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Tolerance capability of desert sheep and goats to exercise heat stress under hot dry conditions, and its correlation with their production performance

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ABSTRACT

The study aims to investigate tolerance capability of desert Barki sheep and goats to exercise heat stress (EHS) under the hot-dry conditions of Coastal Zone of Western Desert, in Egypt. Over the period from 2009 to 2014, mature ewes and does were exposed to exercise heat stress (EHS); walking for 7 km in July and August from 12 noon to 3 pm (simulating summer grazing on poor pasture). Physiological parameters: rectal temperature (RT), skin temperature (ST), respiratory rate (RR) and gas volume (GV) were measured at rest, by 7am, and directly after exposure. Tidal volume (TV) and metabolic rate (MR) were further calculated.

Exposing desert Barki sheep and goats to EHS, raised significantly ($P \leq 0.01$) their physiological parameters (RT, ST, RR, and GV), and decreasing their MR and TV. The main thermoregulatory mechanism of desert Barki sheep to tolerate EHS, was to increase their respiratory heat loss (increase RR and GV). While, Barki desert goats relied mainly on rapid shallow painting, besides reducing heat production. Barki goats showed better tolerance to physical stress under hot dry conditions than Barki sheep. Individual variation, were the main cause of variability in changes the studied parameters with EHS, followed by year and species variation.

Changes in the physiological parameters with EHS were positively ($P \leq 0.05$) correlated with body weight at exposure, insignificantly for yearling and weaning weights. Light weight desert lambs and kids at weaning are less tolerant to physical heat stress. While heavy animals at yearling, especially goats, have difficulty in walking for long distance under heat stress. Medium size desert goats, and relatively sheep, seems to be more compatible with hot dry conditions, than either light or heavy performed animals. For breeding purpose, there is room for selection in desert sheep and goat for tolerance to environmental stress, together with selection for production traits.

1. Introduction

Sheep and goats are the main livestock raised in the hot dry areas of the Near East, where desert communities are relaying on them for their livelihood. The animals there, are facing the challenge of regulating their physiological parameter to the prevailing hot-dry conditions, and the scarcity of pasture and water. The expected climatic changes (CC) in the Near East are most likely increasing average and maximum temperature more than the global rate (Intergovernmental Panel on Climate Change; IPCC, 2014). Furthermore, annual precipitation, and precipitated days are likely to decrease and the risk of drought increase. Heat and drought will be the major factors contributing to the changes of animal production in the hot dry areas over the next 50 years (Gaughan et al., 2008).

These projections reflected potential high environmental stress, with its negative impacts on the animal performance, and adverse effect on the livelihood of the vulnerable desert communities. The harsh effects of the CC are more likely to be effective in the extensive livestock production systems (Drucker et al., 2007). Consequently, and in the context of the expected CC, strategies of the pastoral communities in the hot dry

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areas are based on identifying heat tolerant animals, within their populations. Their main option to cope with the harsh environment, is to exclude animals that are negatively affected by environmental stress. Possible antagonism between animal tolerance to environmental stress and its production performance, is a serious issue for such breeding programs. Very few studies had taken this issue in consideration.

The current study was carried out by Animal Production Research Institute (APRI), in collaboration with International Center for Agriculture Research in Dry Lands (ICARDA). The study aims to investigate tolerance capability of the desert Barki sheep and goats to hot dry conditions at the Coastal Zone of Western Desert (CZWD) of Egypt, through changes their physiological parameters, and to investigate the relationship between animals' tolerance to exercise heat stress (EHS) and their production performance.

2. Material and methods

2.1. Study area

The study was carried out from 2009 to 2014 at Borg-Arab Research Farm. The farm is in the Coastal Zone of Western Desert (CZWD) latitude 31°31′12″ N, and longitude 30°10′12″ E, at 54 m elevation above the sea level. The CZWD extended from Alexandria (Egypt) east to Tripoli (Libya) west, annual rain fall <150 ml, with 3–4 months of poor-quality extensive range in winter and scarce vegetation in the long summer.

