BLOOD METABOLIC PROFILE OF TRANSHUMANT BARUWAL SHEEP GRAZING PASTURES OF TWO DIFFERENT ALTITUDES AT SIMILAR TEMPERATURE HUMIDITY INDEX

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ABSTRACT

The current study was conducted on native Baruwal sheep reared often in transhumance systems in Nepal. The main objective of the study was to examine how altitude affects some physiological and serum chemistry variables, as well as the haematology of these animals. 24 adult animals, 18 nonpregnant and nonlactating females and 6 intact males were discovered in a transhumance flock. Climate data was acquired and physiological measures (rectal temperature (RT), respiration rate (RR), and pulse rate (PR)) were evaluated when the sheep were in two stopovers at altitudes of 2,393 m asl in March and 3,391 m asl in June. We collected and examined grazing sward samples for close examination and blood samples for specific haematological and serum chemical traits. Both stopovers' settings fell within the sheep's thermo-comfort zone, and their pastures had the maximum crude protein content. According to statistical analysis, there was a significant ($p<0.05$) decrease ($p<0.05$) in RT, RR, and PR; a significant ($p<0.05$) increase ($p<0.05$) in PCV, Hb, RBC and serum creatinine; and a significant ($p<0.05$) decrease ($p<0.05$) in platelets, blood glucose, triglycerides, and cholesterol. The results showed that altitude has an impact on the physiology and blood parameters of Baruwal transhumance sheep. The results show that altitude has an impact on the physiology and blood parameters of Baruwal transhumance sheep. The findings of this study may aid in the nutrition and feeding management of transhumant sheep and their grazing strategies.

Keywords: *baruwal sheep, blood, physiology, transhumance system*

INTRODUCTION

The Baruwal is a multipurpose indigenous breed of sheep raised in transhumance in Nepal (Ghimire 1992; Joshi et al. 2004; Wilson, 1997). In the mountains and upper hills where the livestock production transhumance system is practiced, the predominant indigenous breed, Baruwal sheep (*Ovis aries*), comprises 63% of the total population (Upreti & Pradhan, 1998; FAO, 2010). In Nepal's Trans-Himalaya and foothills, transhumance is a common practice oof sheep rearing. The yearly movement of herds to take advantage of predetermined summer and winter pastures is what distinguishes it from traditional livestock farming. Transhumance herding is characterized by summer grazing in high-altitude alpine pastures, gradual descending through mixed forest zones, and winter laying in open fields (Dong et al., 2020). During such travels, the animals are typically kept outside for the majority of the year.

There are notable variations in the composition of the species, the net availability of forage, and the nutritional value of the forage in varied pastures at various altitudes. Barsila et al. (2014a) and Barsila et al. (2014b) have identified various herbaceous flora according to slope and altitude. Seasonality also affects the variation in milk yield and composition of cattle-yak hybrids and other high Himalayan livestock species (Barsila et al., 2016; Barsila et al., 2014b). The nutritional benefit of rich summer pastures at high altitudes cannot be compared to abandoned lands and winter agricultural waste at low elevations. Due to this, several variables, such as altitude, season, and pasture, can impact the blood parameters of transhumance sheep.

The physiological of Baruwal sheep during tranahumant movement are scant (Adhikari et al., 2015; Oli &Gatenby 1990). Furthermore, there is little information on the physiological vitals and metabolic condition of Baruwal sheep during transhumance. According to Gupta et al. (2007) and Opara et al. (2010), haematology and serum biochemiccals are reliable markers of management practices, nutrition and health conditions. They are crucial for monitoring and evaluating the normal physiological status, as well as the performance soundness of animals. According to Mbassa and Poulsen (1993), these characteristics can change depending on several variables, including altitude, feed level, age, sex, breed, season, temperature, and physiological health, etc. Previously, in the western Nepali Himalayas, we examined haematological changes in transhumant Baruwal sheep (Barsila et al., 2020). However, alterations in serum chemistry and physiological traits of the same breed in the eastern Himalayas are less pronounced and scarce.

