MR 1972

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DATE: 1972

TITLE: Influence of a permanent magnetic field on the fluctuations in the threshold of stimulation of isolated skeletal muscle.

SOURCE: Biophysics 16:865-68

MAIN SUBJECT HEADING:

AN	HU	AT	IH	M
ANALYTICS	HUMAN EFFECTS	ANIMAL TOXICITY	WORKPLACE PRACTICES-ENGINEERING CONTROLS	MISCELLANEOUS

SECONDARY SUBJECT HEADINGS: AN HU AT IH M

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INFLUENCE OF A PERMANENT MAGNETIC FIELD ON THE FLUCTUATIONS IN THE THRESHOLD OF STIMULATION OF ISOLATED SKELETAL MUSCLE*

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(*Received* 10 *September* 1969)

We have investigated the influence of a homogeneous permanent magnetic field (p.m.f.) of 2200 Oersted on the threshold of stimulation and fluctuation of the threshold of stimulation of the isolated frog sartorius muscle. Irrespective of the time of conducting the experiment and the region of stimulation, when the muscle was placed in the field the fluctuation in the threshold of stimulation increased although the threshold of stimulation practically did not change. Change in the reaction of the isolated muscle to the action of p.m.f. is described in relation to change in its functional state and also change in the duration of survival of the muscle after 20 hr stay in p.m.f. Increase in the fluctuation of the threshold of stimulation is regarded as the "interference" action of p.m.f. on the specimen.

PREVIOUSLY we established that for an isolated muscle, like a nerve fibre [1, 2] the concept of a fluctuating stimulation threshold exists. The high sensitivity of the fluctuations to changes in the functional state of the muscle enabled us to assume that the fluctuation in threshold of stimulation may also be very sensitive to the action of a permanent magnetic field (p.m.f.)

METHODS

The investigation was carried out on a preparation of the frog sartorius muscle with direct stimulation in the region of entry of the nerve trunk into the muscle or at its proximal end. As stimulus we used electrical square pulses of 0·2 msec duration and 2 sec repetition period. The electrodes were silver and chlorinated. All the investigations were carried out in a humid chamber at constant temperature. The threshold of stimulation was determined in isometric conditions of contractions of the muscle. The amplitude of the stimulation threshold was determined with a type E02/131RFT double beam oscilloscope by means of a Peizo detector specially constructed for these purposes [3]. Each experiment consisted of 36 successive (with an interval of 30 sec) measurements of the amplitude of the stimulation threshold. From this sampling we determined the following statistical parameters: the arithmetical mean determining the inherent value of the stimulation threshold of the muscle in the given experiment (I_T) and the standard deviation which is a measure of fluctuations in the stimulation threshold (Φ_T). In investigating the influence of the magnetic field we used a permanent magnet with the humid chamber and muscle placed in the air gap. The strength of the field in the gap

* Biofizika 16: No. 5, 833–836, 1971.

TABLE 1. EFFECT OF P.M.F. ON THRESHOLD OF STIMULATION AND FLUCTUATION OF THRESHOLD OF STIMULATION OF ISOLATED FROG SARTORIUS MUSCLE

