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# Disproportionate thermophysiological strain between intensively- and extensively-managed goats during summer

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ABSTRACT

Goat keeping is feasible for smallholder farmers in many world regions especially those best suited for extensive management. However, summertime grazing in arid zones entails major challenges to animal thermoregulation and well-being. An experiment was conducted to evaluate the thermoregulatory performance and selected hemogramic parameters in intensively (INT) or extensively (EXT) managed goat kids ($N = 14$). We applied a previously established technique to evaluate body thermal state of freely ranging animals, in which contemporaneous temperatures of the core ($T_c$) and periphery ($T_p$) are chronically recorded. Animals were initially kept for 12 days under INT management. Subsequently, seven animals were transferred to a grazing pasture and gradually transitioned over a four-day acclimatization period, then kept for the last 22 days under EXT conditions. Water drinking was limited to twice daily in both groups. Excessive solar radiation-induced heat load – with daytime black globe temperatures ($T_{bg}$) often exceeding 40 °C – under EXT was primarily responsible ($r^2 = 0.49$; $P < 0.05$) for 0.57 and 1.72 °C rises in $T_c$ and $T_p$, respectively, over INT kids. Unlike the typically biphasic pattern noticed for daily temperatures of both body sites in INT goats, that of EXT counterparts became rather polyphasic, whereby water drinking had drastic and prolonged thermolytic effect, inducing 0.40–0.41 and 0.79–1.45 °C declines in $T_c$ and $T_p$, on midday and afternoon watering bouts, respectively. Despite indication for added daytime heat load, EXT goats displayed lower early morning $T_c$ than INT. All animals exhibited hypohydration, as reflected by rises in hematocrit, serum osmolality, albumin, potassium, and sodium, being more pronounced in EXT conditions. Results emphasize the excessive thermophysiological strain facing grazing animals in arid zones during the summer.



## 1. Introduction

In many regions around the world, small ruminants are the favorite source of animal protein in human food. This is mostly related to their pronounced agility and thermal tolerance while wandering on rough terrain pastures (Silanikove, 2000a,b). Furthermore, in underdeveloped countries, it is less risky to raise lower-cost animals like goats compared to larger ruminants, and it is believed that this concept of small-scale animal agriculture is feasible and can even outpace poverty in many third-world countries (Peacock and Sherman, 2010).

In Jordan, about 70–78% of small ruminant farming is exclusively extensive – mostly following transhumant or agro-pastoral ranging styles – while the remaining percentage is intensively-managed (MOA, 2010). A major detrimental factor behind this outweighed ratio is the scarcity of feed resources and limited pasture land space in

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addition to the high cost of supplemental feeding. Disappointingly too, local pasture areas are increasingly eroding in face of desertification expansion, not only due to rainfall dearth but also to limited and seldom applied water harvest measures. Therefore, the area suitable for grazing is becoming sparser and, hence, animals on the pasture have to roam a more expanded land space searching for feed to merely fulfill their nutritional demands. Such extra muscular work load is, however, counterproductive especially when grazing is combined with stressful climate (Nardone et al., 2010), taking into account the growing worldwide concern towards global warming (Harley, 2011).

Previous reports (Heath and Jessen, 1988; Silanikove, 2000b; El Aich et al., 2007) outlined enormous differences in productive performance between confined animals and those living in their natural habitat. However, limited information is available about the thermophysiological variations in chronically instrumented small ruminants grazing in the field under harsh climatic conditions compared to those kept in enclosed farm settings. The present experiment was conducted to evaluate hemogramic and body temperature responses switching from INT to EXT systems in goat kids during a summer heat wave.

## 2. Materials and methods

### 2.1. Animals and treatments

Fourteen male goat (*Capra hircus*) kids from a flock of F1 generation of *Black Bedouin* × *Damascus* cross, with an initial average body weight (BW) of 30.6 ± 0.4 kg at age of 6.1 ± 0.2 months were used in the current experiment. The hair coat characteristics of this hybrid are generally typical of the *Black Bedouin* goat (described by Finch et al., 1980). All animals underwent a minor invasive surgical procedure to implant a couple of compact, high-resolution temperature loggers into two different body cavity sites (details have been previously described, Al-Tamimi, 2006, 2007). Briefly, one thermologger was aseptically implanted in the intraperitoneal cavity; while the other was embedded subcutaneously, in order to simultaneously record both core ($T_c$) and peripheral ($T_p$) temperatures, respectively. All thermal loggers were pre-programmed to record and store temperature data at 30-min intervals, such that they were all time-mated to get synchronized recordings. All dataloggers were eventually recovered when animals were slaughtered at a local abattoir, a month after the end of the trial. The most common management system of small ruminants in the area falls in the transhumant category, where animal keepers allow their flocks to forage on selected rangelands for few days to weeks, and then relocating elsewhere shortly, targeting better vegetation and/or avoiding overgrazing. Therefore, we mimicked the daily management routine generally followed by goat farmers in the area to implement a similar daily scenario for the EXT group. The selected representative grazing area was characterized by its rough terrain with uneven rocky dispersions, and inconsistently steep topographic curvatures (up to ~35% slopes).