MATERIALS AND METHODS

Study area

The present study was carried out on the transhumance route of Pathivara and Makalu villages in Sankhuwasabha District, Nepal (Figure 1). It consists of various grazing lands, including the aftermath of croplands, fallow lands, mixed forests, mountain terrains, and alpine pastures scattered at different altitudes ranging from 1200 to 4200 m altitude, on which the sheep are grazed mainly under a transhumance system. Most of the area of this transhumance route falls under the Makalu Barun National Park and its buffer zone in the eastern Himalayan climatic regime with an early start (June) and longer stay (till late September) of monsoon with common pre-monsoon rain in April and May contributing greatly to the biomass production. The annual rainfall in the area was approximately 1000-4000 mm, but great variations may appear due to enormous differences in altitude gradient, slope and aspect (DNPWC, 2022).

Study design

Observation of the identified sheep of the transhumance flock was made at two different sites, A and B. Descriptions of the sites are given in Table 1. Sites A and B were laid at those points of the transhumance

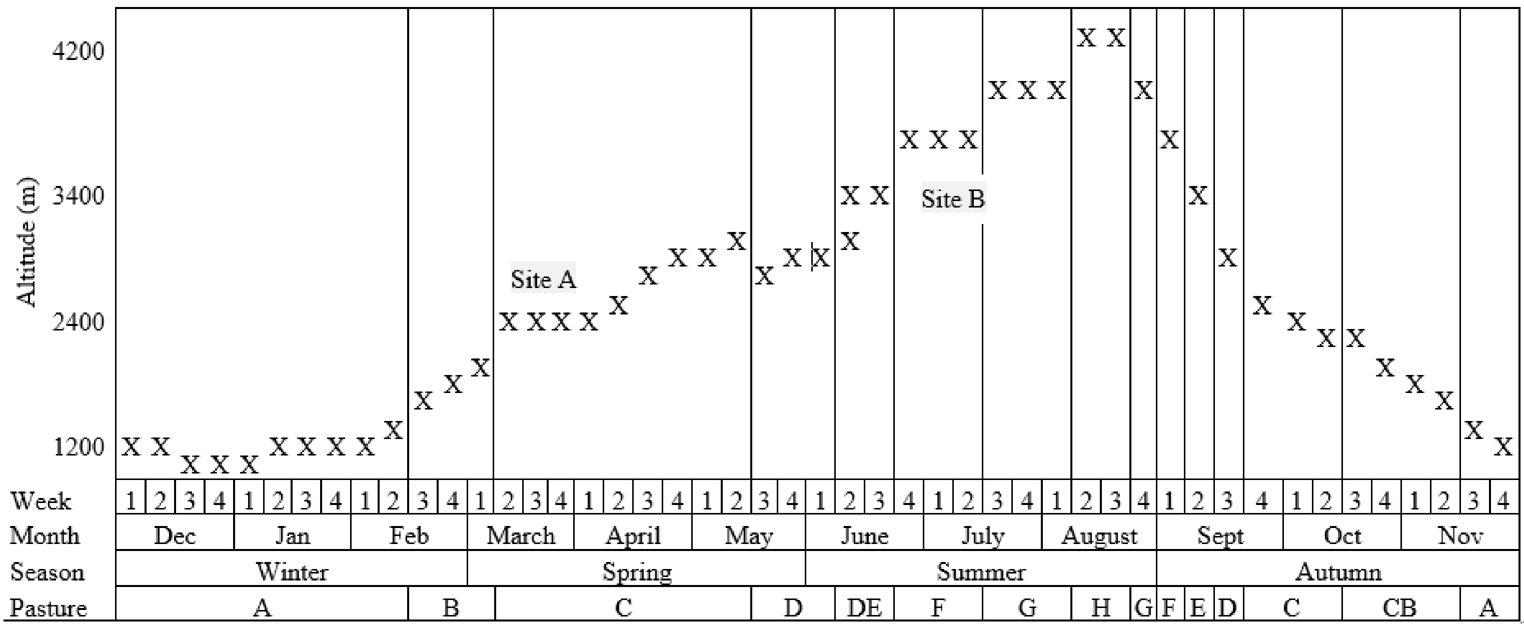

Figure 1 Altitude, Season and pasture interaction with weekly movement pattern of transhumance Baruwal flock under study

