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Ovarian follicular development during post-natal growth in the West African Dwarf goat (*Capra hircus*)

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Abstract

Mammalian ovarian follicular development is known to start in-utero during the embryonic stage, and females are born with all the follicles needed in adult life. This study investigated the morphological changes in the ovaries of West African Dwarf (WAD) goats during post-natal growth. Forty five female WAD goats of specific ages were purposively acquired and used for the study. Five goats each of the following specific ages were acquired: one day old (acquired at birth), 2, 4, 8, 12, 16, 20, 24 and 28 weeks of age. The goats were weighed, humanely euthanized and their ovaries dissected out. The ovaries were grossly observed, and their length, width, thickness and weight were measured. Sections of the ovaries were processed for microscopic examination. Results of the investigation showed that grossly, the ovaries at birth were oblong in shape, smooth and flabby. Macroscopic ovarian follicles were first observed at 4 weeks of age. Ovaries of the 8 week old goats were well enlarged with numerous macroscopically visible follicles. Goats of 12 – 28 weeks of age had ovaries that were similar and smaller than that of the 8 week old goats, but had fewer and larger macroscopically visible follicles. The lengths, weights, thicknesses and widths of the ovaries increased significantly ($p < 0.05$) with age. Histologically, the ovaries consisted of medullary cores of blood vessels and loose connective tissue and a peripheral cortex, containing numerous ovarian follicles at different stages of development in all the age groups. The ovaries at birth contained antral follicles that were smaller. However, large antral follicles with the attributes of completing meiosis I and ovulating were observed as from 12 weeks of age. Corpus albicans were observed as from 16 weeks of age. These findings suggest that the WAD goat probably attains puberty earlier than reported in literature.

Keywords: Ovary; Ovarian follicles; West African Dwarf goats; Post-natal development; Female.

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Introduction

In the genetic female embryo with an XX chromosome complement, the absence of the Y chromosome directs the differentiation of the primordial gonad into an ovary and its associated germ cell cysts (Chassot *et al*., 2008; Jimenez, 2009). Formation, development and differentiation of germ cells, ovary and reproductive tract are coordinated by interactions of numerous proteins and small RNAs (Adhikari and Liu, 2009). Within the developing ovaries of domestic animals, germ cell proliferation and follicular development takes place at the cortex made up of a dense connective tissue containing the majority of the ovarian germ cells. In the central part of the ovary which is less dense, germ cells degenerate and are replaced by a vascular stroma forming the medulla. It has been reported that the primordial follicles are the first small follicles to appear in the mammalian ovaries, and that the initiation of ovarian follicular growth begins soon after primordial follicles first form either during foetal development as occurs in humans and domestic animals or around the time of birth as in rodents (McNatty *et al*., 2001; Sawyer *et al*., 2002; Mehashwari and Fowler, 2008; Nwaogu and Okolie, 2008; McNatty *et al*., 2010; Carvalho *et al*., 2012).

During both pre-natal and post-natal lives, mammalian ovaries undergo a variable amount of caudal descent depending on species, finally occupying a position within the pelvic inlet (McGeady *et al*., 2006; Kumar, 2015; Abiaezute *et al*., 2017). Earlier reports have shown that at birth, each ovary contains numerous primordial follicles, consisting of an oocyte surrounded by a single layer of squamous epithelial cells, with no theca cells, and that the number of primordial follicles present at birth represents the total population of germ cells available to mammalian females during their entire reproductive life (Kezele *et al*., 2002; Findlay *et al*., 2009; Byskov *et al*., 2011). These primordial follicles serve as the source of developing follicles and oocytes that decline with age (Eppig, 2001).

Goats are the most abundant ruminant in Nigeria, with an estimated population of 84 million (Kamer, 2023). Their worldwide population is estimated to be approximately one billion (Utaaker *et al*., 2021). Goats are valued mainly for their meat, milk, fibre and skin, and more people are now becoming aware of its meat, milk and economic potentials (Devendra and Solaiman, 2010). The relevance of goats is greatest in developing countries where they meet socioeconomic, cultural, and recreational needs (Devendra, 1989). The West African Dwarf (WAD) goats are found predominantly in the coastal areas of Nigeria, and are believed to be trypano- and haemoncho-tolerant as they thrive in tsetse and haemonchus worm infested areas (Cheijina *et al*., 2015). The WAD goats are very important in the rural economy as they are typically kept by families for milk, meat or sold for quick cash during needs. They are prolific breeders with multiple births being common, as twins are normal and triplets frequent (Otaru, 2002; Oni, 2002).

