Original Research Article

Effects of Bilateral Ovariectomy (OVX) on Thermoregulation and Blood Constituents in Adult Nubian Goats (*Capra hircus*)

ABSTRACT

Aims: This study was designed to investigate the effects of bilateral surgical ovariectomy on thermoregulation and blood constituents in adult Nubian goats.

Materials and Methods: Twenty female goats were randomly assigned into 2 groups, group A served as control and group B was subjected to bilateral ovariectomy (OVX) by standard surgical method and monitored for 4 weeks. The effect of OVX on rectal temperature (T_r), respiratory rate (RR), heart rate (HR), body weight (BW) and blood components were investigated. The data were analyzed using an independent sample T-test.

Results: In OVX group, both T_r and RR decreased during the experimental period. T_r decreased ($p<0.05$) at week 4 and (HR) ($p<0.01$) increased at week 2 in OVX group. The packed cell volume (PCV), red blood cell count (RBCs) and haemoglobin concentration (Hb) declined ($p<0.05$) in OVX group at week 1. Also, in OVX group, the total leukocyte count (TLC) increased ($p<0.01$) at week 1 and neutrophils ratio ($p<0.05$) at week 2. Both total protein and albumin levels in OVX group were decreased significantly ($p<0.01$) in weeks 1 and 2. Glucose level increased ($p<0.001$) at week 1 in OVX group. The serum levels of urea, GOT and GPT of OVX group were relatively higher compared with control group values.

Conclusions: The study concluded that ovariectomy induced variable effects on thermoregulation, haematological and serum biochemical parameters in adult Nubian goats .

Keywords: Goats, bilateral ovariectomy, thermoregulation, blood constituents .

1. INTRODUCTION

Goats are homeothermic animals with a limited range of body temperature, therefore, excess heat must be eliminated for the animals to be in a thermal balance state [1]. The main source of thermal energy for goats is metabolism, and also other routes are used for thermal energy exchange including conduction, convection, radiation and evaporation [2]. The general homeostatic response of goats to hot conditions include higher respiration rates [3], panting, higher sweating rate [4], decrease in feed intake and metabolic heat production [5] and increase in skin temperature and reduction or constant in heart rate and cardiac output [6]. Previous study reported that the core body temperature is corresponding with the level of female sex hormones, core body temperature decreases with low level and increases with high level of female sex hormones [7].

Blood is an important and reliable medium for assessing the health status of individual animals [8]. Variations in blood parameters of goats are due to several factors such as altitude, nutritional level, age, sex, breed, season, temperature and physiological state [9].

Gonadectomy is one of the most frequently performed surgical techniques in veterinary practice. An ovariectomy is usually performed to prevent sexual activity and eliminate pregnancy or to remove diseased organs (ovarian masses, chronic pyometra, uterine neoplasm) [10-13]. Ovariectomy also has many advantages for animal production, such as improving management by breeding males along with females in the same environment; increasing live weight gain and production of high quality carcass in small ruminants [14-16]. OVX is also used to prevent uterine diseases such as chronic pyometra, uterine neoplasm, ovarian masses and mammary gland tumor in goats, sheep and small animals [17, 18]. In humans, oophorectomy is used in protection against breast and ovarian, fallopian tube and primary peritoneal cancers in women [19]. In addition, it is used in the treatment of

breast cancer [19]. Both pre- and post-menopausal oophorectomy prevents breast cancer [20].

The surgical performance of ovariectomy and associated stress may induce changes in animals. This study was undertaken to report on physiological changes following ovariectomy in adult Nubian goats.

2. MATERIAL AND METHODS

2.1 Experimental Animals, Housing and Management

Twenty adult, apparently healthy female goats , obtained from the local market in Khartoum North , were used in this experiment. The goats were kept in the small ruminant unit at the Department of Physiology, Faculty of Veterinary Medicine, University of Khartoum. Animals were examined clinically and were given prophylactic treatments of anthelmintic injection (Ivomec: 0.02 ml/kg BW: Alpha Laboratories Ltd, India) and antibacterial injection (Oxytetracycline: 7.5 mg/kg BW: Alpha Laboratories Ltd, India). The animals were maintained on a diet of dry lucerne hay (*Medicago sativa*) and tap water *ad libitum*. They were kept for an adaptation period of 2 weeks before experimentation so that they were accustomed to the experimental conditions and collection of blood samples. The study was conducted during December-January, 2019 (maximum temperature 36.5Cº, minimum 9.9Cº, mean relative humidity 29.8%).

2.2 Experimental Design

Twenty female goats were randomly assigned into two groups, group A acted as a control group (12 animals) and group B (8 animals) were subjected to ovariectomy and monitored for 4 weeks. Thermoregulation and blood parameters were measured pre- OVX, and at weeks 1, 2, 3 and 4 following the operation. The thermoregulation parameters were measured at cold dry winter in the morning (7.00 a.m.).

2.3 Surgical Procedure

Bilateral ovariectomy was performed under local anaesthesia according to the method described by [11]. Animals were fasted 12 hours before surgery. The left flank region of each goat was prepared for surgery by clipping and shaving the hair on the proposed surgical site; the site was scrubbed with povidone iodine 10% topical solution. First of all, mild sedation was used (0.05mg/kg xylazine) then, local anaesthesia, 2% w/v lidocaine HCl injection (PSI, Jeddah, Saudi Arabia) 10 ml were used. Ovariectomy was performed on the anaesthetized animal placed on the right side. A small 6 to 8 cm incision was made in the left flank. Two fingers were introduced into the abdominal cavity and the uterus was recognized in its dorsal aspect by following one of the horns to the uterine bifurcation. Once the uterine horn was grasped between the fingers, it was pulled towards the surgical incision. Size "1" chromic catgut was used to transfix the ovarian pedicle before transaction. The laparotomy incision was closed as described above. Antimicrobial Oxytet-LA (Oxytetracyline 20% injection) (Shanghai Gongyi Veterinary Medicine plant, China) and anti-inflammatory Ketaflam (Montajat Pharmaceuticals, Saudi Arabia) medications were used for 5 days after surgery. Figures 1 and 2 show extraction of ovaries during overiectomy operation and ovaries after ovariectomy.

2.4 Physiological Investigations

During the experimental period, rectal temperature (T_r) was measured by a digital clinical thermometer. The RR was measured by visually counting the flank movements for one minute using a stopwatch. The HR was obtained by monitoring the heart sounds for one minute using a stethoscope and a stopwatch. During the experiments, the animals were weighed using a traditional balance (Kinlee - Hanging scale, China). The parameters of erythrocytic indices and leukogram were determined according to the standard methods described in Essentials of Veterinary Haematology [21].Serum total protein concentration was determined by Biuret method [22] using a kit (BioSystems, S.A., Spain). Serum albumin concentration was determined by the colorimetric method of Bromocresol green

[23] using a kit (Bio Systems, S. A., Spain). Serum urea concentration was determined by the enzymatic-colorimetric test (Berthlot) [24] using a kit (BioSystems, S.A., Spain). The plasma glucose concentration was determined by the enzymatic colorimetric method [25] using a kit (Spinreact, S.A., Spain). Serum GOT and GPT activity were determined by the enzymatic method [26] using a kit (Spinreact, S.A., Spain).

2.5 Statistical Analysis

The data collected were subjected to standard methods of statistical analysis using Statistical Package for the Social Sciences (SPSS, version 20). In this experiment, an independent sample T-test was used to assess the effects of overiactomy in adult female goats. The experimental data were expressed as mean values ± SD and were presented in Tables and illustrated in Figures . P value of <0.05 was considered statistically significant.

3. RESULTS

3.1 Thermoregulation(Tr) , Respiratory Rate(RR) , Heart Rate(RR) and Body Weight (BW)

The effects of OVX on Tr , RR , HR and BW are presented in Table 1 .

3.1.1 Rectal temperature (T_r)

The initial T_r values ranged from 37.56 to 37.98°C. The group of goats subjected to OVX maintained lower T_r values compared to the control group until the end of week 4. At week 4, $T_r$values of OVX group of goats was significantly ($P \leq 0.05$) lower compared with the control group (Fig. 3).

3.1.2 Respiratory rate (RR)

The initial mean values of RR ranged from 15 to 17 breaths /min. The general pattern indicates that the RR value of the OVX group was lower compared to the control group during the experimental period (Fig. 4).

3.1.3 Heart rate (HR)

The initial values of HR were close to each other for the experimental groups. The OVX group showed an increase in HR values at weeks 1 and 2, followed by a decline until week 4 compared with HR values of the control group. At week 2, the ovariectomized group had significantly ($P \leq 0.01$) higher HR value compared with the control group (Fig.5).

3.1.4 Body weight (BW)

The initial values of BW were not close to each other, ranging from 20.68 to 23.33kg. There was no significant difference in BW between the OVX and control group during the experimental period (Fig. 6).

3.5 Haematological Parameters

The effects of OVX on haematological parameters are presented in Table 2

3.5.1 Packed cell volume (PCV)

Generally, there was no significant difference between the two groups. The control group maintained an almost steady PCV ($\approx 25\%$). At week 1, there was a decline in PCV for OVX group compared with the control group. At weeks 2 and 3, the OVX group maintained higher PCV values compared with control group. At week 4, the OVX group had lower PCV values compared to the control group (Fig.7).

3.5.2 Red blood cells (RBCs)

The initial mean values of RBCs were close to each other ranging from 11.38 to 11.56 ($x10^6/\mu l$). Generally, there were fluctuations in RBCs values in control and OVX groups of animals during the experimental period. At week 1, there was a significant ($P \leq 0.05$) decline in RBCs values for OVX group compared with control group. At weeks 2 and 3, the OVX group maintained higher RBCs values compared with the control group. At week 4, the OVX group had lower RBCs values compared to the control group (Fig.8).

3.5.3 Haemoglobin concentration (Hb)

The initial mean values of Hb were similar, ranging from 9.81 to 9.96 g/dl. Generally, the treated group had lower Hb values compared with control group, and there were no

significant differences between the two groups until week 4. At week 1, there was a decrease in Hb concentration in OVX group compared with control group. At week 2, the OVX group had slightly higher Hb value compared with the control group (Fig.9).

