Testicular and epididymal responses to growth variation in prepubertal male peranakan etawah goats

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Abstract. This study evaluated the effect of growth rate on the reproductive characteristics of prepubertal male Peranakan Etawah (PE) goats. Six goats aged 7–8 months were grouped based on body weight into high growth (n = 3) and low growth (n = 3) groups. The parameters observed included testicular and cauda epididymis dimensions, spermatozoa concentration, and morphology. High-growth goats showed greater testicular length ($P > 0.05$) and significantly wider testicles ($P < 0.05$) than low-growth goats. However, the relative testicular length to body weight ratio was lower in high-growth goats than in low-growth goats ($P < 0.05$), whereas the relative testicular width did not differ significantly ($P > 0.05$). No significant differences were observed in the cauda epididymis dimensions or their relative ratios to body weight ($P > 0.05$). Although not statistically significant, high-growth goats tended to have higher spermatozoa concentrations and lower total spermatozoa abnormalities. Head abnormalities were slightly higher in high-growth goats, whereas midpiece and tail abnormalities were lower than those in low growth goats. In conclusion, higher growth rates in prepubertal male PE goats are associated with increased testicular size but do not significantly improve spermatozoa quality at this stage of development.

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1 Introduction

Peranakan Etawah (PE) goats are an important genetic resource in Indonesia for meat and milk production. As a locally adapted breed, PE goats help meet the national livestock demand. Breeding success depends on reproductive performance, with testicular morphometry and semen quality being key fertility indicators [1]. Studies have shown an association between testicular size and reproductive traits [2, 3]. In small ruminants, Oyeyemi *et al.* [4] identified scrotal circumference as a breeding indicator in Sahelian bucks. However, most research has focused on postpubertal animals, whereas prepubertal testicular development remains poorly understood. Although body growth affects reproductive traits, studies have primarily used correlation analyses rather than comparing growth categories.

Phenotypic and genetic attributes are fundamental for evaluating reproductive performance in livestock, as they provide insights into heritable variations and underpin evidence-based breeding strategies. Numerous studies across diverse livestock breeds have demonstrated strong associations between quantitative phenotypic traits and reproductive performance [5], highlighting the value of integrated genetic and phenotypic assessments for identifying reliable reproductive indicators [6]. Nevertheless, existing research has predominantly emphasised external body measurements and overall reproductive outcomes, particularly in cattle, while comparatively little attention has been given to the developmental dynamics of the reproductive organs. Consequently, the patterns of testicular and epididymal development during the prepubertal stage in local goat breeds, including Peranakan Etawah goats, remain insufficiently characterised.

The prepubertal period is critical for establishing spermatogenesis. However, information on how prepubertal growth rates influence testicular biometry, cauda epididymis development, spermatozoa concentration and abnormalities in male Peranakan Etawah (PE) goats remains limited. This study evaluated the association between prepubertal growth rate, classified as high or low, and testicular and cauda epididymis dimensions, spermatozoa concentration, and epididymal spermatozoa abnormalities in PE goats. These findings provide a scientific basis for improving the selection criteria and management strategies for breeding bucks.

2 Material and methods

2.1 Animals

Male Peranakan Etawah (PE) goats aged 7–8 months with body weights of 18-38 kg were used. All animals were reared according to the Good Breeding Practice and Green Animal Fodders (BPTU-HPT), Pelaihari, Tanah Laut, South Kalimantan. The animals were slaughtered specifically for research purposes at the BPTU-HPT Pelaihari facility. Following slaughter, the carcass weights were recorded. The six goats were classified into high-(33.8±3.4 kg; n = 3) and low-growth (20.97±2.24 kg; n = 3) groups based on body weight. The parameters evaluated included testicular and cauda epididymis dimensions, sperm concentration, and morphology. This study was approved by the Animal Ethics Committee of IPB University (349 – 2025 IPB).