A: Fallow land, aftermaths of rice field, nearby pastures, locally available fodder trees in periphery of human settlement area of Simma (Pathivara-2) under customary Sajuwa system; B: Similar pastures as in A in Sisne and Chunglung area (Pathivara-4); C: Thulochaur, Bhittagupha, Aahele, Dibulke, Ganesha, Suire, Karmagupha, Sarange (Patches of Kharka in forest area); D: Bhuje, Kalapattal, Nigale, Thapla (Patches of Kharka in forest area); E: Hiledeurali, Mangane, Gaikharka (Border area between forest and alpine area); F: Dhode, Larewa, Thapu, Baule, Jaljala, Jimbughang, Batase than, Thulopokhari; G: Kilathum, pokhari gaira, Pakhe, Bhirkuna, Dhand Kharka, Ratopahara; H: Thulomulkhaarka, Aasabasa.

course that divided the route fairly into three parts according to the altitude gradient. Site A represented the lower range of medium altitude and are laid at 2,393 masl, whereas, site B was at 3,391 masl and represented the lower range of higher altitude. The study was conducted from January 2021 to July 2021 to cover the two seasons (spring and summer/ fall) and two altitude ranges. There was a difference of about 1000 meters in altitude between the two experimental sites.

Table 1. Description of sites on which observations were made during upward movement

Description	Site A	Site B
Place	Thulochour	Hele Deurali
Location	N 27o37.198’ E 87o19.250’	N 27o40.07’ E 87o17.737’
Altitude (m asl.)	2,393 m asl	3,391 m asl
Season of observation	Spring	Summer
Duration of observation	24 to 31st March 2016	11 to 17th June 2016
Altitude category	Lower range of medium altitude	Lower range of higher altitude

Study animals

The experimental animals were 24 adults (age>1.5 years, body weight>30 kg) including 18 nonpregnant and nonlactating females and 6 intact males. The animals were selected from a herd of 162 animals. The whole Baruwal sheep transhumance flock and the experimental sheep selected within that flock were ear-tagged and dewormed with Fenbendazole (Panacure®, Intervet India) at the dose rate of 5 mg/kg body weight one month before taking blood samples in the spring season.

Climate Recording

A temporary weather station was installed near the night resting place (open roof) of the herders’ camp at the pasture. The rain gauze was placed at a height of 1 m from the ground. Under the rain gauze, a digital thermos-hygrometer was installed under the polythene roof. Climate data was recorded during the adaptation and measurement period. Precipitation, minimum and maximum temperature, and relative humidity were recorded daily at 0645 h. The loss of evaporation was not taken into account in the recording of precipitation. To estimate the potential thermal stress of sheep, the 'temperature-humidity index' was calculated as THI = T-(0.31-0.0031×RH) ×(T-14.4) as described by Marai et al. (2007), and values >22.2 have been considered outside the comfort zone (heat stress). In the formula, T means ambient temperature and RH means relative humidity.

Recording of physiological parameters and blood collection

Between 0630 and 0900 hours, physiological data were measured at both locations. Before recording, the animals were gently handled. A digital thermometer was used to take the rectal temperature, a stethoscope was used to measure the respiration rate, and the femoral artery was palpated to determine the pulse rate per minute.

Haematology and serum chemistry analysis

Blood samples were taken from the jugular vein using 1.5-inch needles. Three millilitres of blood were drawn in a sterile EDTA tube and six millilitres in a sterile blank tube to evaluate the haematology and some serum biochemistry profiles of the experimental animals. Blood samples were transported in thermo-cool boxes to the District Hospital in Khandbari, Sankhuwasabha, where they underwent a haematology analysis according to Benjamin (1978).

Blood glucose was estimated in the field while collecting blood samples using a glucometer and test kits (Gluco One, Dr. Morpen®). Serum was separated from blood collected in blank sterile tubes, transported to the District Hospital, Khandbari, Sankhuwasabha, and stored at -20 ° C until analysis. Serum samples were analyzed using an automated clinical chemistry analyzer (Chem 5 $_{v3}$®, Erba).