3.6 Total leukocyte count (TLC) and differential leukocyte count (DLC)

The effects of OVX on TLC and DLC are shown in Table 3.

3.6.1 Total leukocyte count (TLC)

The initial mean values of TLC were close to each other, ranging from 10.01 to 10.33 ($x10^6$/µl). The group of goats subjected to OVX maintained higher values of TLC compared to control group during the experimental period. At week 1, the TLC was significantly ($P \leq 0.01$) higher in the OVX group compared with the control group. There was no significant difference in TLC values between the control and OVX group at weeks 2, 3 and 4 (Fig. 10) .

3.6.2 Lymphocyte ratio

The initial mean values of lymphocyte ratio were almost similar (≈ 53%). Generally, the OVX group had lower lymphocyte ratio compared to the control group. There were no significant differences in lymphocyte ratio between groups at weeks 1, 2 and 3. At week 4, the OVX group had slightly higher value of lymphocyte ratio compared to the control group (Fig. 11).

3.6.3 Neutrophil ratio

The initial mean values of neutrophil ratio were similar. Generally, the OVX group maintained higher neutrophil ratio compared to the control group during the experimental period. At week 2, the OVX group had significantly ($P \leq 0.05$) higher neutrophil ratio compared to the control group (Fig. 12).

3.5.7 Monocyte ratio

The effect of OVX on monocyte ratio in goats is shown in fig. 13. There was no significant difference between groups in monocyte ratio during the experimental period. There was a

decline in monocyte ratiofor the OVX group compared with the control group until week 4 (Fig.13).

3.6.4 Eosinophil ratio

Generally, there was a non-significant decrease in eosinophil ratio in the OVX group compared with the control group until week 3. At week 4, the eosinophil ratio was non-significant higher in the OVX group compared to the control group (Fig.14).

3.7 Blood Metabolites and Enzymes

The effects of OVX on serum levels of metabolites and enzymes are shown in Table 4.

3.7.1 Serum total protein

The initial mean values of serum total protein were similar for the experimental groups of goats. The OVX group had lower serum total protein values compared to control group during the experimental period. At weeks 1 and 2, the OVX group had significantly ($P \leq 0.01$) lower total proteins value compared with the control group. The OVX group maintained lower total proteins values compared with control group at weeks 3 and 4 (Fig. 15).

3.7.2 Serum albumin

The initial mean values of serum albumin were close to each other (3.37 to 3.57 g/dl). The OVX group maintained lower albumin concentration compared to the control group during the experimental period. At weeks 1, 2 and 3, the OVX group had significantly ($P \leq 0.01$) lower albumin values compared with the control group. At week 4, the OVX group maintained lower albumin value compared with the control group (Fig. 16).

3.7.3 Serum urea

The initial mean values of serum urea concentration were not significantly different (45.73 - 46.27 mg/dl). Generally, the OVX group maintained higher serum urea concentration

compared to the control group until week 3. At week 4, the urea value of OVX goats was lower compared with the control group (Fig. 17).

3.7.4 Plasma glucose

The initial mean values of plasma glucose ranged from 47.98 to 48.80 mg/dl. The group of goats subjected to OVX maintained higher plasma glucose level compared to intact goats during the experimental period. The glucose level of the OVX group was significantly higher compared with the control group at week 1 ($P \leq 0.001$), 2 ($P \leq 0.05$) and 3 ($P \leq 0.01$). At week 4, the OVX group maintained non-significantly higher plasma glucose level compared with the control group (Fig. 18).

3.7.5 Serum enzymes

Figs. 19 and 20 illustrate the effects of OVX on the activities of measured serum enzymes. The experimental groups had close initial mean values of GOT and GPT. Generally, there were no significant differences between the two groups. However, from week 1 until week 4, the OVX group maintained slightly higher GOT and GPT values compared with the control group. At week 1, the GPT value of OVX group was higher compared with the control group. At weeks 2, 3 and 4, the OVX group maintained slightly higher GPT values compared with the control group.

4. DISCUSSION

The aim of this study was to evaluate the effects of OVX on basic physiological responses in the goat an animal endowed with anatomical and physiological characteristics appropriate for such investigations. The goat has been used as an animal model in scientific research. The anatomy and physiology of the goat make it appropriate to be used for investigations in various fields of research[27]. Goats were used as an experimental model in surgery [28], trauma [29], castration [30], ovariectomy [31], in exploring physiological responses to haemorrhage [32, 33] and comparative anatomy [34]. Researchers also used the goat as the primary animal model in orthopaedics [35] and zoonotic diseases [36].

The results indicate that the body temperature (T_r) of OVX goats was decreased compared with the control group. Hypothermia after OVX may be attributed to decreased level of ovarian hormones. Pang *et al*. [37] found that oestradiol and progesterone levels deceased on day 5 after ovariectomy in Huanghuai goats. In addition, Aoyama *et al.* [38] indicated that the levels of oestrogen and progesterone concentrations declined to low values after 3 weeks in ovariectomized goats. In humans, the core body temperature corresponds with the level of female sex hormones, and it decreases with low level and increases with high level of female sex hormones [39]. OVX rats without oestradiol treatment exhibited a shift of the thermoneutral zone to lower ambient temperatures and there was skin vasodilatation. Also, oestrogen withdrawal in rats increased the sensitivity of neural pathways that activate heat dissipation effectors [40]. Moreover, the decline in Tr after OVX may be attributed to the post-operative stress which induced mild anorexia .

The increase in body temperature of women in the luteal phase of menstrual cycle is related to the mild pyrogenic effect of progesterone or its metabolites [7, 41, 42]. Previous studies [43] demonstrated that postmenopausal women had lower core body temperatures than premenopausal women. The current results for goats agree with finding of Marui *et al.* [44] in rats subjected to bilateral OVX, the study reported that depletion of plasma oestradiol in female rats immediately affects daily changes of core temperature and HR. The decrease in respiratory rate (RR) in OVX group compared with control group of goats may be attributed to deficiency of female sex hormones. In adult mammals, including humans, research based evidence shows that the ovarian hormones, progesterone and oestradiol, are potent respiratory stimulants [45]. Both hormones act on peripheral and central respiratory control systems via carotid body chemoreceptors and medullary nucleus to increase breathing in response to either hypoxia or hypercapnia [45. 46]. These hormones are considered to have a protective role against disrupted breathing during sleep in females before the menopausal

period [47]. Administration of progesterone at physiological concentrations to males or females caused prolonged stimulation of respiration in cats [48].

The greater heart rate (HR) in OVX group compared with intact goats may be attributed to the effect of stress and depletion of female sex hormones. After surgery, the levels of norepinephrine and epinephrine increased leading to increase in the force and rate of contraction of the heart [49]. An increase in the sympathetic activity in the heart results in both elevated contractility, which leads to increase in stroke volume, and increase in HR in humans [50].

The mean body weight (BW) was slightly decreased in the OVX group of goats after 4 weeks, but there was no significant difference compared with the control. The decrease in BW may be attributed to stress response to surgery, which leads to increased secretion of catabolic hormones, which promote the breakdown of substrates [50]. Protein catabolism results in marked weight loss and muscle wasting in patients after major surgical and traumatic injury [52]. In line with the current results for goats, studies on rats [53] revealed that after one month of OVX, there was no significant difference in mean BW. In contrast, Jeong and Yoon [54] reported that OVX lead to weight gain primarily in the form of adipose tissue in rodents. The final BW of OVX rats was significantly increased and the serum total and low-density lipoprotein (LDL) cholesterol levels were significantly elevated [55]. Other studies reported that OVX rats had higher BW and higher daily food intake [56]. The differences in the response of BW to OVX could be related to animal species, nutrition and experimental conditions.

The data indicate that after OVX, there were non- significant decreases in PCV and Hb concentration and the RBCs decreased significantly in week 1 in the OVX group compared with the control. This response may be attributed to depletion of oestrogen in goats subjected to OVX. Oestrogen increased the haematopoietic stem cell division and erythropoiesis in rodents [57]. The number and function of haematopoietic stem cells was significantly reduced in the OVX rats when compared with the control group [58].

The current study indicates that the peripheral total leukocyte count (TLC) and neutrophil ratio were increased significantly at weeks 1 and 2, respectively, while the ratios of lymphocyte, monocyte and eosinophil decreased non- significantly in OVX group compared with the control group values. The increase of both TLC and neutrophil is attributed to the effects of surgery and inflammation. Surgical stress increased TLC in humans [59, 60]. Cortisol influences neutrophils by both increasing their release from bone marrow and decreasing their removal from the circulation. Also, it decreases the number of circulating lymphocyte, eosinophil, and basophil [61]. Secretion of glucorticoids as a result of surgery leads to reduction in the rate of T-cell proliferation and induces lymphocytopenia in rats [62]. However, previous studies [17, 63] found that TLC, neutrophils, band cells, lymphocytes, eosinophils and monocytes were within normal ranges in bilaterally ovariectomized bitches .

The serum total protein and albumin levels were both decreased in OVX group compared with control group of goats. In humans and dogs, post-operative albumin concentration decreased and acute phase proteins increased [64, 65]. Decreased albumin levels could be related to the effect of depletion of female sex hormones. Gross *et al.* [66] found that albumin excretion was significantly increased, and administration of oestradiol caused significant reductions in albuminuria in uninephrectomized rats subjected to OVX.

The observed increase in urea level in OXX goats is mainly associated with surgery stress. In response to trauma, increase in the secretion of catabolic hormones leads to body protein breakdown [67]. Also, surgery stress responses include increased secretion of both ADH hormone and renin, which promote water and sodium retention and the production of concentrated urine by direct action on the kidney [68].

The increase in plasma glucose concentration in OVX goats is clearly associated with surgery stress responses. Stress hormones signal the liver to breakdown glycogen in order to release glucose into the plasma and stimulate the breakdown of tissue glycogen stores [69]. Furthermore, catecholamines increase the secretion of glucagon [52]. The measured increase in glucose level may also be attributed to decrease in oestradiol following OVX.

OVX and oxygen depletion were associated with decrease in serum insulin level in OVX rats [69].

