ELECTRO-MYOGRAPHIC STUDY OF THE HUMAN ABDOMINAL MUSCLES AFFECTED BY SEXUAL HORMONES

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Recently Takano (1) found a decrease and the subsequent total disappearance of the tone of abdominal muscles due to pregnancy, and also showed that the reaction can be used for an earlier diagnosis of the pregnant state. Apart from that possibility for clinical application, his result is rather amazing, as it suggests a probable effect of sexual hormones on the skeletal muscle. The present investigation deals firstly with the tonicity variations of muscles, measured by means of EMG, with regard to the menstruation cycle, and secondly with the influences on muscles of hormones given to human subjects or animals.

EXPERIMENTAL

For subjects, female adults, prepuberal and menopausal females, male adults, males aged below 15, and castrated individuals were mainly employed. The muscles mainly used were M. obliquus abdominis externus et internus and rectus abdominis, if required. (Note: for brevity, M. obliquus and M. rectus will be used henceforth.) The electrical lead for human subjects consisted of a long needle electrode, because of the heavy subcutaneous deposit of fat in female, a 1/4 mm. Cathelin needle (7.5 cm. in length) into which enamelled 25 µ copper wire was inserted and electrically insulated. For animal experiments a 1/4 mm. subcutaneous injection needle was used.

The two oblique muscles usually showed even at rest discharge patterns proper to their antigravity or respiratory activity (2, 3). Unlike other skeletal muscles, their patterns could hardly be defined accurately, for any unavoidable minute displacement of the tip of the needle caused by the respiratory movement or by others, caused alternately pattern change, and also for the fact that there was another pattern variation associated with the position of the needle applied. The activity of the muscles were graduated simply by the frequency and amplitude of discharges; thus - denotes no discharge, ± sporadic, and +, #, ## for definite, strong, and much stronger discharges.

As remarked above, the abdominal muscles show certain spatial variations in the discharge pattern. The upper region of them indicates generally somewhat stronger activity than the lower. To mitigate this uncertainty in response, several places were tried at the height of navel and on the upper and lower

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regions. The mean of those observations was taken as the activity of the muscle at that moment. At rest M. rectus shows no discharge, and it does so only when the spinal column is bent backward or the abdomen is intentionally strained.

The preparations of hormones used were progesterone, estradiol, testosterone (all oil-soluble), corticosterone (suspended in water), anterior pituitary, placental and gonadotropin hormones (all water-soluble). Corticosterone was made by Merck, North America, Inc., the gonadotropin hormones by Schering A. G., Berlin, Germany, and all the others by Teikoku Hormone Mfg. Co.

RESULTS

A. Menstruation cycle and the activity of abdominal muscles in normal female adults

The at rest discharge pattern of M. obliquus in erect position or lying on the back was observed for 3 months with 26 individuals (age: 19 to 47) having regular menstruation cycles. In the mid menophase (the period between the post- and pre-menstruation), there appear constantly the discharges of tonic NMU, such as seen in fig. 1A. Those tracings also indicate variations due to the respiratory movement, as pointed out some time ago by Tokizane et al. (2). Any intentional oppression given to the abdomen or deep breathing augments this type of discharges, and also provokes the kinetic elements to discharge. (Note: in the present paper following abbreviations shall be employed—‘standing’ for ‘at rest erect position,’ ‘lying’ for ‘lying on the back,’ and ‘bearing down’ for ‘intentional oppression given to the abdomen.’)

