

Solute loads and transfer function of kidney in dromedary camel during dehydration and rehydration in winter and summer

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ABSTRACT

The effect of dehydration and rehydration was studied during winter and summer on solute loads and transfer function of kidney in healthy adult female dromedary camels. Kidney solute loads (KSLs) which included plasma loads (PL) and tubular loads (TL) were determined for glucose, proteins, urea, creatinine, sodium, potassium, chloride, calcium and phosphorus. The dehydration period was of 24 days in winter and 13 days in summer. Water was provided *ad libitum* during control and rehydration periods and was restricted completely during dehydration period. The mean value of TFK during summer control was significantly ($P \leq 0.05$) lower than that in winter control. In winter the mean values of TFK during rehydration phases differed significantly ($P \leq 0.05$) from control values. A similar trend was observed during summer, except that the calculations for TFK could not be made at hour ½ and at hour 2 of rehydration since animals did not void urine. During dehydration periods in both seasons PL and TL mean values decreased significantly ($P \leq 0.05$) from respective control mean values. It was concluded that during dehydration reduction in kidney solute loads was indicative of the water conservation ability of camels because reduced plasma loads and tubular loads resulted in trapping of constituents in the plasma to hold more water.

Key words: dehydration, dromedary, kidney solute loads, rehydration, summer, transfer function of kidney, winter

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Introduction

Salt and water balance is an important function of the kidneys which can be determined by solute loads and transfer function of the kidney. Kidney solute load includes the concentration of a constituent in plasma that is presented to the kidneys per minute (plasma load) and the part of it that filters into the Bowman's capsule (tubular load). Various constituents of plasma alter urine composition, although the degree varies from constituent to constituent, in the same way that maximal urinary concentrating ability is influenced by relative contribution of urea to the total solute composition of final urine (KATARIA et al., 2001a). Some constituents, like proteins, are indicators of the hydration status of the body (KATARIA et al., 2005). Renal handling of salt or electrolytes and water is important in maintaining homeostasis. Any disturbance in this process may evoke sequential changes in other organs or systems as almost all the metabolic processes are either affected or dependent on electrolytes or salt and water concentrations. Determination of kidney solute loads gives the complete picture of the renal functioning of an animal as it involves glomerular filtration rate, effective renal plasma flow and plasma concentration of the constituent. When this aspect is combined with the transfer function of the kidney, which is the ratio of urine volume and water intake, it provides fairly accurate information about water balance by the kidneys. Transfer function of kidney is also significant in determining kidney efficiency during stress periods, particularly due to diseases producing dehydration and water scarcity (MEENA and KATARIA, 2004).

The camel is the most efficient domesticated animal used for transport, milk and meat and has great ability to perform in hostile environments. With the changing scenario of camel management, investigations into the adaptation of camel, with special reference to renal handling of salt and water, is extremely important for proper health management and its economical use. However, there is a paucity of literature on this aspect for dromedary camel. Further in the field conditions the camel faces long periods of dehydration due to unavailability of water, as they are mostly reared in areas suffering from a scarcity of water and experiencing famine conditions. On the other hand, when water is made available to them they drink at length, thereby inducing rapid rehydration. To understand the physiological changes and adjustments taking place during such situations in camels the best experimental model is to simulate these conditions experimentally by restricting water for longer periods (KATARIA et al., 2003) and then by providing water *ad libitum*.

Therefore, an investigation was carried out to discover the changes in kidney solute loads and transfer function of the kidney during dehydration and rehydration in winter and summer in camels.

Materials and methods

Animals. Eight apparently healthy (having no infection and ecto- or endoparasitic infestation) adult female camels (*Camelus dromedarius*) belonging to National Research Centre on Camel, Bikaner, were used.

Experimental design. The experiment was designed to determine kidney solute loads (KSLs) and transfer function of the kidney (TFK) during dehydration and rehydration in winter and summer when the minimum and maximum ambient temperatures (°C) were 5.58 ± 0.46 and 20.43 ± 0.3 during winter and 29.51 ± 0.47 and 44.78 ± 0.41 during summer, and relative humidities (%) were 83.75 ± 3.74 and 48.89 ± 3.41 during winter and 34.22 ± 1.97 and 12.77 ± 1.26 during summer at 8.30 am and 5.30 pm, respectively.

