Using Electrodiagnostic Machine to Study Movement Rhythm Variation

**Background.** Hand movement constitutes the most common daily activities in our life. Hand dexterity is often impaired in patients with neurological disease. We developed an adjunct method, based upon the electrodiagnostic software, for study of motor control and hand dexterity.

**Methods.** Thirty-two normal subjects, 2 stroke patients and 2 Parkinson patients were included in the study. All of them were right-handed, and were asked to pace rhythmic finger tapping at a comfortable rate without cue or any external stimuli. A trigger kit was designed to transform the finger tapping. After using the triggering mode and adjusting the sweep speed, 2 tapping signals were simultaneously displayed on the screen. The first signal was the triggering potential, and the variation in timing of the second signal represented the variation in timing of the inter-response interval. Twenty sweeps were recorded, superimposed and measured on the screen. Movement rhythm variation (MRV) was defined as \( \frac{b}{a} \times 100 \) (b = [maximal interval of finger tapping - minimal interval of finger tapping]; a = [maximal interval of finger tapping + minimal interval of finger tapping])/2. Each subject started with right hand and then left hand.

**Results.** MRV measurement showed excellent intrarater \((r = 0.97)\) and interrater \((r = 0.97)\) reliability. In normal right-handed subjects, the MRV was better in right hand than in left hand (right 16.5 \pm 4.1\% and left 21.0 \pm 7.6\%; \(p < 0.05\)). The MRV improved in stroke patients along with the recovery and improved in Parkinson patients after levodopa treatment.

**Conclusions.** MRV was a good method to provide quantitative data for assessment of hand dexterity. Our study also showed the potential role of MRV in motor control study.
METHODS

Subjects
The study included 32 normal subjects (16 male, 16 female; aged 35-70), 2 stroke patients (2 male, aged 69 and 72) and 2 Parkinson patients (2 male; aged 66 and 68). All the subjects were right handed and were studied after informed consent. Handedness was evaluated with the use of the Edinburgh Inventory.12 None of the subjects had any history of arthritis or tenosynovitis. In the patient group, the study of transcranial magnetic stimulation did not show any abnormal findings in motor responses in the first digital interosseous, such as peak amplitudes, onset latencies or central conduction time. Both stroke patients were diagnosed as having pure motor lacunar infarct with involvement of right face and right upper limb at onset. Both of them were studied twice, the first time in 1 week after onset and the second time in 3 weeks after onset. The first test evidenced a great improvement in the patients, who were able to handle most daily activities. One of them was a pianist and the other one was a famous Chinese writer. Both complained that they were not so expert as before even though without problems in chopsticks for meal. Both Parkinson patients were studied twice, before and 2 weeks after levodopa treatment.

Parameters
The main components of the test were a trigger kit of finger-tapping (Fig. 1) and an electrodiagnostic machine. The filter was set at 1K-30 Hz and the amplitude was 200-500 V per division. If the frequency was kept constant, the waveform and the peak amplitude of trigger signal would be stable without big variation. Based upon the software of electrodiagnostic machine, one tapping was taken as trigger point. The trigger level was set at half of the take-off of peak amplitude. Then, the duration of the trigger signal would not vary more than 0.20 ms. Using the triggering mode and adjusting the sweep speed, 2 tapping signals were simultaneously displayed on the screen. The first signal was the triggering potential, and the variation in timing of the second signal represented the variation in timing of the inter-response interval. In each run, 20 sweeps were recorded, superimposed and measured on the screen. First of all, we measured the minimal and the maximal intervals of finger tapping. Movement rhythm variation (MRV) was defined as $\frac{b}{a} \times 100$ ($b$ = [maximal interval of finger tapping - minimal interval of finger tapping]; $a$ = [maximal interval of finger tapping + minimal interval of finger tapping]/2) (Fig. 2). Each subject started with right hand and then left hand. After practice, 2 runs were recorded for each test and only the better result was

---

**Fig. 1.** Circuit diagram of finger tapping kit. The trigger kit was designed with an AND-gate TTL chip (7408) followed by RC filters. The outputs, Z3 and Z4, were set with amplitude less than 5 mV. The waveform of the RC-trigger-signal could be adjusted through the RC filters (time constant). TTL = Transistor-transistor logic.
Test procedure

Each subject sat in a chair with arms onto a table, elbows flexion to 90° and wrists in neutral position. Each subject practiced at least 2 runs before test. During practice, each subject was cued by auditory stimuli at 2-4 Hz. Then in the test, each subject was asked to maintain similar rhythm as practice, and was instructed to maintain the finger-pad on the kit through the test and to tap softly to avoid a longer duration of movement. They were also instructed to tap with index related muscles only and to minimize co-contraction of another muscles. Thus, the movement rhythm would be kept in the best condition. The finger tapping was self-paced at a comfortable rate.

