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BIOLOGICAL AND MATHEMATICAL ANALYSIS OF DESERT SHEEP AND GOATS RESPONSES TO NATURAL AND ACUTE HEAT STRESS, IN EGYPT

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SUMMARY

Climate change is likely to be a main challenges livestock production faces in this century. Climatic projections for arid and semi-arid zones include increasing annual mean and maximum summer temperatures, intensity of solar radiation and frequent of severe climatic events, e.g. heat waves. This study aimed to assess variation in physiological responses of desert Barki sheep and goats to both natural and acute heat stresses, under the hot-dry conditions of the Coastal Zone of Western Desert, Egypt. Natural heat stress represents increasing ambient temperature, while acute one resembles the expected severe weather events. Fifty nine ewes and twenty-five does were exposed to natural heat stress (NHS) under direct solar radiation in August for three successive days, and biological parameters representing thermal, respiratory and metabolic activities were recorded pre- and post-stress. NHS significantly affected all parameters studied, in terms of change between post- and pre-exposure values. Respiration rate (RR) was almost tripled with significant increase in minute ventilation volume (MVV), in response to NHS in sheep reflecting higher gas exchange than in goats. Increase shallow panting, vasodilatation and decrease heat production (HP) showed to be the primary mechanisms for goats to dissipate heat load. Animal heat tolerance index (AHTI) was developed to assess individual animal response to NHS based on the changes in rectal temperature (RT), RR, MVV, tidal volume (TV) and HP. Respiration rate, followed by rectal temperature were the two main physiological parameters contributing to the AHTI, in both species. To assess variation in body thermal response of the two species to acute heat stress (AHS), 68 desert Barki ewes and 31 Barki does (of which, 40 ewes and 22 does were involved in the NHS trial) were confined in a climatic chamber at>41℃ for 120 min., in Spring of 2010. RT was measured at 3-minute intervals and its records were fitted to a linear mathematical model: $y=a+b\ ln(x) + c\ (ln(x))^2$. Mathematical fitting of RT, resulted in the classification of the sheep and goats into 4 groups according to the value of two main parameters of curve shape; peak value and post-peak slope. The "Low peak with post peak Plateau, LPt" sheep and goat animals were proposed to be the most tolerant. Meanwhile, the "Low peak and Exponential post-peak slope, LEx" goats and the "High peak with post-peak Plateau, HPt" sheep were considered the least tolerant. Animal groups classified as the most tolerant showed to be more common under both NHS and AHS classes, reflecting possible association between tolerance performance of animals under NHS and AHS in the two species.

Keywords: Natural & acute heats stress, Barki, sheep, goats, Egypt

INTRODUCTION

Climate change is likely to be one of the main challenges that livestock production faces during the present century (Bernabucci *et al*., 2010). Future climatic projections for the semi-arid and arid environments are: annual mean temperatures and maximum summer temperatures are likely to increase more than the global average; annual precipitation and number of precipitation days are very likely to decrease; and risk of summer drought is likely to increase (IPCC, 2014). Exposure of small ruminants to heat stress, out of their comfort zone, evokes various physiological thermoregulatory responses to mitigate the effect of heat load. The first response is vasodilatation, especially in ears and legs and evaporation of water from the respiratory tract and skin surface through panting and sweating followed by decreasing metabolic rate (Khalifa, 2003). If such mechanisms failed to control the excessive heat load, rectal temperature increases. Exposure to natural heat load affects a series of biological mechanisms; metabolic activities, mineral balance, enzymatic reactions, hormonal secretions and blood metabolites (Marai *et al*., 2007), and simulate gene expression of some major relevant genes, e.g. the molecular chaperones of heat shock protein family (Charoensook *et al*., 2012). Investigating animal variation in their physiological responses to both acute and natural heat stresses is essential for better understanding of the genetic background of animal tolerance to such abiotic stresses. It will help developing selection strategies for heat tolerant animals that can economically produce under hot/dry conditions.

The present study aims to assess individual variation in biological responses to natural and acute heat stresses in desert Barki sheep and goats, mathematical description of body thermal response to acute heat stress, and therefore investigate association between tolerance performances to both types of stresses.

MATERIALS AND METHODS

The heat stress trials were carried out at Borg-Arab Research Farm, Animal Production Research Institute, located in the hot dry area of Coastal Zone of Western Desert, CZWD (Latitude: 31° 31' 12" N; Longitude: 30° 10' 12" E; Elevation: 54 meters).

