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Full Length Research Paper

Variation of the platelet indices of dromedary camel (*Camelus dromedarius*) with age, sex and breed

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The objective of this study was to determine reference intervals for platelet indices and hematological parameters in Saudi Arabian dromedary camels. Two hundred and twenty one apparently healthy dromedaries of *Majahim* (51 males and 31 females) and *Maghatir* (99 males and 40 males) breeds aged 1 - >10 yrs were investigated. Whole blood samples from the camels were analyzed for platelet count, platelet size indices and hematological parameters using an electrical impedance hematology system. Mean platelet indices values for *Majahim* camels were as follows: platelet count: 212.17 ± 10.76 (x10^9/L); plateletcrit: 0.12 ± 0.01%; Mean platelet volume: 5.28 ± 0.05 fL and platelet distribution width: 26.0±0.37%. Corresponding mean values for *Maghatir* camels were: 211.12 ± 7.53 (x10^9/L); 0.12 ± 0.01%; 5.11 ± 0.04 fL and 24.82 ± 0.30%, respectively. No significant differences in platelet counts and platelet indices were detected between the two breeds. Different platelet indices revealed statistically significant age- and gender-related differences. Hematological parameters showed breed, age and intersex differences in mean corpuscular volume and mean corpuscular hemoglobin. Sex and age-related differences were also found in red cell distribution width in addition to age-related differences in hematocrit and mean corpuscular hemoglobin concentration. Platelet indices revealed significant correlations among themselves and with platelet counts.

Key words: *Camelus dromedarius*, *Majahim*, *Maghatir*, platelet count, plateletcrit, mean platelet volume, platelet distribution width.

INTRODUCTION

Blood platelets are essential components of hemostasis. Their functions include maintaining vascular integrity through the formation of primary hemostatic plug, enhancing vasoconstriction at the site of vascular injury and promoting vascular healing through the release of growth factors to stimulate endothelial cell migration and production of smooth muscles. Surface phospholipids of activated platelets are also involved in activating the coagulation cascade during secondary hemostasis and fibrin formation (Prater, 2003). Apart from their fundamental role in hemostasis, blood platelets perform several other physiological and homeostatic functions (McNicols and Israels, 2008). They are involved in immune responses and host-defense mechanisms such as recognizing and binding bacteria, secreting cytokines and chemokines, recruiting immune cells to the infection sites and clearing invading organisms from the circulation (von Hundelshausen and Weber, 2007). They also release adhesive proteins, growth factors and inter-cellular signals that facilitate wound healing and repair. Besides, platelets are involved in non-hemostatic pathological processes including acute and chronic inflammation and the development and progression of malignant diseases (McNicols and Israels, 2008). The physiological, diagnostic and prognostic relevance of

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Table 1. Platelet indices and hematological parameters in Majahim and Maghatir Dromedary Camels (*Camelus dromedarius*).

Parameter	Majahim (n = 82)		Maghatir (139)		Total (221)	
	Mean ± SEM	Range	Mean ± SEM	Range	Mean ± SEM	Range
PLT (x10^9/L)	212.17 ± 10.76	92.0 - 625.0	211.12 ±7.53	92.0 - 494.0	211.52 ± 6.18	92.0 - 625.0
PCT (%)	0.12 ± 0.01	0.06 - 0.32	0.12 ± 0.01	0.06 - 0.58	0.12 ± 0.01	0.06 - 0.58
MPV (fL)	5.28 ± 0.05	4.60 -6.30	5.11 ± 0.04	4.50 - 6.50	5.17 ± 0.03	4.50 - 6.50
PDW (%)	26.0 ± 0.37	20.70 - 31.20	24.82 ± 0.30	19.50 - 31.20	25.26 ± 0.023	19.50 - 31.20
RBC (x10^{12}/L)	10.38 ± 0.15	7.25 - 14.35	10.55 ± 0.1.36	6.22 - 14.79	10.48± 0.09	6.22 - 14.79
HB (g/dL)	13.19 ± 0.20	8.70 - 16.80	12.82 ± 0.14	9.50 - 19.20	12.96 ± 0.11	8.70 - 19.20
HCT (%)	27.81 ± 0.40	19.81 - 41.02	26.92 ± 0.27	20.19 - 40.34	27.26 ± 0.23	19.81 - 41.02
MCV (fL)	26.71 ± 0.22[a]	22.10 - 31.0	25.65 ± 0.18[b]	21.0 - 30.0	26.05 ± 0.14	21.0 - 31.0
RDW (%)	25.73 ± 0.22	22.10 - 30.80	25.94 ± **0**.18	22.20 - 33.60	25.86 ± 0.14	22.10 - 33.60
MCH (pg)	12.78 ± 0.10 [a]	11.0 - 15.30	12.22 ± 0.07[b]	10.10 - 14.60	12.43 ± 0.06	10.10 - 15.30
MCHC (g/L)	47.81 ± 0.25	40.30 - 52.80	47.67 ± 0.21	41.80 - 55.50	47.72 ± 0.16	40.30 - 55.50
TLC (x10^9/L)	15.95 ± 0.52	6.41 - 23.72	15.54 ± 0.41	4.44 - 23.98	15.95 ± 0.52	4.44 - 23.98

