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# Application of F-Wave Waveform for the Effect of Physical Therapy-Relationship between the Correlation Coefficient of the F-Wave Waveforms and Waveform Identification by Investigators

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## Abstract

**Purpose:** The F-wave shows the excitability of spinal nerve function. There is prior study that it is normal to appear the various F-waves. However, there is no provision for a method of judging whether or not it is the same waveform. The purpose of this study is to find objective evaluation in comparing F-wave waveform.

**Method:** Present 5 trials of 30 F-wave to 3 people who are engaged in F-wave for many years. We compared the results of visually selected waveform and correlation coefficient (hereafter CC) calculated by personal computer.

**Results:** There were 2 F-waves that 3 people checked, the highest value of CC was 0.99, the lowest value of CC was 0.95. There were 10 F-waves that 2 peoples checked, the highest value of CC was 1.00, the lowest value of CC was 0.71. From the above, consistency of 0.95 or more correlation coefficient was recognized, except for one case.

**Conclusion:** F-wave waveform analysis, criterion with a CC of 0.95 was made as a judgment of the same waveform. We think that waveform analysis become index for physical disability improvement in clinical scene and it will be an objective evaluation of influential physical therapy.

**Keywords:** F-wave waveform; Correlation coefficient; Objective evaluation

## Introduction

In recent years, motor imagery has gained attention in rehabilitation therapy. It involves excitation of the same neural mechanism as the actual exercise but without any joint movements. There are many studies on the activation of the brain by motor imagery. However, increasing the excitability of spinal nerves is important as well as the activation of the brain as the job of a physical therapist involves treating muscles and soft tissues. The authors have been studying the excitability of the spinal nerves for many years [1-3]. Suzuki et al. [2] analyzed the F-waves measured in the thenar muscles in hemiplegic patients with cerebrovascular disorder following exercise therapy. F-waves were compared from 9 months to 70 months of the illness. The diversity of F-waves at 70 months was more than that at 9 months. In addition, it was a result of improved muscle tone and voluntary movements of the thumb. Therefore, measuring F-waves is an effective neurological test for evaluating muscle tone and voluntary movements. Herein, we explain the F-waves used as an index of excitability of spinal nerves. The dominant nerve to the muscle was electrically stimulated. Then, retrograde action potentials are transmitted from the stimulation point to the anterior horn cells of the spinal cord. Action potentials that are regenerated in the anterior horn cells of the spinal cord are transmitted to the muscle in an anterograde manner, which are recorded at the muscle. It is normal to record various forms of F-waves. Motor units of various sizes exist in the anterior horn cells of the spinal cord and varying sizes of neurons are excited [4]. Therefore, the waveform varies depending on the size of the exciting neuron. The waveforms of the F-waves should be diverse. In other words, it is necessary to excite neurons of many sizes. There are many previous studies on F-wave waveforms [5-7]. However, there is no detailed rule for comparing waveform type. Therefore, each study uses its own original way. For example, waveforms can be overlapped and judged visually [5]. We compared the results of visual and digital methods as a preliminary step in waveform analysis. In addition, we examined the agreement between the visual and digital results. Furthermore, we think that this field of waveform analysis will be an important measure in future objective evaluation of physical therapy.

## Method

### Subjects

A total of 5 healthy volunteers (2 men and 3 women; mean age, 21.6 ± 0.89 years) participated in this study.

### Method of recording F-waves

A Viking Quest electromyography machine (NATUS, USA) was used to record the F-waves. A pair of round disks was attached with collodion to the skin over the left thenar muscles over the thenar eminence and the first metacarpophalangeal joint. We measured the F-waves by stimulating the left median nerve at the wrist with the muscles relaxed. The maximal stimulus was adjusted up to a value 20% higher than the maximal stimulus that can generate action potentials in the largest compound muscle. To generate F-waves, 30 supramaximal shocks were delivered at 0.5 Hz. The bandwidth filter ranged from 5 Hz to 2 kHz.

### Calculating the correlation coefficient of the F-wave waveforms

The method for calculating the type of F-wave waveform was based on that of a previous study by Suzuki et al. (2016). Microsoft Excel was used to apply a moving average to the F-waves that could be recorded. Next, correlation coefficients (hereafter CC) of combinations

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of the recorded F-wave waveforms were calculated using the CORREL function of Microsoft Excel.

