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Temperature Gradient in Rabbits in Relation to Heat Tolerance

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THE FLOW of heat from the central core of the body to the environmental air occurred in the direction body-skin-hair-air.The rate of this flow was controlled by the physical laws of heat exchange, besides the physiological mechanisms which control heat loss and heat conservation. Similar results were observed in the heat flow in direction body-ear-air.

Shearing the fur coat induced significant decrease in body. skin and ear lobe temperatures. Also respiration and pulse rates Also respiration and pulse rates decreased but insignificantly

When the data were analysed statistically, it was found that body and skin temperatures did not give a clear trend with both spontaneous and previous air temperatures, since hair and ear lobe temperatures were affected by spontaneous air temperature while respiration and pules rates were affected by both spontaneous and previous environmental air temperatures.

The animal produces heat at a rate that the body temperature is normally above that of the ambient air. Heat is lost from the surface of the body and accordingly skin temperature is less than blood temperature and there is thus a gradient of temperature between the deeper parts and the surface of the body (Davson, 1960). The previous author also stated that when the environmental temperature approaches the body-surface temperature, the cooling by convection and radiation becomes nil leaving evaporation as the only means for heat dissipation. Johnson *et al.* (1958) found that rabbits did not show an increase in water evaporation from skin until an environmental temperature of 29.4°. is reached. Beyond this temperature animals increased their surface and respiratory evaporation with rising environmental temperature. Similar results had been obtained on rats and rabbits by Hieronymi and Jaffe (1931); Tennant (1946) and Kintner (1956).

Davson (1960) pointed out that the fur of the rabbit works as an insulatting medium between the animal body and the environment due to the effec of the enclosed still layer of the air. The removing of the fur in the mice, cause a drop in body temperature and increases the rate of oxygen. consumption by 35% (Pearson 1960).

Material and Methods

This work has been carried out in the poultry Research Station, Faculty of Agriculture, Cairo University, Giza, Egypt, during the period from January (1963) till December (1964). The body temperature was measured by inserting the clinical thermometer for one minute in the rectum while skin and hair temperatures were measured by a thermocouple of pointed probe. Respiration and pulse rates were estimated by a manual counter. Air temperature was recorded at the same time of the test. Egyptian native white "Giza" rabbits weighting 3 to 4 kilograms on the average for males and females were used. Rabbits were housed individually in a brick battery building and were fed on concentrate ration composed of wheat bran and barley. Egyptian clover during winter, and shopped green maize leaves were supplied at summer. The study comprised two experiments :

Seasonal variations and temperature gradients

Fifteen adult (2 years old) white "Giza" Egyptian rabbits of both sexes were used throughout a whole year (1963). The test was carried out three times daily, 7 a.m., 1 p.m. and 7 p.m. at weekly intervals. Air temperature, body, skin, hair and ear lobe temperatures as well as respiration and pulse rates were recorded at the same time of the test for every individual.

Shearing the fur coat and temperature gradient

Eight adult male white "Giza" rabbits were divided into two equal groups The fur of one group was sheared and the other was left as a control. Body temperature, skin temperature of the back temperature of mid region of external suface of the ear lobe, respiration rate and pulse rate were recorded as wel as air temperature for ever individual at every twenty min simultaneously for eight hours continuously beginning at 7 a. m.

Results and Discussion

Skin, hair and ear lobe temperatures are liable to be affected to a certain magnitude by both air temperature and body temperature. If we regard the animal, merely as a hot dead body, the heat will flow from the internal core to the surrounding air through the body surface according to the physical laws of temperature in proportion to the temperature gradients between the different sites. But the animal possesses well organised physiological meckanisms which control heat loss and heat retention against any variation in the environmental temperature to keep the body temperature fairly stable. The animal produces continuously heat at such a rate that the body temperature is normally above that of ambient air. Heat is lost from the surface so that the skin temperature is less than the blood temperature, and there is thus a gradient of temperature between the deeper parts and the surface. The flow of heat from the core to the skin occurs through the flow of blood and also by conduction through the flesh along the gradient between the body and skin temperatures (Davson, 1960). Between the body surface and the bulk of the ambient air, there is a layer of comparatively still air, so the drop in temperature on passing from skin to the outer air is not abrupt. Since the rate of loss of heat depends on a magnitude of the temperature gradient, the smaller the gradient the less the rate of heat loss.