Forage sampling and analysis

A total of 20 sward samples of 1 square meter each was randomly selected from the grazing land to assess the nutritional quality of the pastures in the same season and altitude the day before the sheep flock arrived at the pasture. The sward samples were randomly taken in a 100 m-long transect. Two subsamples were selected from the composite sample and weighed using a digital weighing scale (Trisa®, Switzerland). The samples collected at each altitude were weighed, divided into small pieces, and mixed to dry out in the sun.

The sward samples were then brought to the Animal Nutrition Laboratory Division of the Nepal Agricultural Research Council (NARC), Lalitpur, Nepal for the proximate analysis. The dry matter (DM) content was determined by drying to a constant weight at 60 ° C for 48 hours. Chemical analysis was carried out using the standard protocol of the Association of Official Analytical Chemists (AOAC, 1991).

Data Analysis

Data analysis was performed using SPSS software version 20.0. Normality was checked using the Kolmogorov-Smirnov test. Nonparametric tests, Mann-Whitney U test for independent samples (between sexes within the site), and Wilcoxon signed rank test for dependent samples (between sites) were applied to compare the means.

RESULTS

Climatic data

The climatic data from both sites are shown in Table 2. During the observation period in the low altitude, (site A) a mixed climate (open sky, frost, and rainfall on different days) occurred, but at high altitude (site B) the sky was cloudy and rainfall was accompanied most of the time. Although the temperature humidity index at site B was found to be significantly higher than that at site A, both sites were within the comfort zone for sheep having an index below the cutoff level of 22.2 for heat stress.

Table 2. Comparison of climate variables of two study sites in the eastern Himalayas of Nepal

Variable	Site A (Lower altitude/2,393 masl, Spring)		Site B (Higher altitude/3,391 masl, Summer)	
	Mean±SD	Range	Mean±SD	Range
T_{max}	19.47±1.68	17.2-21.6	22.08±0.96*	20.5-22.8
T_{min}	4.71±1.61	1.5-6.3	5.52±0.65	4.6-6.2
RH_{max}	92.37±2.26	88-96	97.60±0.54*	97-98
RH_{min}	46.12±6.08	37-52	61.00±4.69*	56-66
PPT	12.50±19.65	0-52	14.4±5.17	8-22
THI	18.97±1.47	16.95-20.76	21.58±0.86*	20.15-22.18

** Significant ($p<0.05$), T_{max} - maximum temperature (^oC), T_{min} - minimum temperature (^oC), RH_{max} - maximum relative humidity (%), RH_{min} - minimum relative humidity (%), PPT - precipitation (mm), THI - temperature humidity index.*

Pasture quality

The analysis of the pasture samples from both stopovers (sites) is shown in Table 3. The pastures at both stopovers were of excellent quality in terms of crude protein (CP>19%), according to the findings of Upreti and Shrestha (2006).

Table 3. Proximate composition of the herbages of two pasture sites of different altitudes in eastern Himalayas Nepal

Site	Dry Matter (%)	Crude Protein (%)	Ether Extract (%)
A	12.78	21.72	2.11
B	12.09	21.08	1.85

The values are the average of the composite samples (n=2) taken from the mixture of the sward samples (n=20, sampling area=0.1 m2)

Physiological parameters

The physiological parameters recorded are presented in Table 4. In site B (with increasing altitude), the overall physiological parameters were found to be lower than at site A. The rectal temperature (p = 0.001), the respiration rate (p=0.001), and the pulse rate (p = 0.001) showed a substantial decrease. Only rectal temperature (p=0.026) was substantially lower in females than in females.