A window from minimum to maximum onset latency was created in the measured waveforms (Figure 1).

The CC of each waveform was calculated using Microsoft Excel.

### Waveform identification by investigators

Three investigators judged the type of F-waves by visual inspection. Then, consistency between their results and those calculated by Microsoft Excel was evaluated. We judged the same F-wave waveform that two or more of three subjects judged.

## Results

In subject 1 (22 year old male), 1 wave type matched with 2 persons and the CC was 0.71. One wave type matched with 3 persons and the CC was 0.91.

In subject 2 (23 year old male), 3 wave types matched with 2 persons. The CC ranged from 0.98 to 0.99. No waves matched with 3 persons.

In subject 3 (21 year old female), 3 wave types matched with 2 persons. The CC ranged from 0.98 to 1.0. No waves matched 3 persons.

In subject 4 (21 year old female), 2 wave types matched with 2 persons. The CC ranged from 0.96 to 0.99. One wave type matched with 3 persons and the CC was 0.99.

In subject 5 (21 year old female), 1 wave type matched with 2 persons and the CC was 0.98. No waves matched with 3 persons.

To summarize the results, there were 2 CCs in which all subjects matched. The highest CC value was 0.99, the lowest was 0.95 and 100% of CCs were 0.95 or higher. There were 11 CCs in which 2 of 3 people matched. The highest CC value was 1, the lowest was 0.71 and 91% of CCs were 0.95 or higher, with 9% 0.95 or lower. There were 40 CCs in which 1 of 3 people matched. The highest CC value was 0.99, the lowest was 0.09 and 50% were 0.95 or more, 5% were 0.95 to 0.90, 10% were 0.90 to 0.85 and 5% were 0.85 or less.

Three researchers recognized two wave types in all waveform (150 waveforms), and the CC of both waveforms was 0.95 or more. Two researchers recognized 11 wave types matched in all waveform, CC of 10 waveforms out of the 11 waveform was 0.95 or more. One researcher recognized 40 wave types in all waveforms and the CC in half of the 20 waveforms was 0.95 or more (Table 1).

## Discussion

In Figure 2, the first wave is an M-wave and the second is an F-wave. The magnitude and shape of the amplitude depend on the type of exercise unit excited in the spinal anterior horn cell. Figure 3 shows an example of one trial presented to the subject in this study (In). This suggests that various shapes and sizes can be confirmed from the figure shown.

| Correlation coefficient | 1 person match Max: 0.99 Min: 0.09 | 2 persons match Max: 1 Min: 0.71 | 3 persons match Max: 0.99 Min: 0.95 |
|---|---|---|---|
| 0.95 or more | 20 (50%) | 10 (91%) | 2 (100%) |
| 0.95~0.90 | 5 (12.5%) | 0 (0%) | 0 (0%) |
| 0.90~0.85 | 10 (25%) | 0 (0%) | 0 (0%) |
| 0.85 or less | 5 (12.5%) | 1 (9%) | 0 (0%) |
| Total number of checks | 40 | 11 | 2 |

Three researchers recognized the same waveform in two waveform in all waveforms (150 waveforms) and the CC was 0.95 or more