Data in the same row bearing different lowercase letters are statistically different (P≤0.05).
PLT = Platelet count, PCT = plateletcrit, MPV = mean platelet volume, PDW = platelet distribution width, RBC = total erythrocyte count, HB = hemoglobin, HCT = hematocrit, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, RDW = red cell distribution width, TLC = total leucocyte count.

platelet indices is therefore receiving increasing attention in human and more recently in veterinary medicine.

The values of platelet indices differ widely between species and within the species depending on several factors such as breed, sex, age, nutrition and health status. Published information on the values of these indices in dromedary camels is very scant (Hussein et al., 2010). This study was therefore undertaken to expand our knowledge of the normal ranges of platelet count (PLT) and three major platelet indices: plateletcrit (PCT), mean platelet volume (MPV) and platelet distribution width (PDW) in camels in relation to breed, age and sex. Such information is an important pre-requisite for studies on the usefulness of these parameters in the diagnosis and clinical interpretations of diseases, particularly diseases associated with changes in the bone marrow.

MATERIALS AND METHODS

Two hundred and twenty one dromedary camels were randomly sampled at farms in Riyadh region between January to June, 2011. The animals belonged to two indigenous breeds, *Majahim* and *Maghatir*, and comprised a total of 153 males and 68 females, aged 6 month to >10yrs. All of them were apparently normal at the time of sampling. None of them had previous history of hematological disorder and none of the adult females was pregnant or lactating. Ten milliliter (10 mL) blood sample was collected from the jugular vein of each camel into EDTA-K2 vacutainer tube (Becton, Dickinson and Co. USA), gently mixed and transported in ice to the laboratory. The samples were analyzed within 1 h of collection for the following parameters using an electrical impedance hematology analyzer (VetScan HM2 Abaxis Veterinary Diagnostics, Union City, CA 94587 USA): Platelet count (PLT), plateletcrit (PCT), mean platelet volume (MPV) and platelet distribution width (PDW), along with total red blood cells (RBC), hemoglobin (HB), hematocrit (HCT), mean corpuscular volume (MCV), red cell distribution width (RDW), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (HCHC) and total leucocyte count (TLC). The data were statistically analyzed using a general linear model in SAS 8.1 program for Windows. Shapiro-Wilk test for normality showed normal distribution in all parameters. Pearson's correlation tests were used to determine the correlation between PCT, MPV and PDW and corresponding erythrocytic parameters, namely, HCT, MCV and RDW, respectively as well as the correlation between platelet indices among themselves and with PLT (Schork and Remington, 2000). Statistically significant difference was set at $p < 0.05$.

RESULTS

Mean values and ranges of PLT, platelet indices and hematological parameters of *Majahim* and *Maghatir* camels are summarized in Table 1. Statistical analysis using t-test showed that no statistically significant differences were found between these two breeds in overall mean PLT, PCT, MPV and PDW values. Most of the hematological values were also comparable in the two breeds, with the exception of MCV and MCH values which were higher in *Majahim* as compared to *Maghatir* camels ($p<0.05$).

To investigate the effect of age, the camels were divided into three age groups: Juvenile camels, aged 6 months to < 3 yrs; young adults aged 3 to 6 yrs and adults aged more than 6 years (Table 2). Analysis of variance revealed significant age-associated differences in PLT, PCT, MPV and PDW values, as well as hematological indices except RBC, HB and TLC values.