Season	Time after removal from body, hr	Test	Region of nerve trunk							Proximal end						
			number of tests, *N*	mean value of threshold of stimulation of *N* tests, mV	difference, %	significance of difference not less than *P*, %	mean value of fluctuation of threshold of stimulation of *N* tests, mV	difference, %	significance of difference not less than *P*, %	number of tests, *N*	mean value of threshold of stimulation of *N* tests, mV	difference, %	significance of difference not less than *P*, %	mean value of fluctuation of threshold of stimulation of *N* tests, mV	difference, %	significance of difference not less than *P*, %
	$t \leqslant 10$	In field / Outside field	18	140 ± 12 / 135 ± 11	3·7	40·0	6·6 ± 0·5 / 5·0 ± 0·5	32	99·9	9	180 ± 16 / 185 ± 17	2·7	30·0	5·4 ± 0·5 / 4·0 ± 0·5	35	99·9
Winter	$10 < t \leqslant 0$	Ditto	20	200 ± 12 / 200 ± 12	No difference		9·7 ± 0·5 / 7·1 ± 0·5	37	99·9	9	200 ± 17 / 200 ± 17	No difference		6·0 ± 0·4 / 4·3 ± 0·4	40	99·9
	$t > 30$	,,	10	420 ± 22 / 420 ± 32	,,		12·7 ± 0·7 / 8·6 ± 0·7	48	99·9	7	440 ± 29 / 430 ± 30	2·3	40·0	6·8 ± 0·8 / 4·7 ± 0·7	48	99·9
	$t \leqslant 10$	,,	28	220 ± 10 / 215 ± 11	2·3	40·0	11·2 ± 0·4 / 8·2 ± 0·4	37	99·9	11	240 ± 15 / 240 ± 18	No difference		8·0 ± 0·4 / 5·8 ± 0·4	38	99·9
Spring	$10 < t \leqslant 30$	,,	22	350 ± 13 / 360 ± 13	2·8	70·0	14·5 ± 0·6 / 10·1 ± 0·5	44	99·9	11	410 ± 15 / 400 ± 17	3·3	70·0	8·9 ± 0·4 / 6·3 ± 0·4	41	99·9
	$t > 30$	,,	10	480 ± 29 / 470 ± 31	2·1	30·0	19·5 ± 0·8 / 12·4 ± 0·7	57	99·9	7	550 ± 25 / 550 ± 28	No difference		10·6 ± 0·8 / 7·0 ± 0·7	52	99·9
	$t \leqslant 10$	,,	26	90 ± 9 / 90 ± 9	No difference		5·6 ± 0·3 / 4·2 ± 0·3	33	99·9	13	140 ± 18 / 140 ± 11	Ditto		4·9 ± 0·4 / 3·6 ± 0·4	36	99·9
Summer	$10 < t \leqslant 30$	,,	18	210 ± 11 / 200 ± 12	5·0	70·0	8·4 ± 0·4 / 6·2 ± 0·4	35	99·9	11	230 ± 18 / 230 ± 21	,,		5·5 ± 0·4 / 4·0 ± 0·4	38	99·9
	$t > 30$	,,	10	40 ± 24 / 405 ± 19	1·2	20·0	10·5 ± 0·6 / 7·2 ± 0·6	46	99·9	7	420 ± 21 / 420 ± 22	,,		6·4 ± 0·7 / 4·5 ± 0·6	42	99·9
	$t \leqslant 10$	,,	24	85 ± 9 / 85 ± 9	No difference		4·9 ± 0·3 / 3·8 ± 0·3	29	99·9	9	120 ± 15 / 125 ± 18	4·0	30·0	4·2 ± 0·4 / 3·2 ± 0·4	31	99·9
Autumn	$10 < t \leqslant 30$	,,	20	125 ± 10 / 125 ± 12	,,		5·6 ± 0·4 / 4·2 ± 0·4	33	99·9	9	140 ± 16 / 140 ± 14	No difference		4·9 ± 0·5 / 3·6 ± 0·4	36	99·9
	$t > 30$	,,	10	375 ± 21 / 370 ± 12	1·4	20·0	7·0 ± 0·6 / 5·0 ± 0·5	40	99·9	5	400 ± 27 / 405 ± 35	1·2	20·0	5·6 ± 0·6 / 4·2 ± 0·6	36	99·0

was 2200 Oersted. Except for the influence of the field the control and test muscles were in identical conditions. The time of stay of the test muscle in p.m.f. was 25–30 min.

In all, we ran 324 experiments on 100 muscles at different seasons and times after removal of the muscle from the frog.