There are varying reports of ovarian growth and primary, secondary and tertiary (pre-antral and antral) follicular development with or without macroscopically visible follicles within the cortices of newly born domestic animals (McNatty *et al*., 1987; Hopper *et al*., 1993; Kalita *et al*., 2000; 2001; Bukar *et al*., 2006). There are also a large body of knowledge on the pre- and post-natal development of the reproductive organs of domestic mammals (McNatty *et al*., 1995; Evans, 2003; Bukar *et al*., 2006; Abiaezute *et al*., 2018; 2021). However, there is paucity of information in available literature on the morphological development of the ovary and follicular development of the goat, as most descriptions are usually based on the assumption of similarities between the goat and other ruminants (Evans, 2003; Aerts and

Bols, 2010; Silva *et al*., 2016; Komatsu and Masubuchi, 2017). This present study therefore investigated and described the morphological changes that occur during the postnatal development of the ovaries of the West African Dwarf (WAD) goat.

Materials and Methods

Forty-five female WAD goats of specific ages (five each of one day old goats, and goats of 2, 4, 8, 12, 16, 20, 24 and 28 weeks of age) obtained from traditional WAD goat breeders in Nsukka Local Government Area of Enugu state, Nigeria were used in this study. The ages of the goats were purposively chosen. The protocol for the use and care of the goats used for the research was approved by the Institutional Animal Care and Use Committee of the Faculty of Veterinary Medicine University of Nigeria Nsukka

After acquisition, the goats were weighed and euthanized by intravenous injection of 70 mg/kg body weight of sodium pentobarbitone (Kyron Laboratories Ltd., Johannesburg, South Africa) (Abiaezute and Nwaogu, 2015). The ovaries were then dissected out and trimmed of extraneous tissues. Using a ruler and vernier calliper, the length, weight, width and thickness of each ovary was measured as described by Al-Baggal *et al*. (1993). Segments of each ovary was cut and fixed by immersion in Bouin's fluid for 24 hours, then dehydrated in increasing concentrations of ethanol, cleared thrice in xylene and embedded in liquid paraffin wax. Five micrometre thick serial sections were obtained using a rotary microtome (Leitz®, Wetzlar, Germany), mounted on clean glass slides, and stained with hematoxylin and eosin for histological study as described by Suvarna *et al*. (2018), and then studied under the light microscope.

Microscopically, the ovarian follicles in each ovary within each group were identified and classified according to the classification methods of Oxender et al., (1979), Gougeon and Chainy (1987) and Lundy *et al*., (1999) into types 1, 1A, 2, 3, 4 and 5, as follows: Type 1 – Primordial follicles with one layer of flattened granulosa cells surrounding the oocyte; Type 1A – Transitory follicles surrounded by one layer of mixture of flattened and cuboidal granulosa cells; Type 2 – Primary follicles with one to two layers of cuboidal granulosa cells surrounding the oocyte; Type 3 – Small pre-antral follicles with two to four complete layers of cuboidal cells; Type 4 – Large pre-antral follicles surrounded by four or more cuboidal granulosa cells; and Type 5 – Large follicles with antrum and surrounded by more than five cuboidal granulosa cells. The diameters of these follicles with visible oocyte nuclei were measured using the ocular micrometre gauge after it was calibrated with the stage micrometre gauge at 100 × magnification as described by Griffin *et al*. (2006). Images were captured using Moticam Camera 1000 (Motic China group Ltd., Xiemen, China).

Data generated were analyzed by one way analysis of variance (ANOVA), with SPSS version 15 software. Variant means were separated by Duncan multiple range test. Significance was accepted at probability level of $p < 0.05$. Summary of the results were presented as means with standard errors.

Results

The paired ovaries of the female WAD goats at birth were located ventrally, one on either side of the vertebral column just caudal to the kidneys, attached to the surroundings and the reproductive tract by the thin transparent meso-ovarian ligament. Ovaries of WAD goat kids from birth to week 2 of age were creamy in colour, oblong in shape, flabby and soft to touch with smooth surfaces (Figure 1A). At week four of age, one or two macroscopically visible follicles were observed on the surfaces of the ovaries. At week 8 of age, the ovaries were enlarged and ovoid, exhibiting numerous

macroscopically visible ovarian follicles bulging on the surfaces (Figure 1B). At week 12 of age, the ovaries showed few but larger macroscopically visible follicles and the ovaries had migrated caudally and are now located in the pelvic inlet in a caudo-lateral orientation. The ovaries from week 16 to week 28 of age appeared similar to the ovaries of the 12 week old goats, with large macroscopically visible follicles (Figure 1C).

