The H-Reflex Changes During Wrist Flexion and Wrist Extension

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The aim of this study was to find the optimal H-reflex testing conditions regarding the wrist position and forearm muscle contractions. We investigated the effects of weak (at 10% and 20 % of maximal voluntary contraction) isometric wrist flexion and wrist extension on the H-reflex amplitudes in flexor carpi radialis (FCR). In addition, the H-reflexes during passive wrist flexion and passive wrist extension were also evaluated and compared with that at the neutral wrist position. Thus, the factors regarding contractions and mechanical properties to the changes of FCR H-reflex could be scrutinized. The H-reflex amplitudes were significantly different in the seven experimental conditions used in this study, while M-responses were not. Compared to resting neutral wrist position, the H-reflex amplitudes were significantly larger during 10% and 20% wrist flexion. On the contrary, the H-reflex amplitudes during passive and active wrist extensions were all smaller and significantly different from those at neutral positions. However, the H-reflex amplitudes during passive wrist flexion could not be distinguished from that at neutral position. The results indicated that wrist flexion itself exerted a major excitatory input on the alpha motoneurons, while the wrist extension was the contrary. In addition, passive stretch of FCR significantly reduced the H-reflex amplitude, though the passive flexion of the wrist had no effect. This study showed that the FCR H-reflex was strongly modulated in the wrist isometric contraction; high during wrist flexion, and low during wrist extension. This may be functionally important. The results also indicated that minimal tonic contraction (10% MVC) in the wrist flexion position was sufficient to obtain the best test condition. These findings also extend the diagnostic and therapeutic utility of H-reflex testing. In order to maximize the value of reflex studies, the effects of contraction level and joint position must be taken into consideration when setting the test conditions. **(Mid Taiwan J Med 1999;4:220-8)**

Key words

flexor carpi radialis, H-reflex, wrist position

INTRODUCTION

Despite the generally accepted notion that the most useful criterion of abnormality is H-reflex latency changes, the value of H-reflex amplitude as a diagnostic tool is used in radiculopathy [1-3]. Granger and Flanigan [2] noted that evidence of axonal block (amplitude change) occurred much more frequently than latency changes. This fact suggested that H-reflex amplitude, rather than latency is more valuable in the studies of radiculopathies. However, considerable doubt has been thrown on the validity of using the H-reflex amplitude in precise measurements because of its variability [4]. Various methods have been employed to solve this problem. The H/M ratio is one of these. Some

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investigators rejected the H/M ratio as an accurate measurement of spasticity because of the variability of two responses at different stimulus strengths and between different individuals [5]. Other investigators found the criteria for the H-reflex measurement were set [6] and that the reflex was greatly influenced by the patient's comfort and peace of mind. Nevertheless, comfort and ease are not suitable for measurement. In addition, it has also been documented that maintaining the calf muscles at constant length and tension are of greater importance in generating consistent results than the subjects' state of relaxation [7]. Therefore, in the present study, we emphasized on the effects of muscle length and contraction on the H-reflex amplitude.

Length and muscle tension are two important factors that affect the H-reflex amplitudes. H-reflex amplitudes have been reported to decrease during passive muscle stretch [8], and to increase during voluntary muscle contraction [9,10]. Burk et al [11] suggested that voluntary contraction of the test muscle was one of the best methods of reflex reinforcement, which was better than the Jendrdrassik maneuver. The effects of voluntary contractions have been taken into consideration for the methodology of some H-reflex studies [12].

We further specified the length and tension of the test muscle in order to find the optimal testing condition. Isometric tonic contractions were chosen to eliminate changes of the mechanical factors. The flexor carpi radialis (FCR) was chosen because it is a multiple joint muscle. By altering the elbow and wrist joint angles, it is possible to manipulate the length-tension relationship through a wider range. Thus, the factors regarding length and contraction in the changes of H-reflex can be investigated.

MATERIALS AND METHODS

Subjects

Before the experiment, Phalen's test was performed to exclude neurological dysfunction of the wrist. Seven healthy volunteers (4 men, 3 women), aged 20 to 25 yr, who gave written informed consent were included in the study. For all the experiments, each subject was comfortably seated in an armchair and instructed to maintain a relatively stable arousal level of consciousness.