2.2 Growth performance and classification

The animals were classified into high- and low-growth groups based on the longitudinal growth records maintained at BPTU-HPT Pelaihari. The classification was determined by

analysing birth weight and sequential body weight measurements to calculate the Average Daily Growth (ADG) from birth until the age of 7–8 months. These parameters were used to ensure that the grouping reflected the actual growth performance of the bucklings. Comparative data on birth weight, final body weight, and ADG for each group are presented in Table 1.

2.3 Morphometry of testes and epididymides

The testes and epididymides were photographed post-mortem using a handheld digital camera. Digital morphometric analysis of the testes and epididymides was performed using ImageJ software (version 1.54 g; National Institutes of Health, Bethesda, MD, USA). Prior to measurement, the scale was calibrated using a known reference length, after which the testicular and epididymal length, width, and surface area were quantified.

2.4 Semen and spermatozoa evaluation

Sperm concentration was determined using samples collected from the cauda epididymis. The cauda epididymis was carefully dissected using a scalpel blade and scissors to release spermatozoa, followed by flushing with physiological NaCl solution to collect the liberated sperm. The resulting suspension was aspirated using an erythrocyte pipette, and spermatozoa were counted with a haemocytometer under a light microscope at 400× magnification to determine the sperm concentration [2]. The sperm concentration was calculated using the following formula:

Sperm concentration (cells/mL) = number of sperm counted × conversion factor × dilution factor …… (1)

Spermatozoa abnormalities were evaluated by examining diluted sperm samples on microscope slides stained with eosin–nigrosin and observed under high magnification (400× or 1000×) to identify morphological defects [3]. Abnormalities were classified according to the affected sperm region, including head, midpiece, and tail defects. Head abnormalities were identified by deviations in shape or size, such as oversized, undersized, or non-oval heads. Midpiece abnormalities included enlarged, interrupted, or asymmetrical midpieces, and tail abnormalities were characterised by hooked, shortened, or broken tails. The number of abnormal spermatozoa was recorded, and the percentage of abnormalities was calculated using the following formula:

Abnormality percentage = (number of abnormal spermatozoa/total spermatozoa counted) × 100 …… (2)

2.5 Data analysis

Statistical analyses were performed using the SPSS software (version 22.0; IBM Corp., Armonk, NY, USA). Differences between low- and high-growth prepubertal male goats were evaluated using an independent samples t-test. Statistical significance was set at $P < 0.05$, and all data are presented as mean ± standard deviation (SD).

3 Results

3.1 Growth performance and classification

Growth performance data (Table 1) showed no significant differences in birth weights among the groups ($P > 0.05$). However, the high-growth group had significantly higher final body weight ($P < 0.05$) and average daily growth ($P < 0.05$) than the low-growth group. These findings indicate that the divergence in growth trajectories occurred post-natally and was independent of initial birth weight.

Table 1. Growth parameters of Peranakan Etawah bucklings used for growth rate classification.

Parameters	High Growth (n=3)	Low Growth (n=3)	P-value
Birth weight (kg)	3.30±0.68	3.45±0.13	0.725
Final body weight (kg)	33.80±3.44[a]	20.97±2.24[b]	0.006
Average daily growth (kg/day)	0.16±0.02[a]	0.10±0.0[b]	0.007

Note: Different superscripts within a row indicate significant difference ($P < 0.05$).

3.2 Size of the testes

Figure 1a and b illustrate the macroscopic appearance of the testes in the high- and low-growth groups of PE goats. Visually, the testes of the high-growth group appeared slightly larger than those of the low-growth group. Quantitative analysis revealed that, although the testicular length was numerically greater in the high-growth group, this difference did not reach statistical significance (Figure 1c). In contrast, testicular width was significantly greater in the high-growth group than in the low-growth group ($P < 0.05$; Figure 1d). When adjusted for body weight, the relative testicular length was significantly lower in the high-growth group than in the low-growth group ($P < 0.05$; Figure 1e). However, no significant difference was observed in the relative testicular width between the two groups (Figure 1f).

