INTRASCROTAL TEMPERATURE, TESTICULAR HISTOLOGY AND FERTILITY OF HEAT-ACCLIMATIZED RATS

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Summary. Heat-acclimatized rats were exposed to an ambient temperature of 35°C, and the effect on testicular histology, reproductive capacity and body and scrotal temperature was evaluated. Both deep body and intrascrotal temperatures of these animals were found to be higher than those of control rats maintained at 22°C. The intrascrotal temperature in the heat-acclimatized animals and the deep body temperature in the controls were similar. Breeding experiments proved the heat-acclimatized animals to be capable of mating and reproducing, although at a lower rate than the controls. The heat reduced only the mating rate and fertilization. After conception, the groups showed no difference. Histological screening revealed degenerated seminiferous tubules randomly scattered in the testes of the heat-acclimatized rats although most of the tubules showed normal spermatogenesis. These localized necrotic foci resemble the overall appearance of a cross-section of a cryptorchid testis. The heat-acclimatized animals, however, maintain a body to scrotum temperature gradient which enables spermatogenesis to proceed despite the elevated temperatures.

INTRODUCTION

Exposure to high environmental temperature causes hyperthermia in rats. This condition can usually be withstood for relatively short periods of time during which adaptive physiological adjustments are achieved and the hyperthermia disappears. If the animals become heat-adapted, as indicated by their decreased metabolic rate, they can survive high ambient temperatures without becoming hyperthermic (Gelineo, 1934, 1940, 1964) but they have been reported to be unable to mate and reproduce (Gelineo, 1940). Hamilton (1963) showed that rats kept at 24°C became hyperthermic when exposed to 35°C for 21 days and remained so while they were kept at this temperature. When the animals were returned to 24°C, their body temperature reverted to normal.

Previous experiments carried out in our laboratory (Bedrak, Samoiloff, Sod-Moriah & Goldberg, 1971) established that the animals were heat-acclimatized.

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In such animals, the rate of incorporation of [14C]lysine into testicular proteins (unpublished data) resembles that of cryptorchid testes (Davis, Morris & Hollinger, 1964). Cryptorchid testes are maintained at deep body temperature which is higher than the normal testicular temperature in intact animals. In view of the effect of a hot environment on testicular protein synthesis, this study set out to investigate three parameters: (a) intrascrotal and deep body temperatures, (b) reproductive ability, and (c) the histological pattern in the testes of heat-acclimatized animals chronically exposed to a high temperature.

MATERIALS AND METHODS

Animals

The experimental animals were mature albino male rats, obtained at the age of 100 to 110 days, from the colony of the Department of Biodynamics of the Weizmann Institute, Rehovot. The animals were randomly allocated to two groups, each of which was acclimatized to a specific environment for at least 3 months before the initiation of the experiment. A control group was acclimatized to an ambient temperature of 22±2°C and relative humidity of 35 to 50%. An experimental group was acclimatized by chronic exposure to 35±1°C and relative humidity of 25 to 40%. The animals were maintained under controlled conditions of light (14 hr light/10 hr dark) and were allowed free access to rat pellets and tap water.

Temperature measurements

Deep body temperature was measured with a Yellow Spring Tele-Thermistor (Model 44 TD) with a 4 mm-thick thermistor probe (Series 400) inserted 4 cm into the rectum. Intrascrotal temperatures were measured with a thermocouple consisting of 48 s.w.g. enameled copper and constantan wires contained in a 27-gauge hypodermic needle which enabled readings of 40 μV/1°C over the range 0 to 50°C. The needle was inserted into the scrotum when the testes had been displaced to avoid possible damage. Measurements were taken on alternate days for 30 days.

Breeding experiments

Male rats from each group were caged overnight together with pro-oestrous females (in the control room at 22±2°C). Mating rates (percentage of matings confirmed by the presence of spermatozoa in the vagina) and the results of subsequent pregnancies were calculated.

Histological techniques

Tissue samples were fixed in 10% formalin, cut at 7 μm thickness and stained with haematoxylin and eosin (H+E) for microscopic study.

RESULTS

Temperature measurements

Deep body and intrascrotal temperatures were higher in the experimental
Heat-acclimatization and rat testicular function

Text-fig. 1. Deep body (——) and intrascrotal (—–—) temperatures of control (●) and acclimatized (○) rats. Points and vertical lines indicate means and standard errors respectively.

Table 1. Deep body and intrascrotal temperatures in control and heat-acclimatized male rats

<table>
<thead>
<tr>
<th>Experimental group</th>
<th>Control (Mean ± S.E.)</th>
<th>Heat-acclimatized (Mean ± S.E.)</th>
<th>Level of significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of animals</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>36.9 ± 0.052</td>
<td>37.7 ± 0.068</td>
<td>0.001</td>
</tr>
<tr>
<td>Intrascrotal temperature (°C)</td>
<td>35.0 ± 0.109</td>
<td>36.3 ± 0.134</td>
<td>0.001</td>
</tr>
<tr>
<td>Level of significance*</td>
<td>0.001</td>
<td>0.001</td>
<td>—</td>
</tr>
<tr>
<td>Difference between body and intrascrotal temperature (°C)</td>
<td>1.8 ± 0.072</td>
<td>1.4 ± 0.082</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* Student's t test.

than in the control animals (Text-fig. 1). Towards the end of the 30-day measuring period, the intrascrotal temperature of the experimental rats increased almost to the level of the deep body temperature of the controls, but the differences between body and intrascrotal temperatures were maintained in both groups (Table 1). Thus, the body-to-scrotum temperature gradient was similar in both groups though statistically different.

