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Effect of Dehydration on Core Body Temperature of Young Arabian Camels (*Camelus dromedarius*)

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Abstract. Six female Arabian camels (340 ±16.6 kg BW) were used to investigate the effect of dehydration on core body temperature (T_{core}) and some blood constituents. The experiment was performed during summer (38.3 ± 0.29 ^{o}C and 40.0% RH) in Riyadh , Saudi Arabia. Ten days prior to the initiation of the experiment, all camels were surgically implanted intraperitoneally with telemetric temperature transmitters for continuous monitoring of T_{core}. The study lasted 6 weeks and was divided into three periods: the first four weeks represented a preliminary period. Measurements were taken during the fifth week, which is referred to as the "control period", and the sixth week, which is designated the "dehydration period". During the latter period, water was withheld for four days. Blood samples were collected and the concentrations of glucose, total protein, albumin, Na^{+}, $K^{+}$and Ca^{2+}, plasma osmolality and packed cell volume (PCV) were determined. Dehydration during exposure to heat stress affected the T_{core} of these camels. This effect was not significant during the first 24 hours following water deprivation, but from 32 hours onward, T_{core} increased significantly until the termination of the study. The circadian rhythm of the dehydrated camels revealed that T_{core} could fluctuate only by 1.3^{o}C. This increase in T_{core} during dehydration was associated with significant increases in total protein, albumin, PCV, Na^{+} concentrations and osmolality but glucose comcentration was significantly decreased. These findings indicate that, similar to other species of farm animals, the camel is a homeotherm, capable of maintaining its body temperature during dehydration with relatively little daily fluctuations in T_{core}.

Introduction

The Arabian camel (*Camelus dromedarius*) is renowned for its ability to tolerate prolonged water deprivation and to survive under harsh desert environment [1, p. 50]. In the 1950's, Schmidt-Nielsen *et al.* [2] proposed that the camel was not a strict homeotherm, being capable of changing its body temperature markedly in response to alterations in the surrounding environments. They reported that in the absence of heat stress, daily fluctuations in body temperature of the camel were about 2^{o}C, but during dehydration and hot weather, these fluctuations can exceed 6^{o}C. In that way, the animal was capable of storing heat during daytime and dissipating it at night [2]. Zari and Al-

Hazmi [3] similarly reported a 6^{o}C difference between minimum and maximum daily body temperatures of hydrated, heat-stressed camels, whereas Ayoub and Saleh [4] reported fluctuations of only 2.9^{o}C in body temperature of hydrated heat-stressed camels. The discrepancy between these reports might be partially due to many factors such as the environmental conditions, age and physiological status of the animals and the methods of monitoring body temperature. Most of these authors measured body temperature using the rectal thermometers. In the present study, telemetric temperature transmitters were used to determine the effect of dehydration on the circadian rhythm of core body temperature (T_{core}) of young Arabian camels exposed to hot weather.

Materials and Methods

Six, two-year, old female Arabian camels (average body weight 340 ± 16.6 kg) were used in this study. The animals were housed in the Department of Animal Production farm, King Saud University, Riyadh, Saudi Arabia. They were fed twice daily, at 0700 and 1600h, on a mixture of hay and commercial concentarte (160 g crude protien / kg feed). Water was offered *ad libitum*, except during water deprivation period (dehydration period week 6).

Ten days prior to the study initiation, all camels were surgically implanted intraperitoneally with calibrated telemetric temperature transmitters (Mini-Mitter Co. Inc.; Model VHF-T-1; Sun River, Oregon, USA) for monitoring core body temperature at 30 minutes intervals throughout the experiment. Temperature calibration coefficients were generated by collecting time interval data from the transmitters at two known temperatures. Prior to calibration, the transmitters were placed in a water bath with a magnetic stirrer and precision thermometer. The transmitters were placed one inch apart to avoid possible signals interference. Two different temperature points were required, low and high points. The low temperature was approximately 26^{o}C and the high temperature was 45^{o}C.

