EFFECT OF PROLONGED HYPOKINESIA ON THE WATER AND FAT COMPOSITION OF THE HUMAN BODY

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The combined effect of prolonged hypokinesia (30-49 days) and differences in the body position relative to the gravitational vector on the composition of the body was studied in healthy men. The total body water content depends more on the position of the body in space than on the restricted mobility. In the antiorthostatic position, the loss of water takes place chiefly during the first few days. As a result of prolonged hypokinesia the "lean mass of the body" is reduced and so also is its water content. The water content is rapidly restored when motor activity is resumed.
KEY WORDS: *hypokinesia; gravitation; water metabolism; body fat content.*

Changes in water metabolism play an important role in the pathogenesis of disturbances affecting the neuroendocrine and cardiovascular systems during prolonged hypokinesia. Many authorities are of the opinion [1, 5] that changes in the body composition take place during adaptation to hypokinesia.

The effect of a combination of hypokinesia with differences in position relative to the gravitational vector on the human body was investigated.

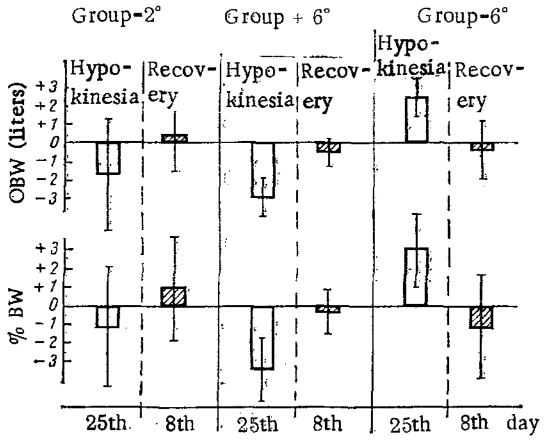

Fig. 1. Effect of position of subjects' body relative to gravitational vector on absolute (OBW) and relative (BW, in % of body weight) body water content. Explanation in text.

EXPERIMENTAL METHOD

Experiments were carried out on 33 healthy males. The movements of three subjects were not restricted. The rest were strictly confined to bed for 30 days. They differed in the position of their body relative to the gravitational vector: For six subjects the foot of the bed was raised by 2° and for another six by 6°; for six subjects the head of the bed was raised by 6°. Twelve subjects were confined to bed for 49 days with the foot of the bed raised by 4°. The subjects were not allowed to sit up even when using the bedpan.

The total body water was determined with the aid of tritium oxide (specific activity 100 μCi/ml), which was injected intramuscularly in a dose of 60-130 μCi. Expired water vapor was collected in a glass trap, immersed in a mixture of ice and water, 2-4 h after administration of the isotope. Activity of the samples was measured with a Mark 1 (Nuclear Chicago, USA)

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TABLE 1. Effect of Bed Rest in the Antiorthostatic Postion on Absolute (OBW) and Relative (BW, in % of body weight) Body Water Content (M ± m)

Indices	Bed rest			Resumption of motor activity	Bed rest			Resumption of motor activity
	15th day	26-27th day	48th day	13th day	5th day	20th day	47th day	4th day
		A				B		
Body weight (in kg)	0.5 ± 0.45 $P=0.1$	1.5 ± 0.37 $P=0.01$	0.8 ± 0.59 $P=0.1$	3.0 ± 0.51 $P=0.01$	—	-0.33 ± 0.58 $P=0.1$	-2.03 ± 1.27 $P=0.1$	-1.48 ± 1.12 $P=0.1$
OBW (in liters)	-1.76 ± 0.52 $P=0.02$	-2.03 ± 0.81 $P=0.05$	-2.84 ± 0.68 $P=0.01$	-0.12 ± 0.47 $P=0.1$	-1.11 ± 0.18 $P=0.002$	-2.01 ± 0.34 $P=0.002$	-2.96 ± 0.39 $P=0.001$	-1.29 ± 0.46 $P=0.05$
BW (in %)	-2.95 ± 0.52 $P=0.01$	-4.17 ± 1.04 $P=0.01$	-4.68 ± 0.74 $P=0.002$	-2.57 ± 0.34 $P=0.001$	—	-2.66 ± 0.31 $P=0.001$	-2.68 ± 0.58 $P=0.01$	-0.66 ± 0.53 $P=0.1$