In 2 to 3 days before the menstruation, the at rest discharges, however, diminish definitely and in the record there appears a small number of weak spikes, like the example shown in B. Yet any bearing down, coughing or laughing, is still capable to enhance the discharges to the extent of + to ++. During the period covering 1 or in some cases 2 days before the menstruation, the menstruation proper, and 1 to 2 days after this, the at rest discharges vanish altogether, in standing or lying (see fig. 1C). Even in this quiescent state, coughing or laughing calls forth a response of the order of ± to +, in many subjects. In the following 1 or 2 days after this period, there appears a revival of the activity to the degree of that of 2 to 3 days before the menstruation. Thereafter the activity returns gradually up to the level of mid menophase. Changes as such is less remarkable in the upper region than in the lower. There occur, however, parallel alterations simultaneously with the latter changes. In the example shown in fig. 2, the lead from the upper region (A) still shows tonic discharges of low voltage (300 to 500 μV), but the other lead from the lower is totally silent.

The M. rectus which becomes only active in bent back or in strong bearing down, follows the lead of the oblique companions and shows a similar decline or increase in its activity.

In fig. 3, a schematic representation of the discharge activity of the abdominal muscles is shown together with the already known excretions of pregnanediol
FIG. 1 (left). Menstruation cycle and action currents of M. obliquus abdominis externus.
—Standing—
A: 10 days before menstruation. B: 2 days before menstruation. C: During menstruation. (Subj. female, aged 28)

FIG. 2 (right). Spatial relations in action current M. obliquus abdominis externus
—Standing—
A: Led from 3 cm. up the navel. B: Led from 3 cm. below the navel.

Schematic Representation of Hormonal Interrelations
During the Sexual Cycle

Activity Intensity of the NMU, Abdominal Muscles

FIG. 3
and folliculoids into urine. [The curves of the excretions are reproduced from Selye's text-book (4).]

Mention must be made here that the normal healthy male adult does not show any periodic change in the electrical activity.

**B. Progesterone, estradiol, corticosterone, testosterone and gonadotrophic hormones and the discharges of female abdominal muscles**

1. **Effect on normal females**

During the mid menophase, between 15 to 10 days before the predicted next menstruation, when the muscles are electrically constantly active, an intramuscular injection of progesterone 15 to 25 I.U. was performed, using the same group of subjects employed before. (The injection of any hormone was usually made into M. biceps brachii.) An example of the electrical response to this drug is seen in fig. 4. All the records were taken with standing or lying.

The normal activity shown in A becomes gradually weakened to that of B, at around 3 to 8 hours after the injection—a state resembling of fig. 1 B, *i.e.* the discharge pattern corresponding to 2 to 3 days before the menstruation. Since then there follows a totally electrically silent period, lasting from 15 to 50 hours or more—an example is seen in C. A slight increase of the intra-abdominal pressure does not cause any discharge. But a stronger pressure, coughing or laughing, is still capable to start discharges of the degree of ± to +.

Fig. 5 shows schematically the general tendency of this drug action in the mid menophase. The shaded area represents the inhibited state of the discharge.

An injection of estradiol 5 to 20 I.U. to female subjects, whose EMG had become quiescent either by the menstruation or artificially by an injection of progesterone 25 I.U. (the period used being 10 to 20 hours from this injection, as ought to be so from fig. 5), induced after 4 to 6 hours a renewed electrical activity of the abdominal muscles. During the subsequent period of 15 to 24 hours the augmented activity resembled that of the mid menophase. On the other hand, an injection alone of similar amount of estradiol or 20 rabbit units of the anterior pituitary hormone during the mid menophase was not able to produce any change in then persisting discharge pattern. If testosterone propionate 1,250 to 5,000 I.U. was given to the female whose abdominal muscles had been made electrically inactive by a previous injection of progesterone of the amount used before, there appeared a new series of activity, like the instance of estradiol—13 out of 15 subjects showed this response. In fig. 5, the dot-dashed line denotes schematically the activity of either estradiol or testosterone (the arrow shows the moment when either one of the hormones was administered).

It would be worthwhile to mention here that the other skeletal muscles, acting antigravitationally like the abdominal muscles, do not indicate any remarkable alteration of their discharges by the injection of progesterone 25 I.U.