Force Measurement

Each subject was seated in a chair with the elbow in 90^0 flexion. The forearm rested on a support, with the hand in a position midway between pronation and supination. When measured in wrist neutral position, the wrist joint was kept in a slight dorsiflexion, the angle being 165^0. Extending or flexing the wrist provided different wrist angles of 100^0 and 250^0. The angle of 100^0 indicated extension and 250^0 indicated flexion. The angles were measured as the included angle between forearm and hand. Joint angle calibrations were all based upon measurements of the angles between the dorsal contour of the forearm and that of the hand. The hand was fixed to a device which the twisting force at the metacarpo-phalangeal joints could be measured with a strain gauge system. The unit of force was given in newtons. The distance between the metacarpo-phalangeal joints and the axis of wrist joint was used to convert the force to wrist torque. The force was displayed in front of each subject. Levels of voluntary contraction were produced with the help of visual feedback. Each subject was asked to produce and maintain an isometric contraction according to the display as precisely as possible. In all experiments, a series of three maximum voluntary contractions (MVC), each lasting for 10 sec, was taken from each of the three trials from which the mean was used to compute 10% and 20% levels of MVC. Maximal wrist flexor and extensor torque at each wrist angle were measured as the mean value for a period between 2 and 4 sec, then, the subject was instructed to make sustained isometric contractions and to vary the intensity. The sustained voluntary contraction started and stopped on separated instructions given by the researcher, which usually lasted for 20 sec. The motor task was to maintain an isometric contraction for 20 sec at the three contraction levels to determine the torque levels for the three wrist angles. Addition measurements at each angle with the wrist being passively stretched, provided 0% MVC, a resting torque. Wrist angle and contraction levels were studied in a randomized order.

H-reflex Recording

Standard disk electrodes were placed on the skin overlying the mid-belly of the FCR with the reference electrode over the ulnar styloid [13]. The muscle belly was identified by palpating its approximate location while the subject carried out primary movements of the muscle. The ground was placed just distal to the ulnar elbow area, and about half way between the stimulating and recording electrodes. An amplifier with the low filter set at 20 Hz and the high filter set at 3000 Hz. The recordings were printed and analyzed off-line. Square wave electrical stimuli of 1.0 msec were delivered from a constant current stimulator through bipolar stimulating electrodes to the median nerve approximately 5 cm above the cubital fossa with the cathode being placed proximally. The stimulating electrodes were fixed to the arm with adhesive tape and Velcro bands. In this study, stimulation frequency was set at once every 5 sec. The electrical stimulus strength ranged from 1 mA to 5 mA, which was near-threshold or slightly supraliminal for direct motor response.

To obviate differences in H-reflex amplitude based on the particular position of the recording electrode on the muscle, the amplitude of the H-reflex was expressed as percentage of the maximal M wave amplitude of the same muscle. The size of the maximum motor response (M_{max}) was measured at the beginning of each experiment . We found that an increasing contraction level up to 30% of maximal voluntary contraction did not influence the amplitude and the shape of M wave.

In addition, at the stimulus intensities used, the M-response was usually a small fraction of the H-reflex, which was usually found on the ascending part of the recruitment curve. In these regions of the curve, changes in the effective strength of the stimulus, possibly connected to alternations in the spatial relationship between cathode and nerve, might induce considerable changes in H-reflex amplitude without significantly affecting the magnitude of the M-response. Therefore, special caution was taken to avoid movement artifacts.

Procedures

To perform the contractions, the subjects were instructed to match their force signals. A series of 16 stimuli with the same magnitudes were delivered to each wrist posture with variant contraction effort. For each contraction level, four H-reflex responses were averaged for each voluntary contraction level. The order of contraction level and wrist posture were randomized. During the contraction, stimuli were administered over the median nerve supplying the contracting muscle. Stimulus levels for flexor carpi radialis were generally raised until a small but consistent M response was produced. With minor adjustments to stimulus strength, the H-reflex appeared as a distinct compound electromyography (EMG) potential that stood out from the on-going EMG. The peak to peak amplitude of the H-reflex, showing the typical repeatable waveform, was selected for measurement. H-reflex latencies were measured from the onset of stimulation. Rectified and integrated electromyographic activity and H-reflexes were measured during wrist flexor contraction in three different postures against various degrees of load. EMG activity of 100 msec was used.

