HEMODYNAMIC AND BIOELECTRIC DISTURBANCES IN STRIATED MUSCLES OF RATS SUBJECTED TO ACCELERATIVE FORCES AFTER A PERIOD OF HYPOKINESIA

(Research Note)

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(Received 31 March, 1970)

Abstract. A series of experimental investigations are described concerning the influence of hypokinesia, acceleration and associated effect of hypokinesia and acceleration in different periods of time on the displacement of plasma proteins and on bioelectric activity of striated muscles. Disturbances in hemodynamic and bioelectric activity of striated muscles by these two factors are discussed.

1. Introduction

The aim of this study was to investigate the effect of a period of hypokinesia on the tolerance to accelerative forces applied for various durations. This type of study may have implications for the practice of aviation medicine and even more so, for considerations pertaining to physiological aspects of prolonged space flight.

2. Method

Male Wistar rats were divided into four groups:

(1) Control group.

(2) Acceleration group – centrifuged $+5g_z$ for 15 minutes, or 1, 2, or 3 hours.

(3) Hypokinetic group – immobilized for 2 months.

(4) Hypokinetic – acceleration group – (3) condition followed by (2) conditions.

At the appropriate time, the animals were given 50 microcuries per hundred grams body weight ^{131}I-albumin. After one hour, animals in groups (2) and (4) were subjected to the acceleration profiles. Then, electromyography was performed on all animals, and they were anesthetized and sacrificed by exsanguination. Specimens of hind leg and foreleg muscles were taken for radioactivity measurements (impulses per milligram dry mass). The radioactivity of the foreleg specimen was given the value of 100, and the difference between specimens expressed in percentage values. The distribution of the radionuclide was examined scyntigraphically in animals of the control and experimental groups, supplemented by examination of animals frozen in liquid nitrogen during actual centrifugation.

3. Results and Discussion

Prolongation of the time of centrifugation resulted in increased radioactivity of the hindleg samples. Marked changes were observed in animals subjected to acceleration

Space Life Sciences 2 (1970) 400–403.

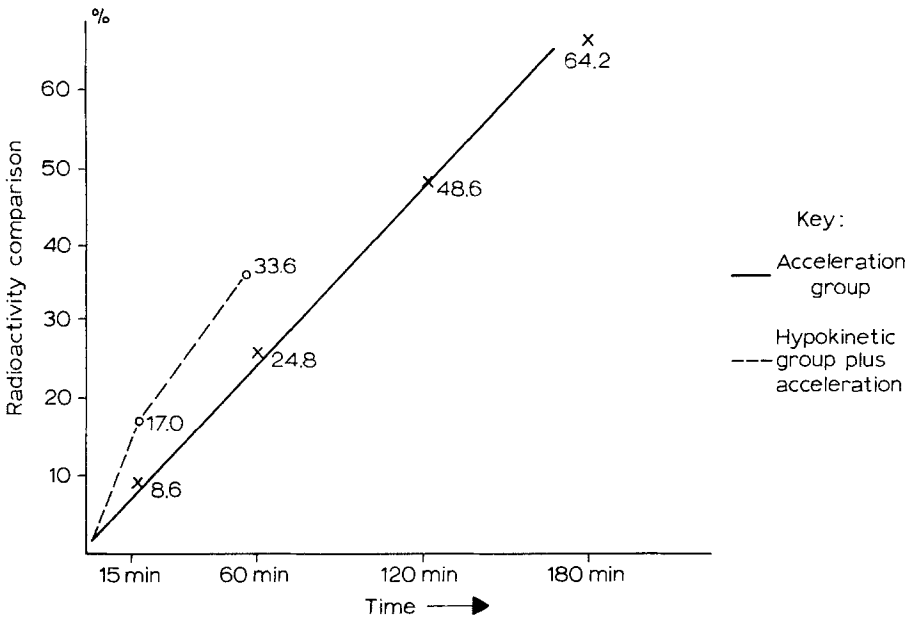

Fig. 1. Influence of time of centrifugation on measured radioactivity of muscle (see text).

