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SHORT COMMUNICATION

The effect of blocking angularis oculi and facial veins on daily water intake in euhydrate and dehydrated Tswana goats under field conditions during summer

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KJM, conceived idea, designed study, collected data & analysis, animal operation, statistical analysis, preparation of manuscript

ABSTRACT

The aim of this study was to assess the importance of selective brain cooling (SBC) in the water economy of Tswana goats by blocking angularis oculi and facial veins in euhydrate and dehydrated goats under outdoor conditions in Botswana during summer. Eighteen male goats were assigned randomly to three treatments of six animals each: non-operated controls (NOC), blocked facial veins (BFV) and blocked angularis oculi veins (BAOV) groups. Daily water intake (DWI) was determined for 65 days in all animals to establish a baseline water intake. The goats were then dehydrated for 24, 48 and 72 hrs. Ambient temperature (T_a) was recorded hourly at the experimental site. DWI data on days with mean ambient temperatures (T_as) of 28, 29 and 31°C were analysed. DWI increase with increasing T_as. At T_as of 28 and 31°C, BAOV and BFV groups had higher DWI than NOC group. No differences were observed after the goats were dehydrated for 24 hours. However, BAOV and BFV groups had higher DWI than NOC group after 48 hours of dehydration with BAOV group consuming 7 % more water than the other two groups. The 2-way interaction between DWI and T_a as well as hours of dehydration tended to be significant at $P < 0.075$ and $P < 0.0650$ respectively. It is concluded that SBC contributes to the water economy of goats by saving on DWI. This saving is particularly important during short term dehydration periods.

Keywords Angularis oculi vein, carotid rete, cavernous sinus, dehydration, selective brain cooling, Tswana goats

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INTRODUCTION

In a pioneering study, Taylor and Lyman (1972) demonstrated that in a running gazelle, a temperature difference of 2.7 °C could be maintained between the brain and the blood in the carotid artery. The authors (Taylor and Lyman 1972) termed this selective brain cooling (SBC) and proposed that it protected the brain from hyperthermia during such a vigorous exercise. There is venous sinus at the base of the brain that drain the nasal passages and this is where blood destined for the brain is cooled within a meshwork of blood vessels called the carotid rete. This meshwork of blood vessels occurs before supplying the brain and has been well documented in artiodactyls and felids (Baker, 1982; Kamau, 1992). A similar vascular arrangement has been described in birds (Kilgore et al., 1979; Bech, and Midtgard 1981; Arad et al., 1984; Itsaki-Glucklich and Arad. 1992).

Although the study by Taylor and Lyman (1972) has never been repeated, recent studies seem to dispute the protective role of SBC on the brain, but rather argue for the possibility of SBC being important for other physiological purposes such as the regulation of water consumption and metabolism during mild winter (Kamau, et al., 2007; Kamau, 2009).

In a review which discussed multiple regulatory mechanisms for SBC, Caputa (2004) suggested that osmoregulation could be an important stimulus of SBC. According to an earlier observation by Hori et al. (1987), 40-70% of pre-optic and anterior hypothalamus temperature sensitive neurons responded to non-thermal stimuli such as osmolality, hypoxia, blood pressure as well as emotional stress.

No literature is available to support the link between osmoregulation and SBC in mammals with a cavernous sinus–rete complex under natural conditions. However, in one study in the fowl (Arad et al., 1984) demonstrated a significant reduction in body-to- brain temperature in dehydrated birds at T_as between 26 and 42 °C under laboratory conditions. A recent study by Fuller et al. (2011) involving bilateral surgical blocking of angularis oculi vein in the sheep demonstrated that SBC was reduced during exposure to heat and dehydration.

The regulation of water intake is multifactorial; osmotic, ionic, nervous and hormonal signals converge on the brain to facilitate an urge to drink (McKinley and Johnson, 2004). An *in vitro* study of neurons from median pre-optic nucleus by Travis and Johnson (1985) showed that 20% of the neurons respond to angiotensin II, 25% to osmolality while there was a significant effect of osmolality and angiotensin on thermosensitivity of 25% of the neurons. Kuznetsov and Kazakov (2000) demonstrated thermosensitivity of neurons that responded to changes in osmolality occasioned by infusion of hypo- and hyper-osmotic sodium chloride into the PO/AH in a study attempting to find the integration of thermal and osmotic afferent signals in the pre-optic/anterior hypothalamus (PO/AH) of anaesthetised cats. The results by Kuznetsov and Kazakov (2000) supported the findings of other *in vitro* studies on brain slices (Nakayama, 1985, Curras, et al. 1991).