As shown in Table 3, no significant intersex differences were recorded in the mean PCT, RBC, HB and TLC values of either *Majahim* or *Maghatir* breeds. However, both breeds exhibited significant intersex differences with

Table 2. Platelet indices and hematological parameters in Majahim and Maghatir Dromedary Camels (*Camelus dromedarius*) according to Age.

Parameter	Juvenile (n = 155)		Young adult (n = 29)		Adult (n = 37)	
	Mean ± SEM	Range	Mean ± SEM	Range	Mean ± SEM	Range
PLT (x10^9/L)	214.14±6.97^a	92.0-625.0	178.8±17.98^b	100.0-473.0	221.8±17.57^a	92.0-625.0
PCT (%)	0.12±0.01^a	0.06-0.58	0.10±0.01^a	0.06-0.28	0.14±0.01^b	0.06-0.29
MPV (fL)	5.09±0.03^a	4.50-6.30	5.06±0.09^a	4.60-6.20	5.48±0.09^b	4.60-6.50)
PDW (%)	24.49±0.25^a	19.50-31.20	25.89±0.70^a	20.70-31.20	28.10±0.58^b	20.70-31.20
RBC (x10^{12}/L)	10.62±0.10	6.22-14.35	10.10±0.29	7.59-12.94	10.16±0.25	7.54-14.79
HB (g/dL)	12.90±0.12	8.70-16.80	12.77±0.30	9.90-16.10	13.48±0.35	9.50-19.20
HCT (%)	27.0±0.25^a	19.81-41.02	26.98±0.31^a	21.73-33.54	28.57±0.70^b	20.68-40.34
MCV (fL)	25.38±0.15^a	21.0-29.0	26.80±0.42^b	24.0-30.0	28.32±023^c	26.0-31.0
RDW (%)	26.46±0.15^a	22.20-33.60	24.93±0.27^b	22.90-28.50	23.99±0.18^b	22.10-26.70
MCH (pg)	12.15±0.06^a	10.10-13.90	12.54±0.13^a	11.50-14.50	13.53±0.14^b	11.90-15.30
MCHC (g/L)	47.86±0.20^a	40.30-55.50	46.74±0.42^b	41.80-50.60	47.81±0.28^{ab}	45.0-51.60
TLC (x10^9/L)	15.36±0.38	4.95-23.72	16.30±0.94	4.44-23.98	17.04±0.74	10.87-23.08

Data in the same row bearing different lowercase letters are statistically different (P≤0.05).
PLT = Platelet count, PCT = plateletcrit, MPV = mean platelet volume, PDW = platelet distribution width, RBC = total erythrocyte count, HB = hemoglobin, HCT = hematocrit, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, RDW = red cell distribution width, TLC = total leucocyte count.

regards to PDW, RDW, MCV and MCH. Besides, *Maghatir* camels had significantly higher PLT and MCHC values in male than female camels, while *Majahim* camels had significantly higher MPV value in male than female camels.

Significant correlations were recorded among the platelet indices and between these indices and platelet count (PLT) (Table 4). Correlation analyses between platelet indices and corresponding RBC indices (Table 5) also showed significant positive correlation between MPV and MCV, significant negative correlation between PDW and RDW and significant positive correlation between PDW and MCV.

DISCUSSION

The present values of PLT, platelet size indices and hematological parameters in *Majahim* and *Maghatir* camels are consistent with those previously recorded in *Najdi* camels (2010). The overall mean PLT value was also comparable to that recorded in other species of wild desert ungulates in Saudi Arabia such as mountain gazelle (*Gazella gazella*), sand gazelle (*Gazella subgutturosa marica*) and in the Speke's gazelle (*Gazella spekei*) (Travis and Eby, 2006). However, it was lower than that recorded in the llama and alpaca (Summerfield et al., 2002), cattle (Ahola et al., 2006), sheep (Jain, 1993) and goats (Boudreaux and Ebbe, 1998). In common with other species of domestic and wild ruminants (Boudreaux and Ebbe, 1998; Travis and Eby, 2006; Hussein et al., 2010; Aljumaah and Hussein, 2011), PLT value in camels exhibited a wide range of variation (92.0 - 625.0 x10^9/L).

