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Excitability of spinal anterior horn cells innervating to the thumb's opponent muscle is increased when the hand is held in a functional position

Yuji NAKAZUMI, Shoko MAHIRA*, Masaki KATO**

拇指対立筋を支配する脊髄前角細胞は手が機能的肢位にある時に興奮性を増す

中角　祐治・間平　祥古*・加藤　将輝**

Abstract

Thumb opposition is important in human daily activity. To analyze the mechanism of facilitation in thumb opposition, we investigated the excitability of spinal motor neurons that innervate to the thumb's opponent muscle, using F-waves. Compared with the basic position, F-wave amplitude increased in the functional hand position. We hypothesized that the sensory input from proprioceptive organs facilitates spinal motor neurons that innervate the thumb's opponent muscle. In occupational therapy, holding the hand in a functional position may be useful for the activation of opponent movement of the hand.

要　旨

拇指対立は握りやつまみ動作に必要であり，作業療法においてこの動作を促通することは重要な課題である。今回，手を機能的肢位に保つことにより，拇指対立を支配する脊髄前角細胞の興奮性が増大するという仮説を立て，短拇指外転筋のF波を用いて検証した。健常成人７名を対象とし，基本肢位と機能的肢位での短拇指外転筋のF波振幅を検定したところ，有意に機能的肢位で記録したF波振幅が増高していた。F波は，脊髄前角細胞の興奮性を表していて，機能的肢位をとることによる末梢からの感覚入力の変化で，F波が高振幅化したと推定できる。握りやつまみ動作に障害のある方には，機能的肢位を基本としたアプローチが有用である。

吉備国際大学保健医療福祉学部作業療法学科
〒716-8508　岡山県高梁市伊賀町８
Department of Occupational Therapy, Kibi International University
8, Iga-machi, Takahashi, Okayama, Japan (716-8508)
*　岡山医療センター金川病院作業療法部
〒709-2133　岡山市北区御津金川449番地
Department of Occupational Therapy, Okayama Medical Center Kanagawa Hospital
449 Mitsu Kanagawa North District Okayama city Japan (709-2133)
**　大阪済生会富田林病院作業療法部
〒580-0082　大阪府富田林市向陽台１－３－36
Department of Rehabilitation, Osaka Saiseikai Tondabayashi Hospital
1-3-36 Koyodai Tondabayashi city Osaka prefecture Japan (580-0082)

Key words：Thumb opposition, Spinal motoneuron, F-wave, Functional position
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Introduction

Thumb opposition is necessary for using precision tools and writing. In occupational therapy, it is very important to recover this function. One method is holding the hand in a functional position. The following 3 theories are considered as underlying mechanisms. First, it shortens the distance between the pulp of the thumb and other fingers. Second, it changes the force vector to opposite angles between the thumb and the flexor muscles of the other fingers. Third, it causes a dynamic tenodesis effect (1) of the flexor digitorum due to wrist extension.

We investigated an additional theory, i.e. the excitability of spinal anterior horn cells innervating the thumb's opponent muscle may increase when the hand is in a functional position. In addition, we tried to prove this hypothesis by using F-waves of the abductor policis brevis muscle.

The F-wave is the compound muscle action potential elicited by recurrent impulses from spinal motor neurons (2). The amplitude of F-waves reflects the excitability of spinal anterior horn cells (3).

Materials and methods

The study subjects were 10 healthy adults (7 men and 3 women), aged between 18 to 55 years. All subjects understood the purpose and methods of this study. In addition, this study had been approved by the ethics committee of Kibi International University.

F-waves were recorded following Kimura's textbook (4). Recording electrodes were placed on the abductor policis brevis muscle according to the Berry-tendon method. The stimulus electrodes were placed on the median nerve at the wrist. Supramaximal electrical stimulations were applied 16 times. M- and F-waves were recorded continuously. The mean amplitude of the F-waves was calculated and divided by the amplitude of the M-wave, and the ratio was defined as F/M amplitude ratio.

At first, the F-waves were recorded in the basic position. The subject sat on a chair and the hand was put on a table, the shoulder was adducted, and the elbow was flexed. The forearm was supinated and the wrist was kept in the neutral position. The fingers and the thumb were adducted and mildly flexed (Fig.1, 4).

Next, recordings were made in the functional position. The forearm was pronated, and the wrist was mildly extended and slightly ulnar deviated. The fingers were mildly flexed and the thumb was kept in opposition. In fact, the hand was placed on a tennis ball (Fig.2, 5).