2.2. Experimental animals

Barki desert sheep and goats, the habitant of the CZWD, are known for their adaptation to the desert conditions (Shebaita and El-Banna, 1982; Aboul-Naga et al., 1985, and Galal et al., 2005). Barki is fat tail sheep, with open coarse wool, white body, and colored head; while Barki goats are black, small size animals with medium size ears. They have been under natural selection for centuries under hot dry conditions (i.e., heat, frequent drought, intensive solar radiation, and extensive grazing on poor pasture). Number of Observation summed up to 608 Barki ewes and 232 Barki does (age ranged from 2 to 6 yrs. at nonpregnant, none lactated status) were included in the study.

2.3. Experimental procedures

During the study period, animals practiced physical exercise under natural heat stress (EHS), of walking for about 7 km in July and August, under direct solar radiation (simulating summer grazing on poor pasture). Animal were fed on corn silage and concentrates, according to their maintenance requirements, and had free access to water except during exercise.

2.4. Meteorological parameters

Dry bulb temperature (DBT) and relative humidity (RH) were measured and recorded at rest, by 7 a.m., and at exposure using alcoholic thermometer and hydrometer, respectively. Temperature -Humidity Index (THI) was calculated according to Hahn et al. (2003); THI = ((DBT*1.8) +32) -((0.55*(RH/100))) *((DBT*1.8) +32)-58, it ranged from 98.6 to 109.3 (Table1), indicating that the animals were under severe heat stress.

2.5. Physiological parameters

Physiological parameters were measured, at rest, and post-exposure to EHS. The thermal ones are rectal temperature (RT, °C), and skin temperature (ST, °C), measured by clinic and infrared thermometer, respectively. The respiratory parameters were respiration rate (RR, res. /min), gas volume (GV, L/min) measured by dry gas meter, and tidal volume (TV, calculated as GV/RR). Oxygen consumption (VO2) and carbon dioxide production (VCO2) were measured using open-circuit technique according to Yousef and Dill (1969), and metabolic rate (MR) was calculated as kcal.BW 0.75/day, according to Brouwer (1965).

Table 1
Metrological parameters at rest and at exposure to physical heat stress.

Year	AT°C*		RH%		THI	
	At rest	At exposure	At rest	At exposure	At rest	At exposure
2009	27.4	45.5	73.0	25.3	71.9	105.8
2010	27.4	47.3	78.0	26.6	71.9	108.5
2011	26.5	43.2	70.7	30.2	71.3	101.1
2012	29.8	41.4	72.2	29.6	74.7	98.6
2013	25.9	47.8	72.7	27.1	71.5	109.3
2014	29.3	41.1	62.9	27.4	75.3	98.6

* DBT: Dry Bulb Temperature, RH: Relative Humidity, THI: Temperature -Humidity Index.

2.6. Production performance

Investigating the relationship between animals production performance and their response to EHS, the following traits were studied (i) weaning weight at 4 months of age (W4) (ii) yearling weight (W12) (iii) body weight at exposure (Bwt) (iv) fecundity, as number of offspring born/mature female/year (Fec.).

2.7. Statistical analyses

Simple correlation coefficients between changes in physiological parameters with EHS, and animal production performance were estimated. Data were analyzed for the effect of fixed factors; specie, year, age, year*age and animal ID (year) using SAS (2009) according to the following model:

$Y_{ijkl} = \mu + S_i + Rj + A_k + R{*}A_{jk} + ID_l(Rj) + e_{ijkl}$ where,

Y_{ijkl} is the value of the studied parameter (RT, ST, RR GV and MR),
μ is the general mean,
S_i is the fixed effect of i[th] studied species, i = 1 to 2 (1 = sheep and 2 = goats),
Rj is the fixed effect of j[th] year, j = 1 to 6 (1 = 2009 … 6 = 2014),
A_k is the fixed effect of k[th] age and, k = 1 to 5 (1 = 2yrs…. and 5 = 6 yrs.)
$R{*}A_{jk}$ is the interaction between j[th] year and k [th] age
ID_l (Rj) is the effect of animal l[th] within R_j, and l = 1to 213 (1 = animal 1 within year 2009….)
e_{ijkl} is the random error distributed by $(0,\sigma_e^2)$

Principle Component Analysis (PCA) was carried out using SPSS (2008) to investigate animal variation in response to EHS, and to identify high and low tolerant animals according to changes in their physiological parameters. Two components were retained for PCA that explained 58.1 of the variances (35.1 and 23 %). (Fig. 1).

