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EXCITABILITY OF HUMAN MUSCLES DURING SLEEP AND WAKEFULNESS

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L. Lapicque [5] has developed the concept of the subordinative effect of centers, based on the observed increase in excitability and prolongation of chronaxie following transection of a nerve. It has, however, been shown by Nasonov and Rozental' [8] that these changes in excitability are due to impulses proceeding from the point of transection of the nerve. The apparent paradoxical increase in chronaxie, with heightening of excitability over the whole of the strength–duration curve, was explained as resulting from the unequal diminutions in the duration (constant b) and intensity (constant a) thresholds of excitability.

The changes in peripheral excitability observed by a number of workers to take place during sleep have been ascribed to disturbances in the subordinative influences of the centers on the periphery. G. Bourguignon and J. B. Haldane [14] have reported prolongation of chronaxie when the subjects fall asleep. This observation was confirmed by P. A. Kiselev and F. P. Maiorov [2, 3]. They examined a number of narcoleptic patients and of healthy individuals during sleep, and found that chronaxie is prolonged during sleep.

In their further researches, F. P. Maiorov and his co-workers studied chronaxie changes during sleep due to various causes, viz., during alcoholic intoxication [1], in aged individuals [11], in juveniles [4], hypnotic sleep [6, 12], and in narcoleptic states [9, 10].

Researchers have shown that increase in chronaxie takes place during sleep (to an extent depending on the depth of sleep), together with regular changes in the ratio of flexor and extensor chronaxies. These findings, which are of great importance for the study of sleep and of subordination, were based exclusively on the use of chronaximetric methods.

Our investigations of the effect of severing a nerve on its excitability [8] have led us to take up a critical attitude towards current concepts of subordination, although we do not reject the existence of central influences at the periphery. We therefore thought it worth-while to reexamine the above-cited data on the subordinative effects of the centers on the periphery during sleep, applying the new methods put forward by D. N. Nasonov and D. L. Rozental [7] for the evaluation of excitability.

EXPERIMENTAL METHODS

We examined peripheral excitability during wakefulness, during sleep during the day, both natural and reinforced by hypnotics, and during nocturnal sleep. We recorded strength–duration curves for the biceps brachii and flexor digitorum sublimis muscles, using a slightly modified condenser chronaximeter, in which the Lapicque shunt had been replaced by a 100 ohm shunt [7]. This permitted the recording of strength–duration curves of

*In Russian.

human muscles using currents of fairly short duration. The stimulating electrode was a chlorinated silver cup filled with 3% agar made up with Ringer solution, which was attached by strips of plaster to the skin over the motor point. This assured the firm attachment of the electrode, with uniform conditions of moisture and pressure against the skin, not depending on the judgement of the experimenter.

Excitability during wakefulness was studied in 5 persons: F., aged 37, A., aged 34, R., aged 36, V., aged 51, and K., aged 21.

A., V., and K. were also examined during sleep. The subjects were examined in a recumbent position. The variations in excitability were recorded for one and the same point daily for a month, and at 10-20 minute intervals over a few hours.* Changes in excitability were evaluated from the variations in intensity threshold (rheobase) and duration threshold (constant a). In addition, and at least once during each examination, we recorded the full strength–duration curve. Rheobase was measured in volts. The value of the constant a was derived in mv-msec. For this purpose, the threshold potential, expressed in mv, was multiplied by duration of action of the current (for short durations), expressed in msec. We derived chronaxie from the ratio a/b. This way of calculating chronaxie is admissible, in view of the circumstance that most of the strength–duration curves for human muscles have n = 1, thus closely enough satisfying Horweg's formula.

EXPERIMENTAL RESULTS

We found relatively only small variations between the values for excitability in the waking state. The maximum deviations from 100% found over a whole month amounted to +48% and - 7% for duration threshold, and to +24% and - 16% for intensity threshold of excitability.

Excitability varied very little during the day. The variations did not exceed ± 20% of the initial excitability.

