Evaluation of the individual intrinsic excitability of the motoneuron pool using the developmental slope of H-reflex

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Abstract The individual intrinsic excitability of the motoneuron pool was investigated by the H-reflex method. A linear regression line was calculated to be fitted to the recruitment curve of the H-reflex evoked at a range of electric stimulation lower than the threshold of the M-response. The slope of this regression line was found to be significantly invariant among repeated measurements within an individual. This invariant slope of the regression line was suggested to be more effective as a parameter to evaluate the individual intrinsic excitability of the motoneuron pool than the ratio of maximal amplitube of the H-reflex to that of the M-response.

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Key Words : Intrinsic excitability, Motoneuron pool, H-reflex, Recruitment curve, Soleus

Introduction

In humans, the monosynaptic Hoffmann (H)-reflex evoked by Ia afferents from muscle spindle to homonymous motoneurons (MNs) is widely used as a tool for investigating the changes in excitability of the MN pool[11)16)]. In a typical H-reflex test, the conditioning stimulus is used to modify the excitability of the MN pool and the effect of this conditioning stimulus is assessed

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by the amplitube of the test H-reflex[9)14)15)]. The degree of the effect of conditioning stimulus on the amplitube of the H-reflex varies in accordance with the intrinsic excitabilities of the MN pool in individual subjects. Studies on the individual differences in the effect of coditioning stimulus on the amplitude of the test H-reflex are very rare. The size of the maximal H-refrex, the ratio of the thresholds for H-reflex and the direct motor response as M-response, and the H-reflex recovery curve have been used as indicators to assess the excitability of the MN pool. However, these indicators are not quite satisfactory because of a large variation of results or of methodological problems[8)10)12)13)]. This study examined whether the developmental slope of the H-reflex evoked at a test-stimulus intensity lower than the threshold of M-response is a useful indicator of the individual intrinsic excitability of the MN pool.

Subjects and Methods

The H-reflex was measured on eight healthy subjects between 18 and 34 years old. All of the subjects had given their informed consent of the experimental procedure in advance of the experiment. The subjects were seated at ease in an armchair. Paired surface electrodes were attached to the skin on the muscle belly of the soleus just above the achilles tendon. Electric resistance between two electrodes was decreased less than 5 KΩ by sandpaper scrubbing of the skin. To record the recruitment curve of H-reflex and M-response, rectangular electric pulses, 0.5 msec in duration, were applied to the tibial nerve at the popliteral fossa at the rate of 0.3 Hz and the intensity of these pulses was gradually increased. H-reflexes evoked by the electric stimulation were recorded through a band-pass filter of 20 Hz to 3KHz. Responses were recorded five times at each stimulus intensity on the thermal pen recorder for the permanent recording. The coefficient of variations of the five responses at each stimulus intensity was less than three percent.
The mean amplitudes of the five responses were adopted to plot the recruitment curve of H-reflex and M-response. To standardize the scale of the recruitment curve for all subjects, both the amplitude of the H-reflex and M-response (the vertical axis of Fig. 1) were calculated relative to the maximum amplitude of the M-response (% of Mmax), whereas the stimulus intensity (the horizontal axis of Fig. 1) was shown by the ratio to the threshold intensity of the M-response (x MT)[16)]. The equation of the simple linear regression line fitted to the developmental curve of the size of the H-reflex was calculated from all records measured at a stimulus intensity less than the threshold of the M-response. The slope of the regression line (RGSLP) was here defined to represent the developmental slope of the H-reflex. Further-