In the beginning, the effect of practice was studied in 10 normal subjects. All of them had at least 4 runs of finger tapping of right index. Each run contained at least 20 sweeps. The first 2 runs were taken as “practice” run and the following two as control. A comparison was made to see if practice would improve the MRV. During practice, all the subjects were instructed to adjust their movement rhythm with visual feedback from the screen of electrodiagnostic machine. The screen would not only monitor their speed and movement rhythm but also concomitant muscle activities at times (Fig. 3). Then, intrarater and interrater reliability was assessed. Each subject was studied with another 6 runs after practice (four runs by a same technician for intrarater comparison and 2 runs by another one for interrater comparison). The interval between 2 runs was at least 30 minutes. Reliability was assessed with the Pearson product moment correlation co-

**Fig. 2.** Measurement of movement rhythm variability index (MRVI). Twenty sweeps were recorded, superimposed and measured on the screen. We measured the minimal and the maximal intervals of finger tapping. MRVI = b/a × 100. 

\[ b = \text{[the maximal interval of finger tapping - the minimal interval of finger tapping]} \]

\[ a = \text{[the maximal interval of finger tapping + the minimal interval of finger tapping]} / 2. \]

**Fig. 3.** (A) Concomitant recordings of finger tapping speed (2 Hz) and related muscle activities. A = surface electromyography of related forearm muscle activities of finger tapping. B = transformed signals of finger tapping. (B) Correlation between muscle activity and finger tapping. Using average technique, 21 finger taps and their related forearm muscle activities were averaged. It clearly showed that electronic signal (B) presented after the peak of muscle activity (A).
efficient. With appropriate control of age, mastering crafts and education, we also analyzed the effect of sex and handedness on movement rhythm.  
The Wilcoxon sign rank test was used to compare the data before and after practice and to study the difference between right and left hands. The Wilcoxon rank sum test was used to study the difference between male and female. A level of \( p < 0.05 \) was considered statistically significant.

**RESULTS**

In the final, ten subjects each had 12 runs in the finger tapping test, 4 for practice (2 for right hand; 2 for left hand), 6 for right hand (4 by technician; 2 by Dr. Liao), and 2 for left hand. Their data were used for inter-rater and intra-rater analysis. In the following 22 normal subjects and 4 patients, they each had 4 runs (2 for right hand and 2 for left hand) after practice.

**Practice effect**

Ten subjects were studied if practice would improve the movement rhythm. In the experiment, they directly entered the program after our instruction. For each hand, the first two runs were taken as practice data, and the following 2 runs as study run. The MRV improved in both hands after practice. Right hand improved from 20.3 \( 7.9\% \) to 17.2 \( 5.3\% \) \( (p = 0.025) \), and left hand from 23.8 \( 8.9\% \) to 20.9 \( 7.1\% \) \( (p = 0.030) \). The result indicated that appropriate practice would help subjects adjust themselves to the environment and perform more skillfully during test.

The following studies were done after practice and at least 2 runs for each experiment.

**Handedness effect**

Handedness effect was evaluated in 7 subjects with the following criteria: right handedness, mastering crafts (such as: experience in piano less than 5 years), exercise (such as: exercise less than twice a week), age (30-40 yrs), and education (all of them were medical doctors). Each subject was asked to tap 4 runs, 2 runs each hand. The movement rhythm was better in right hand (right 16.5 \( 4.1\% \) and left 21.0 \( 7.6\% ; p < 0.02 \)).

**Sex difference**

With control of age, education and crafts, 8 women and 8 men were studied if there was significant difference in sex. Two runs of right index tapping were analyzed and did not show significant difference between men and women (male 18.6 \( 5.2\% \); female 20.8 \( 6.2\% ; p = 0.23 \)).