The lengths of the left and right ovaries of the goats increased significantly ($p < 0.05$) from 0.48 cm and 0.49 cm, respectively in the one day old goats to 1.23 cm and 1.24 cm, respectively in the 28 week old goats (Figure 2). The widths of the left and right ovaries of the goats also significantly ($p < 0.05$) increased from 0.22 cm and 0.24 cm, respectively in the one day old goats, to 0.73 cm in both the left and right ovaries of the 28 week old goats (Figure 3). The thickness of the ovaries increased significantly ($p < 0.05$) from 0.12 cm in both the left and right ovaries of the one day old goats, to 0.64 cm and 0.62 cm, respectively in left and right ovaries of the 28 week old goats (Figure 4). The weights of both left and right ovaries also significantly ($p < 0.05$) increased from 0.02 g in the one day old goats to 0.46 g and 0.45 g in the left and right ovaries of the 28 week old goats, respectively (Figure 5). The ovarian weight percentage of the body weight increased significantly ($p < 0.05$) from a mean of 0.002% at birth (one day old) and peaked to 0.008% at week 8 of age, before significantly declining ($p < 0.05$) to 0.004% at week 28 of age (Figure 6).

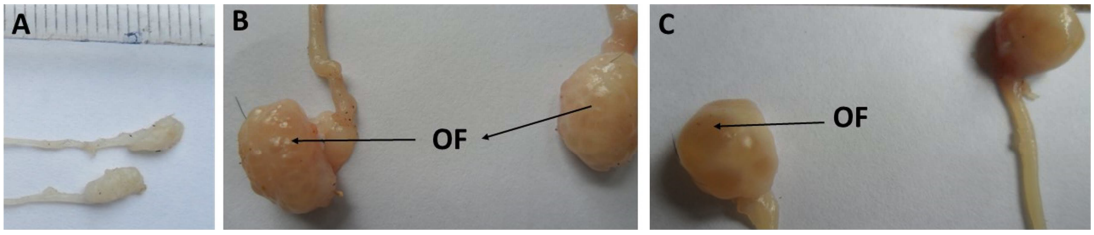

Figure 1. Gross photographs of ovaries of West African Dwarf goats at birth (A), at 8 weeks of age (B), and at 24 weeks of age (C). Note the numerous ovarian follicles (OF) on the surfaces of the ovaries at 8 weeks of age (B), and the fewer and larger ovarian follicles (OF) at 24 weeks of age (C).

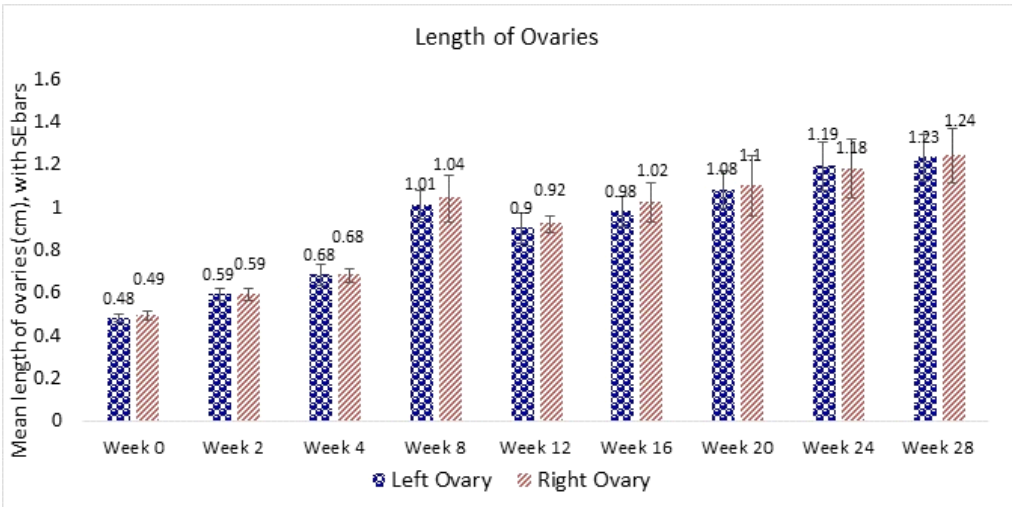

Figure 2. The mean length of ovaries of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