There was moderate increase in both GOT and GPT serum levels in OVX group compared with the control group. The higher levels of GPT and GOT obtained with OVX group could be attributed to the catabolic effects of stress hormones in skeletal muscle and liver. The elevated serum enzymes activity is apparently related to the effect of catecholamines on liver cells. In humans, surgery under general anaesthesia elevated serum levels of GOT and GPT enzymes [71].

5. CONCLUSION

Bilateral ovariectomy induced notable alterations in thermoregulation and haematobiochemical parameters in adult goats. The findings have implications in the fields of gynecology and surgery of small ruminants. The generated information could also be utilized in biomedical context and translational medicine. Further studies are required to monitor the effect of ovariectomy on mineral profile and endocrine responses in the goat model.

ETHICS APPROVAL

This study was approved by the Research Board, Faculty of Veterinary Medicine, University of Khartoum and approved and monitored by the Ethical Committee of Veterinary Council, Sudan.

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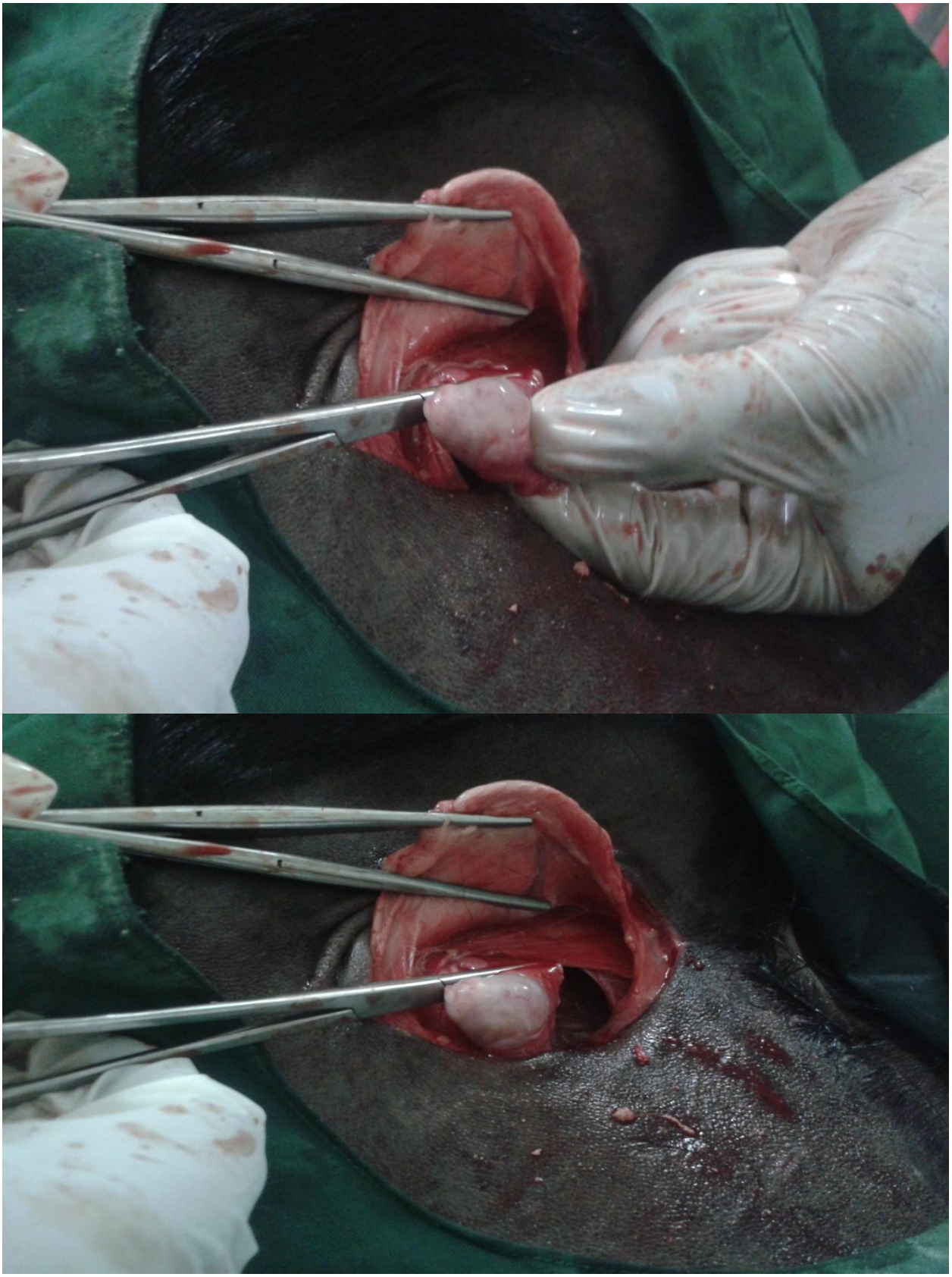

Fig. 1 Extraction of ovaries during operation.

Fig. 2 Ovaries after ovariectomy

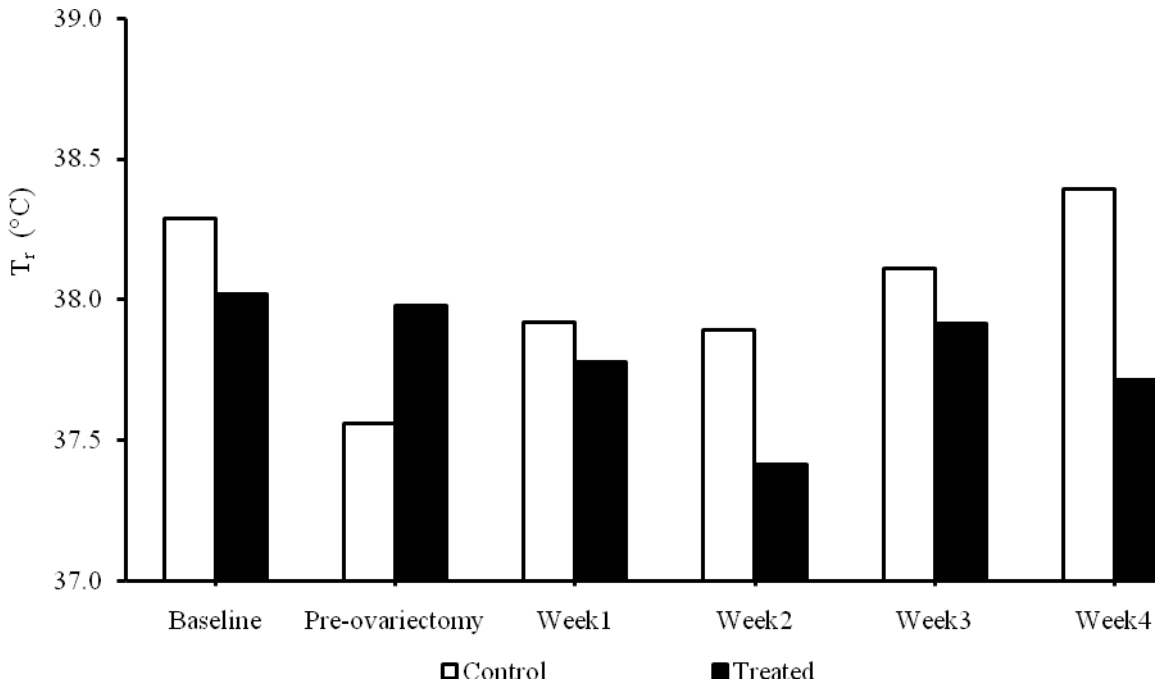

Fig. 3 Effects of ovariectomy (OVX) on rectal temperature, T_r in adult goats.

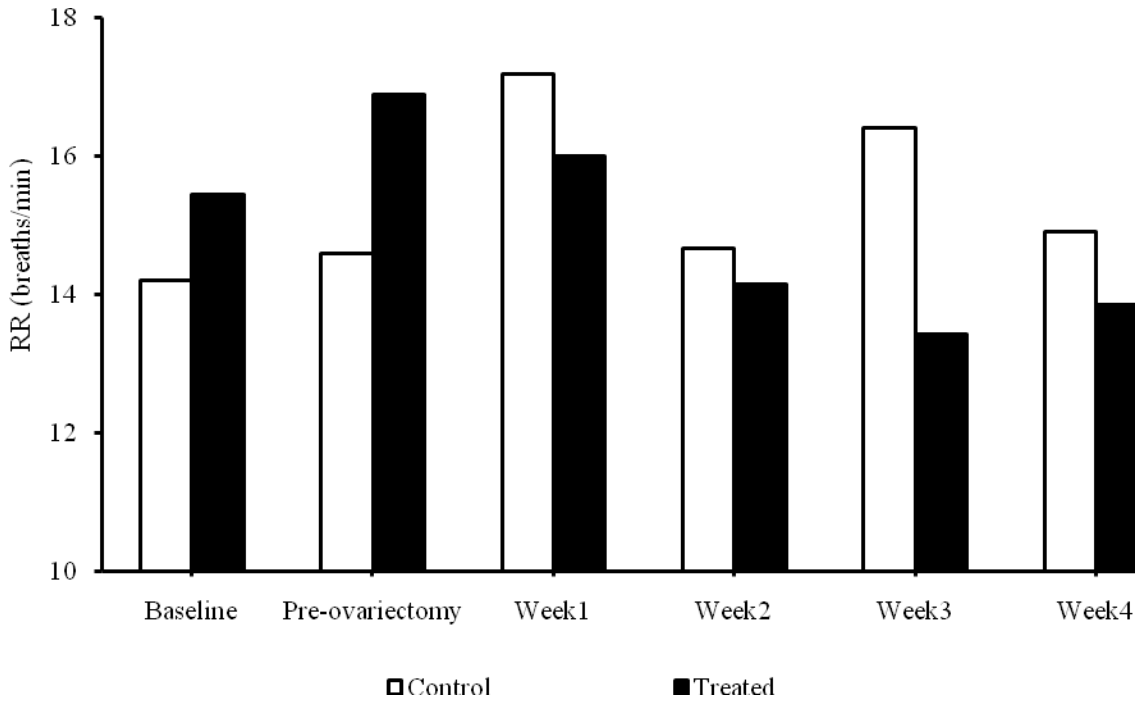

Fig. 4 Effects of ovariectomy(OVX) on respiratory rate, RR in adult goats.