Natural heat stress trial: Fifty-nine Barki ewes and twenty-five Barki does, at non reproductive status, were exposed to natural heat stress (NHS) under direct solar radiation within the period from 12:00 to15:00 for 3 successive days in summer, 2009 (July and August). Meteorological and biological parameters were recorded pre-and directly post-exposure to NHS (under direct solar radiation). Meteorological parameters included ambient temperature (^{0}C), relative humidity (%), atmospheric pressure (mmHg), black bulb temperature (^{0}C), and wind speed (km/hour). Temperature-humidity index (THI) was calculated according to Hahn *et al*. (2003). Individually recorded physiological parameters were classified as: Thermal; rectal (RT), skin (ST) and ear (ET) temperatures (^{0}C); Respiratory: respiration rate (RR, resp/min.), minute ventilation volume (MVV, l/min), tidal volume (TV, ml/resp) and gas change (O2 and CO2); and Metabolic: heat production (HP, KCal/BW$^{.75}$.day^{-1}). RT was measured by clinical thermometer, while infrared thermometer (Raynger ST80 ProPlus; F18C) was used for measuring ST and ET. RR was measured by counting flank movement, and gas exchange was measured using the open-circuit technique according to Yousef and Dill (1969). MVV was measured by Dry Gas Meter and Tidal volume (TV) was calculated as MVV in ml/RR. Percentages of oxygen and carbon dioxide (VO2 and VCO_2) were measured in expired air using Servomex 570 Gas Analyzer. Heat production (HP, KCal/BW$^{.75}$.day^{-1}) was calculated according to McLean (1972).

To assess physiological responses of individuals to NHS, individual variability in responses in main five biological parameters (RT, RR, TV, MVV and HP), as well as their normality, were statistically analyzed. Paired t test was applied to test the effect of NHS exposure (pre- vs. post-exposure means) for the five physiological parameters. Frequency distribution and Shapiro-Wilk Test (Shapiro and Wilk, 1965) for normality were performed for the changes in different parameters (IBM SPSS version 20.0.0).

Animal heat tolerance index, AHTI, to natural heat stress, was developed based on the changes in the five biological parameters. Animals were scored 1 if the change in parameter exceeds 2 standard deviation of its pre-exposure estimates and 0 if else. The sum of the scores was used as the Animal heat tolerance index (AHTI) where animals scored; “0” are the most tolerant, and those scored “5”are the least.

Acute heat stress trial (AHS):

This trial was designed for studying variation in animal thermal response to acute heat stress (imitating severe heat events) using mathematical modeling, and to test the hypothesis weather the more tolerant individuals to chronic/natural heat stress could be also more tolerant to acute one (association of physiological tolerance mechanisms to both). Sixty-eight desert Barki ewes and thirty-one Barki does (of which 40 ewes and 22 does were included in the NHS trial) were confined in a climatic chamber at ambient temperature >41^{0}C for 120 minutes, in April (Spring) 2010. Rectal temperature was measured at 3-minute intervals, along the stress duration. Individual thermal profiles data, for both species, were fitted to the linear mathematical model: $y=a+b(\ln(x))+c(\ln(x))^2$, where “y” is the rectal temperature (^{0}C) at minute “x” (x=3, 6, 9, …, and 120), “a” is the intercept (initial RT at 3-min.), “b” and “c” are linear regression coefficient; “b” is associated with the peak and “c” is associated with the post-peak slope. Animals, sheep and goats, were classified into 4 groups according to peak and post-peak slope; represented by the fitted function parameters “b” and “c”. Curve area was calculated from the second derivatives of all curve points.

RESULTS AND DISCUSSION

Natural heat stress (NHS):

THI, averaged 71.9 and 108.7 for pre- and post-NHS, respectively (Table 1), indicating that animals were at their comfort zone at pre-exposure conditions and out of their comfort zone at the exposure period. Hahn *et al*. (2003) working on cattle, reported that THI is considered as normal: $\leq$ 74; an alert: 75-78; in danger: 79-83 and at emergency: $\geq$84.