Most of the work on the effect of natural sleep on chronaxie was done on the patient A. (15 experiments). She fell asleep very readily during the day, under laboratory conditions. She slept well; her breathing was regular, and her sleep lasted for 2-3 hours. On two occasions sleep was reinforced by administration of 0.2% sodium amytal, when it lasted for 4-5 hours.

At full strength–duration curve was recorded before sleep. Thereafter, at definite intervals, we measured only rheobase and the constant a. On one or two occasions we also recorded the full strength–duration curve during sleep. This aroused no unpleasant sensations in the subject, and so could be effected even during quite light sleep.

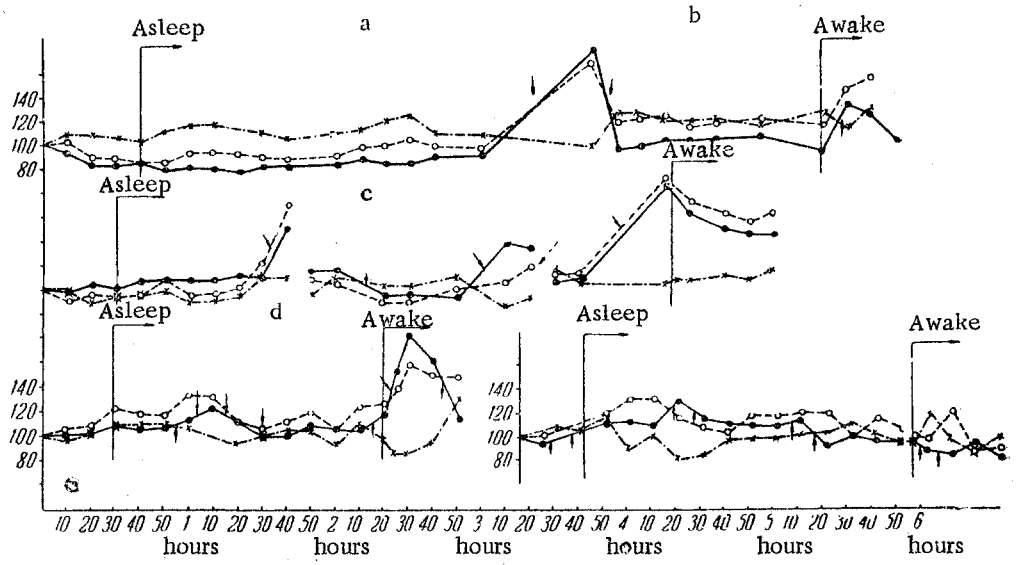
In eleven experiments we determined the excitability of the biceps brachii muscle, and in four experiments we used the flexor digitorum sublimis.

The Figure illustrates variations in b, a, and chronaxie for these muscles during daytime sleep of the subject A.

An examination of the changes found for excitability shows that shifts in the values of both intensity and duration thresholds occurred at the moment when the subject shifted the position of her arm (such moments are indicated by arrows in the diagrams). The variations in excitability observed on such occasions were probably due to displacement of the skin, and hence of the electrode, with reference to the motor point. If, after such a shift, we again found the motor point (shifting the position of the electrode by a few mm usually suffices for this purpose), excitability reverted to its initial value. Occasions on which we thus relocated the motor point are indicated in the Figure by a broken arrow. Such shifts in excitability associated with arm movements are particularly well-defined for recordings from the biceps brachii muscle. This is what would be expected, since displacement of the skin relative to the muscle takes place more readily with respect to the biceps than to the flexor digitorum sublimis.

The values of the constants a and b and of chronaxie may rise or fall during sleep, as during wakefulness. This is evidence that the variations are not associated with falling asleep or awakening, but with displacements of the electrode over the "motor point," due to movements of the arm.

* In observations extending over a month the electrode was removed after each daily determination, the motor point was outlined in ink, and the electrode was reattached to the same point the next morning.



Percentage changes in the values of the constants a and b and of chronaxie during daytime sleep of the subject A.