Animals in the present trial were allowed a 21-day postoperative recovery period prior to initiation of data collection. All animals were grouped in an indoor housing facility, with natural light/dark cycle throughout the recovery period. Subsequently, the EXT group was dispatched to an outer transhumant grazing system. To eliminate the potential response to novelty of the new place and the transfer process, the INT kids were also transferred to another indoor group housing facility (providing an average individual space of 8 $m^2$/animal) at the same time their EXT equivalents were moved (latitude 31°16′19.2″N, longitude 35°44′17.28″E; Wadi Ibin Hammad, Karak, Jordan; with an elevation of 720–790 m above sea level), with both locations being less than 3 km apart. The INT animals were kept in a housing facility within the Agricultural Research Station, Mutah University located in Rabbah, Karak, Jordan; with an elevation of 926 m above sea level. All procedures in the present trial conformed to the "Animal Care and Use" regulations at Mutah University.

The study period was divided into 3 stages with reference to Day 0 as the first day for EXT animals to forage in the range in a typical transhumant extensive grazing system. The 3 stages were Stage 1 (Days −16 to −5; which consisted the baseline pretreatment period for all animals), Stage 2 (Days −4 to −1; transitional acclimatization period), and finally Stage 3 (Days 0–21; treatment period). During Stage 2 – and under the supervision of an experienced collaborative *Bedouin* goat keeper – EXT animals gradually joined a daytime transhumant grazing system of approximately 14 h daily, such that they foraged for the first 3.5, 7, 10.5 and then 14 h (starting with sunrise) on days −4, −3, −2 and −1, respectively. Thereafter, the EXT group was fully disposed to a typical transhumant grazing system (grazing for 13.5–14 h/day) until the end of the trial period, and wandered an average daily distance of about 6–7 km, as measured on Days 0 and 10 using a global positioning system (Ovi Maps, v3.04, mounted on a handheld device, model N8, Nokia, Finland). Animals of both groups were allowed free access to unlimited water drinking twice daily for 30 min each, starting at 12:30 (midday) and 18:30 (afternoon). These time windows were assigned based upon a commonly practiced EXT grazing routine followed by goat farmers in the area, in which animals are taken to the pasture for grazing throughout the daytime (starting with sunrise; between 05:44 and 05:57, and ending with sunset; between 19:36 and 19:48). Water for the EXT group was basically introduced through access to a natural water stream, with temperatures ranging between 24.5 and 27 °C, while that for the INT goats was tap water of comparable temperature range offered in a water trough.

In order to match the feed quality in both groups during the trial, starting 14 days before Day −16 (Day −30) all animals were gradually switched to a mix of feed typically found in the target EXT pasture. The feed was collected by hand-plucking on a daily basis from the EXT pasture and group-fed ad libitum to the INT goat kids. The feed varieties and their percentages consumed while in the EXT pastures were determined based upon the time normally spent on each patch of the pasture land, and the relative distribution of each grazed type in the field. The grazing pasture (and hence, the daily diet for INT) contained the following feed types with their respective as-fed relative quantities: white wormwood (*Artemisia herba-alba*; ~27%), lavender cotton (*Achillea fragrantissima*; ~24%), wheat cuts (*Hordeum vulgare*; ~23%), Judean wormwood (*Artemisia judaica*; ~12%), worm leaf (*Salsola vermuclata*; ~6%), sea orach (*Atriplex halimus*; ~5%), burnet thorny poterium (*Sarcopoterium spinosum*; ~2%), and showk (*Echinops spinosissimus*; ~1%). Animals were weighed at the beginning and end of the study to evaluate animal performance (BW change).

### 2.2. Meteorological measurements

Alongside animal body temperature data, several microclimatic parameters were also collected in parallel. This included dry ($T_{db}$), wet bulb ($T_{wb}$), black globe ($T_{bg}$) and ambient ($T_a$) temperatures, in addition to percent relative humidity (%RH). Both $T_a$ and %RH were measured using a datalogger (HOBO®, H8 Pro RH/Temperature Logger, Onset Computer Corporation, Bourne, MA, USA), while $T_{bg}$ was measured using a customized Vernon's body (a hollow sphere of thin yellow copper, of 15 cm diameter and 2 mm thickness, with the sphere held on top of a 150 cm high arm as shown in Fig. 1), within which a miniature datalogger (iButton DS1921H, Maxim Integrated Products, CA, USA) pendulously suspended in the sphere center. Based upon the fore mentioned microclimatic recordings, several meteorological indices including wet black globe temperature index (WBGT), temperature humidity index (THI), black globe humidity index (BGHI), modified discomfort index (MDI), and effective temperature (ET) were accordingly calculated using equations previously described by Yaglou and Minard (1957), NOAA (1976), Buffington et al. (1981), Moran and Pandolf (1999), and Yamamato et al. (1994), respectively. All microclimatic records were taken at a representative location in the center of the pasture field.

### 2.3. Blood sampling and analysis

On Day 21 (last day of field trial), two blood samples were collected from each animal within 15 min before access to water drinking (12:15 and 18:15) via jugular venipuncture into heparinized and vacutainer tubes, to gain some insight about their hydration status, utilizing some common indices. Heparinized blood samples were used to determine hematocrite (PCV; Haematokrit 210, Hettich, Tuttlingen, Germany), while serum was harvested from vacutainer tubes (by centrifugation for 10 min at 5000 × g) and frozen at −20 °C until analyzed. Serum