RESULTS

Irrespective of the time when the experiment was carried out and the region of stimulation, when the muscles were placed in a magnetic field the fluctuations in the stimulation threshold invariably increased although the mean value about which the

TABLE 2. COURSE OF CHANGES IN FLUCTUATIONS OF STIMULATION THRESHOLD ON EXPOSURE TO P.M.F.

Site of stimulation	Time after removal from body, t, hr	Absolute difference between fluctuations in field and outside field, mV			
		Winter	Spring	Summer	Autumn
Region of nerve trunk	$t<10$	1·6±0·6	3·0±0·6	1·4±0·4	1·1±0·4
	$10<t<30$	2·6±0·7	4·4±0·7	2·2±0·6	1·4±0·5
	$t>30$	4·1±0·9	7·1±0·9	3·3±0·8	2·0±0·7
Proximal end	$t<10$	1·4±0·6	2·2±0·5	1·3±0·5	1·0±0·5
	$10<t<30$	1·7±0·5	2·6±0·5	1·5±0·5	1·3±0·5
	$t>30$	2·1±0·9	1·9±0·9	1·9±0·8	1·5±0·7

fluctuations occurred, that is, the inherent value of the stimulation threshold practically did not change (Table 1). The averaged values of the stimulation threshold and the fluctuation in threshold are indicated with a 95 per cent confidence interval. Analysis of Table 1 shows that a p.m.f. significantly increased the fluctuations in the stimulation threshold of the isolated muscle. As for the stimulation threshold although there were differences, they were insignificant.

The p.m.f. had no after-effect on the value of the fluctuations of the stimulation threshold; on withdrawal of the muscle from the field the fluctuations diminished. The character of the statistical distribution of the spontaneously changing value of the stimulation threshold under the action of a p.m.f. did not change. As outside the field the distribution corresponded fairly well to a normal ($P>0{\cdot}8$).

In the various periods of survival and season of the year the reaction of the isolated muscle to the action of a p.m.f. manifest in increase in the fluctuations in the stimulation threshold differed. Thus, the difference between the values of the fluctuations in the field and outside the field increased as the muscle died off and for a definite period of survival was greatest in the muscles of the spring frogs the general functional state of which in this period is low (Table 2).

Thus, the fluctuations in the stimulation threshold are more sensitive to the action of a p.m.f. than the inherent value of the stimulation threshold and this sensitivity increases with impairment of the functional state of the muscle.

Next we investigated the influence of prolonged exposure of the isolated muscle to p.m.f. The test muscles were placed for 20 hr in a magnetic field after which the measurements of the test and control muscles were carried out outside the field. The investigations were run on 68 paired muscles of 34 autumn frogs, for two orientations of the magnetic field: longitudinal and transverse. Throughout the period of survival except for the influence of the field, the control and test muscles were in identical conditions. The results of the statistical treatment showed that after 20 hr stay of the isolated muscles in a p.m.f. of 2200 Oersted, irrespective of its orientation in the field, the threshold of stimulation increased significantly (by 12 per cent) as did the value of the fluctuations of the stimulation threshold (by 39–49 per cent) but the total duration of survival fell (by 10–11·4 per cent). The statistical significance of the differences in all cases is not below 99 per cent. The role of the orientation of the muscle in the field in the effects of the bioaction of the magnetic field was insignificant and statistically unreliable.

Thus, in contrast to a brief stay (25–30 min), prolonged stay of the isolated muscles in a p.m.f. leads to persistent worsening of the general functional state of the muscle which is now manifest not only in increase in the statistical variability of the threshold of stimulation (increase in the fluctuations) but also in increase in the inherent stimulation threshold and reduction in the total duration of survival.

DISCUSSION

The findings presented indicate that a p.m.f. even on brief exposure possesses a biological action on the isolated muscle. If we support the view that the fluctuation changes in the stimulation threshold are a manifestation of the biological "noise" [4], then the increase in fluctuations on exposure to a p.m.f. in our view expresses the "interference" action of the magnetic field on the biospecimens [5]. This effect is stronger the greater the "noise" in the system.

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