Equipment and Instrumentation

The H-reflex was measured using Neuropack Four mini Evoked Potential

Table 1. The latency of H-reflex of flexor carpi radialis during various levels of isometric contraction in the neutral, flexion and extension positions of the wrist (n = 7)

	Neutral rosition	Wrist flexion	Wrist extension
0% MVC	16.04 ± 0.59*	16.32 ± 0.54	16.62 ± 0.81
10% MVC	15.85 ± 0.57	16.70 ± 0.62	16.91 ± 0.72
20% MVC	16.30 ± 0.54	15.96 ± 0.48	16.45 ± 0.73

* Data are expressed as mean ± SE. MVC = maximum voluntary contractions.

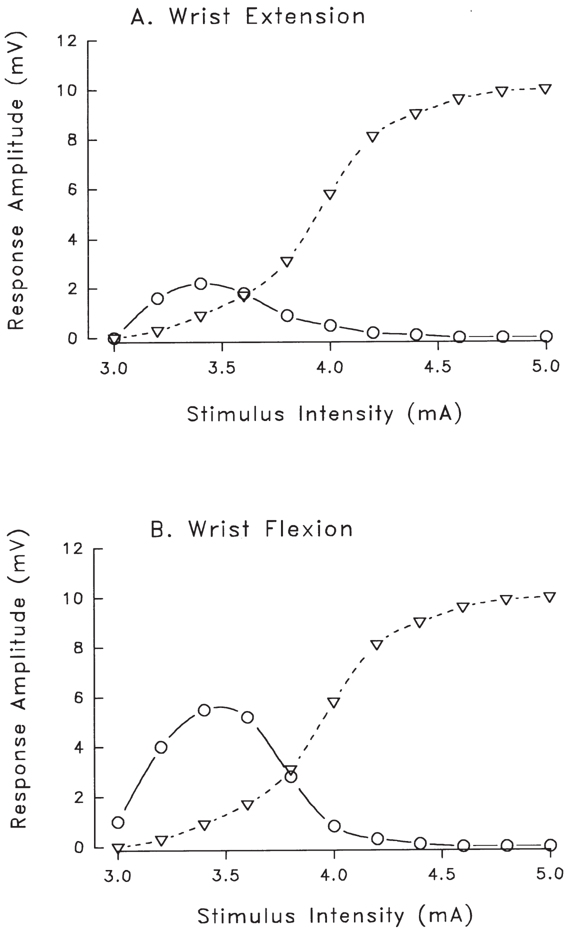

Fig.1 Effects of weak wrist flexion and extension on H-reflex and M-response amplitude as a function of stimulus intensity. The recruitment curves were obtained in one subject, at two different wrist positions. (A) shows the recruitment curve during wrist isotonic extension. (B) shows the recruitment curve during wrist isotonic flexion. (○ and ▽, H-reflex and M-response, respectively).

Measuring System (model MEB-5304K, Nihon Kohden Corporation, Tokyo, Japan). The strain gauge system to measure the force of contraction was Microfet (Hoggan Health Industries Inc., Utah, USA).

Data Analysis

One-way ANOVA for repeated measures was used to study the effect of contraction and wrist position on EMG and H-reflex amplitudes. When significant *F*-tests were obtained, Tukey's test was applied for the post-hoc comparison. A probability level of $p < 0.05$ was used to determine statistical significance.

RESULTS

H-reflex Latency

In order to examine the health of the median nerve and whether latency was task dependent, latencies in the above situations were tested using ANOVA. Table 1 summarized the data from all subjects. The H-reflex latencies were all within the reference range. Latencies were not significantly different in either contraction level or wrist position ($p > 0.05$).

H-reflex Recruitment Curve

The recruitment curves were drawn at different wrist positions (in rest and contraction conditions) to discriminate between effects on the H-reflex connected with the intended tasks and those caused by movement artifacts. The recruitment curve was obtained by plotting H-reflex and M-response amplitudes versus stimulus intensity. Fig. 1 showed the H-reflex-M-response recruitment curves obtained in one subject at wrist flexion and wrist extension positions. An obvious facilitation of H-reflex was seen in the wrist flexion position, and vice versa. At the stimulus intensity used, the direct M response