All physiological parameters studied were significantly affected by NHS (P<0.01, Table 2). The minute ventilation volume (MVV) increased significantly (P<0.01) with NHS in sheep (+18.8%), while it significantly decreased (-13.3%, P<0.05) in goats, reflecting specie differences in respiratory responses to NHS. The considerable increase in sheep MVV is due to the significant increase in RR (188.6%, P<0.01). Meanwhile, the decrease in MVV in goats (-13.3%) is mainly due to less increase in RR than in sheep (81.1%) with the significant reduction in TV (-46.9%, P<0.001). In both species, the changes in MVV were accompanied with significant increase in thermal parameters (RT, ST and ET). Vasodilatation (reflected in the ET increase), shallow rapid panting (increases in RR, GV and decrease TV), and decreasing heat production showed to be the mechanisms to tolerate NHS in sheep and goats. However, the highly significant increase in MVV and RR in sheep and decrease MVV in goats indicate that, under NHS, sheep rely more on respiratory evaporation, while goats are more capable for decreasing HP (-51.8%vs -34.2% in goats and sheep, respectively) and increasing vasodilatation (+11.3% vs. 6.6% in goats and sheep, respectively) to maintain homoeothermy.

***The animal heat tolerance index (AHTI)*:**

Table (3) presents the distribution of the studied Barki sheep and goats according to their changes in RT, RR, MVV, TV and HP, in response to NHS. The two main biological parameters that the most animal changes due to NHS are RR (78% in sheep and 56% in goats) and RT (51% in sheep and 44% in goats). The frequency of sheep changed their physiological parameter more than 2 SD, as a result of NHS was the highest in RR (78%) followed by MVV (54%), RT (51%) and TV (48%) while only 12% changed their HP. In goats, RR was the highest changing biological parameters (56%) followed by RT (44%), TV (28%), HP (24%) and MVV (20%). Field observations showed that RR was the first physiological parameter to change in both species in response to NHS; that was almost doubled in goats and tripled in sheep. Change in RT starts in later stage of the stress, this is in agreement with what had been reported by Marai *et al*. (2007). Normality test indicated that the biological responses in different parameters under NHT were normally distributed in both species except HP in goats (data not shown).

Table 1. Meteorological parameters and THI estimates pre- and post-exposure to NHS

Meteorological parameter	Pre-Exposure To NHS	Post-Exposure to NHS
Black bulb temperature (^{0}C)	27.4^b	47.4^a
Relative humidity (%)	73.2b^a	26.1^b
THI	71.9^b	108.7^a

THI: Temperature-humidity index NHS: Natural heat stress

Table 2. Least Squares Means±SE for physiological parameters pre- and post-NHS

Physiological Parameter	**Sheep**			**Goats**		
	Pre-NHS	**Post-NHS**	**% Change**	**Pre-NHS**	**Post-NHS**	**% Change**
Rectal temp.(C^0)	39.2 ± 0.07	40.10±0.09	2.3**	39.1±0.08	40.0±0.10	2.3**
Skin temp.(C^0)	36.3 ± 0.12	39.4±0.16	8.5**	36.8±0.25	39.6±0.18	7.6**
Ear temp.(C^0)	35.0 ± 0.23	37.3±0.16	6.6**	33.7±0.34	37.5±0.29	11.3**
Respiration rate (resp/min)	31.6 ± 1.52	91.2±5.52^a	188.6**	28.6±1.63	51.8±4.23^b	81.1**
Minute ventilation volume (l/min)	1.6± 0.03	1.9±0.09^a	18.8**	1.5±0.04	1.3±0.05^b	-13.3*
Tidal volume[1] (ml/resp)	54.9± 2.18	23.2±1.1^b	-57.7**	54.2±3.13	28.8±2.29^a	-46.9**
Heat production (kcal.BW$^{.75}$.day^{-1})	18.4± 0.96	12.1±0.56	-34.2**	21.8±1.60	10.5±0.91	-51.8**

*,** For each parameter, intra-specie, estimate differ significantly with treatment: * (P<0.05), and ** (P<0.01).
a, b for each treatments, inter-specie estimate with treatment differ significantly (p ≤0.05)
NHS: Natural heat stress

Table 3. Distribution of sheep and goat according to their change (%) in studied biological parameters and the animal heat tolerance index (AHTI)