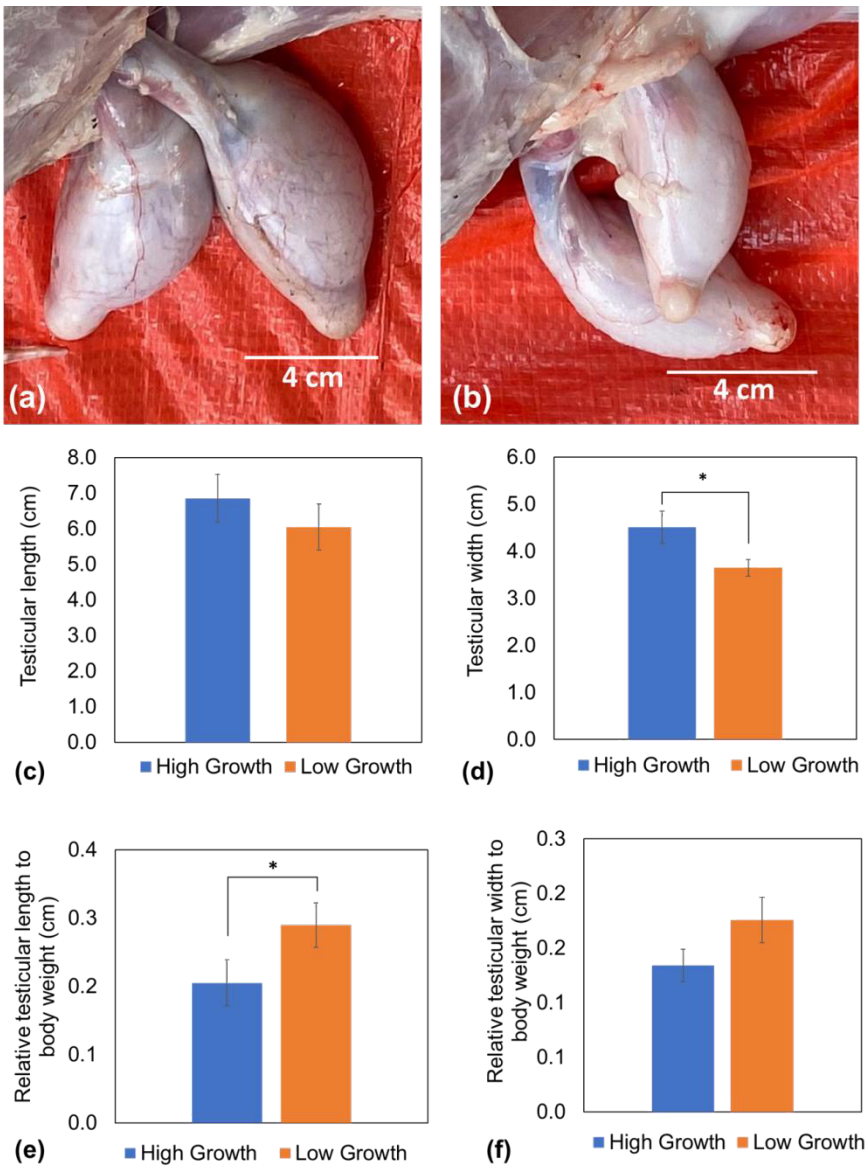

Fig. 1. Testicular organs dimensions in high- and low-growth groups of prepubertal male Peranakan Etawah goats (a): Testicular organ in high-growth groups, (b): Testicular organ in low-growth groups, (c): Testicular length, (d): Testicular width (e): Relative testicular length to body weight, and (f): Relative testicular width to body weight. Asterisks (*) above the error bars indicate statistically significant differences between groups ($P < 0.05$).