Using 5 normal adult females (age: 21 to 47) in their respective mid menophase, and setting beforehand their M. obliquus quiescent by the injection of progesterone 15 I.U. (see example A, fig. 6), an injection of corticosterone 100-
Fig. 4 (left). Effect of progesterone (20 I.U., injection) upon action current of M. obliquus abdominis externus. —Standing—
A: Before injection. B: 4 hours after injection. C: 30 hours after injection. (Subj. female, aged 32)

Fig. 6 (right). Effect of corticosterone after a progesterone inhibition.
A: 15 hours after progesterone 15 mg. injection. B: 2 hours after corticosterone 100 mg. injection. C: 4.5 hours later. (Subj. female, aged 21)
mg. was performed after 13 to 15 hours from the progesterone administration. The electrical discharges of the muscles were observed in every 30 minutes. After 3 to 4.5 hours since the latter injection there appeared comparatively active discharges, like that of C, in 3 individuals in standing, and bearing down or coughing brought the response to a degree of ±. This revived response could be traced for 4 to 24 hours, and since then another quiescent state, like that of A, prevailed. With regard to the other 2 subjects, lesser responses were observed. The initial response of ± in standing, ± or + by coughing or bearing down, and – or ± by bending back in case of progesterone alone used, became somewhat augmented to + or † during 3 to 10 hours from the corticosterone injection. The responses decreased to a level of ± at around 24 hours.

A chorionic gonadotrophin (Primogonyl, Schering)—containing principally the luteogenic and interstitial-cell stimulating factor B of the anterior pituitary body—was given intramuscularly (300 I.U.) to the female in the mid menstrual phase or 4 to 5 days after the menstruation. This suppressed at 1.5 to 2 hours from the injection the original active discharges (standing +, laughing or coughing † and bent back ††) to the level of ± in standing, + by laughing or coughing and + by bent back. At 3 to 4 hours the reaction went on further (standing −, laughing or coughing ± or − and bent back ± or −). But after 5 to 6 hours the suppression effect faded away appreciably in some of the subjects and in the others even an enhancement of the electrical activity could be observed—thus the responses became − to † in standing, ± to † by laughing or coughing and + by bent back. Finally at 20 to 30 hours the discharges returned to the normal state. Similar responses were seen with the totally oophorectomized females.

A gonadotrophic hormone obtained from serum (Anteron, Schering), mainly composed of the factor A of anterior pituitary body, did not show the suppressing action seen in the chorionic gonadotrophin. It behaved more like estradiol or others.

During the menstruation (10 subjects employed), the electrical discharges from the abdominal muscles, as has been shown in section A, fell to nil (in standing or by slight bearing down), or low level (+ for bent back, or ± for coughing or laughing). A preparation of placental hormone 30 to 50 rabbit units injected intramuscularly brought back within 1 to 3 hours the response to a level of ± to + for standing, † for slight bearing down and †† for bent back. But as a whole, this hormone given at the above dose seems to be less active compared with estradiol or testosterone. The anterior pituitary hormone preparation acted similarly like the placental hormone.

2. Effect on prepuberal females

For this purpose, 22 girls aged from 4 years 9 months to 14 years 11 months were employed, and progesterone was injected intramuscularly—the amounts used are seen in the fourth row of the table 1. The time course of the discharge alterations are seen in this table.

It will clearly be seen that those subjects, under the age range 7 to 15 years (except one), show definitely a suppressed discharge activity in 4 to 10 hours.
TABLE 1

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<th>Subject</th>
<th>Age (Year/month)</th>
<th>Body weight (kg.)</th>
<th>Amount inj. (I.U.)</th>
<th>Before inj.</th>
<th>4 to 6 hr. after inj.</th>
<th>8 to 10 hr. do.</th>
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Note: inj. stands for injected or injection. S, B and C denote standing, bearing down and coughing.

after the injection (see the intensity indices of ± and -), and that among 8 subjects of 4 to 6 years—i.e. the age range before the first segregation of the sexual difference—2 show no change at all, 4 show sporadic activities (see the marks ±), while the remaining 2 response with a complete disappearance of the discharges. It may also be said generally that the suppression of the discharges looks to be rather difficult to realize in those younger females. To ascertain this point, a second injection of 25 I.U. was performed a week later to some of those who had shown no definite suppression of activity at the first instance. The results are tabulated within the brackets just below the corresponding first, which show that the increased dosage does not change the response appreciably.