Table 4. Physiological parameters of Baruwal sheep grazing at two altitudinal pasture sites in the eastern Himalayas of Nepal

Parameters	Site A			Site B		
	Overall	Ram	Ewe	Overall	Ram	Ewe
RT	101.18±1.07	101.76±1.17	100.98±0.99	100.35±0.96** p=0.001	100.65±0.84* p=0.026	100.25±1.00** p=0.001
RR	18.38±1.17	18.5±1.37	18.33±1.13	17.42±0.88** p=0.001	17.5±1.04 p=0.06	17.39±0.85** p=0.001
PR	100.67±9.30	99.00±9.87	101.22±9.34	94.33±9.72** p=0.001	96.67±7.96 p=0.225	93.56±10.32** p=0.001

*** Significant at 0.01 level, * Significant at 0.05 level, RT- Rectal temperature (^0C), RR-Respiration rate (times/minute), PR- Pulse rate (times/minute), Values in Mean±SD.*

Haematology

The haematological parameters of Baruwal sheep in transhumance varied as a result of factors including higher altitude, different seasons, and grazing at site B, as shown in Table 5. Significantly higher levels of PCV (p=0.003), Hb (p=0.01), RBC (p = 0.001) and WBC (p=0.002) were observed at site B than at site A. Both sexes experienced a considerable increase, except RBC in men. At site B, there were persistent significant reductions in platelets (p=0.001) and lymphocytes (p=0.024), except lymphocytes in males. Neutrophils were not significantly different between sites B and A overall, but only females (p=0.049) showed a significant increase. In general, no significant change in neutrophils was observed at site B than at site A, but a significant increase was observed only in females (p = 0.049). No sex difference in observed parameters was recorded within a site except that in females there were significantly lower neutrophils (p = 0.040) at site A and lymphocytes (p = 0.033) at site B.

Table 5. Hematologic variables in Baruwal sheep grazing at two altitudinal pasture sites in the eastern Himalayas of Nepal

Parameters	Site A			Site B		
	Overall	Ram	Ewe	Overall	Ram	Ewe
PCV (%)	30.57±2.92	32.00±1.86	30.10±3.10	33.36±2.58** p=0.003	33.76±1.47* p=0.027	32.26±2.88* p=0.016
Hb (g/dl)	10.10±1.06	10.50±0.60	9.96±1.15	10.82±0.83* p=0.010	11.03±0.43* p=0.046	10.76±0.92* p=0.047
RBC ($10^6/mm^3$)	9.03±0.65	9.41±0.53	8.91±0.65	9.95±0.93** p=0.001	10.13±0.56 p=0.116	9.90±1.03** p=0.004
Platelets ($10^3/mm^3$)	465±51	490±32	456±54	422±49** p=0.001	440±59* p=0.028	415±46** p=0.004
WBC ($10^3/mm^3$)	6.60±1.21	6.90±0.88	6.50±1.31	7.92±1.90** p=0.002	8.25±1.23* p=0.046	7.81±2.21* p=0.014
Neutrophil (%)	38.25±6.79	42.17±2.92	36.94±7.25[a]	42.17±5.70 p=0.072	42.00±5.25 p=1.00	42.22±5.98* p=0.049
Lymphocyte (%)	60.25±6.67	56.67±2.65	61.44±7.33	55.75±5.67* p=0.024	56.33±4.88 p=1.00	55.56±6.03*[a] p=0.020

** The difference is significant between sites at the 0.05 level (2-tailed).*
*** The difference is significant between sites at the 0.01 level (2-tailed).*
[a] The difference is significant between men and women within sites at the 0.05 level (2-tailed).
PCV pack cell volume, Hb haemoglobin, RBC red blood cells, WBC white blood cells.

Serum Chemistry

The results of the serum biochemical analysis of Baruwal sheep that graze in two altitudinal pasture sites in the eastern Himalayas of Nepal are shown in Table 6. Site B had significantly lower concentrations of glucose (p=0.001), triglycerides (p=0.001), and cholesterol (p=0.001) than site A. A persistent significant increase in creatinine was observed in both sexes (p=0.004). The amounts of blood urea, albumin, and total protein were similar. Albumin (p=0.001) and total protein (p=0.022) levels were significantly lower in women at location A than in men.