Eight camels were used for TFK, and four for KSLs. The same animals were used in both seasons and each animal served as its own control. The experiment was divided into control, dehydration and rehydration phases. The dehydration phase was 24 days in winter, and 13 days in summer when water was completely restricted. However, feed (dry chaffed *Phaseolus aconitifolius* plants as sole roughage diet) was provided *ad libitum*. Water and feed were provided *ad libitum* during control and rehydration phases which were of 10 and 5 days duration, respectively, in each season.

All camels were catheterised as per the technique of KATARIA et al. (1999) to collect urine samples.

Kidney solute loads were calculated as described by SWENSON and REECE (1996) for glucose, protein, urea, creatinine, sodium, potassium, chloride, calcium and phosphorus. These constituents were measured in the plasma by the methods as described by OSER (1976).

Plasma loads for various constituents were determined as per the formulae given below:

For glucose, urea, creatinine, calcium and phosphorus:

$$\text{PL mg/min} = \frac{\text{Plasma concentration of constituent, mg/dL} \times \text{ERPF mL/min}}{100}$$

For sodium, potassium and chloride:

$$\text{PL mmol/min} = \frac{\text{Plasma concentration of constituent, mmol/L} \times \text{ERPF mL/min}}{1000}$$

For protein:

$$\text{PL g/min} = \frac{\text{Plasma concentration of constituent, g/L} \times \text{ERPF mL/min}}{1000}$$

Tubular loads for various constituents were determined as per the formulae given below:

For glucose, urea, creatinine, calcium and phosphorus:

$$TL \text{ mg/min} = \frac{\text{GFR mL/min} \times \text{plasma concentration of constituent, mg/dL}}{100}$$

For sodium, potassium and chloride

$$TL \text{ mmol/min} = \frac{\text{GFR mL/min} \times \text{plasma concentration of constituent, mmol/L}}{1000}$$

For protein:

$$TL \text{ g/min} = \frac{\text{GFR mL/min} \times \text{plasma concentration of constituent, g/L}}{1000}$$

To calculate the values of plasma and tubular loads, GFR was determined by using inulin clearance and ERPF by para aminohippuric acid clearance (KATARIA et al., 2001b).

The transfer function of the kidney (TFK) was determined as per the formula given by PUROHIT et al. (1972).

$$TFK = \frac{\text{Urine Volume (L) / day}}{\text{Water Intake (L) / day}}$$

Statistical analysis. The experiment in each season was divided into three phases and their subsets, viz. days (dehydration phase) and hours (rehydration phase). For each subset, data were expressed as mean \pm SE of mean. The changes in means were measured as the difference between the control mean and the value at a particular subset, whether each mean change was significantly different from control was assessed by paired 't' test (SNEDECOR and COCHRAN, 1967).

Results

The mean \pm SEM values of plasma and tubular loads of glucose, protein, urea, creatinine, sodium, potassium, chloride, calcium and phosphorus during control, dehydration and rehydration phases in winter and summer are presented in Table 1, and that of transfer function of the kidney in Table 2.

Table 1. Kidney solute loads in camels during dehydration and rehydration in winter and summer (Mean \pm SE, N = 4)