**Reliability**

Ten subjects were included in the experiment. MRV measurement showed excellent intra-rater \( (r = 0.97) \) and inter-rater \( (r = 0.97) \) reliability. A high degree of intra-rater reliability was found on tapping results obtained by technician (18.8 6.2\% versus 17.2 5.8\%; \( r = 0.97, p < 0.0001 \)). We compared the tapping results between 2 examiners (Ms Yang and Dr. Liao) and identified excellent inter-rater reliability (17.2 5.8\% versus 16.4 6.0\%; \( r = 0.97, p < 0.0001 \)).

For the 32 normal subjects, the MRV was 17.7 7.2\% of right hand, and 19.8 6.4\% of left hand. Significant improvement was observed in all 4 patients (Fig. 4), in stroke patients along with their recovery and in Parkinson patients after levodopa treatment.
DISCUSSION

The triggering model of electromyography is built in the software of routine electrodiagnostic machine such as single fiber electromyography. It is widely applied in the assessment of neuromuscular junction disorders and helps the diagnosis of myasthenia gravis. It is also applied to study on the heart rate variation and is useful to evaluate the parasympathetic function. Here, our method was based on the software. A trigger kit was used to transform the movement as a simple signal for analysis of movement rhythm. The trigger kit was easily designed and cost less than US 100 dollars. Our preliminary results indeed indicted the potential of trigger kit in clinical application.

Finger tapping tests may be paced by subjects themselves or according to external cue. Most studies were done with cue. Self-paced task indeed surged the brain activities of supplementary motor area, and cue task probably activated another pathway to link motor activities, such as parietomotor pathway in Parkinson patients to visual cue. It seemed that movement rhythm between self-paced and cue tasks did not reflect a same mechanism. When subjects paced the tapping by themselves, most finger-tapping studies focus on the speed. Based upon the software of electrodiagnostic machine, we can record muscle amplitude, finger tapping frequency and movement rhythm. The muscle amplitude and duration of muscle activities provide information of muscle force and movement duration (Fig. 3). According to the results of practice and the patient group, MRV is clearly a good index of hand dexterity or precision of task. Of course, a biological bias should be kept in mind. When we studied self-paced task, there was always a great variation of the movement frequency among the subjects. Thus, in the practice, sensory cue would help subjects tap at appropriate frequency. Then, in the test without sensory cue, the subject was asked to pace as the previous rhythm.

Because our stroke subjects were almost recovered from the acute event, they could perform most daily activities as before. TMS study also showed that the function of motor pathway was almost intact at the state of rest. However, MRV clearly exploded a dynamic problem in the patients. MRV could be a good method to detect dynamic motor function and to assess subjects with small neurological deficits.

Because of deficits of internal timekeeping or disturbed internal rhythm formation, Parkinson patients may not well perform rhythmic movement without external cue. Shimoyama et al. showed that movement rhythm of Parkinson patients was usually poor in the beginning of finger tapping test. To avoid the bias, both Parkinson patients were instructed to practice at least 2 runs before the study. Their movement rhythm improved a lot after levodopa therapy. It indicated that MRV was also a good objective method to monitor therapeutic effect.

In the study, sex did not play a significant role as observed in the study of Gill but quite different from other studies. Perhaps the method of analysis might count. An appropriate method may validate the clinical application of MRV if the results include standard deviation, mean interval and coefficient variation. In the electrodiagnostic machine, a built-in software is worth consideration, such as the single-fiber electromyography and autonomic function of Nihon Kohden electrodiagnostic product. Single fiber electromyography software is for neuromuscular function and autonomic function software is for heart rate variation and parasympathetic function. In conclusion, we may base upon electrodiagnostic machine to study MRV and assess motor control of neurological patients.

ACKNOWLEDGMENTS

This study was supported by the grant from the National Science Council (NSC91-2314-B-075-043) and the grant from the Taipei Veterans General Hospital (VGH92-307). We were also grateful to Ms HP Yang for her technical support and Ms WY Shen for statistical analysis in the study.

REFERENCES

1. Flanagan JR, Haggard P, Wing AM. The Task at Hand. In: