8.25ng/ml), and week 9
 165 showed an all time high (27.85±14.42ng/ml), followed by a decline at week 12
 166 (10.74±14.40ng/ml). For weeks 0, 3, 6 and 12 there was no significant difference
 167 ($P = .19$) for TT levels. However, TT for week 9 was significantly different from week
 168 0, 3, 6 and 12 ($P = .05$), respectively. It is speculated that the week 9 peak of serum

testosterone levels obtained in this study represents the attainment of sexual maturity (puberty) in Boer male crosses. Bezerra et al. (2009) reported mean testosterone levels varying from $(0.259 \pm 0.172 \text{ ng/ml})$ to $(4.613 \pm 2.892 \text{ ng/ml})$ and (0.521 ± 0.311) to $(3.417 \pm 2.021 \text{ ng/ml})$ in Boer goats starting from 1 month to 8 months of age during dry and rainy seasons. In young Saneen and British Alpine goats, testosterone levels are marked by an initial decline followed by a peak at the time when male reach sexual maturity [16, 17]. As previously stated, testosterone levels increased from week 0 to week 3, after which there was a decline into week 6 before peaking at week 9.

The correlation coefficients (r) for body conformation, testicular traits and serum testosterone levels are presented in Table 2. TT levels recorded a low to moderate correlations with most of the body conformation traits measured in this study. SW is slightly negatively correlated ($r = -0.08$) with TT levels, which is correlated with SC ($r = 0.18$), BL ($r = 0.19$), BW ($r = 0.19$), CG ($r = 0.13$), HTW ($r = 0.11$), respectively. Fourie et al. (2005) found similar results in Dorper rams, where serum testosterone concentration was positively correlated to masculinity ($r = 0.15$; $P = .05$) and scrotal circumference ($r = 0.23$; $P < .05$), which is slightly higher than values reported in the current study. Species difference (ram vs. bucks) could explain the discrepancy in the testosterone vs. SC correlation values.

According to Coulter and Foote (1976), SC is an important trait that is closely associated with the testicular growth and sperm production in males of all meat animals. Thus, selecting males based on their SC would result in larger testes, potentially with the capacity to produce more semen [18]. Being a highly heritable component of fertility, it is important to include SC during evaluating animals for breeding soundness [19]. In the current study, SC was positively and significantly ($P < .001$) correlated to BL ($r = 0.30$), BW ($r = 0.61$), CG ($r = 0.53$), HTW ($r = 0.41$) and SW ($r = 0.33$). Similar results were reported by Fourie et al. (2005) who found positive and significant correlations between SC and BW ($r = 0.38$), BL ($r = 0.34$) and SW ($r = 0.27$) in Dorper rams. Adeyinka and Mohammed (2006) reported positive correlations between TT and BW ($r = 0.30$; $r = 0.43$), SC ($r = 0.42$; $r = 0.52$), and BW and SC ($r = 0.93$; $r = 0.88$) young Boer bucks. Ugwu (2009) reported a highly significant positive relationship between SC and testis weight of West African

201 Dwarf bucks. Testis weight is known to be highly correlated ($r = 0.93$) with testicular
 202 sperm reserves [13] and males with larger testes tend to produce more sperm [21].
 203 It follows that a good measurement of scrotal circumference would be a reliable
 204 predictor of sperm producing capacity.

205 Overall, results from this study indicate that there are significant and positive
 206 correlations between few **body conformation** traits and serum testosterone levels.
 207 However, **a low to moderate correlation** was found between scrotal circumference
 208 and serum testosterone level in pubertal male Boer crosses. In general,
 209 correlations between serum testosterone levels and **body conformation** in this study
 210 were either low or negative. However, testicular size was found to have a higher
 211 correlation with body weight than serum testosterone level in pubertal male Boer
 212 crosses. Based on the results of this study, it is hypothesized that monitoring
 213 scrotal circumference, serum testosterone levels and body conformation traits is a
 214 useful tool for selecting superior breeding Boer goat sires at an early age.

215
 216 Table 2. **Correlation Coefficients (r) for Body Conformation, Testicular Traits and**
 217 **Serum Testosterone in Pubertal Male Boer Crosses**

	BCS	BL	BW	CG	HTW	HW	SC	SW
BL	-0.0819							
BW	0.1677	0.6715***						
CG	0.1739	0.4941***	0.8280***					
HTW	-0.1447	0.5914***	0.6631***	0.4979***				
HW	0.1290	0.3635***	0.4589***	0.3612***	0.3675***			
SC	0.0946	0.3026***	0.6117***	0.5262***	0.4111***	0.1721		
SW	0.0891	0.2771**	0.4994***	0.4671***	0.3897***	0.4539***	0.3291***	
TT	-0.1952*	0.1853*	0.1866*	0.1279	0.1124	-0.1299	0.1776	-0.0851

218 BL= Body Length, BW= Body Weight, CG= Chest Girth, HTW= Height at Withers,
 219 HW= Hip Width, SC= Scrotal Circumference, SW= Shoulder Width, TT =
 220 Testosterone Level

221 *= Significant if $P = .05$

222 ** = Significant if $P = .01$

223 *** = Significant if $P < .001$

224

The present finding of positive correlation for SC with testosterone in the pubertal bucks may indicate the importance of monitoring SC and/or serum testosterone levels in testicular development and the onset of puberty in male Boer goat crosses. Studies in other animal species [9, 13, 14, 15] have increasingly shown the role of testosterone in male reproductive functions. Further studies on the activity of testosterone receptors in the caprine testis around and after puberty are needed to better understand the functional role of testosterone.

4. CONCLUSION


1. There was an intricate relationship among testosterone concentrations, testicular volume, and various body conformation traits.
2. There were significant and positive correlations between body length; body weight and serum testosterone levels. However, low to moderate correlation was found between scrotal circumference and serum testosterone level in pubertal male Boer crosses.
3. Scrotal circumference was found to have a higher correlation with body weight than serum testosterone level in pubertal male Boer crosses.
4. The present results could assist the development and implementation of selection or culling criteria for breeding Boer goat sires at an early age.


ACKNOWLEDGEMENTS

Authors would like to thank Ms. Davi-Anne Phillip for editorial assistance. Also, Mr. Mel Jones and Mr. Danny Williams of the Caprine Unit, and George Washington Caver Agricultural Experimental Station, Tuskegee University, Tuskegee, AL for providing financial and technical support.

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