Parameters	Winter						Summer					
	Control phase		Dehydration phase (24 days)		Rehydration phase (96 hrs)		Control phase		Dehydration phase (11 days)		Rehydration phase (96 hrs)	
	PL	TL	PL	TL	PL	TL	PL	TL	PL	TL	PL	TL
Glucose (mg/min)	2696.04 \pm 780.123	784.742 \pm 45.981	782.509 \pm 34.215	142.733 \pm 10.651	3157.165 \pm 131.806	765.796 \pm 30.708	3464.437 \pm 88.415	549.526 \pm 26.25	438.231 \pm 21.847	55.833 \pm 3.321	3235.975 \pm 116.954	603.96 \pm 17.555
Proteins (g/min)	216.451 \pm 10.473	47.844 \pm 2.100	63.821 \pm 2.656	11.587 \pm 0.521	183.799 \pm 9.389	44.534 \pm 1.903	223.50 \pm 8.104	35.357 \pm 1.231	41.694 \pm 0.953	5.317 \pm 0.266	198.590 \pm 7.446	37.074 \pm 1.244
Urea (mg/min)	633.549 \pm 55.282	139.484 \pm 9.363	965.875 \pm 56.371	175.839 \pm 12.974	622.537 \pm 72.282	150.698 \pm 16.820	873.147 \pm 70.852	137.414 \pm 7.556	375.774 \pm 26.140	48.089 \pm 4.646	788.674 \pm 50.359	149.472 \pm 9.930
Creatinine (mg/min)	42.994 \pm 6.025	9.478 \pm 1.227	38.699 \pm 1.347	5.853 \pm 1.548	43.471 \pm 4.50	10.497 \pm 0.922	61.097 \pm 6.816	9.625 \pm 0.896	27.621 \pm 2.304	3.523 \pm 0.332	55.045 \pm 2.473	10.255 \pm 0.206
Sodium (mmol/min)	476.294 \pm 22.144	105.15 \pm 3.255	154.990 \pm 8.475	28.137 \pm 1.592	429.913 \pm 21.385	104.058 \pm 3.075	494.483 \pm 15.045	78.214 \pm 2.039	95.773 \pm 3.611	12.225 \pm 0.794	456.74 \pm 15.59	85.285 \pm 2.583
Potassium (mmol/min)	15.933 \pm 0.998	3.509 \pm 0.132	4.350 \pm 0.222	0.789 \pm 0.040	14.716 \pm 1.09	3.55 \pm 0.190	15.889 \pm 1.04	2.505 \pm 0.110	2.644 \pm 0.164	0.338 \pm 0.029	14.00 \pm 0.805	2.609 \pm 0.110
Chloride (mmol/min)	313.872 \pm 14.669	69.368 \pm 2.832	105.741 \pm 5.14	19.212 \pm 1.074	283.119 \pm 11.713	68.60 \pm 2.078	334.926 \pm 8.926	52.979 \pm 1.239	68.157 \pm 2.955	8.702 \pm 0.613	308.119 \pm 14.093	57.472 \pm 1.937
Calcium (mg/min)	291.793 \pm 13.306	64.738 \pm 4.123	100.879 \pm 4.931	18.375 \pm 1.290	258.482 \pm 8.926	62.632 \pm 1.193	314.295 \pm 15.365	49.899 \pm 3.513	62.047 \pm 4.06	7.923 \pm 0.668	284.474 \pm 17.920	52.917 \pm 1.918
Phosphorus (mg/min)	130.983 \pm 9.339	29.235 \pm 3.267	38.533 \pm 3.546	7.057 \pm 0.879	107.522 \pm 7.867	26.143 \pm 2.215	139.912 \pm 12.465	22.344 \pm 2.704	24.428 \pm 2.07	3.113 \pm 0.294	108.474 \pm 5.594	20.343 \pm 1.347

PL = Plasma load; TL = Tubular load; N = Number of camels

The PL mean values for glucose, proteins, urea, creatinine, sodium, chloride, calcium and phosphorus were non-significantly ($P>0.05$) higher during summer control than winter, except that of potassium, which was slightly higher during winter control.

Dehydration resulted in a decrease in the mean values of PL and TL of all constituents, except urea in each season. On day 24 of winter dehydration the percentage declines for PL and TL were 70.97 and 81.81; 70.51 and 75.78; 9.98 and 38.24; 67.45 and 73.24; 72.69 and 77.51; 66.31 and 72.30; 65.42 and 71.61; and 70.58 and 75.86 for glucose, proteins, creatinine, sodium, potassium, chloride, calcium and phosphorus, respectively. The percentage increase for PL and TL of urea was 152.45 and 126.06, respectively.