3. Effect on females in menopause

Daily observations of the discharges of abdominal muscles were made with 10 subjects (age: 53 to 70), 5 to 15 years since the commencement of menopause. They all showed a certain discharge pattern which indicates neither periodic change nor complete disappearance. The search made after 15 hours from an injection of progesterone 25 I.U. in standing or lying revealed the fact that the rest discharges could not be recognized altogether, and that bearing down brought no response or a slight activity. Even as late as 70 to 94 hours after
the injection all the subjects showed no discharge at all in standing. It would be of interest to see that either estradiol or testosterone administered after the progesterone inhibition, was able to restart new discharges in these muscles.

4. Observation on totally oophorectomized females

Similar observations on 10 subjects (age: 38 to 49, and 7 to 13 months after the operation) whose both ovaries had been removed, disclosed responses of the degree + in standing, # in bearing down, and when they laughed or coughed their responses increased to as much as #. The intramuscular injection of 15 to 25 I.U. of progesterone reduced within 4 to 5 hours the standing response to nil, but coughing showed responses of the order of = in 6 subjects.

Using the same subjects and after 8 hours following a previous treatment with progesterone 15 I.U.—i.e. at the period when their abdominal muscles were made electrically inert, an injection of either testosterone propionate 1,250 to 2,500 units or estradiol 50 to 100 thousand units reactivated the muscle discharges within 3 to 4 hours.

When the muscles were made electrically non-responsible to standing or bearing down by a similar treatment as above, an intramuscular injection of corticosterone 75 to 100 mg. resulted in a reappearance of the discharges, within 2.5 to 3.5 hours, to a strength of + by standing, or # to = by bearing down—viz. a regain of the muscle activity matching to the state prevailing before the progesterone treatment. This reaction lasted for about 3 to 13 hours, which was just the same duration that could be observed with normal female adults.

With the anterior pituitary hormone the same kind of observations were carried out, the dose employed being 30 rabbit units. After 3 to 5 hours from the injection (the muscles had been made electrically silent previously by the treatment with progesterone), the muscles restored their activity to the degree of + for standing and # for bearing down. They continued to do so for 3 to 4 hours more, then became silent. This hormone, however, showed no such distinctive reaction when given to normal adult females.

The placental hormone 300 I.U. administered alone caused a decreased and subsequent disappearance of the discharges—the action was somewhat weaker than progesterone 20 I.U.

C. Observations on male subjects

1. Healthy normal adults

Exactly similar observations were performed on 10 individuals (age: 20 to 37). The injection of progesterone 25 I.U. could not provoke no definite change in the discharge pattern of their abdominal muscles. In one case, the pattern was somewhat weakened at 6 hours after the injection, and the disappearance of the electrical activity so clearly seen with the female did not take place at all.

2. Healthy males aged 4 to 12 years

The effects of progesterone on 21 subjects are tabulated in table 2.

Without further comment, the comparison of this table to table 1 does clearly show that the juvenile males are less sensitive to this hormone, and those aged
Note: inj. stands for injected or injection. S, B and C denote standing, bearing down and coughing.

over 6 years show hardly any sign of inhibited electrical activity, while more younger ones seem to be somewhat reactive. In 4 out of the 5 cases a definite diminution of the activity to the extent of ±, was noticed especially when a high dosage was used.