Species	**Physiological parameter**					**AHTI (%)**
	RT	**RR**	**MVV**	**TV**	**HP**	
Sheep	30 (50.8)	46 (78.0)	32(54.2)	28 (47.5)	7 (11.9)	59 (100)
Goat	11 (44.0)	14 (56.0)	5 (20.0)	7 (28.0)	6 (24.0)	25 (100)

RT: Rectal temperature RR: Respiration rate MVV: Minute ventilation volume TV: Tidal volume
HP: Production

Acute heat stress (AHS) trial:

The recorded biological response of exposing Barki desert sheep and goats to acute heat stress AHS was the change in RT exponentially after the first 3 minutes. Average value of sheep RT reaches its peak (~40.3^{0}C) in about half an hour from starting exposure (~min.33), thereafter; it went in plateau phase with slight fluctuation around the peak. Rectal temperature then slightly decreased (~40.2 ^{0}C) toward the end of the exposure period (Figure 1). Average goats RT was initiated at 39.1^{0}C in minute 3, and gradually increased reaching its peak of 40.0 ^{0}C, later than in sheep (minute 39), and went in the plateau phase till the end of exposure period (min. 120). In general initial RT, peak value, and 120-min RT were higher in sheep than in goats and sheep attained their peak earlier (Figure 1).

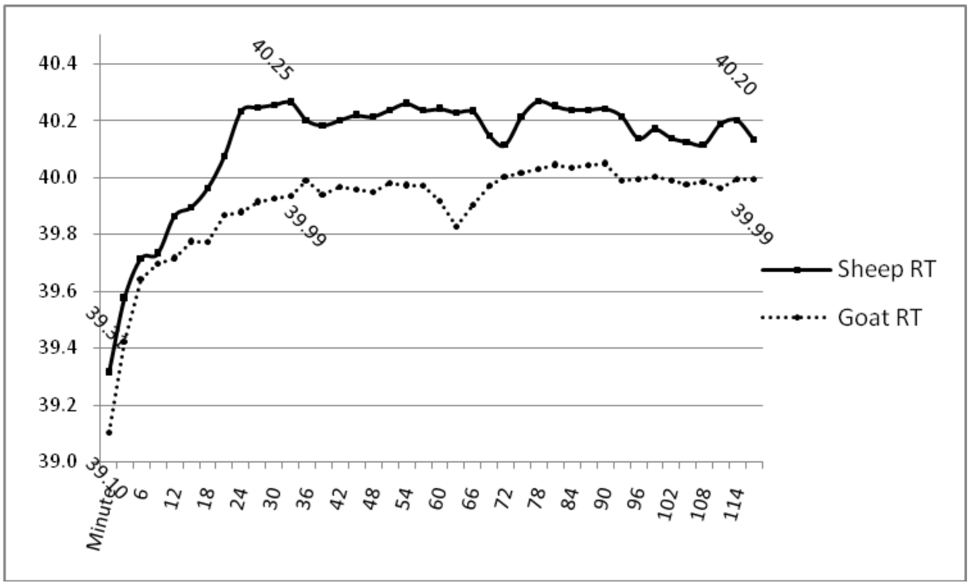

Fig. 1. Mean RT in sheep and goats exposed to acute heat stress (AHS) for 120 minutes, in 3-min intervals