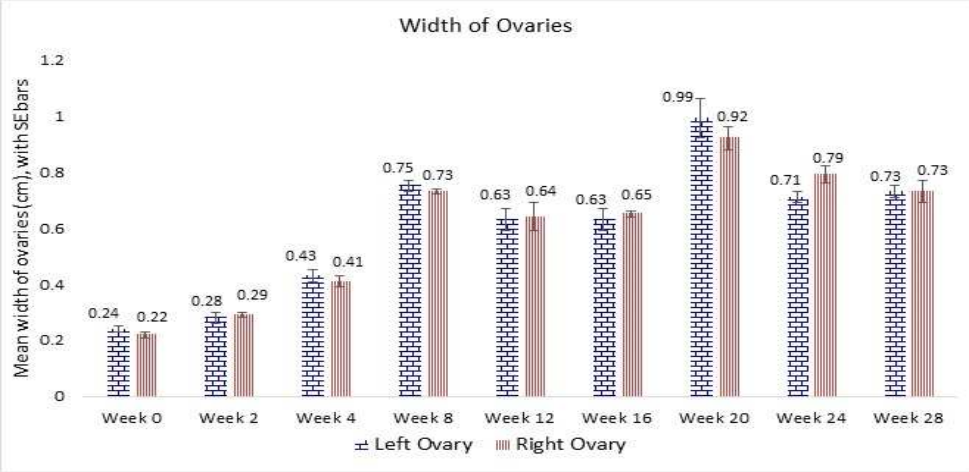

Figure 3. The mean width of ovaries of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

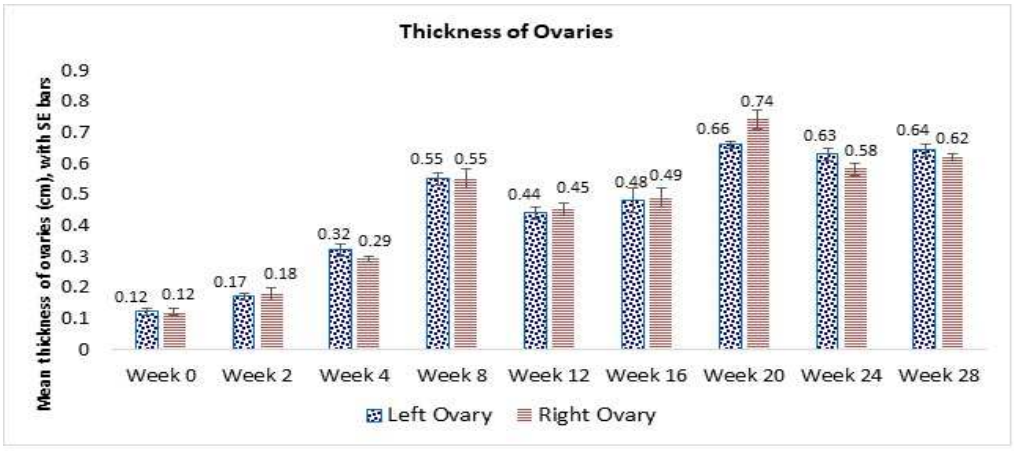

Figure 4. The mean thickness of ovaries of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

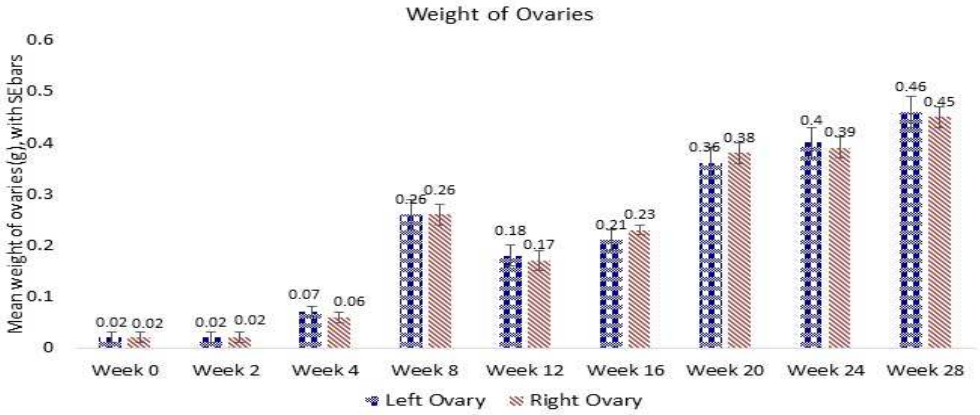

Figure 5. The mean weight of ovaries of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