3. Males, both testicles extirpated

Two healthy individuals, aged 38 and 42, who had been castrated at the ages of 5 and 3 respectively and showed under the usual condition an activity of the abdominal muscles not much different from that of ordinary males, were treated with progesterone of the same dose given to the female subject. Contrary to the normal male, the resultant response was a complete silence of the electrical activity in standing, lying or slight coughing, within 5 hours in one subject and 7 hours in the other after the injection. At around 19 hours both of them were still electrically silent. Later at 24 hours they showed ± responses in standing or lying, and coughing caused a definite response of the degree +. Finally at 40 hours the electrical discharges regained the usual activity.

Under the inactive state of the muscles produced by the previous injection of progesterone 25 I.U. (6 and 9 hours from the injection), another intramuscular injection of testosterone propionate 1,250 I.U. or estradiol 100 thousand units brought about a resumption of the electrical activity, like that seen before the progesterone treatment.
The anterior pituitary hormone given after the progesterone inhibition was shown to be reactive.

**D. Effect of progesterone on the abdominal muscles of the rabbit and rat**

Some control observations were performed on the experimental animals, in order to make certain that the responses described above may not be limited only to the human subject. They were examined either in the normal posture or in an upright position—the hind legs on the floor and the fores held upright.

Firstly two lots (each 10 animals) of normal grown-up rabbits of both sexes (body weight: 2.1 to 4.3 kg.) and two castrated lots (each 10 animals) were employed for this purpose. They were injected intramuscularly with progesterone 10 to 26 I.U. The discharges from their M. obliquus abdominis and rectus were investigated. As naturally be expected, it was rather difficult with those animals to get the normal response at rest, because of their wrigglings when tested and it took some practice before any reliable result could be obtained. Generally they became tame and quiet after 2 to 3 hours following the injection and were responsive to various stimuli.

In case of normal female rabbits or castrated males, the injection reduced the electrical discharges of M. rectus from the preinjection strength of + to a much lower level of — or sometimes +. It caused a more suppression with the oblique muscle—i.e. the response became — or often ±. Still more distinct was the response from the lower part of the abdomen—a total vanishment.

Normal male animals, however, showed no such striking alteration.

Secondly with regard to the rat experiment, each 10 animals of both sexes, weighing 70 to 86 g. were used. Progesterone was injected into the abdominal cavity. With female rats, 3 I.U. of progesterone slowed down decisively their muscular movement within 15 to 20 minutes and at 30 to 60 minutes their responses to a sound stimulation became extremely slight. To a little higher dose of 4.5 to 5 I.U., their motions became sluggish at around 30 minutes, and the tonic response vanished altogether. At 40 to 50 minutes, they ceased to react automatically, and fell into a state of stupor (see fig. 7).

The EMG records led from both extremities at the time when female animals became muscually less active, showed a decrease of the electrical discharges. The tone of those muscles was found to be definitely low. The abdominal muscles behaved similarly and more profoundly. Male rats responded like the female, though in lesser degrees.

Some observations were also performed with chorionic gonadotrophin (Primogonyl, Schering) 300 I.U., injected into the peritoneal cavity of the rat of
both sexes (body weight: 75 to 105 g.). The responses occurred thereat were
not so strong as those seen with the progesterone (3 to 4 I.U.) injection. The
habitual restlessness subsided after 30 to 60 minutes, the motions became slow,
or often they settled down. The eye-lids nearly shut, though they were still
capable to respond to sound stimuli, like tapping the vessel wall with a pencil.

At 2 to 3 hours, they were able to wriggle the extremities when lifted up
by the back. But if they were left undisturbed, they stretched out the legs and
the whole body musculature was seen in a relaxed state, like the case shown
in fig. 7 of the progesterone injection. Such state prevailed for 5 to 6 hours
and then a quick recovery took place—a resumption of the usual restlessness.

E. Female cases of Addison's disease

With 4 cases (age: 25 to 53), who were in so weakened state that they
were unable to do the act of excretion by themselves, the electrical activities
of M. obliquus were investigated in lying in bed. The results revealed no dis-
charges whatever from those muscles, not to mention of course in at rest, but
even in bearing down, laughing, coughing or an effort to raise somewhat the
upper half of the body—with healthy individuals and under those conditions
we may expect undoubtly electrical discharges.