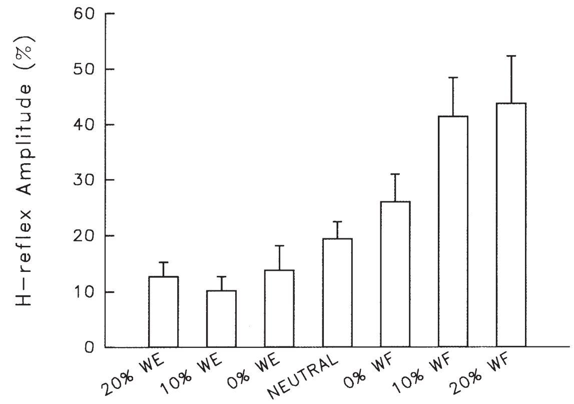

Fig.2 The means ± SE (n = 7) of the ratio of H-reflex relative to M_{max} (maximal M-response) in the seven experimental conditions: 20%, 10%, 0% wrist extension (WE), neutral position, and 0%, 10%, 20% wrist flexion (WF). The 0% wrist extension and 0% wrist flexion indicates passive stretch and passive shortening of flexor carpi radialis, respectively.

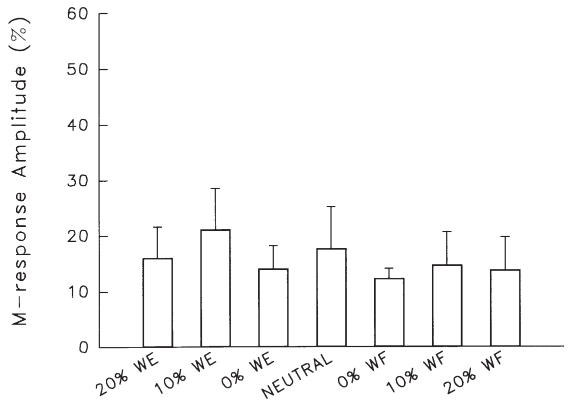

Fig.3 The means ± SE (n = 7) of the ratio of M-response relative to M_{max} (maximal M-response) in the seven experimental conditions: 20%, 10%, 0% wrist extension (WE), neutral position, and 0%, 10%, 20% wrist flexion (WF). The 0% wrist extension and 0% wrist flexion indicates passive stretch and passive shortening of flexor carpi radialis, respectively.

was usually a small fraction of the H-reflex, which was on the ascending part of the recruitment curve. In the region of the curve, changes in the effective strength of the stimulus, possibly connected to alternations in the spatial relationship between cathode and nerve, might induce considerable changes in H-reflex amplitude without significantly affecting the magnitude of the M-response. Therefore, it seems that the aberrant H-reflex and M-response due to movement artifacts could be avoided.

The H-reflex and M-response Changes During Passive Stretch and Isometric Wrist Flexion and Wrist Extension

In our study, wrist position changes plus flexor and extensor contractions affected the H-reflex amplitude. The overall one-way ANOVA showed the effects were significant ($F_{6,36} = 16.02$, $p < 0.001$). On the other hand, the wrist position and flexor and/or extensor contractions had no effect on the M-response amplitudes ($F_{6,36} = 0.47$, $p > 0.05$). Fig. 2 and Fig. 3 showed the ratio of H-reflex and M-response relative to maximal M-responses. A detailed examination showed that a voluntary flexion contraction increased, while wrist extension depressed the amplitude of the FCR H-reflex. That was revealed by Tukey's post-hoc comparison. The Tukey's grouping showed that H-reflex amplitudes during 20% and 10% wrist flexion were distinct from that during 20%, 10%, 0% wrist extension, the H-reflex amplitude being larger in the wrist flexion group. When compared with that during neutral wrist position, H-reflex amplitudes were found to be larger during 10% and 20% isometric wrist flexion, and the H-reflex amplitudes were smaller during 0%, 10% and 20% isometric wrist extension. The H-reflex amplitude in 0% wrist flexion could not be distinguished with that in neutral position. Moreover, the passive stretch [0% wrist extension (WE)] of FCR produced a significant decrease in H-reflex compared with that of the neutral wrist position The statistical results indicated that wrist flexion itself exerted a major excitatory input on the alpha motonerons, while the wrist extension was the contrary. It also indicated that passive stretch of FCR significantly reduced the H-reflex amplitude, though the passive flexion of wrist had no effect.

DISCUSSION

Our study demonstrated that FCR H-reflex was significantly modulated in wrist flexion and wrist extension. The results suggested that both contractile states of forearm muscles, and/or wrist joint position are the sensitive parameters that modify the amplitude of H-reflex. The reflex excitability was facilitated during wrist flexion, and was almost completely inhibited during wrist extension. Although stronger wrist flexion (20% MVC) did not further increase the reflex responses.