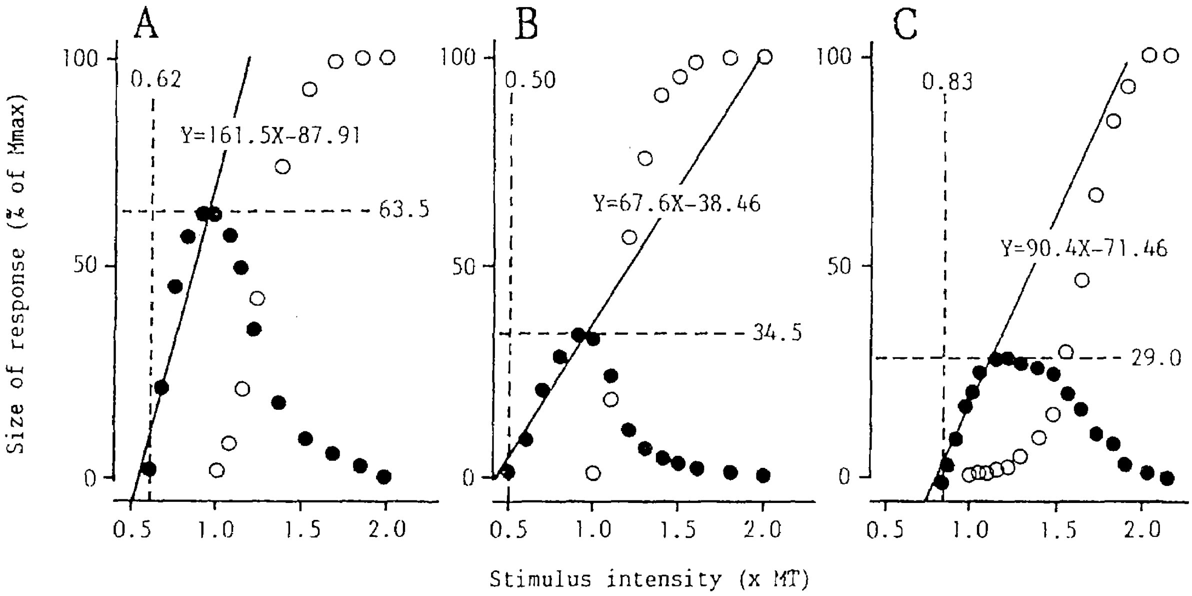

Fig. 1 Three typical examples of recruitment curves of H-reflex (●) and M-response (○). Each plot shows the mean value of five recordings. The vertical axis shows the size of the response as the ratio against the maximal M-response (% of Mmax). The horizontal axis shows the stimulus intensity expressed by the ratio to the threshold intensity of M-response (x MT). Both the horizontal and vertical dotted lines in A, B and C indicate the maximal size and the threshold of H-reflex, respectively. A, B and C show the simple linear regression lines and their equations fitted to the developmental curve of the size of H-reflex measured at a stimulus intensity lower than the M-response threshold. These were calculated from all records obtained at each stimulus intensity.

more, the maximum size of the H-reflex (Hmax) and the threshold of H-reflex (Hth) were also measured. In addition, 27 recruitment curves which had been obtained by the same experimental procedure at the Department of Physiology, Gifu University School of Medicine, have been included in the data analysis in Fig.2.

Results

Fig.1 shows three typical recruitment curves of H-reflex and M-response obtained from three different subjects. Hmax, Hth and the equation of simple linear regression line are respectively shown in A, B and C. Hmax has generally been considered to indicate the firing portion of the MN pool by the peripheral stimulus applied to Ia fibers[13]. Hmax is usually assumed to represent the intrinsic excitability of the MN pool at rest. Accompanying the development of the M-response, the H-reflex is compulsorily attenuated by the collision effect of an antidromic volley of the motor nerve. Accordingly, Hmax is also attenuated by the antidromic volley of motor nerve, showing not fully a firing portion at the NM pool. By contrast, both the RGSLP and