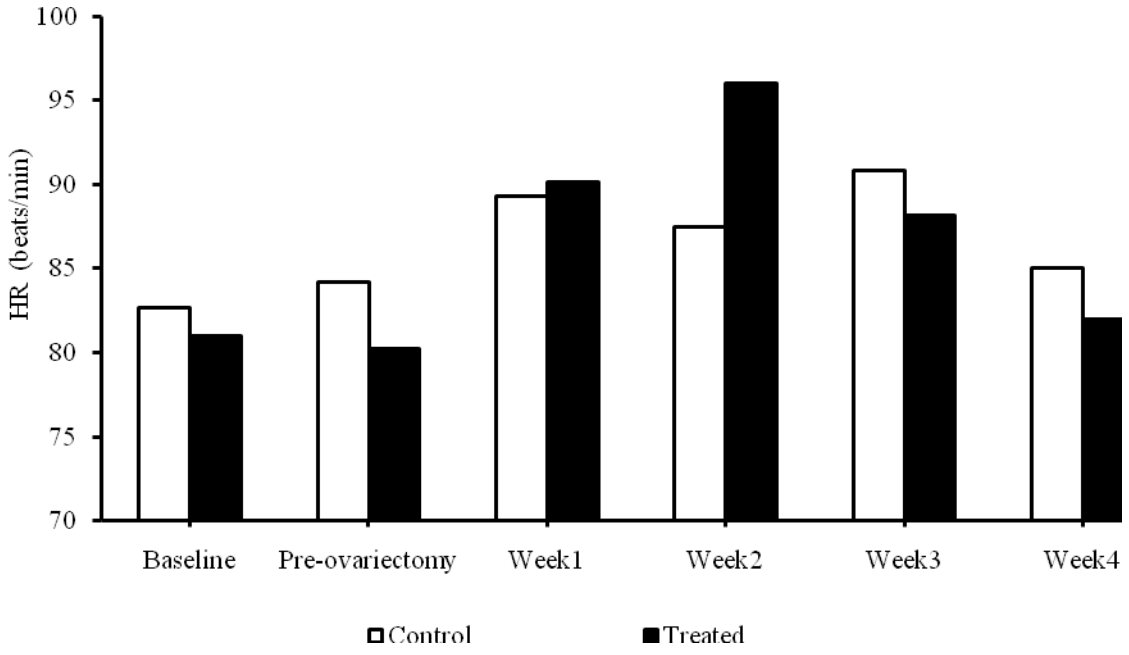

Fig. 5 Effects of ovariectomy (OVX) on heart rate, HR in adult goats.

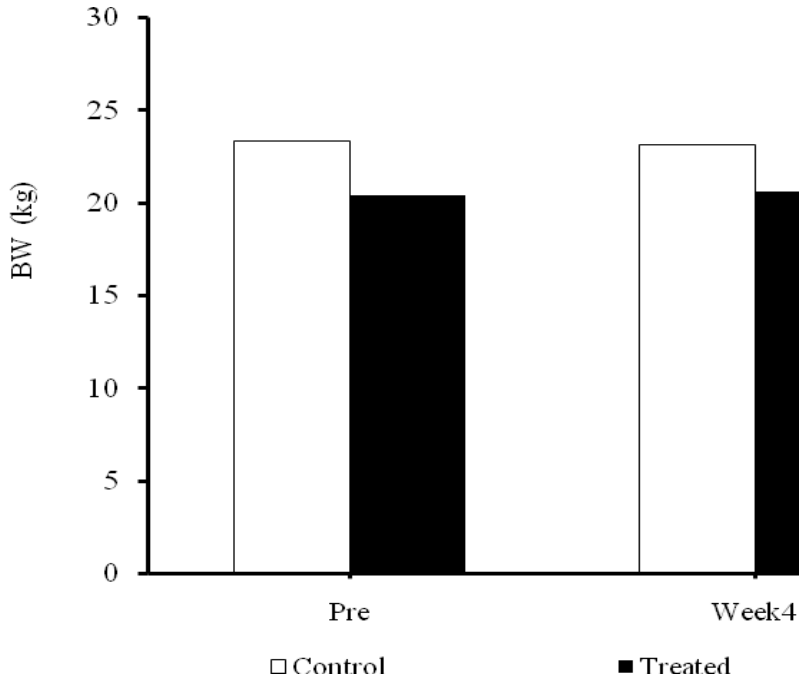

Fig. 6 Effects of ovariectomy (OVX) on body weight, BW in adult goats.

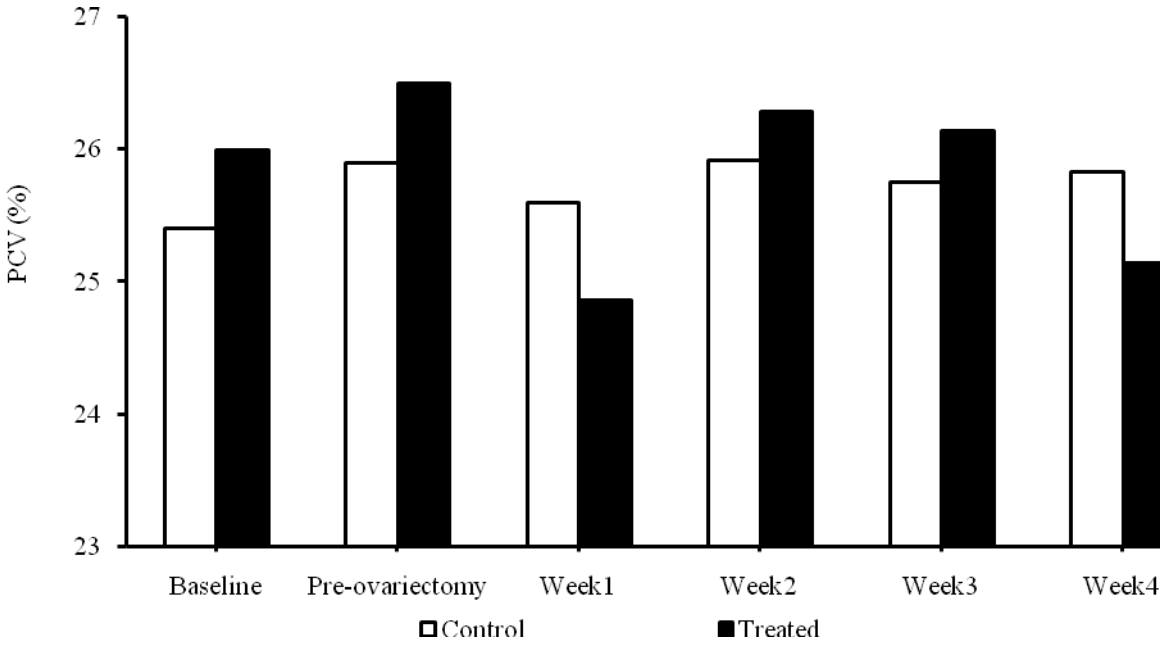

Fig.7 Effects of ovariectomy (OVX) on packed cell volume, PCV in adult goats.

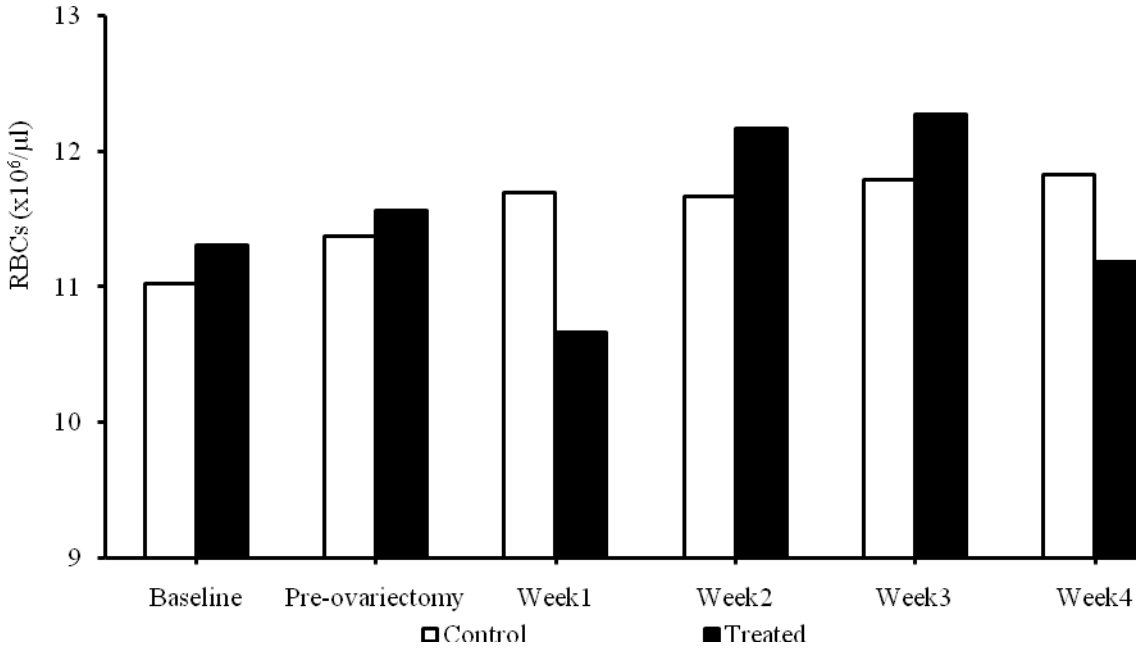

Fig. 8 Effects of ovariectomy (OVX) on red blood cells count, RBCs in adult goats.

