Effects of treadmill running and swimming on plasma and brain vasopressin levels in rats


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Summary. The influence of treadmill or swimming exercise on resting values of plasma and brain arginine vasopressin (AVP), and plasma sodium, potassium, osmolality and proteins was studied after 5 weeks of training using female Wistar rats. The duration of daily training sessions was progressively increased to reach 6 h/day for swim training (S) and 3 h/day for treadmill running (T). Compared to their untrained controls, treadmill and swim training were respectively associated with: 1. a significant lower body weight; 2. a decreased plasma AVP (36.4% for T and 47.4% for S) and hypothalamic AVP (20% for T and 16% for S); 3. a higher hypophyseal AVP (145% for T and 36.3 for S); 4. a decreased plasma osmolality (6.7% for T and 6.1% for S), sodium (1.2% for both) and potassium (15% for T and 22.4% for S); and 5. no change in protein concentration. For T, rectal temperature increased (38.5 ± 0.20 to 39.7 ± 0.5) and for S rectal temperature decreased from 38.6 to 37.7.

The differences observed in AVP contents of the pineal and Harderian glands (enhanced only in the treadmill groups) could be explained by the supposed role of these glands in thermoregulation. Two conclusions could be drawn from this study: 1. there are no parallel changes in the hypothalamic-hypophyseal system (where AVP plays its endocrine role) and the brain (where AVP is a neurotransmitter); 2. plasma changes could be explained by an extracellular fluid expansion with Na and K loss leading to a decrease in AVP secretion.

Key words: Vasopressin — Swimming — Running — Brain — Plasma osmolality

Introduction

Endurance exercise involves not only cardiovascular adaptations but also changes in endocrine responses: this concerns the hormones implicated in the mobilization of energy substrates (Galbo 1983) as well as the hormones involved in blood volume regulation, since the circulatory system has to cope with the fluid loss required for cooling. But repeated bouts of exercise result in an increase in resting plasma volume, which leads to an adaptation of these hormonal systems (Convertino et al. 1980; Convertino et al. 1980; Convertino et al. 1981; Fagard et al. 1985; Francesconi et al. 1985; Geyssant et al. 1981; Gharib et al. 1981; Melin et al. 1980): the resting values of plasma renin activity (PRA) are lowered by training (Geyssant et al. 1981; M'Buyamba-Kabangu et al. 1985; Melin et al. 1980). It has not been possible to demonstrate this for arginine vasopressin (AVP) in man (Wade 1984). But AVP is not only a hormone of primary importance in the regulation of plasma volume and osmolality: AVP seems to have antipyretic (Banet and Wieland 1985) and antinociceptive effects besides its known facilitatory properties on memory processes or centrally mediated autonomic effects (Buijs 1983; De Wied 1983). In addition, extrahypothalamic projections of vasopressinergic neurons have been widely demonstrated in the brain (Dogterom et al. 1978; Dorsa and Bottemiller 1983; Hawthorn et al. 1984), the pineal gland and the organs which present a great analogy with the pineal — the retina and the Harderian gland (De Wied 1983).

The present study was undertaken to evaluate the modifications due to exercise of AVP as a regulatory hormone and vasopressin as a neurotransmitter or neuromodulator in the brain, using two training programs: treadmill running and swimming (Pitts 1984).
Animals and training program. Female Wistar rats (IFFA Credo, Les Oncins, France) were housed 8 per cage in temperature controlled rooms (23°C) with a dark-light cycle of 12/12 h and maintained on Purina Laboratory chow and tap water ad libitum. All animals were received at 4 weeks of age, kept for several days and then randomly assigned to one of the three groups: 1. Sedentary, cage-confined rats; 2. treadmill runners and 3. swimmers (n=8 for each group).

**Treadmill running.** In the treadmill exercise group, the rats initially ran 10 min thrice daily at 20 m·min⁻¹ on a level plane. Thereafter, the duration of each running session was increased by 3 min daily until, after 3 weeks of training, the animals were exercising a total of 3 h/day, 5 days/week. The running sessions were divided into three 1 h sessions that were separated by 30 min rest periods during which the animals had access to food and water. Animals were maintained at the final intensity and duration for two additional weeks (Fig. 1).

**Swimming program.** Exercise consisted of swimming in a plastic barrel (120 x 60 x 60 cm) filled to a depth of 50 cm with water maintained at a temperature of 36 ± 1°C. The first day, the rats swam for 1 h 30 min/day in three 30 min sessions. The duration of swimming was then gradually increased until after 3 weeks the rats swam for a total of 6 h/day, 5 days/week. The swimming sessions were divided into three 2 h sessions separated by 30 min rest periods during which the animals had access to food and water. Animals were maintained at the final intensity and duration for two additional weeks (Fig. 1).

**Methods**

As shown in Fig. 1 both swimmer and runner rats had a reduced growth rate. This body-weight reducing effect is significant as early as the second week of training.

During running, rectal temperature increased significantly from 38.5 ± 0.20°C to 39.7 ± 0.5°C. During swimming, rectal temperature decreased significantly from 38.6 ± 0.12°C to 37.74 ± 0.10°C.

Figure 2 shows plasma AVP, osmolality, Na, K and protein concentrations. Except for protein content (not affected by training), both swimming and running lowered all other parameters studied. This means that no dilution of plasma occurred during the training. The only probable explanation is a loss of Na and K through the urine.

Brain AVP contents are presented in Fig. 3. In the hypothalamus, AVP content was reduced by 30% relative intensity. Since swimming has been shown to be less effective than running in inducing adaptative changes in the respiratory capacity of muscles, the swim duration was twice as long as that for running in order to induce a similar degree of adaptation in both programmes (Holloszy and Booth 1977). After the 5 weeks, the animals were decapitated and exsanguinated. The trained rats were killed approximately 24 h after their last bout of exercise. Rectal temperature was measured before and after running or swimming.

Blood assay. After decapitation, heparinized blood was centrifuged at 4°C and the plasma frozen at −20°C until assay. Plasma sodium, potassium (NaK Radiometer), osmolality (Fisk OR Osmometer) and protein were measured.

Plasma AVP was determined using the Buhlmann Kit, with the exception of the labelling of AVP which was performed in our laboratory using a modification of the method of Greenwood and Hunter (Geelen et al. 1981).

Central nervous system samples (hypophysis, hypothalamus, cerebellum, medulla oblongata, frontal lobe, pineal, retina and Harderian glands) were removed immediately after decapitation and frozen at −20°C, and AVP was measured as previously described (Gauquelin et al. 1983; Geelen et al. 1981). The protein content was measured in each sample.

Statistics. Results were expressed as the mean ± SEM. Statistical significance was determined by Students t test for unpaired data and two-way analysis of variance, Newman and Keuls post-hoc analysis.

The partial correlation coefficient (r) was used to examine the relationships between the variables. Results were considered significant if p = 0.05 or less.

**Results**

As shown in Fig. 1 both swimmer and runner rats had a reduced growth rate. This body-weight reducing effect is significant as early as the second week of training.

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Brain AVP contents are presented in Fig. 3. In the hypothalamus, AVP content was reduced by treadmill running and swimming. The pituitary gland exhibited an increase in AVP content after both running and swimming.

In the pineal and Harderian glands running increased AVP content. In the frontal lobes, no significant differences were observed either after running or after swimming. In the retina, only the swimming programme enhanced AVP content.