The interplay of thermal and osmotic signals in unrestrained goats under field conditions has not been reported. The novel surgical procedure applied in the current study uses possible changes in brain temperature manipulation as well as ambient temperatures to drive water intake as an indirect indicator for both temperature and osmotic stress. The procedure imitates known neural control mechanism for the control of the diameter of angularis oculi and facial veins as observed in the rabbit (Winquist and Bevan 1980) and ruminants (Johnson and Folkow 1988). Johnson and Folkow (1988) demonstrated by *in-vitro* studies in the reindeers that the angularis oculi and facial veins have antagonistic α (causing vasoconstriction) and β (causing vasodilation) adrenergic receptors respectively, that respond simultaneously to sympathetic stimulation.

The aim of this study was to find out the effect of altering SBC through a surgical procedure that divert venous blood from the nasal passages to the cavernous sinus by blocking the facial vein in order to enhance brain cooling, or away from the cavernous sinus by blocking the angularis oculi vein in order to enhance brain warming, on DWI in euhydrate and dehydrated Tswana goats under outdoor conditions during summer

MATERIALS AND METHODS

Animals and their care

Eighteen male Tswana goats between 1.5 -2.0 years and weighing 15 to 38 kg (mean 26.34 ±1.40 s.e) were used in this study. Goats were identified individually by ear tags and randomly allocated to three treatments of six animals each, namely: non-operated control (NOC) group, blocked facial veins (BFV) group and blocked angularis oculi (BAOV) veins group. The surgical procedure for the blocking of the blood vessels was carried out by Veterinary Surgeons at the Botswana College of Agriculture Animal Health Clinic as described in details elsewhere (Kamau et al., 2007). Goats were housed in individual cubicles at night. During the day, the goats had access to a large outdoor run where they were fed as a group with a grower's ration for goats composed of 50 % maize grains, 25% lucerne hay, 22% sunflower seed meal, 2% molasses and 1.0% mineral/vitamin premix. Shade was provided by a number of trees in the run.

Experimental procedure

Two experiments were conducted following each other. During the first baseline setting experiment that lasted for 65 days, DWI was determined daily by first weighing each animal and then allowing it to drink from pre-weighed water in a bucket until it had quenched its thirst. The bucket with the remaining water was then weighed to determine water consumption. Daily hourly T_as were recorded near the experimental site under the shade. Analysis of daily T_a data identified twenty days with mean T_a of 28 ^oC (cool) 29 ^oC (warm) and 31^oC (hot). DWI results on those days are presented for the euhydrate goats. During the second experiment from 66th day, goats were dehydrated by depriving them water for 24, 48 and 72 hrs. Each dehydration period was preceded by two days of normal watering. DWI was determined at the end of each dehydration period and expressed as *per* metabolic body mass to reduce confounding effects of weight during comparison. Each dehydration period was repeated once.

Statistical analysis

Means and standard errors of DWI as well as analysis of variance in the three groups including separation of means (Duncan, 1955) were carried out using Statistica Software (StatSoft, Inc. 1995). Significance of differences between means of DWI were estimated using z-test and the values shown as standard error bars on the graphs.