Mathematical fitting of the individual changes in RT under AHS to linear function resulted in the classification of the sheep and goats into 4 groups according to functions parameters "b" and "c" (the linear regression coefficients associated with the peak and post-peak slope, respectively). The sheep groups are: high peak with post-peak plateau (HPt, n=13); low peak with post-peak plateau (LPt, n=11), high peak with post-peak slope (HSp, n=8) and dual-peak (DPk, n=8), as illustrated in Figure (2). All goats showed lower peak than sheep; they were classified in the following groups; low-peak with post-peak plateau (LPt, n=7), low peak with post peak slope (LSp, n=5), and dual peak (DPk, n=5). A new group was recognized in the goats with post peak exponential profile (LEx, n=5). Initial RT (at 3 min.) differs in the groups of the two species. In sheep, both LPt and HPt showed the lowest initial RT (~39.2^{0}C), followed by the DPk group (~39.6^{0}C), while the HSp showed the highest initial RT value (~40.0 ^{0}C). Both DPk sheep and goats showed similar initial RT (~39.6 ^{0}C), while the other three goat groups showed lower value for it (~39.0 ^{0}C). Animals with post-peak plateau reached their peak later (around min. 30) than animals with post peak slope (around 20-min) in both sheep and goats. Goats showed less variation in curve area estimates than sheep (representing the stored heat load), which may reflects their similar efficiency in heat dissipations. Animal with DPk, had the least curve area estimates followed by the LPt group (Figure. 2). In both species, LPt group (followed by DPk) is proposed to be the most tolerant, due to the observation that they have lower RT initiation value, reach lower peak value at later time and has less under curve area. On the contrary, the exponential post peak, LEx goat group and the HPt sheep group could be considered the least tolerant animals. HPt sheep has higher initiation value (a), earlier and higher peak and larger under-curve area than other groups. In spite of the observation that DPk in both sheep and goat showed higher initiation RT value, they generally show lower peaks and lower RT curve points along the curve. Those animals may have different mechanism of adaptation to AHS based on higher RT set point for minimizing variation between outer environment and inner core temperature (a heterothermy mechanisms as in Camels; Boua'ouda *et al.*, 2014, and Hetem *et al.*, 2011) a hypothesis needs further investigation. The proposed linear model showed low fitness for the DPk groups, in terms of coefficient of determination (R^2), as a measure of goodness of fit (0.26 and 0.43 for sheep and goats, respectively). A Fourier Benferoni Series model was fitted, showing higher R^2 estimates; 0.86 and 0.75, in sheep and goat, respectively (data is not shown).