3. Results

3.1. Changes in the physiological parameters

Changes in the studied physiological parameters with EHS, were statistically highly significant ($P \leq 0.01$) for both desert Barki sheep and goats (Table 2). Respiration rate showed the most detectable changes among the studied parameters, its values reached more than three folds that at rest for Barki sheep and goats, respectively. Gas volume showed highly significant changes ($P \leq 0.01$) with exposure to EHS, the changes were higher in sheep than in goats (more incidence of deep breath). Metabolic rate decreased with EHS, more recognizable in goats than in sheep. Respiration rate and MR showed the widest species variation. Changes in RR with exposure to EHS, averaged 327 % for Barki sheep

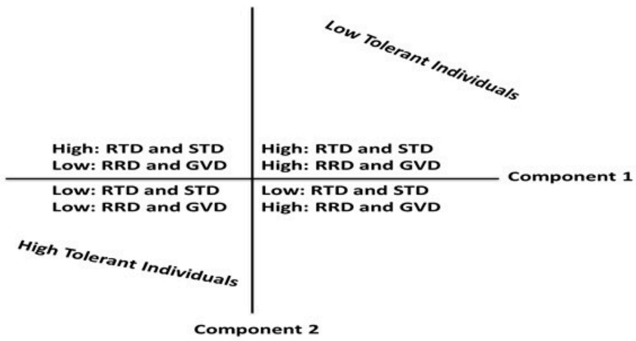

Fig. 1. Principal component analysis of physiological parameters of Barki Sheep and Goats with EHS.

* Thermal parameters (RT and ST) are positively correlated with component 1, and respiratory parameters (RR and GV) are positively correlated with component 2.

Table 2
Changes in physiological parameters of Barki sheep and goats with EHS.

Parameter	Obs. No.	At rest ± SE	Change with EHS ± SE	Range of changes	% of change
A) Barki sheep					
RT(°C)*	608	39.1 ± 0.02	1.5** ± 0.03	0–3.4	3.8
ST(°C)	533	36.8 ± 0.05	4.5**±0.09	0–11.5	12.2
RR(res./min)	608	39.2 ± 0.50	128.2**±1.5	28–218	327.0
GV (L/min)	608	5.8 ± 0.20	9.0**±0.3	−3.2 to 36	155.2
TV(L/min)	608	0.15 ± 0.004	−0.06**±.03	−0.43 to 0.17	−40.0
MR (kcal./day)	608	63.8 ± 1.73	11.1**± 1.92	−121 to 223	17.0
B) Barki Goats					
RT(°C)	232	39.1 ± 0.05	1.7**± 0.04	0–3.0	2.6
ST(°C)	158	37 ± 1.12	2.9** ±0.12	0–7.0	7.8
RR(res./min)	232	26.8 ± 8.30	107.7**±3.1	10–197	401.9
GV (L/min)	232	2.77 ± 1.39	6.33**±0.40	−2.6 to 32.4	228.5
TV(L/min)	232	0.11 ± .003	−.04**±.004	−0.2 to 0.19	−36.4
MR (kcal./day)	232	41.6 ± 1.65	34.4**±3.0	−63 to 177	82.7

* RT: Rectal temp.: ST: Skin temp. RR: Respiration rate, GV: Gas volume, TV: Tidal volume and MR: Metabolic rate.
** Changes are statistically significant at 1 % probability.

and 402 % for Barki goats (Table 2). The corresponding figures for MR were 17 and 83 %, respectively.

The main fixed factor contribute to variation in the changes of physiological parameters with EHS were found to be : animal (year), year, species, and species by year interaction (Table 3). Animal variations contributes the most to the variation in the studied traits, followed

Table 3
ANOVA for changes in the physiological parameters of desert sheep and goats with EHS.

SV	df	MS				
		RT	ST	RR	GV	MR
Species	1	0.11	0.19	6899**	6.6	20,632**
Year	4	0.84*	11.7**	5325**	80.7*	2173
Age	5	0.11	3.67	3669**	36.4	1438
Species *year	4	0.51	4.4	5309**	250.8**	3440
ID(year)	213	0.51**	3.6	1940**	38.9**	1892
Residual	273	0.31	3.5	1220	29.6	1708
R^2		**0.59**	**0.58**	**0.62**	**0.62**	**0.50**

+RT: Rectal temp.: ST: Skin temp. RR: Respiration rate, GV: Gas volume, TV: Tidal volume, MR: Metabolic rate.
* Significant at 5 % probability.
** Significant at 1 % probability.

by species variation and year, and finally species * year interaction. Variation with age was limited, except for RT. (Table 3). The largest variation observed was in RR, it was highly significant ($P \leq 0.01$) for all studied factors. Changes in RR ranged from 28 to 218 resp. /min in sheep, and from 10 to 197 resp. /min in goats. The next parameter contribute to the variation was GV, where changes ranged from -3.2 to 36 and −2.6 to 32.4 L/res. for sheep and goats, respectively. Barki goats showed detectable changes in MR than Barki sheep (35.8 and 11.4 kcal/day, respectively).