Explanation of curves: .–.–. b; x–x Chr; o–o a; solid arrows: changes in position of the arm; broken arrows: relocation of the motor point; a, b, c) biceps brachii muscle; d) flexor digitorum sublimis muscle.

In distinction to the findings of Maiorov and his co-workers, we were unable to observe any pronounced changes in chronaxie. It is evident from the Figure that the variations in chronaxie during sleep are much smaller than are those of the rheobase and of the constant a.

The results of our experiments on the subject A. (biceps muscle) are presented in the Table. This shows the variations in the values of the constants a and b of chronaxie on falling asleep and on awakening. The variations associated with falling asleep are expressed as percentages of excitability when awake, and the changes seen on awakening as percentages of the excitability found before waking. Only those experiments in which the position of the arm did not change during the recording are included in the Table. The data of this Table therefore, refer only to changes in excitability not due to displacement of the electrodes. As appears from the Table, the threefold quadratic error is so much greater than the arithmetic mean that we may assert that the values of the constants a and b and of chronaxie do not change on falling asleep or awakening.

The results obtained with the subject V. were similar (4 recordings taken during daytime sleep, and one during nocturnal sleep). V. only fell asleep after taking 0.2 % sodium amytal, and her sleep was uneasy. As for A., the variations in excitability observed were associated with arm movements.

We examined the variations in excitability of the flexor digitorum sublimis muscle of our third subject, K., during nocturnal sleep. K. fell asleep readily, and slept soundly. We recorded a full strength–duration curve at 10-minute intervals. The excitability constants and the chronaxie were derived from the curves. Our observations showed that the fluctuations recorded were associated with arm movements, but not with falling asleep or awakening. Rises in the curves were, for this subject, due also to another factor, viz., to active contractions of the muscle, since they disappeared when the observer gently unclenched his fist. Chronaxie (derived from the curves, i.e., experimentally) varied very little.

It thus appears that our results are not in agreement with those reported by other authors, since in no case could we observe the increase in chronaxie during sleep, described by Bourguignon and Haldane, Kiselev and Maiorov, and others. We believe that the reason for this difference is that we recorded the full strength–time curves, and that we paid attention to the position of the arm during the experiments, and to the constancy of the pressure of the electrodes against the skin.

TABLE

Changes in the Values of the Constants a and b and of Chronaxie on Falling Asleep (Immediately, and After 30 Minutes) and on Waking (Subject A., Biceps Brachii Muscle)

Date	Falling asleep				Waking		Chronaxie		
	b		a		b	a	Falling asleep		Waking
	Immediately	after 30 min.	Immediately	after 30 min.	Immediately	Immediately	Immediately	after 30 min.	
11/15	+13	+13	+12	—	—37	—27	— 1	+20	+ 6
10/19	+ 3	+ 7	+17	+56	—	—	+13	+44	—
10/20	0	0	— 4	— 9	+ 7	— 2	— 4	— 8	— 8
10/20	— 3	0	—21	—16	0	— 5	—18	—17	— 4
10/23	— 8	— 8	— 5	— 6	—	—	0	+ 3	—
10/27	+10	+29	+13	+36	—2	0	+ 3	+ 5	+ 3
10/30	— 8	+ 4	+ 8	+ 3	—	—	+19	— 1	—
10/31	—	—	—	—	—	0	—	—	0
11/2	+ 3	—	+ 3	—	+ 8	0	+ 4	—	— 7
11/9	0	— 4	— 3	+ 6	—10	— 5	+10	+16	+ 6
11/10	— 5	0	0	0	—	—	+ 5	0	—
Mean	+0.5 ±2.24	+4.5 ±3.67	+2% ±1.127	+8.7 ±8.7	—5.66 ±6.71	—5.6 ±3.69	+3.1 ±1.017	+6.9 ±5.95	—0.57 ±2.24

We think it is possible that in some special cases sleep may be associated with changes in peripheral excitability. The results of our present research point, however, to the conclusion that no significant changes in the constants defining peripheral excitability take place during the forms of sleep studied by us.

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