The average temperature gradient all over the year showed the highest value between hair and air temperature 9.2°C. followed by the gradient between skin and hair temperature 6.1°C. while the lowest gradient was between body and skin 0.6°C. this means that tJe flox of temperature from the core through blood, lymph and tissues to the skin surface was restricted, so this channel for heat dissipation must not be the major way in rabbits and there must be another pathway for dissipating heat such as respiration and ear temperature (Tables 1 and 2). This is in agreement with Davson (1960), who stated that in animals with hairy coats, two physiological mechanisms are available, by increasing the contribution of the lungs and respiratory passages as emplified by panting to increase heat loss by evaporation (Shelley and Hemingway, 1940). Temperature gradients body-skin-hair-air varied greatly with seasonal variations in air temperatures. Gradient between body and air temperature was 24.8°, 15.9° 12.9° and 10.0°C. for winter, spring, autumn and summer respectively (Table 1). The same trend can also be noticed between body-skin-ear and air temperatures (Table 2). In animals with hairy coats, like rabbits, physical regulation consists in modifying the insulating layer of air in contact with the skin. By fluffing up the hair at winter the depth of the temperature gradient between skin and ambient air is increased and the rate of heat loss decreased (Davson, 1960), while at summer hair shedding will decrease the density of the hair and so decreases the layer of still air.

It is clear from Table 2 that the temperature gradient between body and ear lobe temperatures was very high in winter, while least differences were found at summer, due to great seasonal ear lobe temperature changes. These great seasonal differences in ear lobe temperature occurred because,

TABLE 1. Temperature gradient between body temperature, skin temperature, hair temperature and air temperature (Average of male and female)

Items Season	body temp. skin temp. °C	skin tempt. air temp. °C	Hair temp. air temp. °C	body temp. air temp. Total difference	body temp. C.
Winter	0.7	8.7	15.4	24.8	39.3
Spring	0.8	6.7	8.4	15.9	39.4
Summer	0.6	4.4	5.0	10.0	39.5
Autumn	0.4	5.4	7.1	12.9	39.4
Average	0.6	6.1	9.2	15.9	39.4

TABLE 2. Temperature gradient between body temperature, ear lobe temperature and air temperature

Items / Season	Body Ear temp. °C	Ear temp. Air temp. °C	Body temp. Air temp. °C	Ear temp. °C	Air temp. °C
Winte	19.7	5.1	24.8	9.6	44.5
Spring	11.0	4.9	15.9	28.4	23.5
Summer	5.6	4.4	10.0	33.9	29.5
Autumn	8.3	4.6	12.9	31.1	26.5
Average	11.2	4.7	15.9	28.3	23.5

of its special characteristics. Its thin skin and very short hair coat render it readily affected by any variation in the air temperature. On the other hand, highly controlable arrangement of vasodilation and arteriovenous shunts render it readily affected by the body temperature. In accordance with the very high gradient in winter and the fear of excess heat loss through ear surface, the ear lobe is folded and dragged very close to the body surface so that the functional carrier in heat loss is almost one quarter of the full ear surface. Also, at summer ear lobes spread wide and far away from the body. Heat loss to the environment is controlled by this law F + C/D = Total conductance (Davson, 1960), where F = Flow of blood through the flesh along the gradient between the body and skin (ear lobe) temperature. C = Specific conductance of tissues heat must pass as a fairly definite quantity depending on the nature of the tissue, and D = The depth of the gradient. This law in a special sense can be applicable to rabbit's ears which possess the power to shunt blood from the central to the peripheral regions of the reverse by arteriovenous anastomosis (Johnson *et al.*, 1957 and Davson, 1960).

Effect of shearing fur coats of rabbits

Body surface of rabbits is tightly protected from direct effect of environmental temprature changes by the great insulating property of the rabbit's fur, which apparently interferes greatly with heat loss.Non-evaporative cooling. environment, shoould beeffected by many hoomthermic mechanisms. These mechanisms compensate for the extreme conditions including changes in the rate of evaporative cooling and cooling, by such factors as fur thickness and body configurarion.