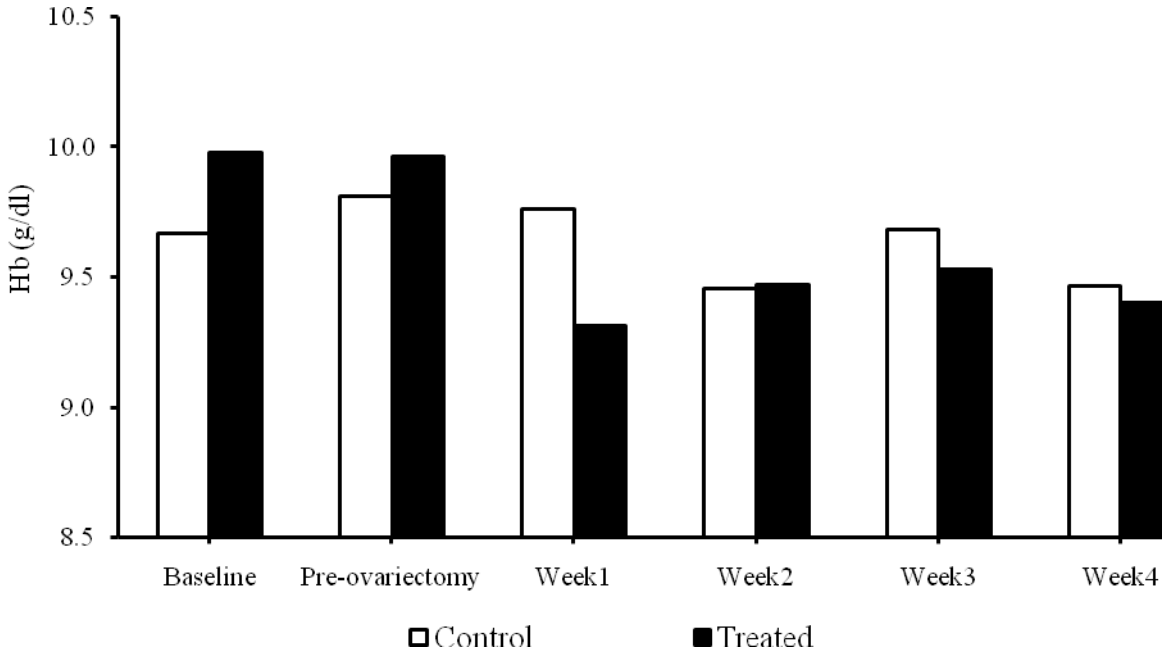

Fig. 9 Effects of ovariectomy (OVX) on haemoglobin concentration, Hb in adult goats.

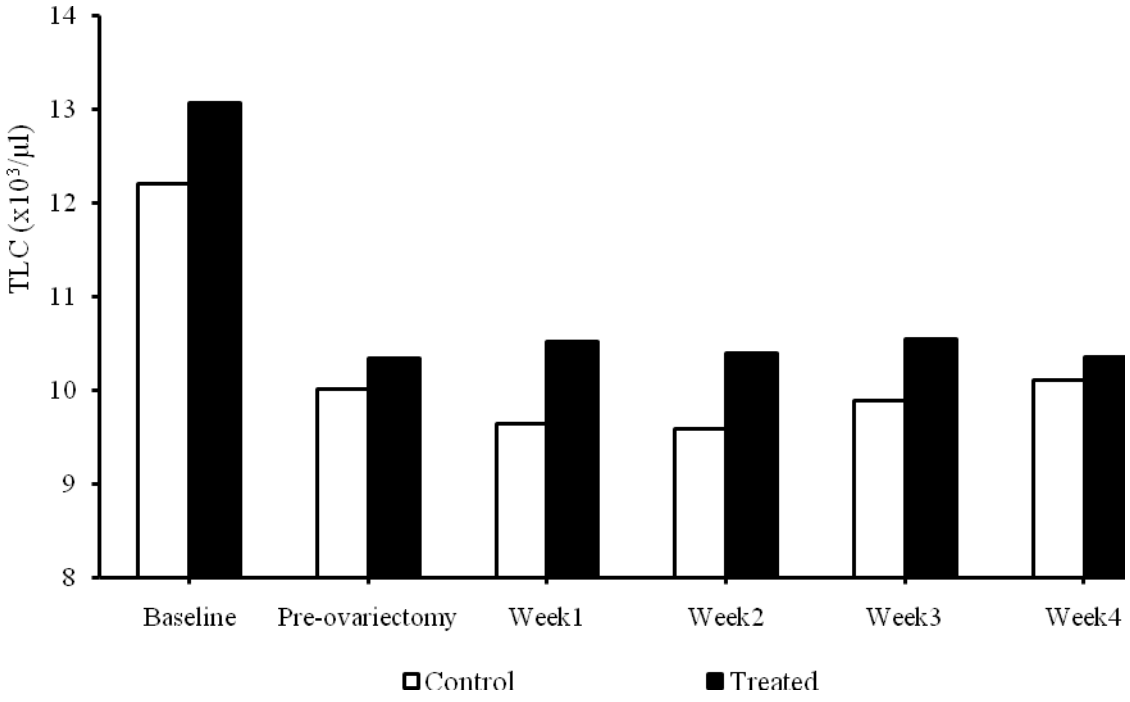

Fig. 10 Effects of ovariectomy (OVX) on total leukocyte count , TLC in adult goats.

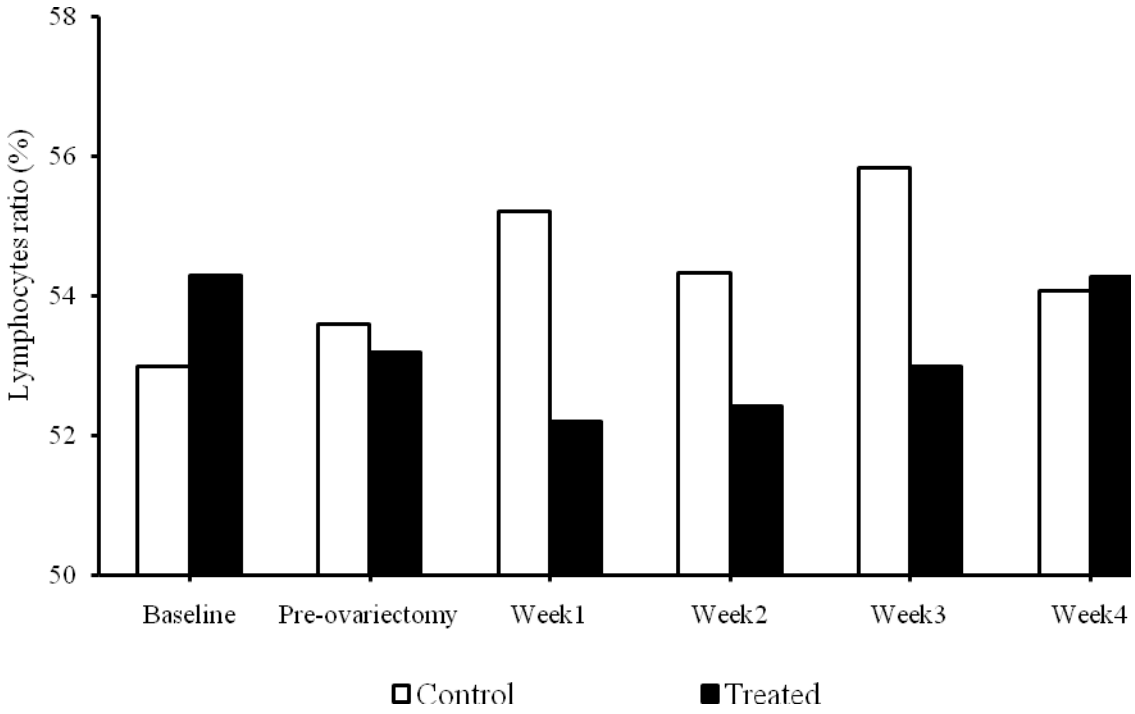

Fig. 11 Effects of ovariectomy (OVX) on lymphocytes ratio in adult goats.

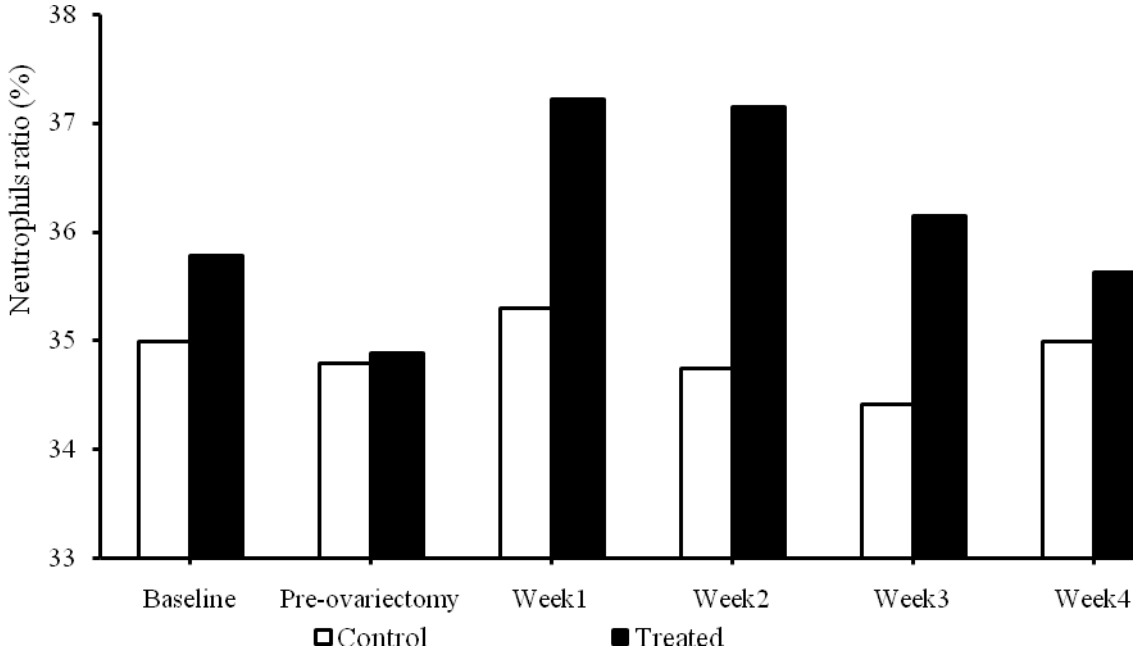

Fig.12 Effects of ovariectomy (OVX) on neutrophils ratio in adult goats.