3.3 Size of the cauda epididymides

Figure 2 shows the dimensions of the cauda epididymis in the high- and low-growth groups of PE goats. Both cauda epididymis length and width tended to be greater in the high-growth group than in the low-growth group; however, these differences were not statistically significant ($P > 0.05$; Figure 2a,b). When normalised to body weight, the

relative length and width of the cauda epididymis were lower in the high-growth group than in the low-growth group, although these differences did not reach statistical significance (P > 0.05; Figure 2c, d).

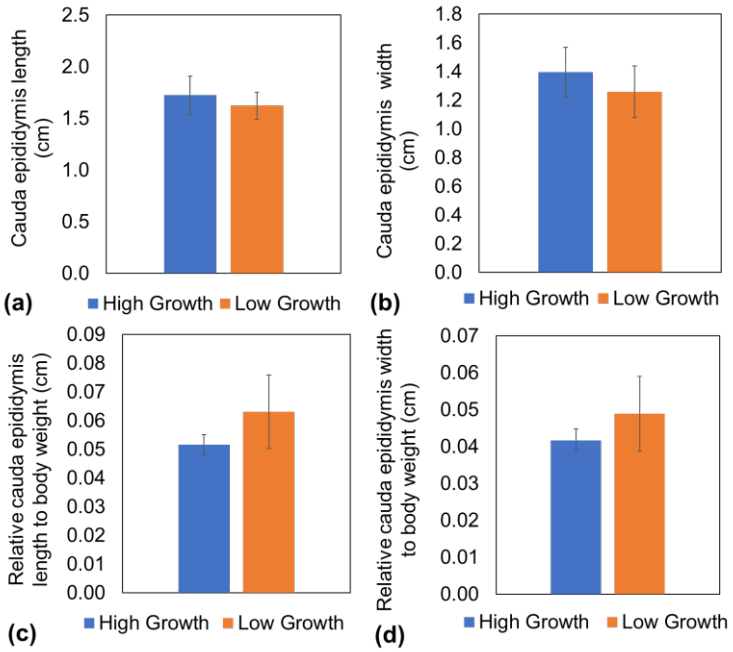

Fig. 2. Cauda epididymis dimensions in high- and low-growth groups of prepubertal male Peranakan Etawah goats. (a): Cauda epididymis length, (b): Cauda epididymis width, (c): Relative cauda epididymis length to body weight, and (d): Relative cauda epididymis width to body weight.

3.4 Spermatozoa concentration and abnormalities

The high-growth group exhibited a numerically higher spermatozoa concentration than the low-growth group; however, this difference was not statistically significant (P > 0.05; Figure 3a). Conversely, the percentage of total spermatozoa abnormalities was numerically higher in the low-growth group than in the high-growth group, although this difference was not statistically significant (P > 0.05; Figure 3b).

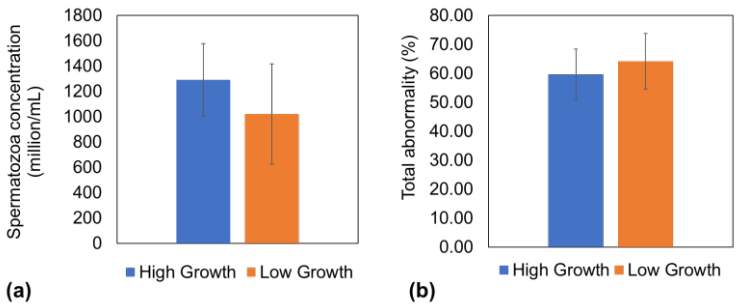

Fig. 3. Spermatozoa concentration and total abnormalities in high- and low-growth groups of prepubertal male Peranakan Etawah goats. (a): Spermatozoa concentration, (b): Total abnormality.

Figure 4 illustrates the distribution of spermatozoa abnormalities in the head, midpiece, and tail regions. The high-growth group exhibited a higher proportion of head abnormalities than the low-growth group (Figure 4a), including double-headed spermatozoa (Figure 4a1) and macrocephaly (Figure 4a2). In contrast, the proportions of midpiece and tail abnormalities were lower in the high-growth group than in the low-growth group (Figures 4b,c). However, none of these differences reached statistical significance ($P > 0.05$). The observed midpiece abnormalities included bent (Figure 4b1) and thickened midpieces (Figure 4b2), whereas tail abnormalities included coiled (Figure 4c1) and bent tails (Figure 4c2).