Note. Differences from initial values shown.

liquid scintilation counter. To calculate the body water content a correction was introduced for tritium incorporated into the organic tissue structures (0.98 [2]), and another for differences in the quantity of ordinary and superheavy water in the expired water vapor (0.94 [8]). The error of the method was 2%. The fat content was determined by the equation [10]:

$$F = \frac{2 \cdot 118}{D} - 0.78 \times BW - 1 \cdot 354,$$

where F is the fat content (in %), D the specific gravity of the body, and BW the relative water content in the body (in % of the body weight).

The volume of the body was determined from the volume of water displaced on total immersion during maximal expiration.

EXPERIMENTAL RESULTS AND DISCUSSION

The body water content was found to depend on the position of the body in space (Fig. 1): it was reduced in the −6° antiorthostatic position and was increased in the +6° position (head of the bed raised). In the − 2° antiorthostatic position the body water content was unchanged at the end of the experiment. Consequently, the total body water is affected more by the position of the long axis of the body relative to the gravitational vector than by the hypokinesia itself.

A change in the position of the body is known to cause redistribution of the intravascular fluid [4, 9]. Compared with the horizontal position, in the antiorthostatic position there is evidently a greater increase in the intrathoracic blood volume and an increase in the central venous pressure. Through a series of neuroendocrine mechanisms (inhibition of secretion of antidiuretic hormone, renin, and aldosterone), the latter causes increased elimination of water and salts from the body [6, 7]. In subjects kept for a long time in the orthostatic position, blood is retained in the lower half of the body and its central volume is reduced [3]; this evidently leads to stimulation of the antidiuretic system and inhibits the excretion of sodium. As a result the body water content rises.

In six subjects the total water content was determined on the 15th, 26th, and 48th days in the antiorthostatic position. The indices of water metabolism were changed the most during the first 2 weeks of hypokinesia (Table 1A). Whereas throughout the whole period of bed rest the subjects lost 2.8 liters, during the first 15 days of hypokinesia the water content fell by 1.8 liters, or 62% of the total water loss.

Evidently in the antiorthostatic position the initial changes in the gravitational state of the body took place in the earlier period of bed rest. In the other six subjects, therefore, the body water content was determined on the 5th day of hypokinesia, and again on the 20th and 47th days in the 4° antiorthostatic position. These determinations confirmed that the rate of water loss was highest in the early periods of the experiments; later the amount of fluid continued to fall, but much more slowly (Table 1B). The elimination of water by man in the antiorthostatic position thus takes place during the first few days.

Toward the end of the experiment (46th-47th days of hypokinesia) both the absolute and the relative water content of the subjects decreased. However, these changes evidently cannot be regarded as dehydration, for considerable changes in body composition are possible during a long-term experiment, with disturbance of the ratio between the fat and nonfat components. For example, changes in the ratio between these two components in favor of fat has been shown to occur as early as after the first day of bed rest [1].

Calculation of the fat content during the first days of resumption of motor activity showed that it was the same as initially ($+ 0.4 \pm 0.88$ kg). The "lean mass of the body" (the difference between the body weight and the fat content), on the other hand, fell by 2.4 kg after 46 days of hypokinesia ($P < 0.01$), and on the 4th day of the recovery period it was still 1.9 kg below its initial value ($P < 0.02$). In the first case the relative percentage of water in the "lean mass of the body" also fell (by 2.1%; $P < 0.01$), an indication of dehydration.

During prolonged bed rest in the antiorthostatic position, not only was the nonfat component of the body reduced, but so also was the water content. The water content is quickly restored when motor activity is resumed.

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