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

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Authors' contributions

This work was carried out in collaboration between all authors. Author CO designed the study, performed the statistical analysis, and wrote first and many drafts of the manuscript. Author OBT was actively involved protocol development, and manuscript revision following the various reviewer's comments and suggestions. Author LK carried out field experimentation and managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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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, Alabama. 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 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 levels (TT). Although, results show a non-significant relationship between TT levels and many body conformation traits, serum testosterone levels were lowly and positively correlated to BL (r = 0.19), BW (r = 0.19). Whereas, CG (r= 0.13), HTW (r= 0.11) and SC (r = 0.18) were non-significant. SC was moderately correlated to BL (r = 0.30; *P*= 0.001) and SW(r = 0.33; *P*< .001) and strongly correlated with BW (0.61), CG (r = 0.53), HTW (r = 0.41) respectively. In addition, SC and BW increased (P<.01) linearly from week 6 through 1. It is speculated that the week 9 peak of TT levels obtained in this study

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represents the attainment of sexual maturity (puberty) in Boer goat male crosses. Based on the results of this study, we hypothesized that SC measurements, when used in conjunction with TT 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 selection pressures placed on indigenous goats of the region by farmers [2]. Genetic progress in the meat goat industry requires the identification of superior meat goat sires. The most accurate way to test a sire's genetic worth is to perform breeding soundness evaluation (BSE) and also generate progeny from the animal [3]. BSE predicts the potential fertility of a buck. It is based on an examination that includes tests for physical soundness, scrotal circumference, semen quality, and in some cases, serum testosterone profiles, and libido/mating ability.

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

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

The relationship between body measurements and serum testosterone in 10-12 month old Dorper rams was reported by Fourie et al. [9]. Serum testosterone did not have a significant correlation with most of the body parameters measured [9]. However, serum testosterone concentration in rams was positively correlated to masculinity (muscle score), and scrotal circumference. Scrotal circumference was positively and significantly correlated with body weight, body length, chest dept, shoulder height, shoulder width, hindquarter width, canon bone length, masculinity wedge shape, selection index and age. Rams with a wedge shape scores between five and seven were significantly heavier than those with type scores between two and four. Collectively, Fourie et al. [9] 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 between all testicular measurements, semen volume and motility [10]. 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. MATERIALS AND METHODS

2.1 Animal Management

Twenty five pre-pubertal male Boer goat (Boer x Kiko) crosses (110.11± 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 (*fenbendezole*) 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 12/215 d of age).Body weight, (BW, kg) was recorded using a MTIAHS500 Sheep and Hog Scale System). Whereas body condition score (BCS) was scored on a subjective 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 (the vertical length from the thoracic vertebrae to the ground) was determined with the aid of a metric ruler.

2.3 Testicular Measurements

The scrotal circumference was determined in 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 from 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 4ºC for 10 minutes and aliquoted into separate vials which were kept frozen at -4ºC until testosterone assay.

2.5 Serum Testosterone Assay

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

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

2.6 Statistical Analysis

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

3. RESULTS AND DISCUSSION

The means and standard deviations for body conformation, testicular traits and serum testosterone levels (TT) are shown in Table 1.

Table 1. Body conformation, testicular traits, serum testosterone in pre-pubertal male boer goat crosses

Parameters	Week 0 (N= 25)	Week 3 (N=23)	Week 6 (N= 23)	Week 9 (N=23)	Week 12 (N= 23)
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 Wither (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)

**Means ± Standard Deviations*

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

The average SC at week 0 was (22.87±2.42cm), with a slight decline into week 3 (22.54±1.77cm). However, SC increased linearly from week 6 through week 12 (23.22±0.86cm, 24.53±1.43cm and 26.05±1.35cm), respectively. There was no significant difference for SC between weeks 0, 3, and 6; and week 6 and week 9 (*P*= .15), respectively. In addition, SC and BW increased correspondingly from week 6 through week 12 (23.22±0.86cm; 31.95 ±2.64kg) (24.53±1.43cm; 34.72±2.98kg) and (26.05±1.35cm; 37.46 ±3.44kg), respectively. The average TT level at week 0 or 131 d of age was 5.625±6.03ng/ml, with a slight increase into week 3 or 152 d of age (8.74±11.26ng/ml, *P =.09*). Also, there was a decline *(P=.11*) in TT level at week 6/173 d of age (7.48±8.25ng/ml), and week 9/194 d of age showed an all time high (27.85±14.42ng/ml), followed by a decline at week 12/215 d of age (10.74±14.40ng/ml). For weeks 0, 3, 6 and 12 there was no significant difference (*P*=.19) for TT levels. However, TT for week 9 was significantly different from week 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±0.172 ng/ml to 4.613±2.892ng/ml and 0.521± 0.311 to 3.417± 2.021ng/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]

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 correlation with most of the body conformation traits measured in this study. Whereas coefficients for: SW with TT and TT with CG were non-significant. 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 TT 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 animal evaluation for breeding soundness [19]. In the current study, SC was positively and significantly (*P< .001*) correlated to BL (r = 0.30), BW (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) in young Boer bucks. Ugwu (2009) reported a highly significant positive relationship between SC and testis weight of West African Dwarf bucks. Testis weight is known to be highly correlated (r = 0.93) with testicular sperm reserves [13] and males with larger testes tend to produce more sperm [21]. It follows that a good measurement of scrotal circumference would be a reliable predictor of sperm producing capacity.

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

Table 2. Correlation coefficients (r) for body conformation, testicular traits and 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

BL= Body Length, BW= Body Weight, CG= Chest Girth, HTW= Height at Wither,
HW= Hip Width, SC= Scrotal Circumference, SW= Shoulder Width, TT = Testosterone Level
**= Significant if P =.05*
***= Significant if P =.01*
****= Significant if P<.001*

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, scrotal circumference, 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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