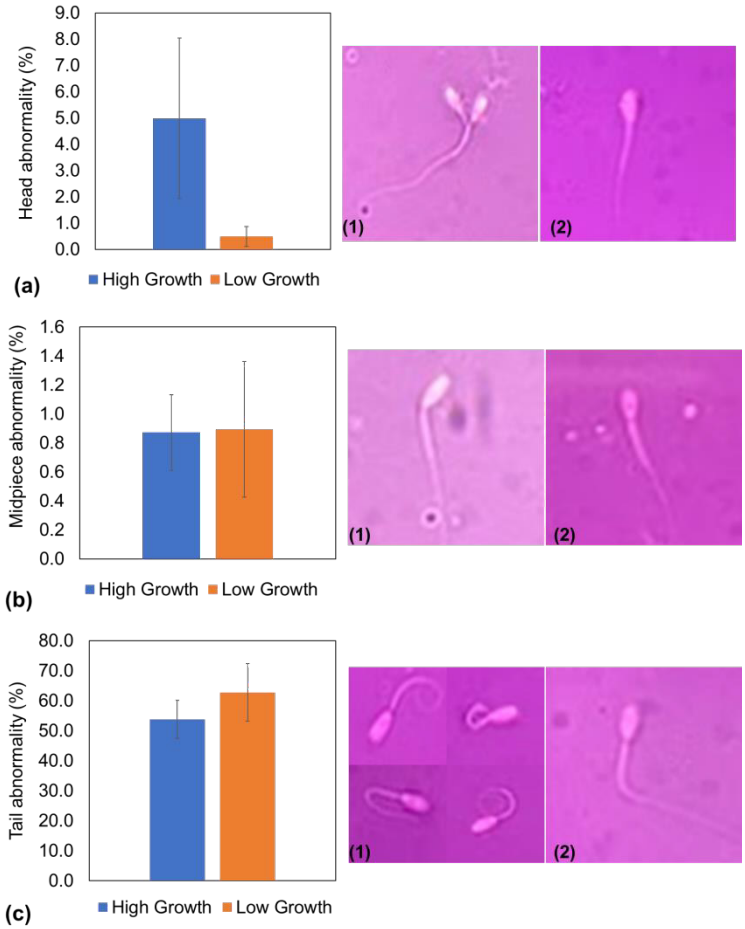

Fig. 4. Head, midpiece, and tail abnormalities in high- and low-growth groups of prepubertal male Peranakan Etawah goats. (a): Head abnormality, (a1): Double head, (a2): Macrocephaly (b): Midpiece abnormality, (b1): Bent midpiece, (b2): Thick midpiece, (c): Tail abnormality, (c1): Coiled tail,and (c2): Bent tail.

4 Discussion

In this study, we investigated the influence of growth variation on male reproductive parameters in prepubertal Peranakan Etawah goats, with particular emphasis on testicular and epididymal morphometry and sperm concentration and morphology. The findings provide an integrated overview of the relationship between somatic growth and

reproductive development, with detailed interpretations of each parameter presented in the subsequent sections.

4.1 Growth profiles and testicular morphometrical characteristics

Growth performance determines reproductive maturity, as organogenesis scales with body mass in developing small ruminant species. Postnatal growth in prepubertal bucklings is decisive in determining testicular dimensions. The emergence of growth divergence despite identical birth weights (Table 1) indicates that metabolic efficiency during the prepubertal phase dictates reproductive organ development. The high-growth phenotype provides a robust physiological framework for supporting testicular tissue expansion as animals approach maturity.