forces of more than 1 hour duration. In Figure 1 the radioactivity of the extremities of animals frozen during centrifugation is presented. Data for group (2) and group (4) are presented. In all instances the radioactivity of hindleg samples was found to be higher than that of foreleg samples. This can be explained by redistribution of blood under accelerative forces. Increase in radioactivity of hindleg samples in rats sacrificed by exsanguination after only 15 minutes of centrifugation can be explained by extravasation of ^{131}I-albumin. Hemodynamic disturbances induced by accelerative forces appeared earlier and more pronounced in the immobilized group. These animals also demonstrated a markedly lower tolerance to acceleration. They survived only 22–37 minutes. The percentage displacement of the radionuclide attained +62%.

We interpret these findings to be a reflection of an increase in permeability of vascular walls to albumin. This interpretation is strengthened by comparison of results obtained in animals frozen during the last minutes of centrifugation and rats sacrificed by exsanguination 15 minutes after the experiment began. In the former case the actual blood distribution during centrifugation is observed; in the latter, the 15 minute period between the end of centrifugation and death produced by exsanguination allows at least a partial normalization of blood distribution. Also, exsanguination permits removal of a great part of the blood stored in the peripheral vessels. In preliminary experiments using ^{51}Cr-globulin, no significant differences between hind and foreleg samples were found after 1 hour of centrifugation. This indicates that the permeability increase is not sufficient to permit migration of globulin having greater molecular weight than albumin.

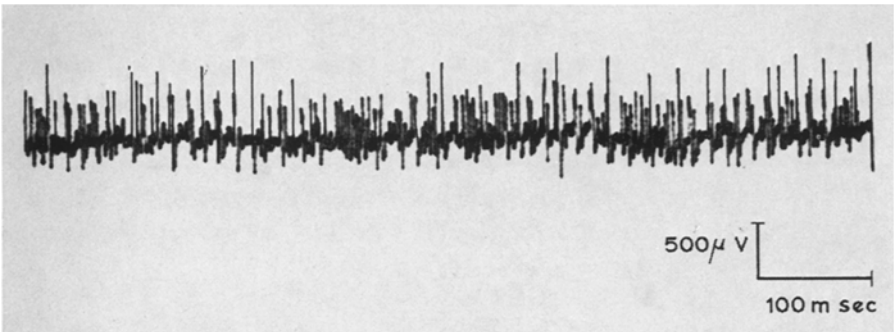

Fig. 2. Electromyographic record of normal gastrocnemius muscle. Maximal effort shows high voltage potentials with amplitude of 500–1000 μV.

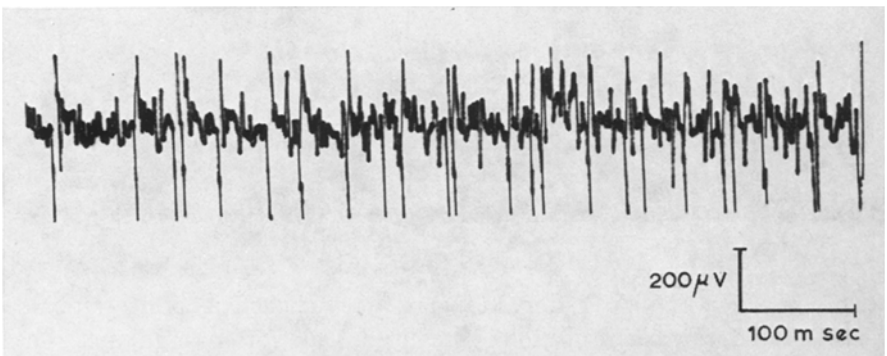

Fig. 3. Electromyography after acceleration (+5 g_z) for 3 hours. Note high voltage potentials (amplitude 500–500 μV. Disturbances in integration activity in motor units is expressed by increased numbers of polyphase potentials.