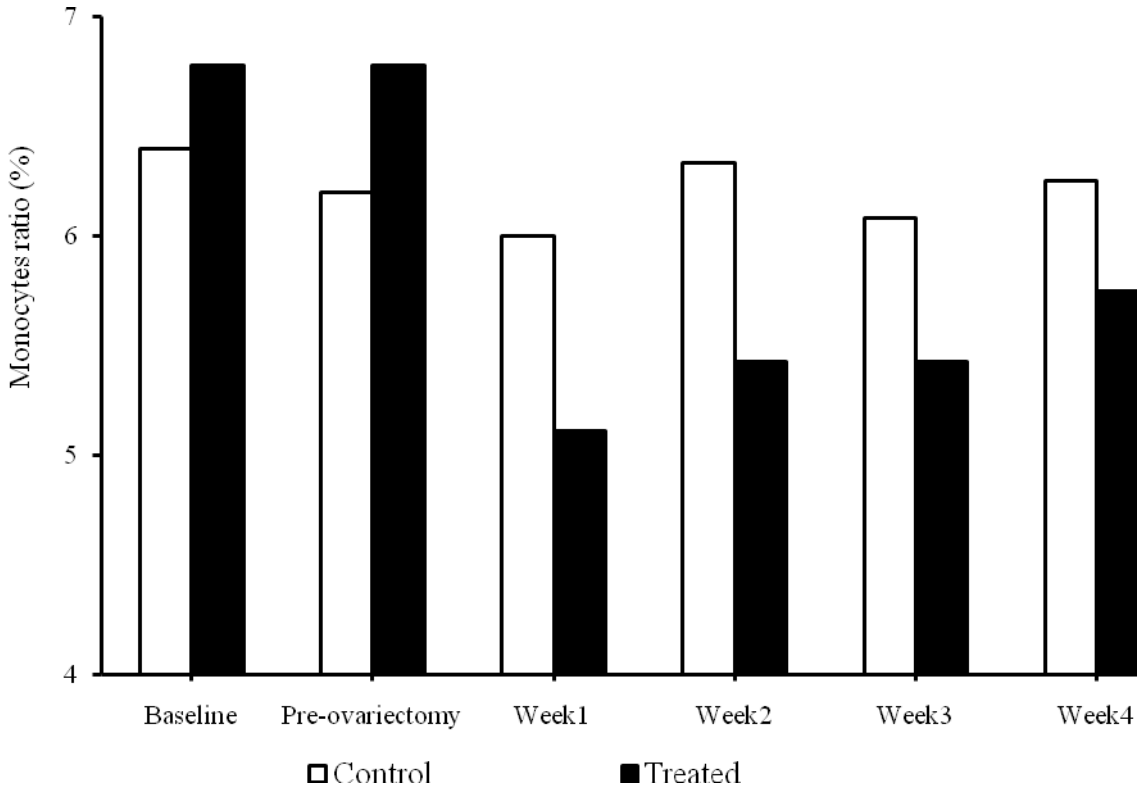

Fig.13 Effects of ovariectomy (OVX) on monocytes ratio in adult goats.

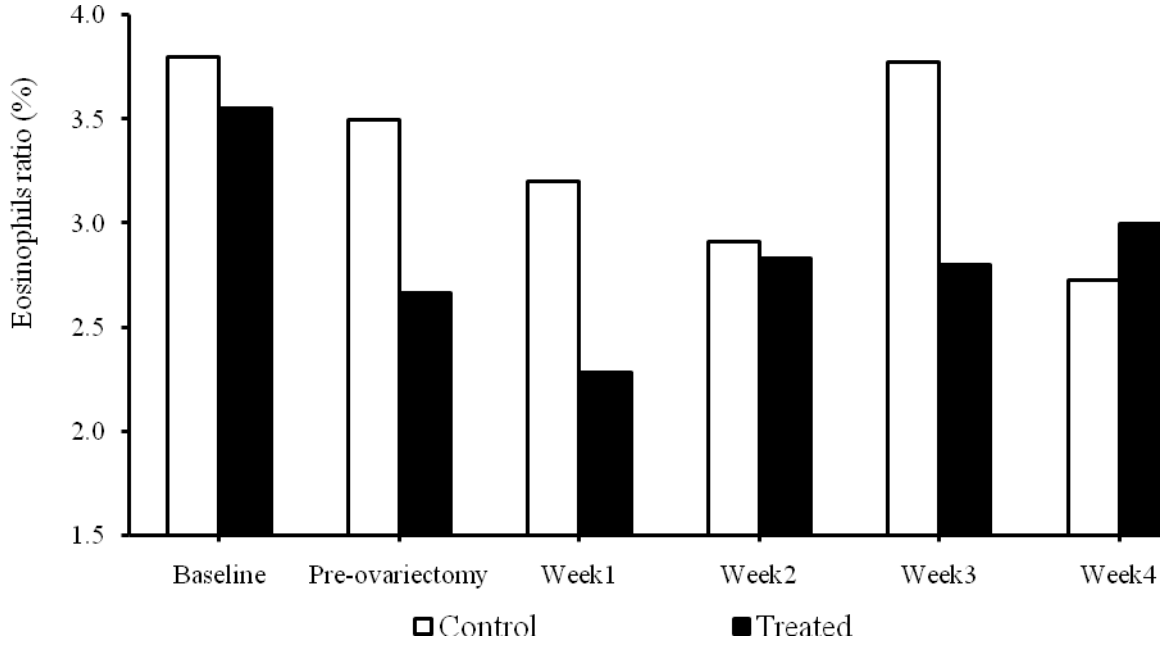

Fig. 14 Effects of ovariectomy (OVX) on eosinophils ratio in adult goats.

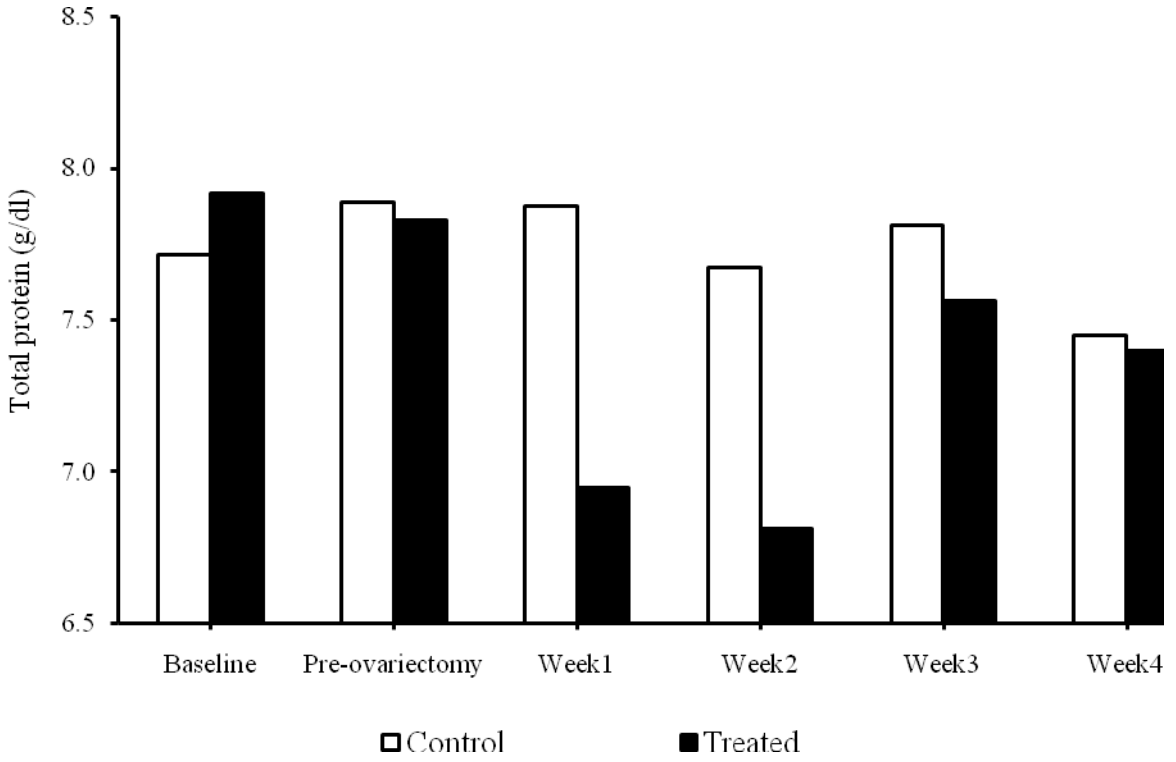

Fig. 15 Effects of ovariectomy (OVX) on serum total protein concentration in adult goats.

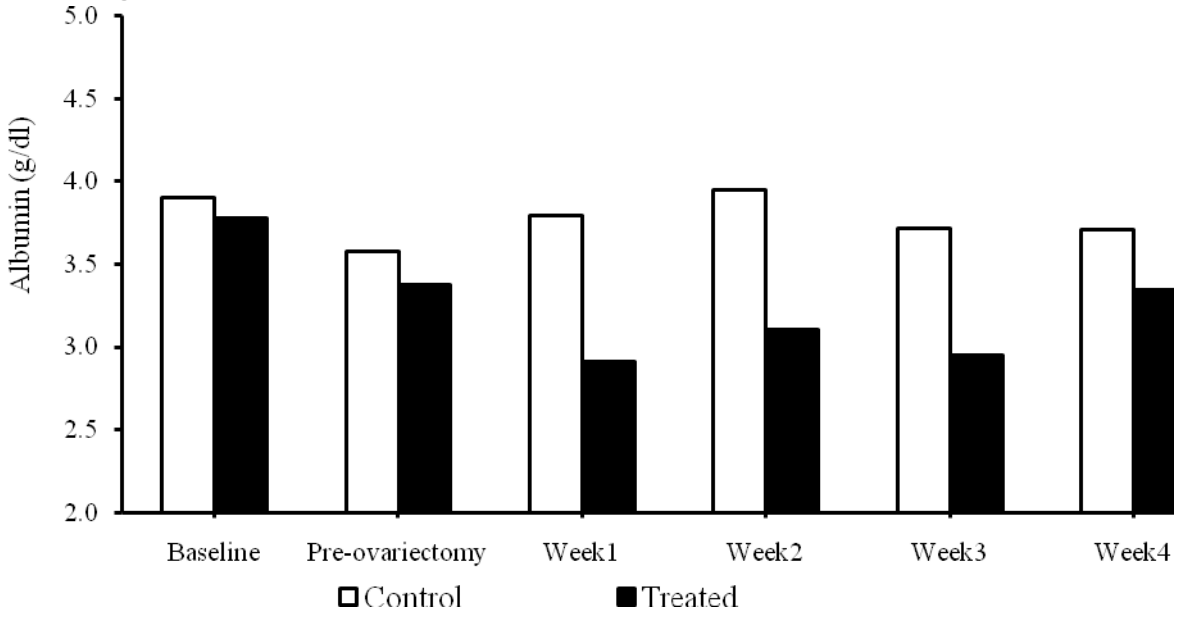

Fig. 16 Effects of ovariectomy (OVX) on Serum albumin concentration in adult goats.