The sensory input caused by the contact between the skin of the palm and the tennis ball might have produced a facilitation effect. To measure this effect F-waves were also recorded in the basic position

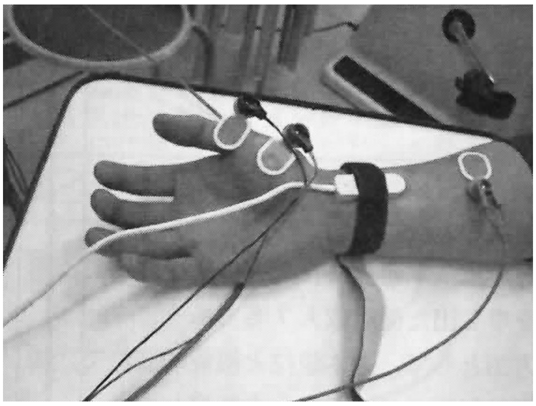

Fig. 1: Basic position: The forearm was supinated and the wrist was kept in the neutral position. The fingers and the thumb were adducted and mildly flexed.

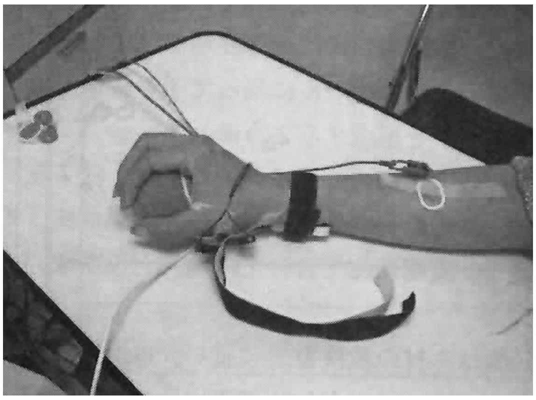

Fig. 2: Functional position: The forearm was pronated, and the wrist was mildly extended and slightly ulnar deviated. The fingers were mildly flexed and the thumb was kept in opposition. In fact, the hand was placed on a tennis ball.

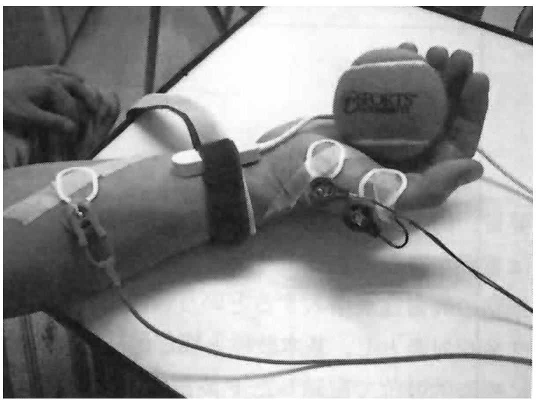

Fig. 3: Supplementary test: F-waves were also recorded in basic position with the tennis ball on the palm.

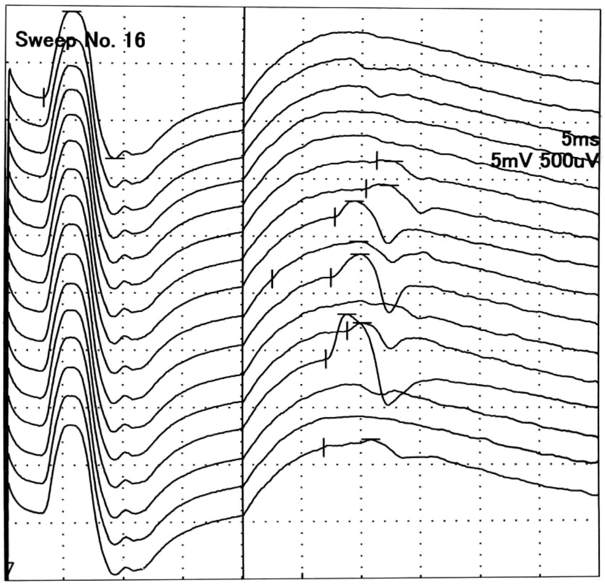

Fig. 4: M-waves and F-waves in 55 years old male, recorded in the basic position. F/M amplitude ratio is 3.1%.

