INDIVIDUAL DIFFERENCES IN SPECIFIC COLD ADAPTATION AND THEIR RELATIONSHIP TO STRESS AND AGGRESSIVE BEHAVIOR IN MICE

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When the ambient temperature falls, besides specific and nonspecific morphological and physiological changes [6, 9], modification of certain forms of behavior, including aggressive, also takes place [2, 5, 13]. Intraspecific aggression as an important component of zoosocial relations participates in the formation of hierarchical and territorial population structures appropriate for the ecologic conditions [3, 11, 13]. The simultaneous study of physiological and behavioral responses to environmental influences and the analysis of their interdependence are thus important for an understanding of the mechanisms of integration of adaptive reactions, taking place at the individual and population levels.

In the investigation described below on mice of the outbred Swiss line, relations between aggressive behavior and individual differences in specific and nonspecific response to prolonged exposure to cold were studied.

EXPERIMENTAL METHOD

Experiments were carried out on 42 males aged 4-6 months. The mice were put in individual cages 2 weeks before exposure to cold and were kept at a temperature of 19-21°C. The temperature was then lowered to 6-8°C. Before and after exposure to cold for 5 weeks the calorigenic response to noradrenalin (NA) and parameters of aggressive interactions of the animals were determined. The interval between these investigations was 3-4 days. To assess the corticosteroid function of the mice blood samples were taken from the retroorbital sinus 9-10 days before exposure to cold (background) and 1, 7, and 30 days after a fall of temperature, The response to intraperitoneal injection of NA in a dose of 400 μg/kg was investigated at an ambient temperature of 28°C. To assess changes in energy metabolism, the oxygen concentration in the air leaving the chamber containing the animals was measured by an NM 5122-194 paramagnetic gas analyzer, the accuracy of which was increased to 0.02%. The volume velocity of the air supply was reduced to normal values. Aggressive behavior was studied in the paired mating test. The mice were kept in separate compartments of a four-compartment cage for 16-18 h before testing. During the test the passages between two neighboring compartments were opened and parameters of agonistic behavior were recorded for 15 min. Each animal was tested .twice with different partners and the mean value of the behavioral parameters determined. The plasma 11-hydroxycorticosteroid (11-HCS) level was determined fluorometrically [7].

EXPERIMENTAL RESULTS

An increase in the calorigenic response to NA in small mammals is a typical manifestation of specific adaptation to a low ambient temperature [4, 6]. Before exposure to cold the total increase in oxygen consumption in response to NA was 3.3 ± 1.1 ml·g$^{-2/3}$ during the 24-min recording period. After exposure for 5 weeks to a low temperature, the calorigenic reaction was increased fourfold ($p < 0.001$). Individual differences in the response to NA at the end of exposure to cold were used to distinguish groups of mice differing in the efficiency of specific adaptation to cold: group 1 (20 individuals) — the total increase in oxygen consumption in response to NA exceeded the average level; group 2 (18 mice) — the total increase was less than the average level; group 3 — four mice dying during exposure to the low temperature. It must be pointed out that under conditions of thermal comfort the animals of these groups did not differ in their calorigenic response to NA.

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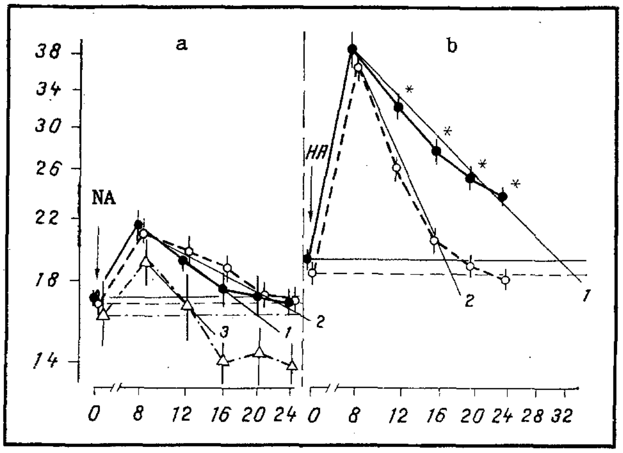

Fig. 1. Calarigenic response to NA in mice differing in efficiency of specific adaptation. Abscissa, time (in min); ordinate, oxygen consumption (in ml/g$^{-2/3}$). a) Before exposure to cold; b) after exposure to cold. 1) High efficiency of specific adaptation; 2) low efficiency; 3) mice dying during exposure to cold. High lines indicate linear approximation of descending part of curve before intersection with initial level of oxygen consumption. *p < 0.05) — Differences between animals of groups 1 and 2 are significant.

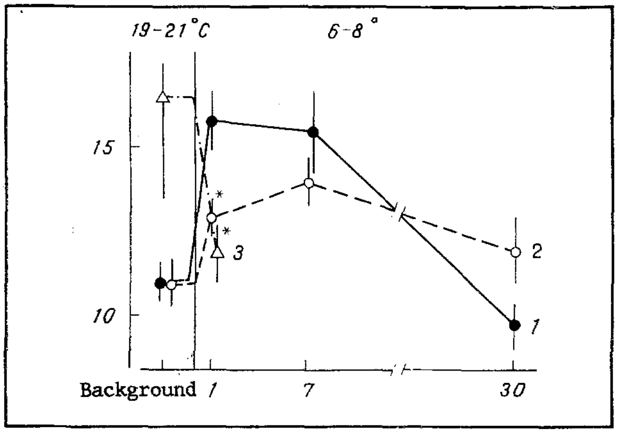

Fig. 2. Plasma 11-HCS levels in mice differing in efficiency of specific adaptation to cold. Abscissa, time (in days); ordinate, 11-HCS concentration (in μg/100 ml). *$p < 0.05$ — Differences from animals of group 1 are significant. Remainder of legend as to Fig. 1.