Table 6. Serum chemistry variables in Baruwal sheep looking at two different altitudes in the eastern Himalayas, Nepal

Parameters	Site A			Site B		
	Overall	Ram	Ewe	Overall	Ram	Ewe
Glucose (mg/dl)	77.33±7.09	75.83±7.91	77.83±6.97	72.17±6.30** p=0.001	69.33±4.36* p=0.027	73.11±6.66** p=0.004
Triglyceride (mg/dl)	71.92±21.34	63.91±9.99	74.60±23.59	51.44±13.46* p=0.001	53.97±6.70* p=0.046	50.60±15.14** p=0.004
Cholesterol (mg/dl)	66.59±10.39	69.59±14.32	65.59±9.03	53.29±9.88** p=0.001	56.77±13.84* p=0.046	52.13±8.37** p=0.002
Total Protein (g/dl)	5.91±1.00	6.73±0.50	5.64±0.99[a]	5.71±0.87 p=0.553	5.95±0.81 p=0.116	5.63±0.90 p=0.776
Albumin (g/dl)	3.36±0.48	3.86±0.25	3.20±0.43[b]	3.28±0.52 p=0.123	3.60±0.31 p=0.116	3.17±0.53 p=0.326
Creatinine (mg/dl)	0.92±0.16	0.97±0.15	0.91±0.16	0.99±0.09** p=0.004	1.09±0.09* p=0.046	0.95±0.06* p=0.020
Urea (mg/dl)	48.25±8.45	46.75±9.21	48.75±8.40	45.17±5.47 p=0.123	47.91±5.99 p=0.753	44.26±5.15 p=0.058

** The difference is significant between sites at the 0.05 level (2-tailed).*

*** The difference is significant between sites at the 0.01 level (2-tailed).*

[a] The difference is significant between men and females within the site at the 0.05 level (2-tailed).

[b] The difference is significant between males and females within the site at the 0.01 level (2-tailed).

DISCUSSION

Environmental Factors

Transhuman mobility, according to Moktan et al. (2008), is typically a strategy to deal with poor climatic conditions and utilize available herbage. The environmental conditions along with the migration route are generally comparable during the time spent at a certain altitude and season, keeping animals, in particular, in their comfort zone. If evaluated simultaneously, the lowest and highest elevation of the pastures of transhumance sheep would differ noticeably. The average ambient temperature was found to decrease by 2 °C (3.6 °F) for every 300 m of elevation gain, according to Cymerman et al. (1996).

The widespread notion is that higher elevations typically have cooler temperatures. Higher altitudes in this study were recorded with significantly higher maximum temperatures, relative humidity and temperature-humidity indices than lower altitudes, as indicated by the migration and settlement of a typical transhumance flock. As one may expect, the measurement season is to blame for the discrepancy. Since it rains more frequently and creates more water vapour throughout summer, the relative humidity will increase along with the temperature. The habitat was determined to be comfortable for sheep with a temperature humidity index (THI) of 22.2 at both lower and higher altitudes (Marai et al. 2007), despite changes in climatic conditions.

Physiological parameters

In the present study, the overall result showed that the mean values of physiological parameters in Baruwal sheep of transhumance were significantly higher at lower altitudes. Changes in rectal temperature were highly significant for sex, but respiration and pulse rate were higher in females. According to Brown-Brandl et al. (2003) and Singh et al. (2003), rectal temperature and respiration rate are associated with the surrounding temperature and humidity. According to a study by Sabuncuoglu (2004), the parameter that is most likely to change in response to alterations in the environment and climate is the rate of respiration. According to Chaurasia et al. (2010) and Pangestu et al. (2000), a higher rectal temperature, an increased rate of respiration, and an increased pulse rate were accompanied by a significantly higher ambient temperature in low altitudes. Warm receptors on domestic animals' skin light up in response to ambient temperature. These receptors signal to the hypothalamus, which then causes the breathing rate to rise to cool the body (Hafez, 1968).