RESULTS AND DISCUSSIONS

. The results for the first experiment are shown on Figure 1. DWI (mean ± s.e) of the NOC group during the relatively cool days when the mean T_a was 28 ^{o}C was 0.095 ± 0.012 L/kg $^{0.75}$/day which was not significantly different compared to 0.121 ± 0.011 L/kg $^{0.75}$/day for the BFV but was significantly lower (P<0.05) than 0.134 ± 0.008 L/kg $^{0.75}$/day recorded for the BAOV groups. On the days when T_a was 29^{o}C, DWI for the NOC group was 0.181± 0.008 L/kg $^{0.75}$/day. This was significantly (P<0.02) higher than 0.164 ± 0.011 L/kg $^{0.75}$/day for the BAOV group. DWI for the BFV was 0.160 ± 0.006 L/kg $^{0.75}$/day and similar (P > 0.05) to that of the BAOV group. On the days with T_a of 31^{o}C, DWI of the NOC was 0.177 ± 0.008 L/kg $^{0.75}$/day. This water intake was similar (P > 0.05) to 0.194 ± 0.01 L/kg $^{0.75}$/day, for the BAOV and 0.187 ± 0.007 L/kg 0.75/day for the BFV groups. Analysis of variance followed by separation of means and 2-way interaction between DWI and the environment tended to be significant (P<0.0745).

DWI of the NOC group at the three prevailing ambient temperature was 0.151 l/kg $^{0.75}$/day. This was slightly higher than 0.143 l/kg $^{0.75}$/day reported for the same breed of goats under similar summer conditions (Adogla-Bessa, and Aganga, 2000). By blocking the angularis oculi veins in euhydrate goats, the brain cooling effect of the blood from the nasal passages was removed revealing the capacity of the venous blood from the nasal passages to cool the arterial blood at the rete cavernous sinus complex. The operation resulted in a mean increase of DWI by 27% over that of the NOC group at the T_a of 28^{o}C and, for some unexplainable reason a decrease of 9% at 29^{o}C

Thus, on average, the presence of SBC resulted to an 18% saving in DWI of the goats with T_a's changing from 28 to 29^{o}C. These are ranges of temperatures that are frequently encountered in Botswana during summer.

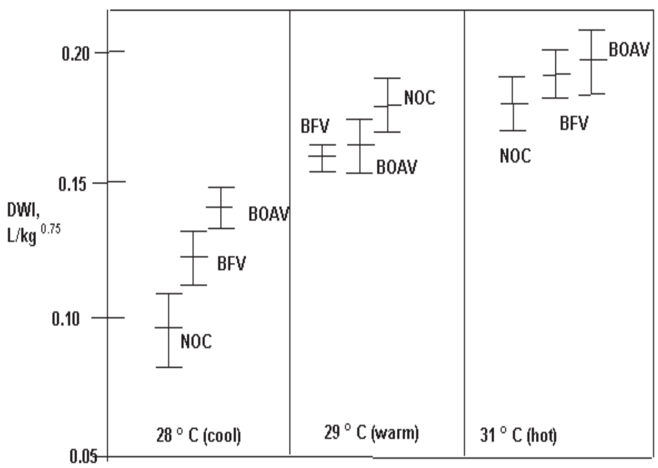

Figure 1. Means (middle line) ± s.e of DWI for NOC, BAOV and BFV blocked groups during cool, warm and hot days

This seems to confirm a suggestion by Mitchell et al., (2002) that SBC switches heat loss from evaporative to non-evaporative modes and ultimately conserves water. Ambient temperature of 31 ^{o} C is an important threshold temperature in thermoregulation since respiratory rate in small ruminants begins to increase at this critical temperature under field conditions (Kamau, and Maloiy. 1985). In the present study, goats were observed to have an increased respiratory rate at this temperature particularly during the middle of the day. Due to SBC, DWI was reduced by an average of 10 % at this temperature. The operation reported in the present study and its effects mimicked the carotid rete of arid-zone mammals which employ selective brain cooling to reduce the inclination for evaporative heat loss thus resulting in water conservation. Such a strategy would be advantageous in arid environments such as Southern Africa where water resources are both limited and variable (Mitchell *et al.*, 2002) and would become important with advent of climate change.

Goats with blocked facial veins did not decrease DWI at 31^{o}C compared to those with blocked angularis oculi veins contrary to what was expected. The ligature for blocking the facial vein was right at the base of the Y junction between the facial vein and the angularis oculi vein. The reasons for this observation are not clear. However, it is possible that by blocking the facial vein, some of the blood may not have been directed into the angularis oculi veins thus lowering the expected enhancement of arterial blood heat loss from the carotid rete at the cavernous sinus. The results presented here support an earlier study that demonstrated by means of application of extracorporeal heat exchangers under laboratory conditions that without SBC, goats increased respiratory evaporative water loss (Kuhnen, 1997).