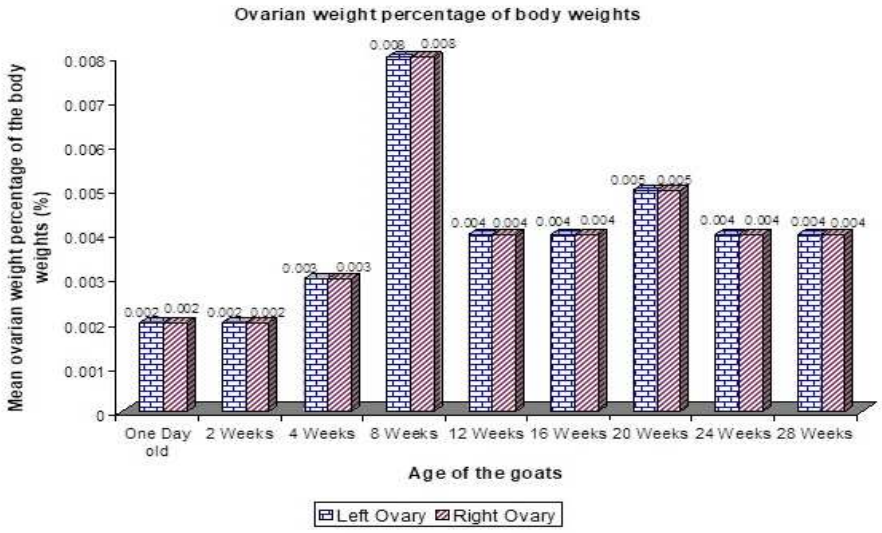

Figure 6. The mean ovarian weight percentage of of body weight of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

Histologically, the ovaries of the goats at all ages were composed of an outer peripheral cortex and an inner medulla. A simple squamous to cuboidal epithelium covered the surface of the ovary. The tunica albuginea, a thick fibrous connective tissue lied immediately beneath the surface epithelium. The cortices were very cellular consisting mostly of spindle shaped cells in which ovarian follicles at varying stages of development were enclosed. From birth (one day old) to week 2 of age, numerous Type 1 or primordial ovarian follicles were observed close to the periphery, underneath the tunica albuginea of the cortex (Figure 7). Numerous Types 1A and 2 ovarian follicles were also observed within the follicular zone. The number of follicles decreased with increase in the size of the follicle, as there appeared to be much fewer Types 3, 4 and 5 ovarian follicles which were however, larger in size. The Type 5 antral follicles in the ovaries of the one day old and 2 week old goats were small in size measuring 302.30 ± 14.02 µm and 319.21 ± 14.34 µm in diameter, respectively (Table 1). Also present were numerous corpus atreticum with the lining cells showing some level of hypertrophy and, which were arranged in cords (Figure 8). At week 4 of age, the ovaries had larger Type 5 antral follicles of mean diameter of 1079.22 ± 304.96 µm in the ovarian cortices (Table 1). In the ovaries of 8 week old goats, numerous similar sized large Type 5 antral follicles were observed within the cortex and other types of follicles were observed pushed to the periphery of the cortex just beneath the tunica albuginea (Figure 9). The ovaries of the 12 week old goats showed a sharp observable decrease in the number of Type 5 antral follicles compared to the ovaries of the 8 week old goats, with only a few antral follicles (Figure 10A). The ovaries of goats between weeks 16 – 28 of age were very similar to that of the 12 week old goats (Figures 10B), although the white body (corpus albicans) was first observed in the ovaries of the 16 week old goats (Fig 10B). The mean diameters of Types 1, 1A, and 2 ovarian follicles for all groups studied showed no significant differences ($p > 0.05$) across the age groups while the mean diameters of Types 3, 4 and 5 follicles significantly ($p < 0.05$) increased as the ages increased (Table 1). The medulla of the ovaries of WAD goats at birth (one day old) were centrally located and consisted of a loose connective tissue framework. Within the

medulla were spaces or channels, rete ovarii, without any observable epithelium. There were also thin-walled blood vessels and at the base of the hilus was a mass of distinctly dark staining epithelioid cells, hilus cells. The medulla of the ovaries of the 2 and 4 week old goats were similar to the ovaries of the one day old goats and the rete ovarii had simple squamous epithelium. The medulla of the ovaries of the 8 week old goats appeared small as it was under compression by the numerous developing Type 5 antral follicles within the cortex. The medullae of the ovaries of the 12 to 28 week old goats were similar to the medulla of the ovaries of the 4 weeks old goats, with the presence of the rete ovarii, epitheloid hilus cells and blood vessels.