Estradiol 100 thousand units intramuscularly injected, however, brought back
the extinct electrical activity within 8 to 10 hours. Remarkable outbursts of
discharges to the extent of + in lying, + by bearing down, or # by coughing
or laughing were observed.

They reacted similarly to corticosterone (intramuscular injection of 50 mg.),
and after 6 to 10 hours the muscles showed responses of the order of + in lying,
+ in bearing down and # in the effort to raise the upper part of the body.
The hormone 50 mg. per day, given in the form of tablets for the purpose of
treatment, showed after 7 hours already a certain reappearance of the at rest
electrical activity in lying. This regained activity remained the same so far as
the dosing was continued (the observation lasted for 3 days). After 40 hours
from the last dose taken, those 4 subjects were re-investigated. They all showed
— responses in lying, and also — to bearing down, laughing or coughing. A
dose of 30 mg. per day did not show any discharge.

DISCUSSION

Electro-myographical studies of human abdominal muscles were performed,
using diverse subjects—differing in sex, age, and bodily condition. The aims
of the present description were strictly limited to the following two points: the
state of activity of the muscles as it occurs and the probable hormonal control
over it. Much of the details being spared for future description, only a brief
discussion of the results shall be given below.

Periodicity in activity. Among the groups of subjects, only the normal
female adults (see section A) showed a cyclic change, which is regular and is
closely associated with the menstruation cycle. While either in the normal
male adult (A) or the female in menopause (B3), we could not detect any
change in the discharge intensity that could be accounted for as such, if not regular. Those subjects came under our observation for fairly a long period, and therefore, the constant activity of the muscles observed must be undisputable. In the other groups we never encountered a single instance which might be taken as a sign of periodic activity.

**Progesterone.** This hormone produced by the corpora lutea is shown to be endowed with the following amazing properties with regard to the inhibition of electrical discharges of the abdominal muscles. i) Complete inhibition was obtained in case of the normal female adult in mid menophase (B1) and menopausal or totally oophorectomized females (B3, B4). ii) Partial inhibition was observed in the juvenile female before the onset of menstruation (B2) or juveniles of both sexes, aged below 6 years, when a relatively large dose was administered (B2, C2). iii) No action was seen with the normal adult (C1) and juvenile male, aged over 6 years (C2). Incidentally these observations suggest rather interesting supposition that the segregation of sexuality may take place at the age around 7 years.

The existence in the normal female adult of the periodicity and the peculiar response to progesterone suggest strongly that the activity of the abdominal muscles is controlled by sexual hormone or hormones and that progesterone is one of the hormones involved therein.

**Estradiol.** This, one component of the folliculoids, acts antagonistically to progesterone. In the case where the muscles showed incessant discharges and a pre-treatment with progesterone made them electrically silent, the administration of this hormone revives the discharges—such as seen in the normal female adult in mid menophase (B1), totally oophorectomized female (B4), menopausal female (B3) and castrated male adult (C3).

The antagonism here shown may supply a clue, very probably not the whole, for the elucidation of the interrelations seen in the composite fig. 3. In the mid menophase (see the central portion of the figure), the high excretion and presumably high production of the folliculoids (estradiol included—see the left maximum in the curve F) may stimulate the activity of the abdominal muscles. Coupled with this, the low excretion of pregnanediol, similarly assumed low production of progesterone (see the curve E) and hence a lesser inhibition may not interfere with the maintenance of the high rate of muscular activity—thus the plateau in the activity intensity curve resulted in this period. During the premenstruation period (see the right portion of fig. 3), *i.e.* 7 to 8 days before the bleeding, the maximum of the pregnanediol excretion appears. With it the strong inhibitory action of progesterone outdoes the stimulation effect of the folliculoids even with their large production, judged from the other maximum in the curve F. The fall of the activity intensity seen in the lowest curve may thus find an explanation. The dominant position of progesterone seems to be maintained during the bleeding and 1 or 2 days after it, and the diminished or completely vanished state of the electrical discharges seen in section A results. Such are, as remarked above, a tentative explanation of the periodicity of the muscles' activity in the normal female adult. The story would
be by far incomplete, as the effects of other hormones which shall be treated immediately, may show.