Platelet size indices (MPV, PCT and PDW) along with platelet counts are important markers of platelet size, function and reactivity (Bath and Butterworth 1996; Žvorc et al., 2010). The present results confirmed earlier observations that PCT and MPV values in camels were far less (~50%) than those in humans. This is consistent with the findings of Lewis (1976) who reported that camel platelet diameter was considerably smaller than that of human platelets (1 µm versus 2-3 µm). In addition to their smaller size, camel platelets also exhibited much less anisocytosis than human platelets, with mean PDW in camels being <27% as compared to 46.8% in humans (Wiwanitkit, 2004). The PCT, MPV and PDW values in camels were also lower than those reported in our laboratory for other Arabian desert ungulates.

The mean platelet number and platelet indices in the present camels did not differ significantly between *Majahim* and *Maghatir* breeds. Besides, no significant inter-sex differences were found in PLT and PCT values in either breeds while significantly higher MPV and PDW were recorded in female camels. These results are at variance with those reported in humans where all of these indices were gender-related, with higher PLT, PCT and MPV values in women and higher PDW value in men, suggesting "a hormonal influence in their regulation" (Nagata et al., 2003; Butkiewicz et al., 2006; Santimone et al., 2011). None of the present female camels was pregnant and therefore the effect of pregnancy on platelet values in these animals could not be investigated. However, in human females, platelet count and PCT were shown to decrease with gestational age while MPV and PDW did not change during gestation (Mercelina-Roumans et al., 1995).

Breed, sex and age are among the factors known to

Table 3. Platelet indices and hematological parameters in Majahim and Maghatir Dromedary Camels (*Camelus dromedarius*) according to sex

Parameter	Males (n=51)		Females (n=31)		Males (n=99)	
	Male (n = 51)	Female (n = 31)	Male (n = 99)	Female (n = 40)	Male (n = 150)	Female (n = 71)
PLT (x10^9/L)	208.46±12.82	218.46±19.63	215.89±8.19	196.26±16.70	213.90±6.66	200.81±12.80
PCT (%)	0.11±0.01	0.13±0.01	0.11±0.01	0.11±0.01	0.12±0.01	0.12±0.01
MPV (fL)	5.20±0.06^a	5.41±0.09^b	5.08±0.04	5.19±0.08	5.11±0.04^a	5.29±0.06^b
PDW (%)	25.32±0.67^a	27.31±0.67^b	24.43±0.33^a	25.85±0.59^b	24.70±0.26^a	26.50±0.45^b
RBC (x10^{12}/L)	10.51±0.19	10.17±0.26	10.50±0.17	10.31±0.24	10.59±0.11	10.25±0.18
HB (g/dL)	12.97±0.23	13.55±0.34	12.89±0.23	12.81±0.32	12.87±0.12	13.16±0.24
HCT (%)	27.54±0.51	28.24±0.66	26.27±0.33	27.63±0.65	26.95±0.26	27.90±0.46
MCV (fL)	26.02±0.25^a	27.84±0.30^b	25.38±0.32^a	24.14±0.30^b	25.40±0.15^a	27.46±0.21^b
RDW (%)	26.41±0.25^a	24.61±0.31^b	26.04±0.29^a	24.92±0.26^b	26.36±0.16^a	24.78±0.20^b
MCH (pg)	12.43±0.11^a	13.35±0.10^b	12.02±0.38^a	12.63±0.13^b	12.19±0.07^a	12.96±0.11^b
MCHC (g/L)	47.71±0.35	47.81±0.25	48.60±0.47^a	46.71±0.32^b	47.92±0.20	47.28±0.25
TLC (x10^9/L)	15.32±0.68	15.95±0.72	16.72±0.54	15.26+0.84	15.53±0.39	15.10±0.57

Data in the same row bearing different lowercase letters are statistically different (P≤0.05).
PLT = Platelet count, PCT = plateletcrit, MPV = mean platelet volume, PDW = platelet distribution width, RBC = total erythrocyte count, HB = hemoglobin, HCT = hematocrit, MCV = mean corpuscular volume, MCH = mean corpuscular hemoglobin, MCHC = mean corpuscular hemoglobin concentration, RDW = red cell distribution width, TLC = total leucocyte count.

Table 4. Correlation coefficients among platelet parameters.