Table 2. Transfer function of the kidneys (TFK) in camels during winter and summer (Mean \pm SEM, N = 8)

Main effects	Winter	Summer
Control phase	0.305703 ^a \pm 0.013954	0.068943 ^a \pm 0.004458
Rehydration phase 1/2 hour	0.004519 ^b \pm 0.000296	-
2 hrs	0.006581 ^c \pm 0.000425	-
12 hrs	0.034187 ^d \pm 0.001863	0.003400 ^b \pm 0.000358
24 hrs	0.045945 ^e \pm 0.002578	0.003256 ^b \pm 0.000223
48 hrs	0.203261 ^f \pm 0.0018226	0.016614 ^c \pm 0.000947
72 hrs	0.260579 ^g \pm 0.012895	0.023634 ^d \pm 0.00137
96 hrs	0.280605 ^{ag} \pm 0.015082	0.051979 ^{ac} \pm 0.003042
120 hrs	0.294004 ^{ag} \pm 0.015925	0.061734 ^{ac} \pm 0.003750

Subclass means within a given season superscribed by same letter do not differ significantly ($P>0.05$) from each other. N = Number of camels.

On day 11 of summer dehydration the percentage declines for PL and TL were 87.35 and 89.83; 81.34 and 84.96; 65.0 and 56.96; 54.79 and 63.39; 80.63 and 84.36; 83.25 and 86.50; 79.65 and 83.57; 80.25 and 84.12; and 82.54 and 86.06 for glucose, protein, urea, creatinine, sodium, potassium, chloride, calcium and phosphorus, respectively. Rehydration in each season resulted in an increase in the mean values of all constituents. At hour 96, control levels were almost attained in each season.

The mean value of TFK during summer control was significantly ($P \leq 0.05$) lower than winter control. In winter, the mean values of TFK during control and rehydration phases differed significantly ($P \leq 0.05$) from each other. The mean value at hour 96 of rehydration approached control mean value, as the difference between them was non-significant ($P > 0.05$). A similar trend was observed during summer, except that the calculations for TFK could not be made at hour $\frac{1}{2}$ and 2 of rehydration, since animals did not void urine.

Discussion

The mean values of plasma loads of different constituents in winter and summer during control phase reflected their amounts in plasma that were presented to the kidneys each minute. The mean values were non-significantly higher due to a non-significant rise in effective renal plasma flow (ERPF) during summer. As plasma loads were dependent upon ERPF, the higher concentrations of plasma constituents, along with high ERPF, resulted in higher plasma loads.

During the dehydration phase the amount presented to kidneys by the plasma reduced drastically, possibly due to a decrease in ERPF in each season (YAGIL and BERLYNE, 1978). This resulted in increased plasma concentrations of the constituents in the present study during dehydration. KATARIA et al. (2002b) also reported a rise in serum constituents during dehydration in dromedary camels. This feature directly reflected towards the water conservation ability of camels, as hypernatraemia helped the camel to hold water (KATARIA et al., 2002b). Higher plasma urea levels indicated camels' ability to utilize urea nitrogen during dehydration (NYANG'AO et al., 1997).

The tubular loads of different constituents showed the part of the respective plasma loads that filtered into Bowman's capsule. These were the amounts presented to the tubules regardless of whether or not they were reabsorbed. They were dependent upon GFR. Therefore, in contrast to the plasma loads, the tubular loads were found to be lower for most of the constituents in summer as GFR was low in summer (MEENA and KATARIA, 2003). With the progression of dehydration the amount presented to tubules were greatly reduced *pari passu* with GFR. As rehydration tended to restore GFR the tubular loads also returned towards normal control mean value. Rehydration caused an increase in mean values of PL due to the restoration of normal renal plasma flow. Plasma urea levels rose greatly in dehydrated camels and therefore a greater amount of urea was presented to kidneys during winter dehydration. KATARIA et al. (2001a) observed higher urea clearance during winter in camels. Increased plasma creatinine could also be the outcome of decreased GFR and increased muscle breakdown during dehydration (KATARIA et al., 2002b).