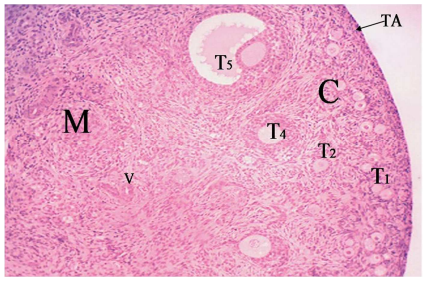

Figure 7. Photomicrograph of ovaries of West African Dwarf goats at birth showing the tunica albuginia (TA) covering the ovarian cortex (C) containing T1, T2, T3, T4 and T5 follicles at different stages of development. Within the medulla (M) are blood vessels (V). H & E; × 100.

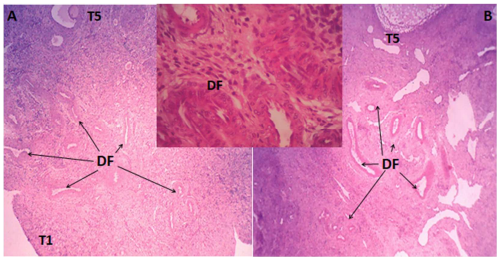

Figure 8. Photomicrograph of ovaries of West African Dwarf goats at birth (A) and at 4 weeks of age (B), showing Types 1 (T1) and 5 (T5) ovarian follicles, rete ovarii (OV) in the medulla. Note the numerous corpus atreticum (DF) H & E; × 100. Inset: Higher magnification of the hypertrophied cells of the corpus atreticum (DF). H & E × 400.

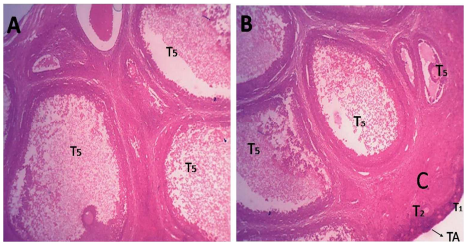

Figure 9. Photomicrograph of ovaries of West African Dwarf goats at 8 weeks of age, showing the numerous similar sized Types 5 (T5) ovarian follicles that filled the ovaries. There are also Types 1 (T1) and 2 (T2) ovarian follicles in the cortex (C) covered by the tunica albuginea (TA). H & E; × 100.

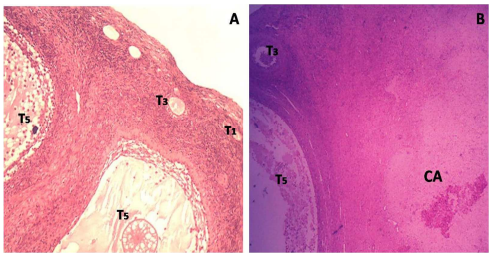

Figure 10. Photomicrograph of ovaries of West African Dwarf goats at 12 weeks of age (A) and 16 weeks of age (B), showing Types 1 (T1), 3 (T3) and 5 (T5) follicles. Note the corpus albicans (CA) in the week 16 ovary (B). H & E × 100.

Discussion and Conclusion

Grossly, follicles were observed in the female ovaries for the first time at week 4 of age in this study, which was similar to reports of macroscopically visible follicles on the surfaces of the ovaries of ruminants few weeks after birth by some authors (Desjardins and Hafs, 1969; Bukar *et al*., 2006), but at variance with the reports of others (Erickson, 1966; Kennedy *et al*., 1974; Mc Natty *et al*., 1987; Hopper *et al*., 1993). Macroscopically visible follicles at week 4 of age probably indicated the first initial response of the ovary to the neonates maturing gonadotrophins, leading to initiation and increased vesicular follicular growth which accounted for subsequent significant increases observed in weight, length and thickness of the ovaries with age. This pattern of ovarian

growth in WAD goat had also been reported in heifers (Desjardin and Hafs, 1969) and lambs (Kennedy *et al*., 1974), who opined that the increase in ovarian weight with age was due to increased number of vesicular follicles. The ovarian weight percentage of the body weight which peaked at week 8 before declining suggests that the ovaries attained their maximal size and weight at this age, which was probably due to the numerous numbers of growing follicles becoming responsive to the stimulation by gonadotrophins and attaining vesicular sizes at the same time.

Table 1. The mean diameter of the ovarian follicles of West African Dwarf goats from Day 1 (birth) to week 28 of post-natal life.