Table 6 showed that both body, skin and ear lobe temperatures decreased significantly by shearing the fur coat of rabbits at an environmental temperature of 27°-32°C., which facilitate heat dissipation to the surrounding environment by direct contact of the lower air temperature to the higher temperature of skin surface. Body temperature dropped in sheared rabbits due to high rate of heat dissipation by convection and evaporative coolling of insensible water of bare skin surface to the environmental air. The difference between maximum and minimum body temperature was 0.1°C. and 0.3°C. for the control and sheared groups respectively which demonstrates the decreased ability of sheared rabbits to keep their body temperature almost constant against the variations in climatic conditions by changing fur thickness or body configuration (Johnson *et al.*, 1958). Skin temperature changes showed the same trend observed in body temperature. Although ear lobe temperature showed also the same trend but it decreased by a higher rate due to the vasomotor action which closed the shunts of the ear lobes of the sheared

TABLE 6. **Mean values of body, skin and ear lobes temperatures for sheared and control rabbits.**

Items		Time in hours									
		Before exp.	1	2	3	4	5	6	7	8	Av.
Body Temp.	sheared	39.7	39.5	39.4	39.3	39.4	39.5	39.5	39.6	39.5	39.5
	control	39.7	39.7	39.7	39.7	39.8	39.7	39.7	39.8	39.8	39.8
Skin Temp.	sheared	39.7	39.6	38.7	38.7	39.0	39.0	39.2	39.5	39.4	39.0
	control	38.7	39.0	39.2	39.1	39.1	39.2	39.4	39.7	39.7	39.3
Ear lobe Temp.	Sheared	34.1	34.3	34.4	34.9	35.4	35.6	35.7	35.4	36.1	35.4
	control	34.0	34.7	35.3	35.6	35.5	36.3	36.8	37.2	37.1	36.1
Resp. rate/min.	sheared	240	209	207	221	225	230	257	249	246	231
	control	242	241	240	239	231	232	244	249	248	241
Puls rate/min.	sheared	240	241	238	233	241	243	251	242	243	242
	control	242	244	245	244	237	241	248	256	255	245
Air temp		27.0	28.0	28.5	30.5	32.5	33.5	34.0	33.0	32.0	31.5

TABLE 7. Analysis of variance for Giza rabbits as affected by shearing the fur (F test)

Items	Source of variation	D.F.	Sum of square	Mean square	F value
Body temperature	Treatment	1	0.23	0.23	5.75*
	Diurnal	7	7.38	1.05	26.25**
	Interaction	23	3.76	0.16	4.00**
	Error	16	0.69	0.04	—
Skin temperature	Treatment	1	23.32	23.32	14.31**
	Diurnal	7	0.79	0.11	0.07
	Interaction	23	29.84	1.30	0.80
	Error	16	26.08	1.63	—
Ear lobe temperature	Treatment	1	57.70	57.70	6.68*
	Diurnal	7	214.79	30.68	3.55*
	Interaction	23	119.15	5.18	0.39
	Error	16	138.20	8.64	—
Respiration rate	Treatment	1	3960	3960	0.67
	Diurnal	7	56790	8112.6	1.39
	Interaction	23	17862	776.61	0.13
	Error	16	93733	5858.31	0.13
Pulse rate	Treatment	1	1776	1776	0.76
	Diurnal	7	72178	10311.14	4.41**
	Interaction	23	4818	209.50	0.09
	Error	16	37325	2332.80	—

** Significant at 1% level of probability.
* Significant at 5% level of probability.

groop to lessen heat dissipation from the ears to the environmental air(Johnson *et al.*, 1957 and Konradi, 1960). Respiration rate also decreased in sheared group in order to decrease heat loss by water vaportization from lungs. Also, pulse rate decreased to lessen the flow of the blood in the peripheral blood vessels of the bare skin and ear lobes to store heat against flow, but these changes in both respiration and pulse rate according to shearing effect were not significant (Table 6).

Since respiration rate, skin and ear lobe temperatures are liable to be affected to some extent by both air temperature and body temperature, these relations were studied statistically. It is interesting to notice that the body temperature differences in males showed no significant relation with air temperature changes at evening and only at 5% level of probability while in females the relation was always significant at 1% level. At the same time, skin temperature relation to air temperature, showed the opposite trend; females showed no significant relation except at noon, however, the relation in most cases was significant at 5% level of probability. This difference may be due to the difference in body size as related to body weight which is of higher value in females. This ratio increases the environmental effect on body temperature (Johnson *et al.*, 1957). Hair and ear lobe temperatures and respiration rate showed highly significant relation with air temperature (Tables 3 and 4). The

TABLE 3. **Correlation coefficients (r values) between the body reaction (tems) and air temperature at successive day times**