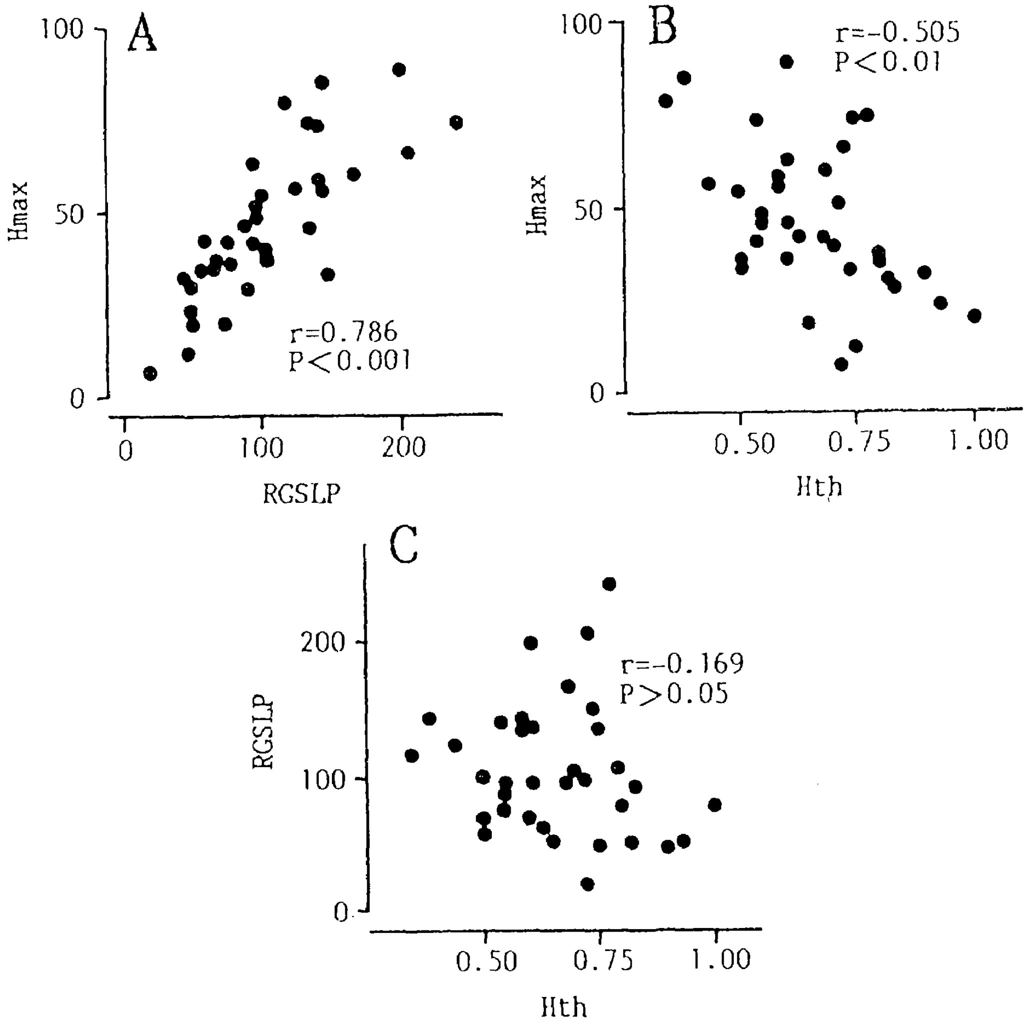

Fig. 2 Scattered plots of the respective correlations of three parameters, the regression slope (RGSLP), the maximal H-reflex (Hmax) and the threshold of H-reflex (Hth). The number of data was 35. A: RGSLP correlates with Hmax ($r=0.786$, $P<0.001$). B: Hth correlates with Hmax ($r=-0.505$, $P<0.01$). C: There is no significant correlation between Hth and RGSLP ($r=-0.169$, $P>0.05$).

Hth are independent of the antidromic volley of the motor nerve (i.e., by the developed M-response).

To evaluate the relationship between Hmax, Hth, and RGSLP presented in Fig. 1, the respective correlations of these three parameters were calculated (Fig. 2). Hmax correlates to both RGSLP ($r=0.786$, $P<0.001$) and Hth ($r=-0.505$, $P<0.01$), while, no significant correlation is found between RGS LP and Hth ($r=-0.169$, $P>0.05$). Hth approximates the threshold of the M-response with the decrease in Hmax, which indicating that Hmax cannot fully account for the excitability of the MN pool. Consequently, RGSLP may be a better parameter for evaluation of the intrinsic excitability of the MN pool than Hmax.