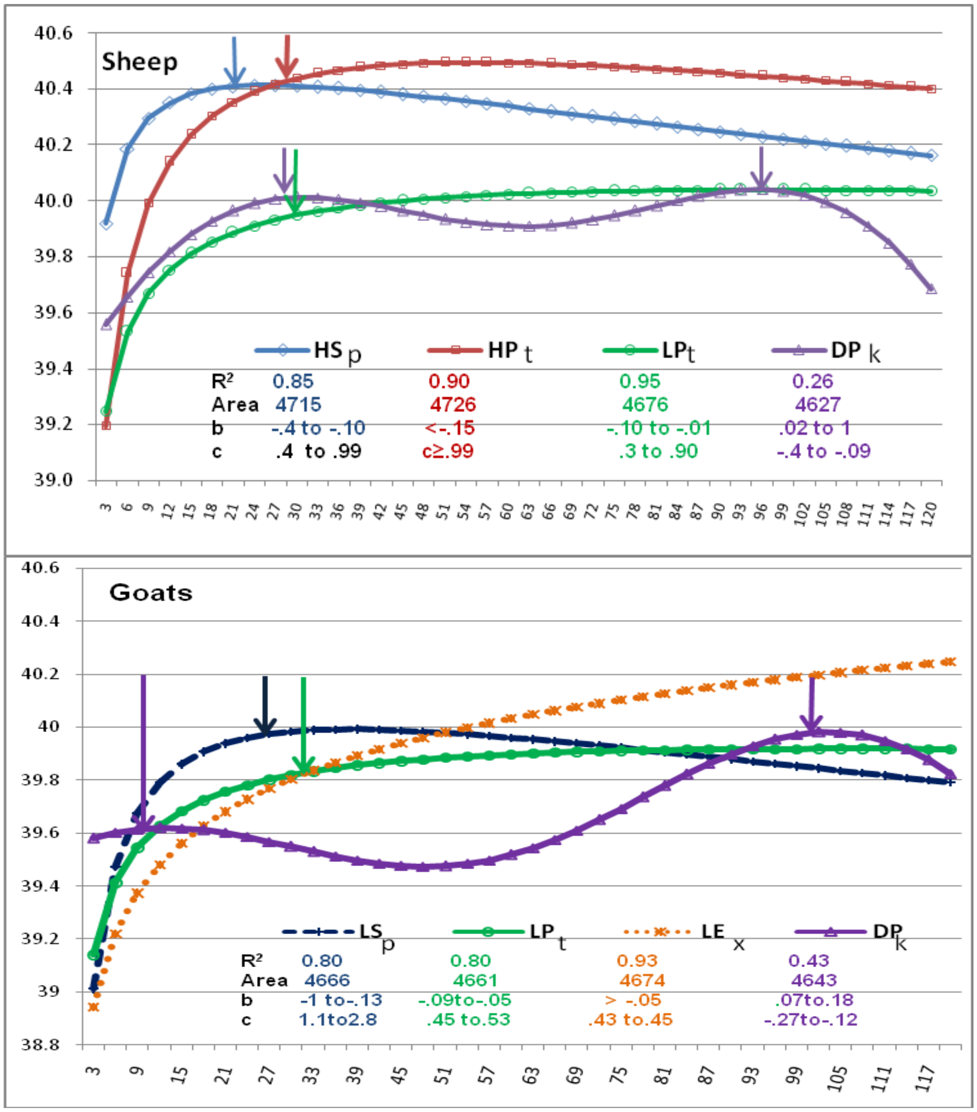

Fig. 2. Schematic profile of rectal temperature (RT) of sheep and goats according to their peak and post-peak slope under AHS conditions

Relationship between animal response to NHS and AHS:

Table (4) showed the frequency table for animals, common in both stress trials, according to their response to AHS (rows represent the 4 types of RT curves) and NHS (column represent 4 NHS stress groups). NHS groups were grouped in 4 groups, as scored groups 0 and 1 were joined in one group of "high tolerant animals or G1", because the common number of animals in both NHS and AHS was limited.

Sheep with post-peak plateau (LPt and HPt), with low initial RT, were more frequent in G1 and G2 (more tolerant to NHS groups) having 9 sheep out of 14 (46%) in G1 and 6 sheep out of 9 (67%) in G2 (Table. 4). The same trend was valid in goat, as both LPt and LSp groups, with lower RT initiation point ("a" parameter) were dominant in G1 (8 goats out of 11; 73%), as indicated in Table (4). Low value of initial RT seems to be commonly associated with tolerance to NHS. Utilizing RT as indicator for animal tolerance to heat and lamb viability has been previously reported (Brien *et al.*, 2014 and Al-Haidary, 2004). LEx goats, with exponential RT profile, considered as the least tolerant to AHS, are double presented in G4, than other group, providing low number of observation available. Generally, animals grouped as more tolerant to either NHS or AHS are more commonly presented, reflecting possible association between tolerance performances of individuals to both stressors in both species.

Table 4. Frequency analysis of NHS and AHS classification groups

	NHS groups				Total
Sheep	G1	G2	G3	G4	
(Total)	(14)	(9)	(14)	(3)	(40)
LPt	**4**	4	2	1	11
HPt	**5**	2	6	0	13
HSp	3	2	3	1	9
DPk	2	1	3	1	7
Goat					
(Total)	(11)	(3)	(3)	(5)	(22)
LPt	4	0	2	1	7
LSp	4	0	0	1	5
LEx	1	1	1	2	5
DPk	2	2	0	1	5

LPt: Low peak with post-peak plateau HPt: High peak with post-peak plateau DPk: Dual Peak
HSp: High peak with post-peak slope LEx: Low peak with exponential post peak

CONCLUSIONS

Indigenous desert Barki sheep and goats showed clear specie differences in response to heat stress under the hot dry conditions of the CZWD. Under NHS, sheep showed higher increase in RR, MVV and decrease in TV (shallow rapid panting) and therefore gas exchange. Goats showed more capability of decreasing their metabolic rate (HP) and increasing vasodilatation (ET) in response to NHS. Developed animal heat tolerance index, AHTI, was successfully used in grouping animals according to their biological tolerance performance, based on thermal, respiratory and metabolic parameters in sheep and goats. Application of AHTI showed that respiration rate and rectal temperature were the two main biological parameters that majority of animals change in response to NHS. Under AHS, goat initial RT, RT peak and curve points were generally lower than the sheep's ones. Fitting the proposed linear model to RT performance data, under AHS, successfully grouped sheep and goat into 4 groups, according to "b" and "c" parameters. The Dual-peak groups, in sheep and goats showed higher initial RT, lower peak and limited fluctuation along the curve than the other groups, indicating possible different mechanism (e.g. heterothermy), a hypothesis needs more investigation. The LPt sheep and goat groups showed lower initial RT, lower peak value and later peak time and less under-curve area, indicating more tolerance to AHS. Sheep and goats groups with lower initial RT were more frequent in the more NHS-tolerant groups, indicating possible reliance on RT for pre-assessment of animal tolerance to NHS (a hypothesis also needs larger number of tested animals to be verified). Generally, animals grouped as "more tolerant" under either NHS or AHS showed more common individuals than those of other groups, reflecting possible association between individual's biological tolerance mechanisms to either stressors.