Identifying which neural mechanisms correspond with the H-reflex change in intact humans was difficult. Nevertheless, some discussion of how the wrist position and contraction relates to H-reflex changes seems warranted. It is clear that in order to change the H-reflex amplitude, some neural activity must alter function somewhere in the reflex arc.

Evidence of soleus H-reflex modulation during ankle isometric contraction [14,15] may be referred and compared with the FCR H-reflex changes in our study. Several types of neural mechanisms modify the excitability of the soleus motoneuronal pool during contraction of ankle flexor or extensor muscle. It has been found that, during isometric contraction of ankle flexor (or extensor muscle), the excitability of the soleus motoneurons (as the final common path) is regulated by the summation of facilitatory and/or inhibitory synaptic inputs onto motoneurons in the soleus. During dorsi-flexion (contraction of pretibial muscle, i.e. the antagonist of the soleus muscle), reinforcement of inhibitory synaptic inputs is mediated by both Ia inhibitory interneurons, which are facilitated by the direct motor commands descending from the upper brain, and the peripheral Ia feedback inputs induced by activation of the γ- loop, which accompanies contraction of pretibial muscle as the antagonist of the soleus muscle. This reinforced inhibition is a main cause of the reduction of excitability of the soleus motoneuron pool. During ankle plantar flexion (contraction of the agonist), on the other hand, it has been found that the soleus motoneurons are facilitated by both direct motor commands, descending from the upper brain to the soleus motoneuron pool and increasing homonymous peripheral Ia feedback input caused by the activation of the γ-loop accompanying the contraction of the soleus muscle as the agonist of plantar flexion [16,17]. Wrist FCR H-reflex may be regulated in the same way as ankle plantar flexor. During wrist extension (contraction of wrist extensors, the antagonist of the wrist flexors), the FCR H-reflex is inhibited by the reciprocal inhibition from the wrist extensor contraction. However, the FCR H-reflex is facilitated both by the descending motor command and the increasing homonymous peripheral Ia input from the agonist muscle. Other possible neural mechanisms such as presynaptic inhibition, recurrent inhibition etc., may play a role on the FCR motoneurons during the contraction of either the agonist or antagonist [6]. Accordingly, the present results with respect to the H-reflex amplitude changes due to wrist isometric movement. It would imply a decrease in the excitability of the FCR motoneuronal pool during wrist extension and an increase during wrist flexion occurs.

In addition, the different mechanical properties of muscles in the three wrist postures may account for part of the FCR reflex changes. The FCR was chosen because it is a multi-joint muscle, the wrist movements would produce maximal length and tension changes in FCR. Owing to muscles' in-series elastic properties, the length-tension factor would be the most favorable and maximum isometric force, it would be the greatest when the wrist is in a position of slight extension, therefore, less effort is needed to attain same level of force. Conversely, the force of contraction is weaker when the wrist flexors contract from a short-than optimal position. The ineffectual contraction is due to the combination of lack of excursion of antagonist (passive insufficiency) and active insufficiency when muscle attachments are close together on a slack and attempting to contract on the lower portion of length-tension curve [18]. These may account for part of our results that larger H-reflex response was needed to attain the same level of contraction, when the wrist was contracting during a shorten posture than during neutral or lengthen posture. Also, there was no significant difference in H-reflex amplitudes between 10% and 20% MVC wrist flexion. This may indicate that the initial contraction of wrist flexor was already enough to activate most of FCR motoneuron responsible for the H-reflex when the wrist was in flexion position. Thus, further contraction in the wrist flexors was ineffective to produce larger responses. There is evidence that different muscles seem likely to differ in their initial activation level in this respect [19].