Parameter	PCT (%)	MPV (fL)	PDW (%)
PLT (x10^9/L)	0.80**	0.39*	0.34**
PCT (%)		0.43**	0.32*
MPV (fL)			0.91**

* P<0.05 ** P<0.005.
PCT, Plateletcrit; MPV, mean platelet volume; PDW, platelet distribution width.

Table 5. Correlation coefficients between PLT, PCT, MPV and PDW with their parallel red blood cells parameters (RBC, HCT, MCV and RDW).

Parameter	RBC(x10^{12}/L)	HCT (%)	MCV (fL)	RDW (%)
PLT(x10^9/L)	0.26	0.26	-0.17	0.23
PCT (%)	0.07	0.11	-0.02	0.23
MPV (fL)	0.01	0.05	0.46**	-0.32*
PDW (%)	0.25	-0.08	0.60**	-0.44**

* P<0.05 ** P<0.005.
RBC, Total erythrocyte count; MCV, mean corpuscular volume; RDW, red cell distribution width.

affect the haemogram in different species of animals (Jain, 1993). In the present study, most hematological parameters were closely comparable in the two camel breeds. However, MCV and MCH were significantly higher in *Majahim* than *Maghatir* camels and in female versus male camels. On the other hand, HCT, MCV, MCH and MCHC values were highest in adult camels aged >6 yrs as compared to younger camels. The RDW is a new quantitative measure of anisocytosis in red blood cells. Its value in the camel ranged between 22.1 to 33.6%, which is similar to that of the Arabian oryx but lower than that recorded in goats (Piccionei et al., 2010)

and palm cevet, *Paradoxurus hermaphroditus* (Salakij et al., 2007) and higher than that recorded in humans (Wiwanitkit, 2004), cattle (Yilmaz and Yeşilbağ, 2008), sheep (Fazio et al., 2011), equines (Thrall et al., 2004), African buffalo (Beechler et al., 2009) and desert gazelles. Accor-ding to Žvorc et al. (2010), RDW value is elevated in conditions associated with increased red cell destruction such as hemolytic diseases and in those associated with decreased red cell production, such as iron deficiency anemia and vitamin B12 deficiency.

The values of Pearson's correlation for platelet parameters in the camels were at variance with those reported in humans (Wiwanitkit, 2004). In camels, the correlation was significant between each platelet index and the remaining platelet indices. However, no significant correlation was found between platelet indices and either RBC or HCT, while significant positive correlation was found between MPV and MCV and significant negative correlation between PDW and RDW. In humans, there was no significant correlation between PCT and HCT nor between MPV and MCV while significant correlation was found between PDW and RDW suggesting that anisocytosis of red blood cells and platelets might co-occur in humans (Wiwanitkit, 2004). The results in camels were also different from those reported in dogs and cats in which both MPV and PDW varied in a negative relationship with PLT (Weiser and Kociba, 1984; Boudreaux and Ebbe, 1998; Bommer et al., 2008).

No information is currently available regarding the clinical interpretations of platelet indices in camels, while only a few studies have been documented on the association between these indices and disease conditions in other species of animals, particularly large animals. In general, however, platelet indices can provide information about the underlying conditions of anemia and thrombocytopenia (Kaito et al., 2004; Vizioli et al., 2009; Žvorc et al., 2010). MPV, along with MCV, can serve as an indirect indicator of bone marrow disturbances and response to infections (Wiwanitkit, 2004; Yilmaz and Yeşilbağ, 2008). The PCT or platelet mass is regarded as "the most relevant physiological parameter of platelet status," and its value decreases significantly during thrombocytopenia and the resultant decline in platelet number (Žvorc et al., 2010). The PDW is a measure of platelet anisocytosis and increase in its value has been reported in sickle cell anemia in humans (Amin et al., 2004). It may also be useful in the diagnosis of immune thrombocytopenia in humans (Kaito et al., 2004) as well as the diagnosis and monitoring of human and canine endotoxemia (Yilmaz et al., 2008).

Finally, some of the diseases known to affect platelet indices in man and animals, particularly diseases associated with hemolytic anemia, hypersplenism or impaired bone marrow function may occur in camels and it is therefore imperative to determine the usefulness of platelet indices in the prognosis and diagnosis of these diseases in camels.

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