Correlation items/Air temp.	Morning		Noon		Evening	
	Female	Male	Female	Male	Female	Male
Body temperature	0.80	0.44	0.74	0.32	0.78	0.63
Skin temperature.	0.26	0.61	0.63	0.68	0.50	0.67
Hair temperature	0.93	0.95	0.96	0.92	0.96	0.95
Ear lobe Temp.	0.99	0.99	0.98	0.96	0.99	0.95
Respiration rate .	0.85	0.77	0.89	0.87	0.93	0.92
Pulse rate . . .	0.61	0.60	0.63	0.58	0.71	0.66

TABLE 4. Simple regression coefficients (b values) of the body reaction (Items) and air temperature at successive hourse of day time and its significance as tested by (F test)

Regression items/air temp.	Morning		Noon		Evening	
	Female	Male	Female	Male	Female	Male
Body temperature	0.009**	0.008	0.007**	0.CC4	0.009**	0.007*
Skin temperature.	0.01	0.04**	0.03*	0.03*	0.03*	0.03*
Hair temperature	0.42**	0.54**	0.41**	0.31**	0.39**	0.41**
Ear lobe temp.	1.24**	1.39**	0.83**	0.66**	0.79**	0.79**
Respiration rate	4.47**	4.74**	5.35*	5.99**	5.35*	7.01*
Pulse rate	2.14*	2.25*	1.98*	1.90*	2.26**	2.33*

** Significant at 1% level of probability.

* Significant at 5% level of probability.

large b value in case of ear lobe temperature and respiration rate-with air temperature, could be explained on basis that items are in direct contact with air. The pulse rate showed small values of relation (r and b) at 5% level, this may be a secondary response to direct variation in air temperature through respiration and ear lobe channels.

The data were analysed to find out the effect of successive variation (day time variation) in air temperature on the different body reactions. Partial regression was carried out between each item with the spontaneous temperature and the previous (day time) temperature (Table 5). Respiration rate was affected more than other items. The effect of spontaneous air temperature at noon (N, M and N) was very high (by 2.1 = 16 32). This may be due to that at noon (high temperature), was preceded by cold previous air temperature (morning). On the other hand, the effect was very low in the evening (by 1.2 = 0.45) which was preceded by high temperature (noon). The same trend was found in pulse rate as it is physiologically related to respiration (Table 5). Hair and ear lobe temperature were directly affected by spontaneous temperature irrespective of previous temperature (Table 5). Body and skin temperatures did not give a clear trend with both spontaneous and previous air temperatures, since they were affected by air temperature indirectly through other physiological activities of the body.

TABLE 5. Partial regression coefficients of body reactions (Items y) over spontaneous and previous day times air temperatures (X), at morning (M), noon (N) and evening(E) in male rabbits.

Previous (X_1)	Items (Y)/air temperature and spontaneous (X_2)	Partial regression coefficient of items on	
		Previous air temperature by 1.2	Spontaneous air temperaure by 2.1
Body temperature .	(N)/Air temperature (M) : (N)	—0.029	0.028
Body temperature .	(E)/Air temprrature (N) : (E)	—0.003	0.006
Skin temperature. .	(N)/Air temperature (M) : (N)	0.06	—0.03
Skin temperature. .	(E)/Air temperature (N) : (E)	0.01	0.02
Hair temperature .	(N)/Air temperature (M) : (N)	0.04	0.37
Hair temperature .	(E)/Air temperature (N) : (E)	0.14	0.28
Ear lobe Temp.	(N)/Air temperature (M) : (N)	0.26	0.44
Ear lobe Temp. .	(E)/Air temperature (N) : (E)	0.44	0.34
Respiration rate . .	(N)/Air temperature (M) : (N)	12.63	16.32
Respiration rate . .	(E)/Air temperature (N) : (E)	3.16	0.45
Pulse rate	(N)/Air temperature (M) : (N)	—25.19	22.49
Pulse rate	(E)/Air temperature (N) : (E)	—1.51	3.74

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تأثير درجات الحرارة على التحمل الحرارى للأرانب

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أثبت البحث أن قص شعر الأرانب خفض حرارة الجسم والجلد وصيوان الأذن وسرعة التنفس وسرعة النبض .

ولايمكن اعتبار درجة حرارة الجلد والجسم مقياس دقيق لدرجة حرارة الجو السابقة أو الحالية حيث يؤثر فى ذلك دور صيوان الاذن والفرآء .