Several possible applications of the present findings could related to clinical situations. The H-reflex has been used to study neurological pathologies affecting both the lower and upper limbs [20,21]. Our study showed four clinical applications and using the contraction-enhanced H-reflex in diagnostic testing. Obviously, larger H-reflex responses by lower stimulus intensity has advantages. In our study, isometric wrist flexor contractions had significant effects on the H-reflex augmentation. We found that minimal tonic isometric contractions, even as low as 10% MVC, were sufficient to attain the optimal H-reflex amplitude. Previously, the impression among the majority of clinicians seems to be that the H-reflexes can be reliably obtained only from the gastronemius-soleus muscles [1]. Despite this fact, reports of H-reflex at rest or during facilitation by muscle contraction from forearm muscles have appeared in addition to several reports and reviews on the of the gastronemius-soleus muscles [11]. Furthermore, when surface recorded contraction enhanced H-reflexes were obtained at lower stimulus intensities, a more clear separation of H wave from M wave was attained. The correct wrist positions were shown to be important during the test conditions. The H-reflex amplitude was constantly higher in shorter muscles than in longer muscles in different wrist position and manipulations. These coincided with the Mathew's notion that constant muscle length is required to obtain the consistent results [7]. Our findings suggested that, in addition to the contraction enhanced H-reflex, wrist postures may exert a strong influence on the results. However, the relative importance of the two factors remain uncertain and need to be elucidated. It is critical that the patient's joint position and compliance in contracting muscle should be carefully monitored.

Another important point is to consider both amplitudes and latency change as a criteria of abnormality. The H-reflex latency has long been used in the test of nerve conduction. While Granger [2] observed that nerve blockage (amplitude change across the lesion) occurred much more frequently than did disproportionate latency changes, White [3] suggested that H-reflex amplitude, rather than latency, criteria of abnormality might be of the most value in the study of radiculopathies. Some have found this to be the case in the study of S1 radiculopathies [1].

Joint positioning while resting and during exercise as a therapeutic media has also been explored. Our studies showed even simple passive flexion or extension of joints in the absence of EMG activation is sufficient to produce a consistent H-reflex modification. To exercise the muscle in shorter length, it may be useful in facilitating flaccid muscles. The opposite may be employed to strengthen the muscles without inducing spasticity.

The validity of inferring H-reflex amplitude changes in all situations was done previously [22]. In that study, we further increased the contraction level to 30% MVC. In contrast to this study, the H-reflex amplitude depression was observed. It may be argued that the decreased H-reflex in higher contraction levels is due to a saturation of motoneuron pool. Whether the same results can also be obtained from another muscle is still not certain. Since muscles have different function and mechanical properties, they may have different motor control strategies. Thus, dissimilar ranges and levels of responses may be expected.

In summary, muscle length (or joint position) and contractile state of the muscles are the two components of joint movement. We have shown that both factors contribute significantly to the regulation of the FCR H-reflex. However, it was not possible to answer the relative importance of the two components. The mechanism which the two factors interact over a range of torques and angles may be not simple. Further studies about these variables for both agonists and antagonists need to be done.

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手腕屈曲及手腕伸張收縮時的H－反射變化

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爲了尋找最佳的H－反射測試情況，於本研究中，我們探討是否微弱的(10%，20%最大自主收縮)手腕等長屈曲以及手腕等長伸張收縮影響撓側屈腕肌的H－反射高度。再者，亦探討於撓側屈腕肌被動拉長或被動縮短的情況下，H－反射高度是否有變化。於本研究中，我們選擇撓側屈腕肌H－反射作爲觀察的對象，期望對於撓側屈腕肌以及其拮抗肌的收縮狀況，以及長度等因素對於H－反射的影響有更清楚的了解。結果顯示，於七個實驗情況(0%，10%，20%手腕等長屈曲，10%，20%手腕等長屈曲，以及中性手腕姿勢，其中0%代表撓側屈腕肌被動的拉長或縮短)H－反射高度具有統計上的差異，而M－反應則是無差別。當與中性手腕姿勢時的反應相比較時，10%，20%手腕屈曲時的反射是顯著的增加，相反的，在0%，10%，20%手腕伸張時反射是顯著的被抑制。被動手腕屈曲時的反射高度與中性手腕姿勢是沒有區別的，但H－反射於0%手腕伸張時，明顯的被抑制。此結果之可能推論：手腕屈曲對於撓側屈腕肌的運動神經元有主要的促進作用，而手腕伸張則是相反的抑制作用。當撓側屈腕肌被動的拉長時，H－反射明顯的被抑制，但當它被動的拉長時，則無效果。此研究顯示：撓側屈腕肌的H－反射高度是受到手腕動作的調節的。於手腕屈曲時H－反射加強，當手腕伸張，或被動拉長時則是被抑制。結果亦顯示，於手腕屈曲時些微的收縮(10% MVC)即足以達成最佳測試情況。此種結果可延伸應用至臨床的診斷與治療。（中台灣醫誌 **1999;4:220-8**）

關鍵詞

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