Breeding experiments

The mating rate of experimental males was much lower than that of control males (Table 2). In addition, a greater proportion of the females which mated with experimental males did not conceive. In those females which did conceive, the type of male used had no subsequent effect on implantation (determined as the number of metrial glands expressed as a percentage of corpora lutea), pregnancy losses and average number of young born, live or dead.
Histological findings

Certain changes were noted in the testes of experimental animals (Pl. 1, Figs 1 and 2). Although the general histological pattern resembled that of normal control testis, spermatogenesis was severely affected in several adjacent seminiferous tubules in which necrobiosis of the germinal epithelium could be observed. The necrobiotic foci were irregularly scattered among adjacent, intact tubules. The degenerated tubules did not exceed 20% of the cross-sections of the seminiferous tubules. Slight hyperplasia of the Leydig cells was noted. The epididymal epithelium of the experimental animals was intact and normal spermatozoa were found in the lumen.

DISCUSSION

The deep body temperature of heat-acclimatized and control female rats (Sod-Moriah & Yagil, 1973) increased and remained high as long as the animals were kept in the hot environment (35°C). Within 30 min of their being moved to the control room (22°C), their temperature reverted to normal. All animals exhibited similar values for deep body temperature in both environments; that is, both controls and heat-acclimatized animals were hyperthermic at 35°C, and exhibited a normal temperature at 22°C, irrespective of the initial acclimatization temperature.

The experimental rats in this study were exposed to an environment of 35°C for 3 months and their reduced metabolic rate (Gelineo, 1934, 1964) indicated that they were indeed heat-acclimatized (Bedrak et al., 1971) though their deep body temperature was higher than that of controls. The intrascrotal temperature of the heat-acclimatized animals was also higher, resembling the deep body temperature of the controls and therefore similar to the environmental temperature of cryptorchid testes. Another study in our laboratory showed that the rate of incorporation of [14C]lysine into testicular proteins of heat-acclimatized rats (unpublished data) resembled that of the cryptorchid testis (Davis et al., 1964). This suggests that the elevated testicular temperature of heat-acclimatized rats is the apparently 'normal' temperature (Davis, Firlit & Hollinger, 1963) of the testes in such animals.
Fig. 1. A cross-section of a testis from a heat-acclimatized rat. Some degenerated seminiferous tubules can be seen among adjacent normal tubules.

Fig. 2. A cross-section of a testis from a heat-acclimatized rat showing a ‘normal’ seminiferous tubule containing spermatozoa adjacent to a degenerated tubule.

(Facing p. 266)
Heat-acclimatization and rat testicular function

It is known that spermatogenesis may be arrested by transferring scrotal testes permanently into the abdominal cavity. This effect is accepted as being due to the high temperature in the abdominal cavity (Nelson, 1951; Anderson, Anderson & Quaade, 1955; Clegg, 1960). In the heat-acclimatized rats, the scrotal temperature was similar to control deep body temperature, nevertheless spermatogenesis proceeded and only a limited number of segments of seminiferous tubules were non-active. Breeding experiments proved these animals to be fertile, although less so than the controls. The mating rate seemed lower and, among the females that mated, there seemed to be fewer conceptions (Table 2). The type of male used did not appear to have any other detrimental effect. Pregnancy continued normally and the experimental rats produced a similar number of young to those produced by the controls. Prolonged exposure to 35°C may increase the proportion of seminiferous tubules with arrested spermatogenesis. A previous study (Bedrak et al., 1971) noted that when the males were exposed to 35°C for only 4 to 5 weeks, no necrotic tubular foci could be observed. It is concluded that the long exposure to the high ambient temperature caused some degree of damage. This localized damage resembled that caused by the high ‘ambient temperature’ in the cryptorchid testis. The adverse effect of cryptorchidism on spermatogenesis may therefore be due not merely to the increased temperature as such since the scrotal testes of the experimental animals showed active spermatogenesis at the same high temperature. The mere presence of the testis in the scrotum also has no major effect, since heating of the scrotum to body temperature arrests spermatogenesis (Blackshaw & Massey, 1972), as does cryptorchidism (Clegg, 1960). The role of the scrotum is apparently to maintain a temperature gradient between body and testis rather than maintaining a specific, relatively low temperature. It is suggested therefore that this gradient is essential for spermatogenesis since in heat-acclimatized males the gradient was maintained and spermatogenesis continued despite the increased body and scrotal temperature. Similar testicular temperatures without the commensurate gradient, as in the cryptorchid testis, or the heated scrotum, were detrimental to spermatogenesis.

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REFERENCES