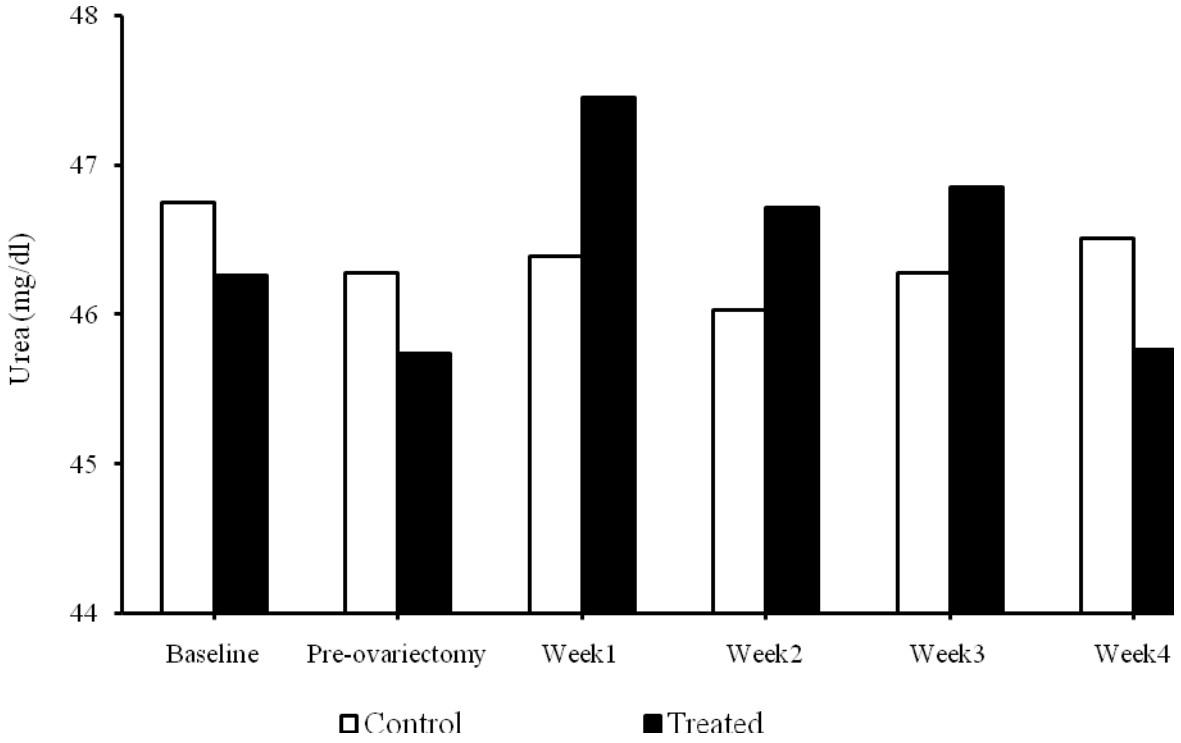

Fig. 17 Effects of ovariectomy (OVX) on serum urea concentration in adult goats.

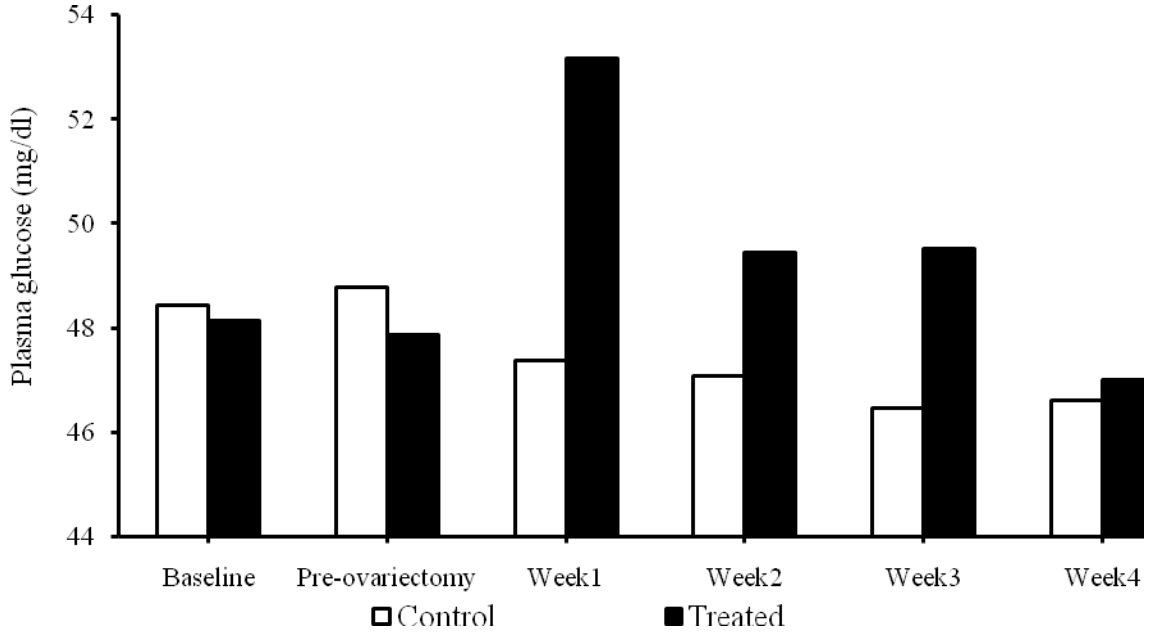

Fig.18 Effects of ovariectomy (OVX) on plasma glucose concentration in adult goats.

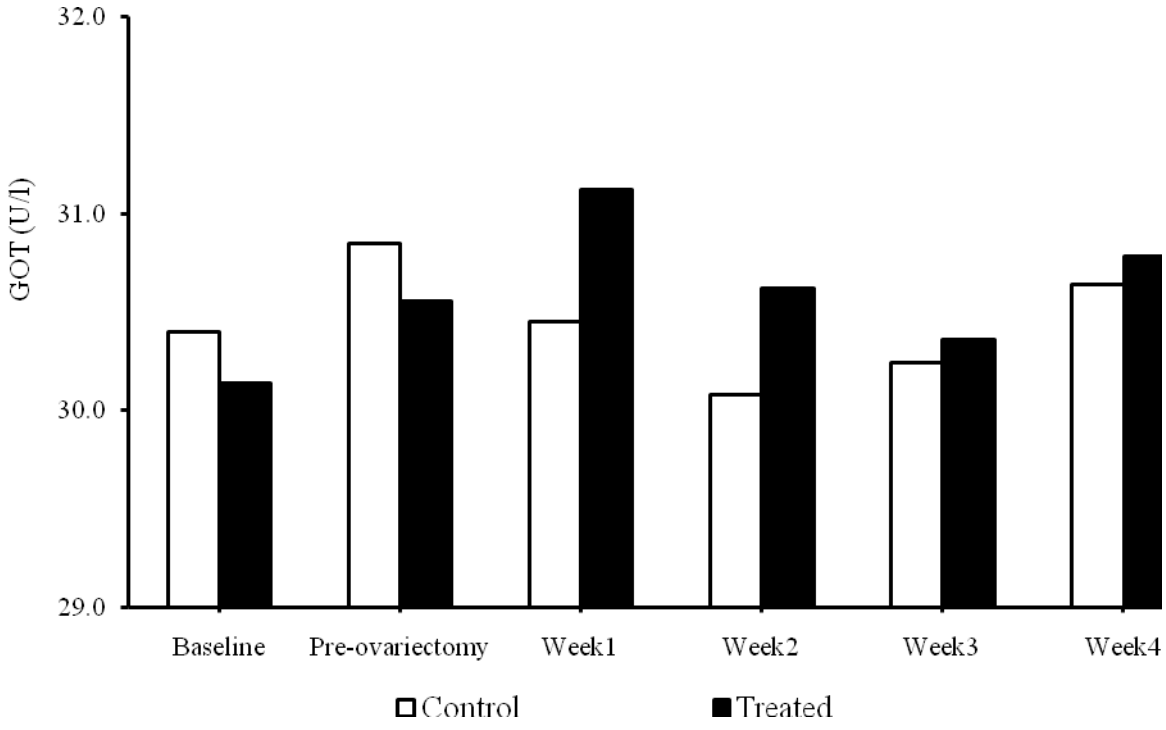

Fig.19 Effects of ovariectomy (OVX) on serum glutamic oxalacetictransaminase, GOT concentration in adult goats.