The higher control mean TFK value during winter was due to lower water intake and higher urine production than in summer. This showed that a normally hydrated camel had fairly good TFK, since environmental temperature was low. During summer, even normally hydrated camels (control) had a depressed TFK, owing to conservation of water by decreasing urine production. In summer, water intake was 2.32 times higher and urine output was 1.95 times lower than that in winter. KATARIA et al. (2002a) also observed depressed renal functions in the heat of summer in camels. The lower value of TFK in control camels during summer was indicative of an adaptive mechanism to retain fluid in body despite the large level of water intake. According to YAGIL and BERLYNE (1978) the reduction in water turnover of camels was accompanied by reduced excretion of urine. MEENA and KATARIA (2004) also observed increased TFK during cold than hot environmental temperatures in sheep.

As TFK was the ratio of urine volume and water intake, no observations were recorded during the dehydration period because there was complete water restriction. However, the effect of dehydration could be well inferred by the observations of the rehydration phase regarding TFK. Significantly lowered values of TFK during the early hours of the rehydration phase indicated the effect of dehydration on renal functions. PUROHIT et al. (1972) also observed a highly significant effect of dehydration on TFK in sheep, as urine volume was decreased during dehydration and water restriction was partial. Despite the intake of large volumes of water, kidneys still maintained their function in a depressed state to provide an advantage for dehydrated camels, so that after rehydration the animal would be able to retain water in the body to replenish the body fluid compartments. Most of the physiological changes that occurred in the dehydrated camel were water conserving mechanisms (MACFARLANE et al., 1963). It was observed that normal TFK was achieved after 96 hours of rehydration in both seasons, indicating progress towards attainment of normalcy in renal functions.

Conclusions

The determinations of KSLs of different constituents helped in relating them to renal functions in order to measure the changes in salt balance during dehydration and rehydration in dromedary camel. The reduction in KSLs was a part of the ability of camels to conserve water to tolerate dehydration due to water restriction. Reduced plasma loads and tubular loads resulted in trapping of constituents in the plasma to hold more water. Not a single report could be traced on camels regarding transfer function of kidneys. The results of present study showed that calculations of TFK could serve as a good index of the water retention ability of the kidney, particularly to assess a camel's adaptability in the summer season or in periods of water scarcity.

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SAŽETAK

Istražen je učinak dehidracije i rehidracije u tijeku zime i ljeta na opterećenje tekućinom i prijenosnu sposobnost bubrega u zdravih ženki dvogrbe deve. Opterećenje obuhvaća plazmalno (PO) i tubularno (TO) opterećenje, a određivano je za glukozu, bjelančevine, mokraćevinu, kreatinin, natrij, kalij, klor, kalcij i fosfor. Razdoblje dehidracije trajalo je 24 dana zimi i 13 dana ljeti. Životinje su po volji pile vodu tijekom kontrolnoga i rehidracijskoga razdoblja, ali vodu nisu dobivale u tijeku dehidracijskoga razdoblja. Srednja vrijednost prijenosne sposobnosti bubrega u tijeku ljetnih mjeseci bila je značajno niža ($P \leq 0,05$) u odnosu na zimsko kontrolno razdoblje. Zimi su se srednje vrijednosti prijenosne sposobnosti bubrega za vrijeme rehidracije značajno razlikovale u odnosu na kontrolne vrijednosti ($P \leq 0,05$). Sličan je trend zabilježen ljeti, osim što izračuni nisu mogli biti učinjeni sat i pol te dva sata nakon rehidracije, jer životinje nisu izlučivale mokraću. Srednje vrijednosti PO i TO bile su značajno manje u odnosu na kontrolu ($P \leq 0,05$) u tijeku dehidracijskoga razdoblja u oba godišnja doba. Zaključuje se da je smanjeno opterećenje bubrega u tijeku dehidracije dobar pokazatelj sposobnosti čuvanja vode s obzirom na to da smanjeno plazmalno i tubularno opterećenje dovodi do zadržavanja sastojaka u plazmi koji imaju sposobnost osmotskoga zadržavanja vode.

Ključne riječi: dehidracija, dvogrba deva, bubrežno opterećenje, rehidracija, ljeto, prijenosna uloga bubrega, zima