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REFERENCES

Al-Haidary, A., 2004. Physiological responses of Naimey sheep to heat stress challenge under semi-arid environments. International Journal of Agriculture & Biology, 06:307–309

Bernabuccia, U., N. Laceteraa, L. H. Baumgarda, R. P. Rhoadsa, B. Ronchia and A. Nardonea, 2010. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal, 4:1167-1183

Boua'ouda, H, M. R. Acha'aban, M. Ouassat, M. Oukassou, M. Piro, E. Challet, Kh. El Allali and P. Pevet, 2014. Daily regulation of body temperature rhythm in the camel (Camelus dromedarius) exposed to experimental desert conditions. Physiological Reports, 2(9):e12151.

Brien, F. D., S. W. P. Cloete, N. M. Fogarty, J. C. Greeff, M. L. Hebart, S. Hiendleder, J. E. Hocking Edwards, J. M. Kelly, K. L. Kind, D. O. Kleemann, K. L. Plush and D. R. Miller, 2014. A review of the genetic and epigenetic factors affecting lamb survival. Animal Production Science, 54: 667–693.

Brouwer, E., 1965. Report of sub-committee on constants and factors. In Blaxter K. L. (ed) Energy metabolism. Academic press, London: pp.441-443.

Charoensook, R, K. Gatphayak, A. R. Sharifi, C. Chaisongkram, B. Brenig and C. Knorr, 2012. Polymorphisms in the bovine HSP90AB1 gene are associated with heat tolerance in Thai indigenous cattle. Tropical Animal Health & Production, 44:921–928.

Hahn, G. L., T. L. Mader, and R. A. Eigenberg, 2003. Perspectives on development of thermal indices for animal studies and management. In Proc. Symp. Interactions between Climate and Animal Production, 31-44. Published as EAAP Technical Series No. 7.

Hetem, R.S., B. A. de Witt, L. G. Fick, A. Fuller, S. K. Maloney, L. C. R. Meyer, D. Mitchell, and G. I. H. Kerley, 2011. Effects of desertification on the body temperature, activity and water turnover of Angora goats. Journal of Arid Environment, 75: 20–28.

IBM Corp. Released, 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

IPCC, 2014. Climate Change: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 688.

Khalifa, H. H., 2003. Bioclimatology and adaptation of farm animals in a changing climate. In: Interactions Between Climate and Animal Production. EAAP Technical Series 7:15-29

Marai, I. F. M., A. A. El-Darawany, A. Fadiel, and M. A. M. Abdel-Hafez, 2007. Physiological traits as affected by heat stress in sheep-A review. Small Ruminant Research, 71: 1–12.

McLean, J. A., 1972. Loss of heat by evaporation. In: Heat Loss from Animals and Man, Monteith and Mount, eds, pp 19–31. Proceedings 20th Easter School in Agricultural Science, Butterworths, London.

Shapiro, S. S., and M. B. Wilk, 1965. An analysis of variance test for normality. Biometrika, 52 (3–4): 591–611

Yousef, M. K. and D. B. Dill, 1969. Resting energy metabolism and cardiorespiratory activity in the burro, *Equus Asinus*. Journal of Applied Physiology, 27: 229-232.

التحليل البيولوجى والرياضى لإستجابة الأغنام والماعز الصحراوية للإجهاد الحرارى الطبيعى والحاد فى مصر