**Table 1:** Correlation coefficient and people dispersion for each trial.

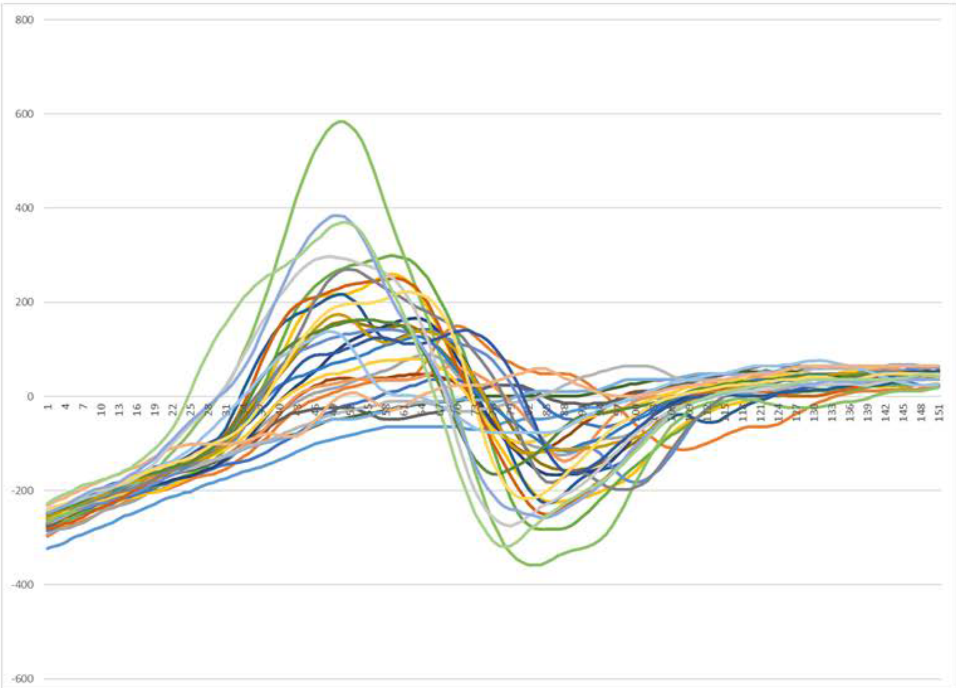


**Figure 1:** Raw F-wave waveform.
Only the F-wave was cut out from the measured waveform

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In a study of waveform analysis by Suzuki et al. [1-3], the F-wave was measured from the thenar muscles in hemiplegic patients with cerebrovascular disorders during exercise therapy. F-waves were evaluated during 9 to 70 months of illness. The F-wave at 70 months showed greater variability than at 9 months. In addition, there was improvement of muscle tone and voluntary movement of the thumb. Therefore, F-wave measurement is effective neurological test for evaluating muscle tone and voluntary movement. However, there are no criteria for comparing waveforms. A similar study examined the presence or absence of matching by overlaying waveforms for visual observation, but a study based on data was only performed by Suzuki et al. [1-3].

There is presently no basis for determining reproducibility and consistency in waveform analysis. A similar study visually determined the presence or absence of consistency. The data in this study can be used to validate waveform analysis using visual judgement in future research. F-waves were visually evaluated in five subjects by three experienced researchers. We confirmed the consistency of results for the three subjects by comparing CCs. The results showed that 2 of 3 had the same waveform, and in all but 1 of 11 waveforms, the CC was 0.95 or more. Three researchers recognized 2 wave types, and the CC of both waveforms was 0.95 or more. Only one out of three subjects matched, but the correlation coefficient was variable and the consistency was poor. However, the CC matched in 2 out of 3 people, with consistency of 0.95 or more expect for 1 type. In other words, F waveforms judged by two or more of three subjects showed consistency of 0.95 or more. One case was excluded. The correlation coefficient is said to judge the presence or absence of correlations of 0.7 or higher. However, when comparing F waveforms with a CC of 0.7, major differences can be recognized visually (Figure 4). It is hard to say that similar spinal anterior horn cells are excited. When comparing F-wave waveforms with a CC of 0.95 which bordering from this study, recognize almost matching (Figure 5). This degree of match suggests the possibility of excitation of similar spinal anterior horn cells.