Differences between mice of groups 1 and 2 with respect to the total effect of NA were due primarily to differences in the rate of recovery of energy metabolism. This will be clear by examining the time course of oxygen consumption plotted between logarithmic coordinates (Fig. 1). The time for complete recovery in mice of group 1 increased after exposure to cold from 17.2 ± 2.5 to 31.6 ± 3.6 min ($p < 0.01$). In the mice of group 2 it was unchanged at 22.0 ± 3.8 and 17.8 ± 1.6 min respectively. Differences in the time of recovery are indirect evidence of a decrease in the rates of NA inactivation in the mice of group 1.

A fall of ambient temperature was accompanied by activation of mechanisms of the stress reaction, and judging by the 11-HCS concentration at the beginning of exposure to cold, this was maximal in mice of group 1 and minimal in the mice which died during exposure to a low temperature (Fig. 2). After 30 days a complete (group 1) or partial (group 2) restoration of corticosteroid function to its initial level was observed. Individual differences in plasma 11-HCS concentration correlated with parameters of specific adaptation to cold, and in particular, with the total increase in energy metabolism in response to NA. The glucocorticoid level, moreover, measured at the beginning of exposure to cold, correlated positively with the calor-

TABLE 1. Aggressive Behavior of Mice of Outbred Swiss Line before and after Exposure to Cold, Depending on Efficiency of Specific Adaptation to Cold

Behavioral parameter	Conditions of keeping (temperature, °C)	Efficiency of physiological adaptation to cold			Significance of differences
		group 1 (high)	group 2 (low)	group 3 (dying)	
Number of aggressive acts (total number of attacks, bites, and fights)	19—21	18,2±5,4 (20)	17,9±4,4 (18)	0,7±0,5 (4)	$p_{1,\,2-3}<0{,}01$
	6—8	46,4±9,1* (20)	21,6±5,7 (18)	—	$p_{1-2}<0{,}05$
Number of acts of passive defensive behavior	19—21	4,7±2,9 (20)	8,9±3,0 (18)	7,7±1,8 (4)	—
	6—8	6,1±1,8 (20)	15,7±3,8 (18)	—	$p_{1-2}<0{,}05$

Legend. $^*p < 0.05$ compared with conditions of thermal comfort. Number of animals given in parentheses.

igenic reaction ($r = 0.32$; $p < 0.05$), but at the end of the exposure, it correlated negatively ($r = -0.33$; $p < 0.05$). Previously similar relations between specific and nonspecific mechanisms of response to the prolonged action of cold were observed in a study of rats of inbred lines, differing in reactivity to stress [1].

The behavioral characteristics of the animals also correlated to a definite degree with the parameters of specific adaptation to cold. For instance, mice dying during exposure to cold had significantly lover aggressiveness than those which survived (Table 1). Under conditions of thermal comfort, mice of groups 1 and 2 did not differ from each other in the parameters of agonistic behavior. At the end of exposure to cold, however, mice with high efficiency of specific adaptation to a 100 temperature had a larger number of aggressive actions and a smaller number of acts of passive defensive behavior compared with the less adapted mice.

Thus more efficient individual adaptation to cold is combined with a lower level of stress of the animals and with an increased tendency toward their dominance in zoosocial conflicts. These relations may be based on mechanisms connected with the action of cold on catecholamine metabolism, changes in which in the central and peripheral components of the sympathicoadrenal system had a significant influence also on the pituitary-adrenal system and on aggressive behavior [8, 10, 12].

LITERATURE CITED

1. L. A. Gerlinskaya and M. P. Moshkin, Probl. Éndokrinol., No. 4, 63 (1984).
2. F. Z. Meerson, Adaption, Stress, and Prophylaxis [in Russian], Moscow (1981).
3. E. N. Panov, Animal Behavior and the Ethologic Structure of Populations [in Russian], Moscow (1983).
4. Yu. F. Pastukhov, The Ecologic Physiology of Animals, Part 3 [in Russian], Leningrad (1962), pp. 92-103.
5. A. D. Slonim, Zh. Obshch. Biol., No, 1, 118 (1978).
6. V. V. Khaskin, Synergetics of Heat Formation and Adaptation to Cold [in Russian], Novosibirsk (1975).
7. S. Udenfriend, Fluorescent Analysis in Biology and Medicine Russian translation], Moscow (1965).
8. J. F. Henry and F. M. Stephens, Stress, Health and the Social Environment: a Sociobiologic Approach to Medicine, New York (1977).
9. J. LeBlank, Nonshivering Thermogenesis, Prague (1971), p. 99.
10. K. A. Miczek and J. F. De Bold, Hormones and Aggressive Behavior, New York (1983), pp. 313-347.
11. D. H. Morse, Behavioral Mechanisms in Ecology, Cambridge (1980).
12. E. V. Naumenko, Central Regulation of the Pituitary Complex, New York (1973).
13. D. R. C. Prescott, Can. J. Zool., **65**, No. 5, 522 (1987).