Data from the second experiment is shown on Figure 2. Goats in the NOC group had a DWI of 0.192 ± 0.011 L/kg $^{0.75}$/day after 24 hours dehydration which was not significantly different from 0.186 ± 0.009 L/kg $^{0.75}$/day for the BFV group but significantly (P<0.05) higher than 0.160 ± 0.012 L/kg $^{0.75}$/day for the BAOV group. After 48 hours dehydration, DWI remained almost the same level at 0.180± 0.010 L/kg $^{0.75}$/day for the BFV group but that of the NOC group decreased significantly (P<0.01) to 0.134 ± 0.011 L/kg $^{0.75}$/day. However, for the BAOV group there was a highly significant increase (P<0.001) to 0.227± 0.015 L/kg $^{0.75}$/day

When goats were subjected to 72 hours of dehydration; DWI for the BOAV increased significantly to 0.540 ± 0.008 l/kg 0.75/day while DWI increased to 0.513± 0.009 l/kg $^{0.75}$/day for the NOC group and 0.513 ± 0.008 L/kg $^{0.75}$/day for the BFV group. These DWI values were however not significantly (P>0.05) different from each other. A two way interaction between DWI and periods of dehydration tended to be significant (P<0.065)

During dehydration, the three groups were exposed to the same ambient temperatures and water deprivation that are possible under goat management in an arid and semi-arid environment such as Botswana. Although not directly measured, changes in osmolality and/or plasma volume may have driven the animals to increase water intake. There was no difference in DWI between groups after 24 hrs dehydration. However, after 48 hrs a clear separation between groups was observed with mean DWI of the BAOV group increasing by 71% while that of the BFV group by 33% compared to that of the NOC group. However after 72 hours of dehydration, NOC and the BFV groups increased their DWI to the same level but the BAOV group drunk 7.8% more than the two groups. This showed that even after the longest period of dehydration goats were subjected to, those using SBC continued to save some water but to a lesser extent than after 48 hours. This suggested some form of attenuation of signaling mechanism for water conservation driven by dehydration stress

CONCLUSIONS

The study showed that in the euhydrate goats, a 10-18 % reduction in water uptake was attributed to SBC at ambient temperatures between 28 and 31 ^{o} C. When goats were dehydrated for 24 hours no water saving due to SBC was observed. However, after dehydrating the goats for 48 hours NOC group reduced DWI by 30% compared to the full capacity of 42% observed in the BAOV group. The capacity to save water by SBC was however reduced to 7.8 % after 72 hours of dehydration. SBC is therefore an important physiological mechanism in the water economy of goats. Watering goats every 48 hours would exploits fully, the capacity of SBC in water conservation of the Tswana goats

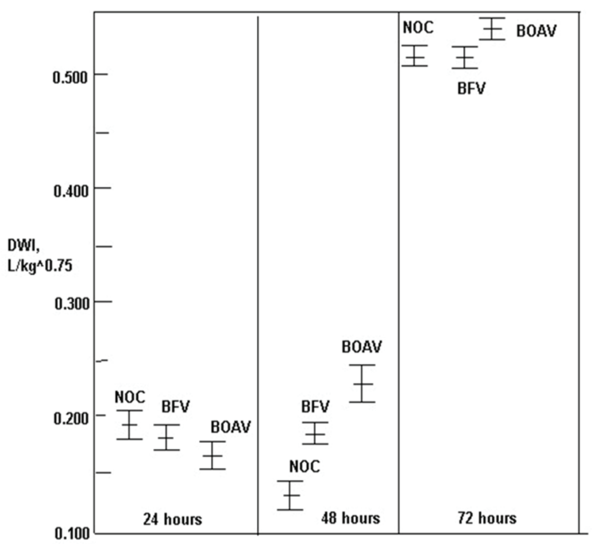

Figure 2. Means ± s.e DWI for NOC, BAOV and BFV blocked groups after dehydration for 24, 48 and 72hours

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Conflict of interest None

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