A functional test was utilized consisting of determination of swimming time. Electromyography was also determined. No differences were noted between control and experimental animals regarding swimming time. However, there were marked disturbances in bioelectric potential. Analysis of electromyographic records demonstrated that a single exposure to $+5g_z$ acceleration during 3 hours causes an increase of percentage of polyphasic potentials and their amplitude. Comparison of Figures 2 and 3 demonstrates this.

We presume that the changes observed in the electromyographic records are connected with blood displacement during the centrifugation. Engorgement with arterial and venous blood in the peripheral parts of the muscles results in different environmental conditions at the muscle fiber level and causes disturbances in the integration activity of individual motor units. Hence, the markedly increased polyphasic potentials are observed.

Immobilization of the animals for a period of 8 weeks causes a decrease in amplitude of the electromyographic record. Single fibrillation potentials seen. These observations confirm that immobilization causes not only signs of atrophy from inactivity but also

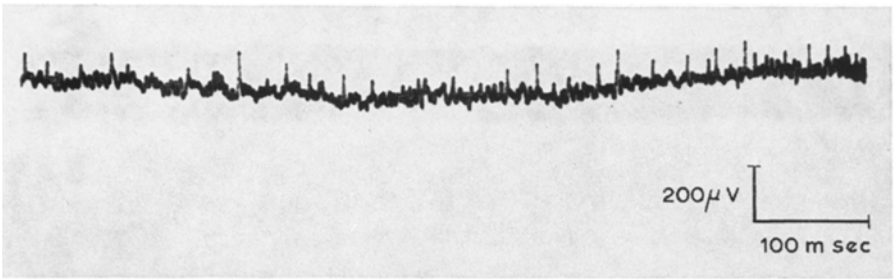

Fig. 4. Electromyographic record following 8 week immobilization period. Maximal effort shows low voltage, amplitude 30–100 μV. Single fibrillation potentials are visible.

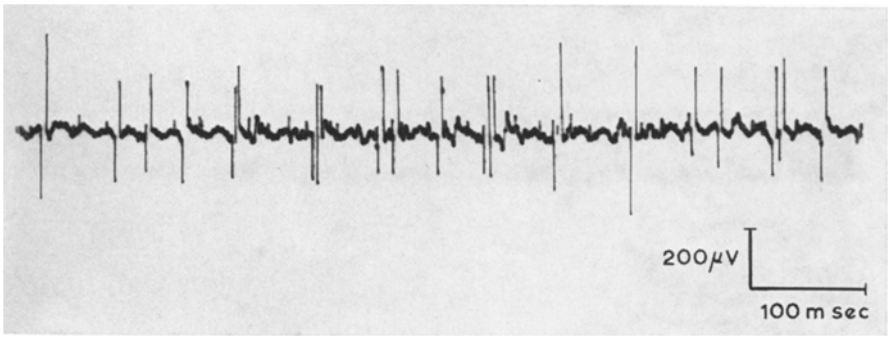

Fig. 5. Electromyography following 8 week immobilization plus subjection to acceleration ($+5\ g_z$). Note single high voltage rhythmical potentials with amplitude 300–400 μV, sometimes collecting in groups.

would seem to indicate some evidence of muscle denervation. The latter may be explained by trophic disturbances in the nerve trunk caused by other circumstances of afferent and efferent impulsation in immobilized conditions.

Immobilized animals, when subjected to accelerative forces, demonstrate a visible reduction in bioelectric activity of the muscles. Single high-voltage rhythmic potentials are seen, collecting in groups.

The demonstrated electromyographic findings raise the question of associated influence of hypokinesia and accelerative forces on the functional state of spinal motor cells. We presume that the changes observed are connected with the functional state of peripheral neurons and hemodynamic disturbances.

4. Conclusions

(1) Measurement of radioactivity of ^{131}I-albumin in muscle shows that in animals subjected to accelerative forces ($+5g_z$) for more than 1 hour a redistribution of albumin is seen.

(2) Hemodynamic disturbances are earlier and more profound in animals subjected to the associated influences of hypokinesia and acceleration.