The findings of this study, however, suggest that while Baruwal sheep transhumance rectal temperature, respiration rate, and pulse rate are higher in thermos-comfort zones at lower altitudes than in thermos-comfort zones at higher altitudes, the maximum environmental temperature is noticeably lower at low altitudes. If the cold temperature is not a contributing factor, the problems brought on by exposure to high altitudes can be first attributed to the drop in oxygen partial pressure in the surrounding atmosphere and the subsequent reactions of the body. Chronic hypoxia brought on by low oxygen partial pressure at high elevations induces a significant decline in body temperature regardless of whether the cold stimulus is provided or removed (Nair & George 1972). The size of the high-frequency component of heart rate variability, which is typically regulated by the parasympathetic nervous system (Hedman et al., 1995), is also decreased by hypoxia due to a shift in sympathovagal nerve contact toward dominance of the sympathetic system (Perini et al., 1996).

Haematological Variables

In the present study, PCV, Hb, RBC, and WBC have been found to increase significantly at higher altitudes than at lower altitudes. A significant decrease in platelets and lymphocytes was found at higher altitudes. No significant sex differences were detected in PCV, Hb, RBC, WBC, and platelets but significant sex differences have been observed in neutrophils at lower altitudes and lymphocytes at high altitudes. The effects of altitude and season on hematologic parameters in sheep have been explained by some researchers, where PCV, Hb and WBC were significantly higher at high altitude (Šoch et al., 2011; Titaouine & Meziane 2015) and significantly higher in fall than in spring, Reduced partial pressure of oxygen in highly elevated land leads to increased levels of erythropoietin that stimulate erythropoiesis as an adaptive mechanism to cope with lower oxygen levels (Jessen et al., 1991; Storz & Moriyama 2008). In the condition of reduced partial oxygen pressure in the arteries under hypoxia, a modified physiological phenomenon occurs by either changing the concentration of Hb in the blood or changing the oxygen binding affinity of the Hb (Storz, 2007). The former mechanism is more important in the acclimatization response of lowland natives, and the latter one is more important in genetically hypoxia-adapted highland natives ((Birks et al., 1975; Hochachka & Somero, 2002; Lenfant, 1973). Therefore, significantly higher PCV, Hb and RBC values at higher altitudes of 3,391 m asl provide evidence of the adaptability of Baruwal sheep in transhumance to reduced atmospheric oxygen.

There are very limited studies in farm animals related to the effects of altitude on platelet count. Some studies are carried out in humans and have shown conflicting results. Studies in mice and rats with hypobaric hypoxic exposure have more consistent results of reduced platelet count, (Birks et al., 1975). In the study, platelet count decreased significantly at high-altitude sojourn of migratory sheep, which is favoured by the findings of several workers in the human (Lehmann et al., 2006; Sharma 1981). On the contrary, Hudson et al. (1999) demonstrated higher mean platelet count in residents of high altitude and a significant and sustained elevation in platelet numbers with high-altitude ascent. According to Singh and Chohan (1972), in a rapid sojourn to high altitude, there is a tendency of hypercoagulation with increased platelet count, and through a continuous stay in high altitude, there is a regression of state of hypercoagulation with reduced platelet count. A suggested cause of decreased platelet count in sustained hypoxia at high altitudes is stem cell competition between erythroid and platelet precursors (McDonald et al., 1992). The result of this study, a significant decrease in platelet count and a significant increase in RBC at high altitudes, also indicated stem cell competition between RBC and platelet precursors.

In sedentary flocks, Šoch et al. (2011) had reported higher WBC levels at high altitudes, and the magnitude of the increase is greater in the spring season. In the present study, higher WBC was also recorded at high altitudes but in the summer/fall season compared to the spring season values at lower altitudes. As other sources concerning changes in blood markers of migratory flocks at different altitudes are scarce, we can summarize it just as a response to stress and the environment. In the present study, significantly less lymphocyte percentage has been recorded at high altitudes. A similar result has been shown (Facco et al., 2005) on the flow cytometric analysis during acute and chronic altitude exposure in humans. It may be due to depressed cell-mediated immunity since immunity prolonged high-altitude exposure blunts the T-cell activation (Meehan et al., 1988) but has little effect on the humoral immunity (Mishra & Ganju, 2010).