Age of the Goats	Mean diameter (µm) of the ovarian follicles, with standard error in bracket					
	Primordial (Type 1)	Transitional (Type 1A)	Primary (Type 2)	Small Pre-antral (Type 3)	Large Pre-antral (Type 4)	Antral (Type 5)
One day old	29.60 [a] (1.29)	38.51 [a] (1.68)	57.08[a] (4.23)	83.50[a] (3.51)	234.65[a] (10.25)	302.30[a] (14.02)
2 Weeks old	29.43 [a] (1.59)	40.17[a] (1.29)	57.25[a] (3.92)	85.62[a] (3.88)	237.83[a] (9.45)	319.21[a] (14.34)
4 Weeks old	30.11 [a] (2.78)	40.37[a] (2.17)	56.54[a] (4.87)	82.45[a] (5.18)	243.11[a] (10.17)	1079.22[ab] (304.96)
8 Weeks old	28.75 [a] (1.99)	40.64[a] (3.06)	58.54[a] (4.47)	121.56[b] (5.29)	341.41[b] (9.09)	1645.01 [bc] (105.82)
12 Weeks old	30.04 [a] (3.32)	40.26[a] (2.10)	58.91[a] (5.03)	123.67[b] (5.44)	348.82[b] (11.70)	2650.00 [cd] (699.78)
16 Weeks old	28.35 [a] (2.08)	40.11[a] (3.16)	56.31[a] (4.48)	120.51[b] (7.17)	359.38[b] (8.36)	3252.51[d] (391.04)
20 Weeks old	29.52 [a] (2.18)	40.71[a] (2.76)	55.74[a] (5.68)	124.73[b] (4.29)	350.92[b] (12.24)	2380.03[cd] (377.03)
24 Weeks old	29.57 [a] (2.43)	39.86[a] (2.67)	53.91[a] (3.50)	127.89[b] (5.64)	345.64[b] (10.52)	2582.52[cd] (537.84)
28 Weeks old	29.77 [a] (2.27)	39.85[a] (3.27)	53.03 (5.10) [a]	130.67 (6.74) [b]	356.21 (12.02) [b]	2925.50[d] (454.67)

[a, b, c, d] Different superscripts in a column indicate significant difference ($p < 0.05$) between the means across the age groups

Histologically, the post-natal development of the ovaries of WAD goat in this study was similar to that of other ruminants with regards to the observations on the Types 1, 1A, 2, 3, 4 and 5 ovarian follicles at birth (one day of age) [Erickson, 1966; Kennedy *et al*., 1974; McNatty *et al*., 1987; Hopper et al., 1993; Cui and Yu, 1999; Bukar *et al*., 2006]. This observation suggests the occurrence of pre-natal folliculogenesis in WAD goats which has been confirmed by reports in other ruminants (Russe, 1983; Jantosovicova *et al*., 1996; Nwaogu and Okolie, 2008; McNatty *et al*., 2010; Carvalho *et al*., 2012). Pre-natal folliculogenesis is thought to be due to exposure of foetal ovaries to high level of maternal gonadotrophins which may be essential for normal foetal reproductive development, and thus plays an important role in programming the foetus for reproductive capacity in adult life (Mellin *et al*., 1966; Brooks *et al*., 1995). However, several hormones and intra-ovarian factors with a developed and functional endocrine feedback system have equally been demonstrated to contribute to the development of the ovaries of mammalian foetuses (Challis and Brooks, 1989; Adashi, 1996; Lun *et al*., 1998; Siler-Khodr, 1998; Tisdall *et al*., 1999; Quirke *et al*., 2001; Wang and Roy, 2004; Smith *et al*., 2014). Likewise, it is thought that the combination of foetal and maternal hormones and intra-ovarian factors may be responsible for foetal folliculogenesis recorded in WAD goats in this study.

Although, most of the large tertiary and antral follicles reportedly observed pre-natally in the ewe were reported to undergo atresia just before birth (Jantosovicova *et al*., 1996), the result of this study suggest that most of the large tertiary and antral pre-natal follicles just before birth did not degenerate but continued to grow post-natally, as equally reported in female Sahel goat kids at birth (Bukar *et al*., 2006). This could be due to species differences, the tropical climate, environmental or nutritional factors.

The number of primordial follicles recorded in this study were numerous at birth (one day of age) and fewer at week 28 of age, indicating a steady decline as the animal aged, implying a steady depletion of the follicles. This suggests that new primordial follicles were not being formed as the goats aged. There had been earlier reports that the number of ovarian follicular reserve in mammals was established during foetal life and that they served as the only source of developing follicles that declined with age (De Pol *et al*., 1997; Gosden *et al*., 1997; Eppig, 2001; Kezele *et al*., 2002; Byskov *et al*., 2011). However, in contrast, few earlier reports had suggested neo-genesis and existence of post-natal germ-line stem cell (Johnson *et al*., 2004; De Felici, 2010; White *et al*., 2012).