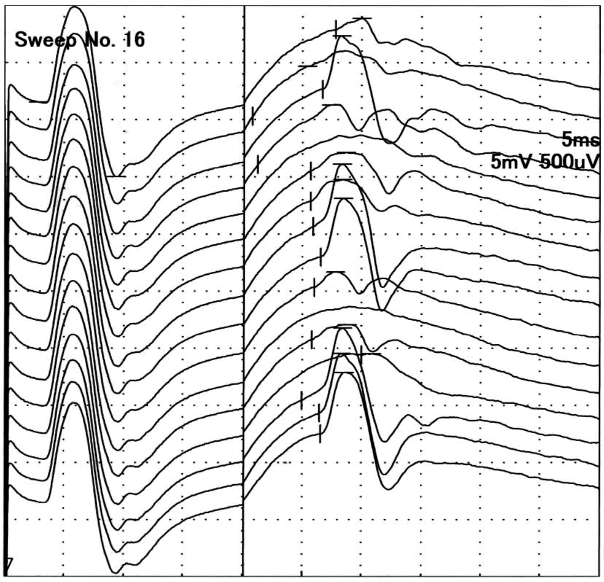

Fig. 5: M-waves and F-wave in the same subject of Fig. 4, recorded in the functional position. F/M amplitude ratio is 5.7%.

Table: Average F/M amplitude ratio (n=10)

	Mean Standard Deviation
Basic Position	2.1 ± 0.9 %
Functional Position	3.9 ± 1.7 %
Supplementary test	2.1 ± 0.8 %

with the tennis ball on the palm. We call this experiment as the supplementary test (Fig.3).

Results (Table)

F/M amplitude ratio in the basic position was 2.1 ± 0.9% (mean ± standard deviation), and the corresponding value in the functional position was 3.9 ± 1.7%. The difference between these two values was statistically significant. (paired t-test, $p<0.05$)

In the supplementary test, the F/M amplitude ratio in the basic position was 2.1 ± 0.9% and the corresponding value was 2.1 ± 0.8%. The difference between those values was no statistically significant.

Discussion

F-wave latency is commonly used for peripheral nerve conduction study during clinical examination (5). The amplitude of F-wave is used as a monitor of upper motor neuron disorder (6).

When supramaximal stimulation is applied to the peripheral nerve, antidromic impulses propagate in all axons of α-motoneurons. If the somatodendritic spike continues for more than the refractory period of the axon hirocke, orthodromic impulses can pass the axon hirroke. Then, the impulse reaches the neuromuscular junction and the F-wave can be recorded (7).

In normal subjects, the F-wave amplitude is 1% to 4% of the M-wave, representing the percentage of α-motoneurons that backfire. This percentage is regulated by motor control systems in the spinal cord, e.g., recurrent inhibition, reciprocal Ia inhibition and Ib inhibition.

Many papers reported a high F/M amplitude ratio in patients with spasticity (8). In addition, it has been reported that recurrent inhibition from Renshaw cells changes their excitability according to the afferent input from proprioceptive organs (9).

According to our experiment, F/M amplitude ratio increases by holding the hand in the functional position. The spinal motor neurons that innervate to the thumb's opponent muscle showed increased excitability in this setting. When the thumb is held in the opponent position, the abductor pollicis brevis muscle is shortened, resulting in decreased excitatory input from its muscle spindle. In addition, the adductor pollicis muscle is elongated which results in increased inhibitory input via Ia reciprocal inhibition. Therefore, we suggest that this mechanism is facilitated by the sensory input from mechanoreceptors in the joint capsule. These proprioceptive inputs decrease the inhibitory signal to α-motoneurons, e.g., recurrent inhibition, or activate the excitatory system from extra pyramidal tracts.

Using a long opponent splint that keeps the hand in functional position (10), thumb opponent muscle must be facilitated.

According to the result of the supplementary test, the sensation on the skin from the tennis ball should not have an important effect on the motor neurons in this setting. However, in patients with bilateral brain damage or neonates sensations of the skin of thier palms stimulate the thumb opponent muscle, demonstrated as grasp reflex.

The intrinsic hand muscle is mainly controlled by the pyramidal tract. However, this study showed that thumb opposition is largely controlled by proprioceptive inputs from joint mechanoreceptors.

The excitability of the spinal anterior horn cells innervating to the thumb's opponent muscle is increased when the hand is held in a functional position.

In occupational therapy, holding the hand in a functional position may be useful for activating the opponent movement of the thumb.

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