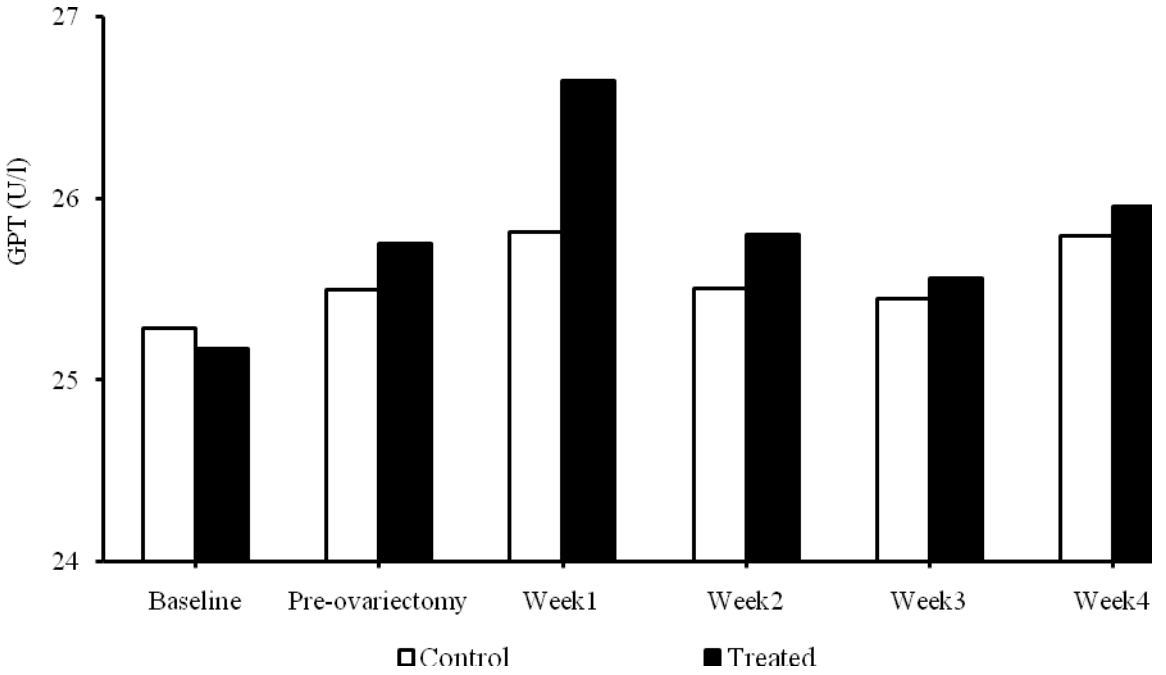

Fig. 20 Effect of ovariectomy (OVX) on serum glutamic pyruvic transaminase concentration, GPT (U/L) in adult goats.

Table 1. Effects of ovariectomy (OVX) on rectal temperature (T_r), respiratory rate (RR), heart rate (HR) and body weight in adult goats.

Parameters	Groups	Baseline	Pre- OVX	Week 1	Week 2	Week 3	Week 4
T_r (°C)	Control	38.29±0.27^{a}	37.56± 0.50^{a}	37.92±0.83^{a}	37.89± 0.79^{a}	38.10±0.73^{a}	38.39±0.46^{a}
	Ovariectomized	38.02±0.43^{a}	37.98±0.52^{a}	37.77±1.45^{a}	37.41±0.64^{a}	37.91±0.36^{a}	37.71± 0.63^{b*}
RR (breaths/min)	Control	14.20± 3.73^{a}	14.60±3.30^{a}	17.20±2.74^{a}	14.66±4.09^{a}	16.41±3.89^{a}	14.91±1.97^{a}
	Ovariectomized	15.44± 3.46^{a}	16.88±2.66^{a}	16.00±4.00^{a}	14.14±2.26^{a}	13.42±3.35^{a}	13.85±3.38^{a}
HR (beats/min)	Control	82.70±4.44^{a}	84.20±7.95^{a}	89.30±5.75^{a}	87.50±6.62^{b**}	90.81±4.14^{a}	85.00±3.86^{a}
	Ovariectomized	81.00±5.04^{a}	80.22±5.16^{a}	90.11±5.81^{a}	96.00±4.28^{a}	88.14±5.27^{a}	82.00±1.63^{a}
Body weight (kg)	Control		23.33±3.45^{a}				23.10±3.06^{a}
	Ovariectomized		20.68±2.62^{a}				20.58±3.22^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.
: Significant at P≤ 0.05: Significant at P≤ 0. 01*

Table 2. Effects of ovariectomy (OVX) on PCV, RBCs and Hb concentration in adult goats.

Parameters	Groups	Baseline	Pre-OVX	Week1	Week 2	Week 3	Week 4
PCV (%)	Control	25.40±2.98^{a}	25.90±3.17^{a}	25.60±3.37^{a}	25.91±3.60^{a}	25.75±3.38^{a}	25.83±3.40^{a}
	Ovariectomized	26.00±3.29^{a}	26.50±2.56^{a}	24.85±3.93^{a}	26.28±2.69^{a}	26.14±2.67^{a}	25.14±2.67^{a}
RBCs (x10^{6}/µL)	Control	11.03±0.68^{a}	11.38±0.61^{a}	11.70±0.94^{a}	11.66±0.98^{a}	11.79±0.83^{a}	11.83±1.02^{a}
	Ovariectomized	11.31±0.37^{a}	11.56±0.28^{a}	10.66±0.70^{b*}	12.17±1.00^{a}	12.27±1.07^{a}	11.18±1.16^{a}
Hb (g/dL)	Control	9.67±0.54^{a}	9.81±0.69^{a}	9.76±0.65^{a}	9.45±0.38^{a}	9.68±0.57^{a}	9.46±0.32^{a}
	Ovariectomized	9.97±0.71^{a}	9.96±0.56^{a}	9.31±0.70^{a}	9.47±0.47^{a}	9.52±0.42^{a}	9.40± 0.14^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.
**: Significant at P≤ 0.05*

Table 3. Effects of ovariectomy (OVX) on total leukocyte count (TLC) and differential leukocyte count (DLC) in adult goats.

Parameters	Groups	Baseline	Pre-OVX	Week 1	Week 2	Week 3	Week 4
TLC (x10^3/µL)	Control	12.21±1.64^{a}	10.01±0.62^{a}	9.64±0.52^{b**}	9.58±1.10^{a}	9.89±0.66^{a}	10.10±0.32^{a}
	Ovariectomized	13.06±2.06^{a}	10.33±0.34^{a}	10.52±0.71^{a}	10.40±0.79^{a}	10.54±0.89^{a}	10.35±0.37^{a}
Lymphocyte ratio %)	Control	53.00±3.09^{a}	53.60±2.83^{a}	55.22±2.48^{a}	54.33±4.43^{a}	55.83±3.27^{a}	54.08±3.17^{a}
	Ovariectomized	54.30±5.57^{a}	53.20±4.61^{a}	52.20±5.43^{a}	52.42±5.12^{a}	53.00±4.72^{a}	54.28±3.30^{a}
Neutrophils ratio (%)	Control	35.00±2.21^{a}	34.80±3.15^{a}	35.30±3.16^{a}	34.75±2.37^{a}	34.41±2.67^{a}	35.00±2.82^{a}
	Ovariectomized	35.77±2.90^{a}	34.88±3.65^{a}	37.22±3.49^{a}	37.14±1.77^{b*}	36.14±2.19^{a}	35.62±2.72^{a}
Monocytes ratio (%)	Control	6.40±1.57^{a}	6.20±1.39^{a}	6.00±0.77^{a}	6.33±1.15^{a}	6.08±1.24^{a}	6.25±1.21^{a}
	Ovariectomized	6.77±1.30^{a}	6.77±1.64^{a}	5.11±1.76^{a}	5.42±0.78^{a}	5.42±1.27^{a}	5.75±1.03^{a}
Eosinophils ratio (%)	Control	3.80±1.22^{a}	3.50^{a}±1.35^{a}	3.20±1.75^{a}	2.90±2.02^{a}	3.77±2.04^{a}	2.72±2.28^{a}
	Ovariectomized	3.55±1.33^{a}	2.66±1.22^{a}	2.28±1.25^{a}	2.83±1.16^{a}	2.80±1.64^{a}	3.00±1.78^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.
**: Significant at P≤ 0.05 **: Significant at P≤ 0. 01*

Table 4. Effects of ovariectmy (OVX) on serum total protein, albumin, urea and plasma glucose concentrations and serum enzymes activities in adult goats.

Parameters	Groups	Baseline	Pre-OVX	Week1	Week2	Week3	Week4
Total protein level (g/dL)	Control	7.71±0.41^{a}	7.88±0.38^{a}	7.87±0.40^{a}	7.67±0.49^{a}	7.81±0.54^{a}	7.45±0.50^{a}
	Ovariectomized	7.91±0.39^{a}	7.83±0.48^{a}	6.94±0.65^{b**}	6.81±0.56^{b**}	7.56±0.49^{a}	7.39±0.61^{a}
Albumin level (g/dL)	Control	3.90±0.55^{a}	3.57±0.28^{a}	3.79±0.59^{a}	3.94±0.54^{a}	3.71±0.46^{a}	3.70±0.57^{a}
	Ovariectomized	3.77±0.39^{a}	3.37±0.54^{a}	2.90±0.66^{b**}	3.10±0.67^{b**}	2.95±0.45^{b**}	3.34±0.55^{a}
Urea level (mg/dL)	Control	46.75±1.91^{a}	46.27±2.18^{a}	46.38±2.93^{a}	46.03±1.93^{a}	46.27±2.71^{a}	46.51±1.90^{a}
	Ovariectomized	46.26±1.80^{a}	45.73±1.90^{a}	47.45±1.78^{a}	46.71±1.91^{a}	46.85±1.80^{a}	45.76±2.16^{a}
Glucose level (mg/dL)	Control	48.43±1.47^{a}	48.80±0.93^{a}	47.37±1.52^{b***}	47.09±1.75^{b*}	46.47±1.78^{b**}	46.61±2.54^{a}
	Ovariectomized	48.03±2.12^{a}	47.98±1.70^{a}	53.16±2.72^{a}	49.44±2.74^{a}	49.53±2.20^{a}	47.01±2.03^{a}
GOT (U/L)	Control	30.40±0.77^{a}	30.85±1.13^{a}	30.45±0.80^{a}	30.08±0.93^{a}	30.24±1.34^{a}	30.64±1.45^{a}
	Ovariectomized	30.13±2.14^{a}	30.55±1.79^{a}	31.12±1.24^{a}	30.62±1.33^{a}	30.36±1.24^{a}	30.78±1.34^{a}
GPT (U/L)	Control	25.28±0.86^{a}	25.50±0.89^{a}	25.82±0.82^{a}	25.50±0.75^{a}	25.45±1.25^{a}	25.79±1.18^{a}
	Ovariectomized	25.17±0.44^{a}	25.75±0.82^{a}	26.65±1.03^{a}	25.80±0.93^{a}	25.56±0.90^{a}	25.95±1.02^{a}

a, b: Mean values within the same column bearing different superscripts are significantly different.
: Significant at P≤ 0.05: Significant at P≤ 0.01***: Significant at P≤ 0.001*