**Corticosterone and anterior pituitary hormones.** The facts discussed above would naturally lead us to conjure the possible interplay of other internal secretion glands of intimate relation to the sexual hormones, the adrenal cortex and anterior pituitary body.

Corticosterone is reactive, after the inhibition by progesterone being effected, in the sense that it is capable to restart the electrical discharges, though in somewhat weaker grade than estradiol. Such instances are seen with the normal female adult in mid menophase (B1), or with the totally oophorectomized female (B4).

It would not be out of place to point out that in the man-like female referred in B1, who did not show any definite progesterone inhibition, there might be an unbalanced state in these hormones, possibly an excessive production of corticosterone, because it is known that in female an excessive functional activity of the adrenals brings about musculine features.

The anterior pituitary hormone here employed is, like corticosterone, stimulative following the progesterone inhibition. In case of the oophorectomized female (B4), and or the normal female during menstruation when the discharges naturally vanish, it is able to provoke a new set of discharges (B1).

Thus the antagonism between progesterone and the two hormones has been proved to exist.

The anterior pituitary hormone used, however, was of a complex nature, and one of the factors, prolan B (Primogonyl, Schering, the preparation is not strictly free from prolan A) seems to have a progesterone-like action (B1). While the other, prolan A (Anteron, Schering) acts like estradiol (B1). The antagonism between progesterone and the anterior pituitary hormone may probably be due to the dominance of prolan A in the preparation used.

**Testosterone.** The most potent antagonism against progesterone would naturally be expected in this hormone. This has amply been proved in the normal female in mid menophase (B1), oophorectomized female (B4), castrated male adult (C3) and in the menopause female (B3), following the pretreatment with progesterone.

In general, it has shown that the activity of the abdominal muscles is under the controls of hormones, sexual or otherwise, and that progesterone by virtue of its specific inhibitory action occupies the unique position among the hormones investigated, which is very probably shared with the chorionic gonadotrophin.

Selye (4) and Stephens (5) described a narcotic action of progesterone—the loss of the muscular tone—on the rat. The present author has also verified a similar action on the rabbit and rat (see section D). The fact therein observed that while the dorsal and extremity muscles were still showing the electrical activities, the abdominal muscles, especially those of the middle and lower abdomen showed scarecely any sign of the discharge, and the observation referred in B1 that the other antigravity muscles do not show any perceptible change in their discharge pattern under the action of progesterone, strongly indi-
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...cates the possibility that like all the hormones having special effectors in animal body, progesterone finds its effector in the skeletal muscles, more selectively the abdominal muscles, in the sense that it lowers the muscular tone.

To the mechanism of this specific action of progesterone, the author is so far unable to present any definite explanation. The general trend of the present observations is in favour of the idea that this hormone may not react directly with the muscle, but very probably through the intervention of somatic motor nervous system. The findings of Bickers (6), Hejek and Sokol (7), and others that strong uterine movements can be observed during the follicular phase and a decrease of the movements in the luteal phase, are in fair accordance with the fluctuation of discharges, closely following the menstruation cycle, of the abdominal muscles, especially of M. obliquus abdominis int. et ext. in their antigravity action. An obvious inference from such coincidence may lead us to assume an intervention of autonomic nervous system, in which the brain stem reticular formation including the lower portion of thalamus [according to Rhines and Magoun (8)] may play an important role. This may suggest further that the normal interaction of the reticulospinal suppression and facilitation would somehow be unbalanced directly or indirectly by progesterone to a direction of weakening the facilitation, causing thus a suppression of the impulses from the cortical motor area down to the peripheral effectors—resulting in the partial inactivity or the total abolishment of the electrical discharges of the muscle. This would certainly explain some parts of the animal experiments—slowing down of the muscular movement or the state of stupor (see section D), or would be useful for the elucidation of the cases of human subject. But at present it remains a pure working hypothesis, and surely lacks to explain the specific action of those hormones on the abdominal muscles.