من المرجح ان تمثل التغيرات المناخية التحدي الرئيسي الذي يواجه الإنتاج الحيواني خلال هذا القرن. تشمل التوقعات المناخية للمناطق القاحلة وشبه القاحلة تزايد كل من متوسط وأقصى درجات حرارة صيفية، زيادة شدة الإشعاع الشمسي و زيادة تكرار الأحداث المناخية المتطرفة مثل الموجات الحارة. هدفت هذه الدراسة إلى تقييم الاختلاف في الاستجابات الفسيولوجية للأغنام و الماعز البرقي الصحراوية للإجهادات الحرارية الطبيعية والحادة، و ذلك في ظل الظروف الحارة الجافة للمنطقة الساحلية من الصحراء الغربية بمصر. حيث يمثل الإجهاد الحراري الطبيعي تزايد درجات الحرارة المصاحبة للتغيرات المناخية المتوقعة في حين يمثل الإجهاد الحراري الحاد تعرض الحيوانات للظواهر الجوية المتطرفة المتوقعة (الموجات شديدة الحرارة). تم تعريض تسعة وخمسون نعجة وخمسة وعشرون عنزة إلى الإجهاد الحراري الطبيعي (Natural Heat Stress, NHS) تحت أشعة الشمس المباشرة لمدة ثلاثة أيام متتالية في شهر أغسطس. سجلت المؤشرات البيولوجية التي تمثل التغير في كل من الأنشطة الحرارية والتنفسية والتمثيل الغذائي قبل وبعد التعرض للإجهادالحراي. اظهرت النتائج ان للإجهاد الحراري الطبيعي اثر معنويا علي جميع القياسات البيولوجية في صورة التغير بين قيمها قبل و بعد التعرض للإجهاد. حيث تضاعف معدل التنفس (RR) ثلاثة أضعاف تقريبا مع زيادة كبيرة في حجم التنفس بالدقيقة (MVV) و ذلك في الأغنام مما يعكس قدرتها على التبادل الغازي بشكل يفوق الماعز. في حين تميزت الماعز بزيادة كل من معدل اللهاث الضحل (Shallow panting) و إتساع الأوعية الدموية (vasodilatation) و انخفاض الإنتاج الحراي (HP) كآليات أساسية لتبديد الحمل الحراري بالماعز. و بناء علي نتائج التغير في المقاييس البيولوجية تم وضع دليل تحمل الإجهاد الحراي (Animal Heat Tolerance Index, AHTI) لتقييم الإستجابة الفردية للحيوان للإجهاد الحراري الطبيعي على أساس التغير في كل من درجة حرارة المستقيم (RT) و معدل التنفس بالدقيقية (RR) و حجم التنفس بالدقيقة (MVV) و حجم التنفسة الواحدة (TV) و معدل الإنتاج الحراري (HP). اشارت النتائج بان معدل التنفس يليه درجة حرارة المستقيم هما المعلمان الرئيسيان اللذان يسهما في دليل مقاومة الإجهاد للحيوان في كلا من الاغنام و الماعز. و لتقييم التباين في إستجابة الجسم إلى الإجهاد الحراري الحاد (Acute Heat Stress, AHS) لكلا من الأغنام و الماعز ، تم إحتجاز عدد 68 نعجة و ٣١ عنزة برقي صحراوية (منها ٤٠ نعجة و ٢٢ عنزة سبق تضمينهم في تجربة مقاومة الإجهاد الحراري الطبيعي) في غرفة مناخية علي درجات حرارة اعلي من ٤١ درجة مئوية لمدة ١٢٠ دقيقة (ساعتان) و ذلك في ربيع عام ٢٠١٠. تم قياس درجة حرارة المستقيم كل ٣ دقائق و تم التمثيل الرياضي لبيانات التغير الحراري للمستقيم علي مدار ساعتي الإجهاد علي النموذج الرياضي الخطي : $y=a+b\ ln(x) + c\ (ln(x))^2$. و اسفرت عملية التمثيل الخطي لتغير حرارة المستقيم الي تصنيف الحيوانات من الأغنام و الماعز الي اربع مجموعات وفقا لقيم اثنين من المعالم الرئيسية لشكل منحنى التغير الحراري و هما قيمة الذروة وإنحدار ما بعد الذروة. و اعتبرت مجموعة الحيوانات "منخفضة الذروة مع استقامة انحدار ما بعد الذروة " (LPt) من الأغنام والماعز هي الاكثر تأقلما مع الإجهاد الحراري الحاد في حين اعتبرت مجموعتي الماعز "منخفضة قيمة الذروة واسية منحدر ما بعد الذروة" (LEx) و الأغنام "مرتفعة قيمة الذروة و مستقيمة إنحدار ما بعد الذروة" (HPt) هما الأقل مقاومة للإجهاد. وأظهرت الأفراد المصنفة على أنها الأكثر مقاومة شيوعا في إطار كل من نوعي الإجهاد الحراري (الطبيعي و الحاد)، مما يعكس ارتباط محتمل بين أداء مقاومة الحيوانات لنوعي الإجهاد في كل من اللأغنام و الماعز.