Principal Component Analysis (PCA) of changes in physiological parameters with EHS under hot dry conditions, indicated wide species variation (Fig. 2). It is worth noting that most of the Barki goats are in the high tolerant quarter (beneath left), while Barki sheep are scattered all over.

3.2. *Correlation with production performance*

Simple correlation coefficients between changes in physiological parameters of desert Barki sheep and goats with EHS, and their production traits were positive and low for RT, ST, RR, and GV, where negative for MR (Table 4). Light animals from both species (<30 kg in sheep and < 20 kg in goats) and heavy ones (>45 in sheep and >35 kg in goats) were affected by EHS more than medium size ones (Fig. 3). Heavy weight does seem to have difficulty in walking for long distances, under direct solar radiation, to graze poor pasture. Correlation estimates tend to be negative for weaning weight (at 4 months), which confirm that light lambs and kids at weaning are sensitive to physical stress under hot conditions, thereafter. On the other hand, yearling weight were positively related to changes in physiological parameters with EHS, especially goats.

Correlation estimates with fecundity (number of lambs born /ewe mated) was significant for RT and ST in Barki ewes. Reproductive performance of Barki ewes was negatively affected with the prevailed hot dry conditions, while fecundity of Barki does was not affected with their tolerance to EHS. Type of relationship of desert sheep and goats' productivity with their tolerance to EHS were investigated through estimating linear and cubic regression of productive traits with physiological response to EHS. Three types of relationships were recognized; the most common one was linear ascending order with increasing production performance. The second type was linear descending order (i.e., RT with FC in goats, and RR with W4 in sheep and goats). The interest third shape was an ascending (or descending) order for low and high performed animals, with a plateau for the medium performed ones (Bw4 with RR and RT in goats, and Bwt with GV in both species).

4. Discussions

The studied physiological parameters of desert sheep and goats, related to adaptation to environmental conditions, changed significantly with exposure to EHS. Substantial increase in respiratory rate (shallow rapid painting), was the first physiological mechanism utilized by desert sheep and goats to tolerate environmental heat stress, as reported by Nejad and Sung (2017). However, with more energy needed for walking activity in the present work, Barki sheep were not able to control fully their activity under EHS, they regulate it by more incidence of deep breath. Indian Malpura sheep, adapted to long distance walking, increased their RR and RT significantly with grazing stress (Sejian et al., 2011). The same authors indicated a major role of adrenal and thyroid glands in this behavior.

Species variation in the physiological response with EHS were significantly high ($P \leq 0.01$) in RR and GV. Multiplying RR beside incidence of deep breath, was the main regulatory response of desert Barki sheep to EHS, under hot dry conditions. Significant species differences in ST could be related to the isolation role of the coarse wool fleece of Barki sheep from solar radiation (Khalifa et al., 2002). Year