The follicles observed in the ovaries of WAD goats in this study, from one day old to 28 weeks of age were either quiescent (primordial) or growing (pre-antral or antral) follicles. However, majority of the follicles existed as primordial or Type 1 follicles. The lack of statistically significant differences in the diameters of the types 1, 1A and 2 across all age groups indicate a similar growth phase under the influence of intra ovarian factors. The significant differences in diameters observed in the Types 3, 4 and 5 follicles from the one day old to the 28 weeks of age goats suggests initiation of rapid growth phase from the Type 3 follicles, leading to the antral stage. Different growth phases suggest influences by different growth factors. These observations agree with earlier reports that the pre-antral phase of folliculogenesis is independent of the influence of gonadotrophins, but are regulated by locally produced intra-ovarian growth factors while the antral phase is regulated by gonadotrophins (McGee and Hsueh, 2000; Orisaka et al., 2009; Ciftci, 2014). Thus, it is probable that the transition from the small pre-antral (Type 3) to large pre-antral (Type 4)

follicles in this study was the gonadotrophin responsive stage when the follicles began to respond to gonadotrophins. The presence of antral follicles in the ovaries of the one day old and 2 week old goats suggest that folliculogenesis was initiated by local intra-ovarian factors but could not be completed as shown by the small size of the antral (Type 5) follicles. It is thought that this may be due to hormonal insufficiency in the female goat kids at these ages. Oliver *et al*. (1998) clarified that primordial follicles can develop to the pre-antral follicles in the absence of follicle stimulating hormone (FSH), but development of pre-antral follicles to antral follicles are dependent on FSH for survival and in its absence degenerates. They further reported that follicular degeneration during the pre-pubertal period was due to the presence of threshold levels of FSH that are able to initiate antral development but insufficient enough to support follicular growth to term. Thus, it may be inferred in this study that the pre-pubertal WAD goats may have produced enough FSH which are necessary to stimulate antral follicular development but the quantity produced was insufficient to complete the necessary development required at the antral stage and subsequently the follicles underwent atresia.

The present study demonstrated that the Type 5 antral follicles attained their maximum diameter size of 3.2 mm (3252.2 ± 391µm) by week 16. This pattern of increase in size of antral follicles from birth to 6 months was reported by Kalita *et al*., (2000 and 2001) in Assam goats. Although, varying sizes of follicles at ovulation had been reported in small ruminants ranging from 4 – 7 mm in diameter (Bartlewski *et al*., 1999; Campbell *et al*., 2003; Mohammadi *et al*., 2010), other reports have shown that 86% of goat oocytes with follicles larger than 2.0 mm are destined to progress to metaphase II (De Smedt *et al*., 1992). Crozet *et al*. (1993) however reported that only a small proportion of them have the capability to support embryonic development. Earlier reports have it that, generally, for oocytes to resume meiosis, which is initiated by a pre-ovulatory surge of luteinizing hormone (LH), their size must exceed 80% of their final diameter (Miyano and Hiroa, 2003; Rahman *et al*., 2008). This suggests that the WAD goat ovarian follicular size at week 12 of age (2650.00 ± 699.78) may be matured enough for the oocytes to resume meiosis, ovulate and probably support embryonic development. Furthermore, the presence of corpus albicans in the ovary of the goats at week 16 of age suggests that the first ovulation in the WAD goat may have occurred earlier than this age. Corpus albicans are remnants of ovulated Graffian follicles usually seen about two weeks after ovulation and which appear as white bodies in the ovarian cortex (Mescher, 2010). These histologic features are correlated with published changes in neuroendocrine profiles of rats as the hypothalamic-pituitary-gonadal axis matures (Picut, *et al*., 2015). This finding suggests that the WAD goats used for the study probably attained puberty earlier than reported (5 – 7 months) by Akusu *et al*., (1986). More so, reports indicated early attainment of puberty (3 – 6 months) in the Pakistani Dwarf goat, a similar type of goat, based on hormonal profile (Khanum *et al*., 2000).

Based on the results of the study, it was concluded that the WAD goat probably attains puberty earlier (3 – 5 months). However, it should be noted that puberty in mammalian females precedes the development of physical maturity, and that although they become capable of reproducing, their efficiency particularly with respect to their fecundity has not reached its maximum and thus the females are not fully competent at this stage. More also, first ovulation may not necessarily coincide with first oestrus.

Conflict of interest

The authors declare that there are no conflicts of interest regarding this study.

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