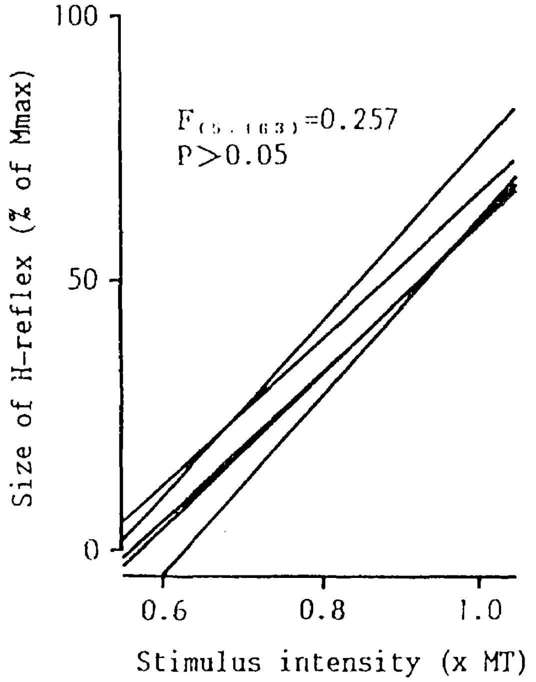

Fig. 3 Variations of recruitment of H-reflex in six trials obtained an individual at a stimulus intensity lower than the threshold of the M-response. Each simple regression line was calculated from all recordings taken in one trial. The statistical analysis determining the identity of regression slope (RGSLP) revealed no significant difference between six RGSLPs [$F_{(5,163)}=0.257$, $P>0.05$].

Furthermore, the degree of variance for six RGSLPs recorded in an individual subject was calculated to determine the individual intrinsic RGSLP. These experiments were carefully done by the same procedure on the different days. As illustrated in Fig.3, no significant difference was seen among the six RGSLPs obtained in an individual [$F_{(5,163)}=0.257$, $P>0.05$[5], not significant], this suggested that the RGSLP represents the individual intrinsic excitability of the MN pool.

Discussion

In this study, a new approach was used evaluate the excitability of the MN pool. Firstly, RGSLP is a better indicator of motoneuronal excitability than the Hmax, because the former is independent of Hth but the latter is dependent on Hth. In other words, Hmax does not always show the real excitability of the MN pool, because an antidromic volley of the motor nerve coupled with the development of the M-response disturbs the development of the H-reflex. Secondly, there was no significant variation among the six RGSLPs recorded in an individual. This suggests the existence of intrinsic RGSLP. In general, the excitability of the MN pool varies with the number of firing cells (recruitment gradation)as well as the modulation of the firing rate of already discharged neurons (rate gradation)[6]. In this experiment, the latter is unlikely to occur because the peripheral electrical stimulus applied to evoke the H-reflex at rest was too short to change the firing rate of MN. Thus the former is likely to be the main mechanism determining the RGSLP or the developmental slope of H-reflex. Taking into consideration the 'size principle' theory, which postulates that small and low-threshold motor units are firstly recruited[2)3)4)], we believe that RGSLP is influenced by the composition of different motor unit types within a MN pool. However, the MN pool of the soleus muscle is believed to be dominated by slow motor units[1)]. If this is the case, the recruitment gradation of MNs in the soleus muscle would be mainly mediated by the synaptic input which controls the excitability of the MN pool. Recently, Kernell and Hultborn[7)] reported on the quantitative aspects of the gradation of motoneuronal recruitment. They pointed out that a variation of the excitatory command signal to the MN pool may alter the number of firing MNs. Furthermore, not only the command signal itself but also any steady synaptic background (bias) activity may be an important factor. This hypothesis has not yet been fully supported by experimental evidence. The mechanisms underlying the RGSLP of the recruitment curve of the H-reflex remain to be studied by manipulation of the synaptic input to the MN pool.

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H 波発達曲線勾配による運動ニューロンプール興奮性の評価

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要　旨　　ヒト脊髄運動ニューロンプール興奮性を示す新たな指標としての，M 波閾値の刺激強度以下での H 反射の発達勾配の妥当性を，従来用いられてきた H／M 比率法との比較から検討した．H／M 比率法ではの M 波誘発に伴う α 運動線維の逆行性伝導による H 反射の閉塞現象が避けられず，H 反射の最大値は H 反射と M 波の閾値差に依存することから，求められた H 反射の最大値が必ずしも運動ニューロンプール全体に対する反射性に興奮しうる運動ニューロンの割合を示さないことが判明した．一方，H 反射の発達勾配は H 反射と M 波の閾値差に依存しなかった．従って，H 反射の発達勾配は従来用いられてきた H／M 比率法より，安静時における脊髄運動ニューロンプール興奮性の指標としてはより妥当なものであることが示唆された．また，その個人内変動に有意差は認められず，個人に固有な H 反射の発達勾配，すなわち運動ニューロンプール興奮性の個人の特性を示す可能性が示唆された．

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