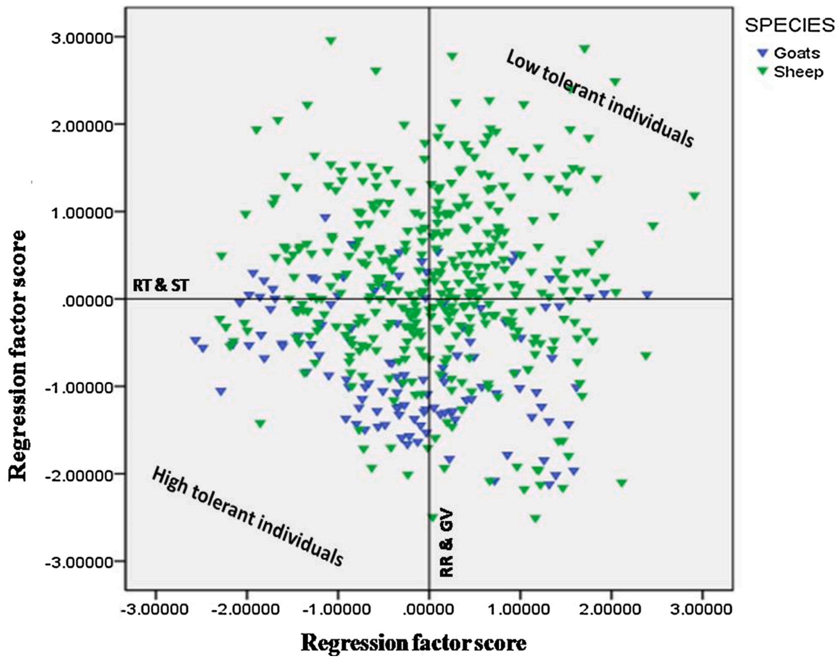

Fig. 2. Dispersion of observations as per Principal Component Analysis.

Table 4
Simple Correlation coefficients of changes in physiological parameter with EHS, and production traits.

	No.	RT+	ST	RR	GV	MR	Index
Sheep							
Bwt++	607	0.076*	0.099*	0.037	0.188**	−0.084*	0.06
W4	295	−0.105	−0.146*	−0.052	0.071	0.040	−0.04
W12	297	0.133*	−0.037	0.196**	0.082	−0.018	0.04
Fec.	174	0.262**	0.201*	0.126+	0.126	−0.030	−0.01
Goats							
Bwt	232	0.126*	0.012	0.090*	0.176**	−0.119	0.04
W4	80	−0.016	0.067	−0.110	0.055	0.271*	0.07
W12	80	−0.009	0.257	−0.001	0.269**	0.308**	0.06
Fec.	80	−0.132	−0.230	−0.016	−0.095	0.085	0.17

+ RT: Rectal temperature; ST: Skin temperature; RR: Respiration Rate; GV: Gas volume; MR: Metabolic rate.
++ Bwt: body weight at exposure; W4: weaning Weight; W12: yearling weight; Fec.: fecundity.
* Significant at 5 % probability.
** Significant at 1 % probability.

*species significant interaction in ST, RR and GV can be due to different species interaction with different THI in the studied years.

Species variation between sheep and goats in response to physical stress under hot conditions, can be attributed in principle, to differences in body size of the two species, in addition to other physiological differences mentioned by Payne and Wilson (1999). Body size and shape are the most dominant morphological characteristics that affected the animal's thermoregulatory mechanisms in hot environment (Silanikove, 2000a). The small body size of the desert goats helps in the evaporative heat loss (Abdel-Samee (1997). The studied Barki sheep weighed in averaged 37.3 kg, with a wide range from 25 to 63 kg; whereas, Barki goats averaged 24.3 kg, ranged from 15 to 45 kg. Intra-species variation was recognizably observed in RR and GV (incidence of deep breath), which reflected also in the MR, more in goats than in sheep. Principal Component Analysis (PCA) of changes in physiological parameters with EHS under hot dry conditions, indicated wide species variation (Fig. 2). It is worth noting that most of the Barki goats are in the high tolerant quarter (beneath left), while Barki sheep are scattered all over. Aboul-Naga et al. (2011) reported high individual variation in Barki goats than in sheep, in response to natural heat stress, under hot dry conditions.

Association between changes in the physiological parameters of desert Barki sheep and goats with EHS, and their production performance are well recognized in their body weight at exposure. The heavy Barki sheep have to practice deep breath and decrease their metabolic rate to cope with the heat exercise stress, under hot dry conditions. On the other hand, correlation tended to be negative for weaning weight (at 4 months). This means that light lambs and kids at weaning is sensitive to physical stress under hot arid conditions, thereafter. Light and heavy weight animals from both species were more affected with the EHS, indicating that neither light nor heavy animals are favorable to bred under the extensive arid hot conditions, especially desert goats. Heavy goats are not compatible with the physical stress under hot arid conditions, they have difficulty in walking for long grazing distance.

Reproductive performance of Barki ewes seems to be negatively affected with the hot dry conditions than does. Hansen (2009) stated that thermal stress compromises fertility through direct effect of hyperthermia on the reproductive axis, or through the indirect effect of thermal stress on reducing metabolic heat production, leading to changes in energy balance and nutrient availability. Desert Barki goats are reported to be fertile and of better fecundity than Barki sheep (Aboul-Naga et al., 2014). Silanikove (2000a, 2000b), and Shkolnik and Choshniak (2006) reported that Black Sinai goats are better tolerant to harsh desert environment than any other desert species.