The surgical procedure was performed in fasting animals, food being withheld for 24 hours and water for 12 hours prior to surgery. The camels were restrained and the left side of the flank of each was cleaned, shaved for an adequate area surrounding the surgical site, surgically scrubbed with antiseptic 1% iodine solution and rinsed with 70% alcohol. The skin at the surgical site was sprayed with an antiseptic solution (Tetravel Aresol) and left to dry. The surgery was performed under local anesthesia. A 20 cm vertical incision was made in the middle of the left skin and musculature for insertion of the temperature transmitter (40 mm diameter, 70 mm length). The incision was then sutured and ten days post-surgery the sutures were removed.

Ambient temperature (T_a) was monitored continuously at 30-minute intervals, using data logger (Pace Scientific, USA) and relative humidity (RH) was recorded using a hygrograph. The temperature humidity index (THI) was used to incorporate the effect of humidity and the ambient temperature, which was calculated according to this equation:

THI= T_d-(0.55-0.55X RH) (T_d-58); where T_d= dry bulb temperature in Fahrenheit, RH= relative humidity percentage in decimals [5, p.3].

The study lasted for six weeks; the first four weeks served as a preliminary period during which surgical insertion of transmitters was carried out and the incisions healed. Measurements of T_{core} and other parameters were made through the fifth (control period) and sixth (dehydration period) weeks. During the dehydration period (the sixth week), water was withheld for four days.

Heparinized blood samples were collected by jugular venipuncture during the control period and at the end of the dehydration period. Packed cell volume (PCV) was determined shortly after sample collection. Plasma was then separated by centrifugation and stored at -80^{o}C until analyzed for the concentrations of glucose, total protein, albumin, sodium, potassium, calcium and plasma osmolality. Total protein was assayed using the Biuret method as described by Henry *et al*. [6] and albumin concentration was determined according to the method of Rodkey [7]. Globulin level was calculated as the difference between total protein and albumin concentration. Glucose concentration was determined by glucouse oxidase reagent kit (Randox, UK), while the plasma levels of Na^+, K^+ and Ca^{2+} were measured using flame photometry. Plasma osmolality was estimated using an osmometer (Wescor, Logan UT, USA).

Data were statistically analyzed using SAS [8, p. 284]. The data were analyzed with ANOVA using the general linear model proceeding of SAS. The response differences were considered to be significant when the error probabilities were less than 0.05.

Results and Discussion

A distinct T_{core} rhythm has been reported in cattle [9, 10], sheep [11] and goats [12]. In a recent study [13], we have shown that under thermoneutral conditions, the T_{core} of camels exhibited a diurnal rhythm reaching maximum at noon and minimum during the early morning, with amplitude of 0.5^{o}C. Exposure to heat stress (38.7 ± 0.1^{o}C, 40.6% RH and THI=88.82) resulted in a significant upward shift on the daily rhythm with amplitude of 0.7^{o}C. In agreement with Al-Haidary [13], core body temperature of heat-stressed camels (38.3 ± 0.29^{o}C) in the present study exhibited a monophasic variation reaching maximum (37.2^{o}C) at 1600h and minimum (36.7^{o}C) at 0500h.

Water deprivation during exposure to summer heat stress had a significant effect ($P<0.005$) on core body temperature of camels. The T_{core} follows the same diurnal pattern as the air temperature, but with low amplitude. No significant change in T_{core} was recorded during the first 24 hours, then the core body temperature of dehydrated camels started to increase significantly after 32 hours and continued to rise until the end of the study (Fig. 1). The circadian rhythm of the dehydrated camels shows that T_{core} can fluctuate by 1.3^{o}C. These findings are in contrast with other investigators, who reported

that body temperature of dehydrated camels could fluctuate daily by 6°C, from 34°C to 41°C [2, 14]. According to these authors, this increase in body temperature during the day reduces the temperature gradient between the animal and its immediate environment, which reduces the heat gain, and at night camel dissipates the excess body heat via non-evaporative means. Zari and Al-Hazmi [3] reported 6°C daily fluctuations of body temperature of hydrated heat-stressed camels, but offered no explanation for this large amplitude even though the animals were watered daily and could thus utilize water for the cooling process. On the other hand, a report by Cleland [15] indicated that fluctuation in the rectal temperature of hydrated, heat-stressed camels was 2.9°C.

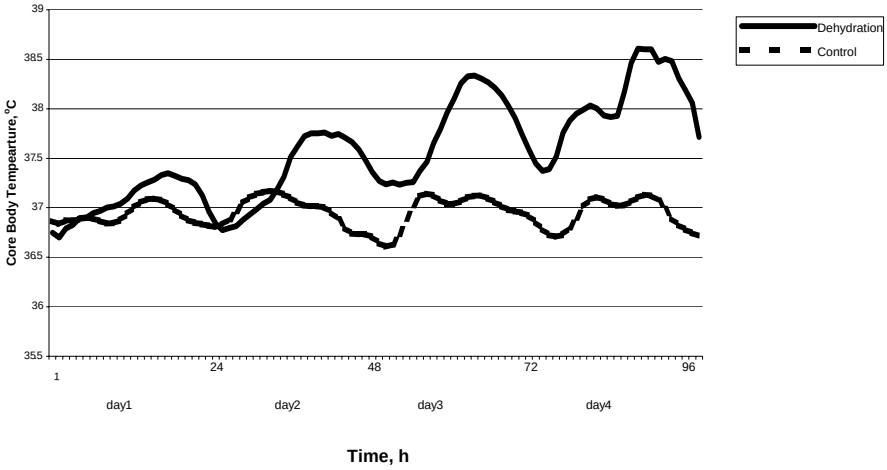

Fig. 1. Average hourly value of core body temperature during 4-day dehydration period in young Arabian camels.

Monitoring T_{core} with a telemetry system demonstrates that camels in the present study are homoeothermic animals that can maintain near constant body temperature within a narrow range of environmental conditions. The slight increase in T_{core} during exposure to heat stress challenge might be due to the fact that these animals dissipated excess body heat to the surrounding environment to maintain normal body temperature. Evaporative heat losses from the respiratory tract and from the skin are the main avenues for heat loss. Lack of water for prolonged time, however, might hamper the animal's ability to dissipate heat, resulting in an increase in body temperature and hyperthermia. Further studies are therefore needed to elucidate the effect of extended periods of dehydration on T_{core} of the Arabian camel.

The concentrations of Na^+, K^+, Ca^{2+}, glucose, PCV, total protein, albumin and globulin, and the plasma osmolality are presented in Table 1. These values are within the normal ranges that have been reported in camels [4, 16, 17, p. 80]. The increase in T_{core} of camels during dehydration in the present study was associated with significant

increases in Na^+, albumin, PCV, osmolality and total protein. These findings are in concordant with other authors [4, 18, 19]. Osmolality, which reflects the concentration of minerals in the plasma, increases with exposure to heat stress and/or dehydration, and Na^+ is the most abundant osmotically active solute in the extracellular fluid. The mechanisms that control Na^+ balance are the major ones defending extracellular fluid volume [20, p. 274]. Thus, the higher ($P<0.005$) level of Na^+ during dehydration was apparently to maintain extracellular fluid volume. Albumin plays a major role in controlling the osmotic pressure and maintaining a normal plasma volume. Therefore, albumin is considered to be a part of the adaptive mechanism known to occur in the thermally-stressed animals to maintain an expanded extracellular fluid to provide water for the cooling process [21]. However, since no measurement was made for the plasma volume, it is not possible at this point to determine whether these increases were due to hemoconcentration or represented an actual increase of these parameters as an attempt to maintain proper plasma volume during dehydration.