Testicular biometry offers insights into the reproductive development and fertility of male animals. In this study, although the testicular length was greater in the high-growth group, the difference was not statistically significant (Figure 1c), whereas the testicular width was significantly greater (Figure 1d). Testicular width is more closely linked to testicular volume and seminiferous tubule mass than to length, explaining its sensitivity to growth differences. Similar body weight and testicular biometry relationships have been reported in small ruminants [7]. When normalised to body weight, the relative testicular length was significantly lower in the high-growth group (Figure 1e), indicating disproportionate somatic growth relative to testicular development. This suggests that testicular growth does not scale linearly with body growth, and additional physiological regulators, including endocrine control of spermatogenesis, may affect relative testis size [8]. In contrast, the relative testicular width did not differ between the groups (Figure 1f), indicating a stable relationship with body weight. As all animals were of similar age and under identical nutrition, growth differences likely stemmed from genetic factors. Studies have shown that genetic selection for growth traits does not necessarily compromise reproductive performance, as growth and fertility may be regulated by partially independent genetic pathways [9].

4.2 Cauda epididymis biometry

The epididymis plays a pivotal role in sperm maturation and storage. In the present study, although the high-growth group exhibited numerically larger cauda epididymal dimensions, these differences were not statistically significant (Figure 2a and b). This finding indicates that enhanced somatic growth and increased testicular width did not result in a proportional expansion of the epididymal sperm storage compartments. Given that the cauda epididymis serves as the primary reservoir for mature spermatozoa [4], the comparable epididymal dimensions observed between groups may partially account for the similar sperm outputs. Collectively, these results suggest that epididymal development may be regulated, at least in part, independently of the overall body growth. This regulation is consistent with previous evidence indicating that reproductive organ size is governed by complex genetic and cellular mechanisms involving the coordinated processes of cell proliferation, growth regulation, and endocrine feedback [10].

4.3 Spermatozoa concentration and abnormalities

Spermatozoa quantity and quality reflect the integrated functions of the testis, epididymis, and endocrine system. In the present study, although the spermatozoa concentration tended to be higher in the high-growth group, this difference did not reach statistical significance (Figure 3a), indicating that increased testicular size alone is insufficient to ensure greater

spermatozoa output. Spermatozoa concentration is regulated not only by spermatogenic activity within the testes but also by epididymal storage capacity, hormonal balance, and efficiency of spermatozoa maturation [11]. Furthermore, neither the total spermatozoa abnormalities nor the region-specific defects involving the head, midpiece, or tail differed significantly among the growth groups (Figure 3b). Although the high-growth group exhibited a slightly higher proportion of head abnormalities and lower proportion of midpiece and tail abnormalities (Figure 4), these patterns did not indicate a consistent or biologically meaningful effect of growth status on spermatozoa morphology. Head abnormalities are generally associated with disruptions during spermatogenesis, whereas midpiece and tail defects are more closely linked to post-testicular maturation and motility [12]. Beyond intrinsic spermatozoa defects, spermatozoa movement and functional competence may also be influenced by external factors, including interactions with biomaterials in the female reproductive tract [13, 14]. Following ejaculation, spermatozoa fertility is further modulated by various physiological and molecular factors within the female reproductive environment. Local microenvironmental conditions and interactions with reproductive tract fluids and epithelium regulate spermatozoa survival and function, whereas hormonal and molecular mechanisms govern spermatozoa transport and capacitation [15]. Collectively, the comparable cauda epididymal dimensions and spermatozoa abnormality profiles observed in this study suggest that both spermatogenic and post-testicular maturation processes were maintained at similar functional efficiencies in both growth groups.

5 Conclusion

Variation in prepubertal growth among Peranakan Etawah bucklings was associated with testicular development, particularly testicular width, but not with epididymal size, spermatozoa concentration, or spermatozoa morphology. While an association exists between growth rate and testicular development during the prepubertal phase, epididymal and sperm parameters do not appear to vary by growth category. Future studies should examine how growth rate relates to testicular development and whether early-life interventions can improve spermatogenic capacities.

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