5. Conclusions

The interest finding from the study, is that desert sheep and goats are producing and reproducing successfully under the environmental stress of hot dry areas, where they have been raised and selected naturally for centuries. Desert goats seems to tolerate physical stress under hot dry conditions (simulating summer grazing on poor pasture), better than desert sheep. Species variation is due in principle, to different body size

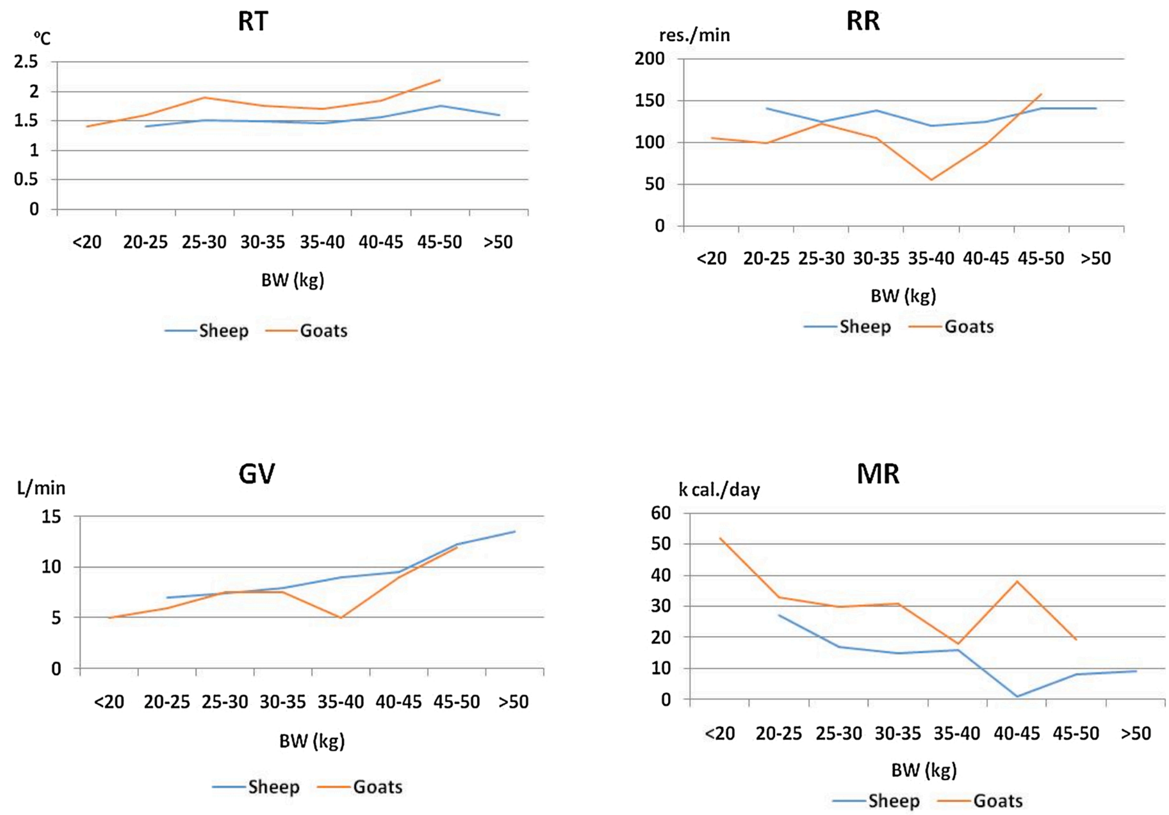

Fig. 3. Changes in physiological parameters of Barki sheep and goats with EHS in relation to their body weight.

between the two species, beside other physiological differences between the two species. Medium performed desert goats and sheep (within their breed performance), seems to be more compatible with hot dry conditions.

The results indicated room for selection, within the desert sheep and goats' populations, for heat tolerance to hot dry conditions together with selection for production traits; i.e. growth performance, mature body weight and fecundity.

Declaration of Competing Interest

The authors declare no conflict of interest that would prejudice the impartiality of this scientific work.

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