Table 1. Effect of 96 hours dehydration on some biochemical and hematological parameters in young Arabian camels

Parameters	Control	Dehydration
Na (meq/l)	154.4±4.6**	197.4±4.6
K (meq/l)	7.4±0.6	8.5±0.6
Ca (meq/l)	2.7±0.12	2.6±0.12
Total protein (g/l)	73.6±2.7*	82.2±2.7
Albumin (g/l)	45.9±1.3**	56.2±1.3
Globulin (g/l)	27.6±2.7	26.0±2.7
Osmolality (mOs/l)	341.6±4.0**	360.6±4.0
PCV (%)	32.4±0.73**	36.0±0.73
Glucose (mg/dl)	106.6±6.9*	84.8±6.9

*P<0.05, **P<0.005

Camels in the present study decreased their feed intake significantly after 24 hours of water deprivation, and stopped eating after 72 hours, apparently in order to reduce endogenous metabolic heat production, and thereby reduce water required for the evaporative cooling. The significant decreases ($P<0.005$) in glucose level during dehydration was most likely a result of the decrease in feed intake and/or to possible reduction in the secretion of caloregenic hormones known to occur in heat-stressed animals.

In conclusion, water deprivation for 96 hours resulted in a significant increase in T_{core}, with 1.3°C amplitude. This was associated with changes in Na^+, osmolality, albumin, PCV and glucose level. More importantly, camels were able to maintain normal body temperature during dehydration with little daily fluctuation in T_{core}.

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تأثير الحرمان من الماء على درجة حرارة الجسم الداخلية لصغار الإبل العربية

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ملخص البحث. في هذه التجربة تم دراسة تأثير الحرمان من الماء على الإبل حيث استخدم ستة من الإبل العربية (متوسط أوزانها ٣٤٠±١٦.٦ كغم) بهدف معرفة أثر الحرمان من الماء على درجة حرارة الجسم الداخلية وبعض مكونات الدم. قبل بداية التجربة بعشرة أيام زُرعت مجسات حرارية جراحيا في كل حيوان وذلك لمتابعة التغيرات اليومية في درجة حرارة الجسم الداخلية كل ٣٠ دقيقة طول فترة التجربة. استغرق إنجاز هذه التجربة ستة أسابيع، حيث كانت الفترة الأولى فترة تمهيدية (أربعة أسابيع) تلاها فترة جمع البيانات لفترة المقارنة (الأسبوع الخامس) وفترة الحرمان من الماء (الأسبوع السادس). جُمعت عينات دم وقُدر فيها كل من الجلوكوز، البروتين الكلي، الألبيومين، الجلوبيولين، الصوديوم، البوتاسيوم، الكالسيوم وأسموزية البلازما وكذلك نسب المكونات الخلوية. اتضح من هذه الدراسة أن الحرمان من الماء في فصل الصيف (٣٨.٣±٠.٢٩°م، ٤٠٪ رطوبة نسبية) كان له تأثير معنوي على درجة حرارة الجسم الداخلية، ولم تتضح هذه التغيرات خلال الأربعة وعشرين ساعة الأولى ولكن بعد ٣٢ ساعة من الحرمان من الماء بدأت درجة حرارة الجسم بالارتفاع حتى نهاية التجربة. وبمتابعة التغيرات اليومية للجمال المحرومة من الماء نجد أن التموجات اليومية في درجة حرارة الجسم الداخلية كانت ١.٣°م. هذا الارتفاع في درجة الحرارة صاحبه ارتفاع معنوي في تركيز كل من الصوديوم والألبيومين ونسب مكونات الدم الخلوية والأسموزية والبروتين الكلي بينما انخفض تركيز جلوكوز الدم معنويا. ونستخلص من دراستنا هذه أن الإبل المجهدة حرارياً والمحرومة من الماء كانت قادرة على المحافظة على درجة حرارة أجسامها شبه ثابتة وبدون حدوث تموجات واسعة.