Serum chemistry

With increased altitude, a significant decrease in glucose, triglyceride and cholesterol; and a significant increase in creatinine as detected in transhumance sheep. Various research results have shown that acute or chronic hypoxia influences blood glucose and related hormones, but the influence is mostly inconsistent (Abu Eid et al., 2018; Cheng et al., 1997; Jones et al., 1983). Hypoxia is reported to induce insulin secretion in newborn rats but inhibits it in juvenile rats (Chen et al., 2007; Raff et al., 1999) has demonstrated an early increase and a delayed decrease in blood glucose levels in rats at a simulated altitude of 5000 m asl in a hypobaric chamber. In humans, unchanged blood glucose levels in response to acute hypoxia (Brooks et al., 1991), increased blood glucose after 3 days of hypoxia (Sawhney et al., 1991), and decreased blood glucose below sea level control group after acclimatization to altitude hypoxia ((Fernández-Rodríguez et al., 2015; Young et al., 1992) have been reported.

Zemp et al. (1989) reported that a high-altitude sojourn decreases the blood level of insulin. The decrease in blood glucose levels in this study may be mediated by the decline of blood insulin levels in high altitudes. In the present study, triglyceride and total cholesterol levels were found to decrease significantly with increasing altitude. The finding is supported by similar findings in dairy cattle (El-Masry & Marai, 1991; Titaouine & Meziane, 2015) and rabbits (Okab et al., 2008). They attributed these alterations to the variation in thyroid activity between climatic conditions. Low ambient temperature in comparison to low altitude promotes thyroxin secretion when exposed to high altitudes. The thyroxin hormone activates both liver processes that remove cholesterol from the bloodstream and cholesterol production. Plasma cholesterol level decreases as a result of the latter process outpacing the former. In humans, plasma total cholesterol and LDL cholesterol levels were shown to be significantly reduced (De Mendoza et al., 1979; Verratti et al., 2015). Residents of high altitudes have been found to have elevated HDL cholesterol levels, according to (Atbaev, 1985; Coello et al., 2000; Sharma, 1990). So, the significant decrease in total cholesterol level in the present study may be based on high altitude hypoxia (Benso et al., 2007), regardless of the temperature in the thermo-comfort zone, resulting in decreased LDL-cholesterol and increased HDL-cholesterol which facilitates clearance of former from the circulation. However, further studies, concerning LDL and HDL cholesterol, are required for its verification.

In the present study, a significant increase in creatinine levels was found due to altitude. The results agree with those of (Titaouine & Meziane, 2015). Cirillo (2010), Kreider (2003), Samra and Abcar (2012) claimed that skeletal muscle breaks down phosphocreatine to liberate energy, resulting in the production of creatinine. The relationship between its concentration and muscle mass is inverse. Blood creatinine levels are correlated with muscular dystrophy or exercise (Caldeira et al., 2007). The significant increase in creatinine observed in the current study may be due to higher levels of muscular activity. Genetic characteristics may play an important role in the high-altitude adaptability of transhumance Baruwal sheep similar to the Tibetan sheep (Wei et al., 2016). So, similar research in Baruwal sheep can verify their genetic adaptability at high altitudes.

CONCLUSION

The results of the physiological, haematological, and blood biochemical parameters of Baruwal sheep in transhumance could be an important reference value for researchers, veterinarians, and herders. The result shows that one of the factors governing the stay and movement of the transhumance herd is the environmental factor affecting the animals, especially in the thermo-comfort zone. The temperature, respiration rate, and pulse rate recorded in the summer season in high-altitude pastures are found to be decreased compared to the values observed in the spring season in lower-altitude. Analysis of blood parameters shows that PCV, Hb, RBC, WBC, and creatinine increase, whereas platelets, glucose, triglycerides, and cholesterol levels decrease when the herd is in high-altitude summer pastures but no significant changes in total protein, albumin, and blood-urea. Most of the changes are attributed to high-altitude hypoxia regardless of the temperature because the THI at both stopovers was within the comfort limit. It is difficult to separate the individual effects of different factors (altitude, season, and pasture) on the blood values of animals under the transhumance system because simultaneous changes in these factors occur with the movement pattern. So, the findings of the present study suggest that altitude, season, and pasture quality have individual and interaction impacts on the blood parameters of Baruwal sheep fed transhumance.

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