Before closing the discussion, mention must be made that whatever the explanation may be, the facts made known by the present investigation are in good agreement with the findings of Takano (1) referred at the commencement of this paper. They give a definite experimental support for his argument to apply the EMG method to the earlier diagnosis of pregnancy. There may be a further possibility opened for testing the effectiveness, the first time of appearance or the duration of action of a given sex-hormonal preparation.

SUMMARY

The action current of the abdominal muscles was studied with the technique of EMG, using diverse subjects—normal female and male adults, juveniles and castrated individuals. To supplement the observations, some animal experiments and the observation on the cases of Adison's disease were performed.

1. Normal female adults. They are the only subjects who show periodic changes in the discharge—occurring simultaneously with the menstruation cycle. The electrical discharges are very much weakened in a few day before and after the menstruation, or totally vanished during the menstruation proper. The active discharges in the mid menophase can very effectively be suppressed by progesterone, and less so by chorionic gonadotrophin. Following a pretreat-
ment with progesterone and the muscles made electrically silent, testosterone, estradiol or corticosterone brings about a new outburst of the electrical activity.

During the menstruation, the decreased or vanished discharges can be made active by estradiol or in lesser degree by the placental hormone, anterior pituitary hormone or chorionic gonadotrophin.

2. Prepuberal females. Juveniles, age over 7 years, show the inhibitory response to progesterone, but those age below 6 years indicate a faint response, if any.

3. Females in menopause. These show a distinct progesterone inhibition.

4. Totally oophorectomized females. No periodicity was detected. Progesterone inhibits effectively the discharges. Testosterone, estradiol, corticosterone, anterior pituitary or placental hormone revives the discharge which has been suppressed by progesterone.

5. Normal male adults. No periodicity was observed. Progesterone is non-reactive.

6. Juvenile males. Those age over 6 years can hardly respond to progesterone and those below show a faint response, if any.

7. Castrated males. No periodicity was observed. After the progesterone inhibition, testosterone, estradiol or anterior pituitary hormone brings back the electrical discharge.

Animal experiments. A large dose of progesterone given to the female or castrated male rabbit induces a decrease or totally suspension of the electrical discharge of the abdominal muscles. The male animal responses with much lesser degree.

A very large dose of progesterone administered to the female rat brings a quiet state or even stupor. The abdominal muscles decrease or loose the discharges faster than all the others.

Adison's disease. In severe cases, the disappeared electrical activity of the abdominal oblique muscles can be made active by the injection of estradiol or corticosterone.

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REFERENCES

1. TAKANO. in preparation.

**ADDITION IN PROOF**

The later experiments were performed with synthetized preparations, regarded clinically having the same action as the follicular hormone. The substance used were 4,4'-dihydroxy-γ, δ-diphenyl-n-hexane (Suron, Teikoku Hormone Mfg. Co.) and the sodium salt of 4,4'-dihydroxy-α, β-diethylbibenzyl (Robal, Chugai Seiyaku Co.). The doses administered were 10 to 15 mg. The female subjects employed were in the state of menstruation or of quenched activity by progesterone 10 I.U. injection. The artificial preparations showed much lesser activity than the natural. Suron showed after 4 to 7 hours from the injection a weak response of ± to + in standing, which lasted for 2 to 6 hours. Robal provoked after 4 to 5 hours a response of the order of +, though the discharge patterns observed were less conspicuous compared with the natural specimen.