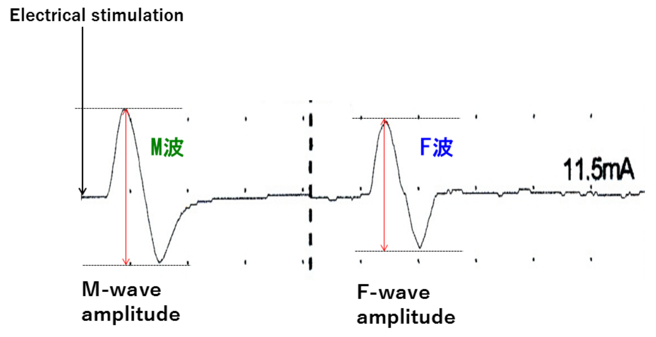


**Figure 2:** Actual F-wave.
The first wave is M-wave, the second wave is F-wave. Wave height means amplitude

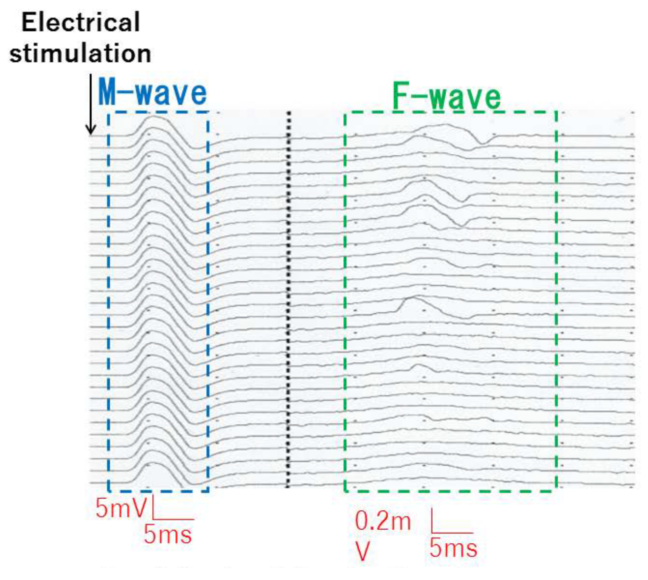


**Figure 3:** F-wave by 30 electrical stimuli.
There are various shapes of F-waves

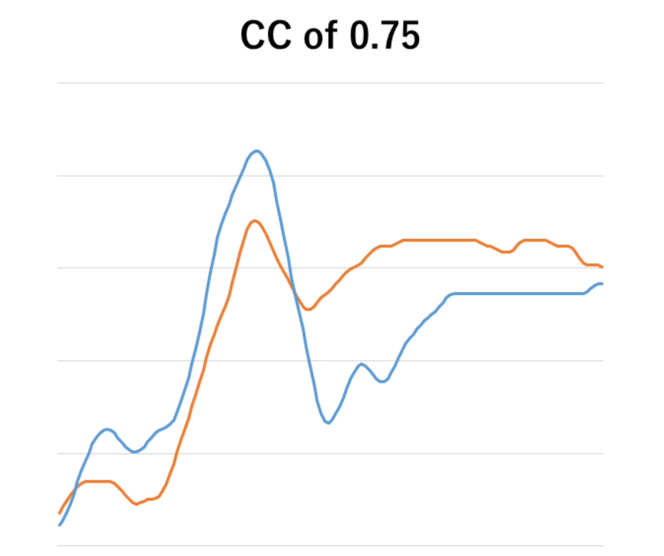


**Figure 4:** F-wave waveform with a correlation coefficient of 0.75.
Popular, the correlation coefficient is said to judge the presence or absence of correlation with 0.7 or more. However, when comparing F-wave waveforms with a CC of 0.7, recognize major differences by visually

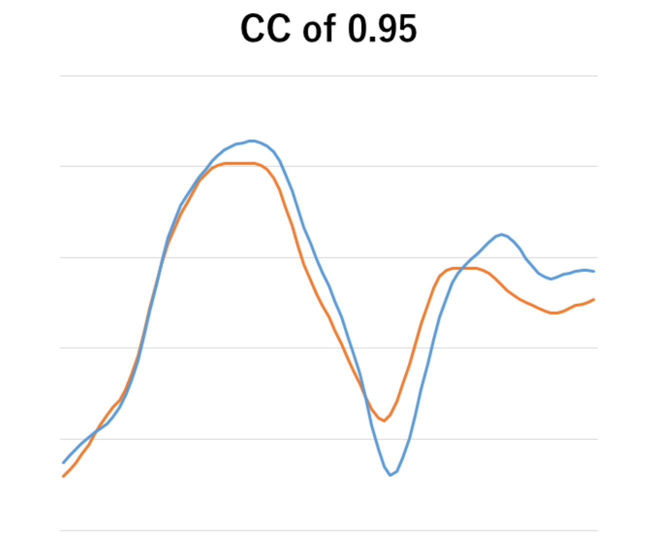


**Figure 5:** F-wave waveform with a correlation coefficient of 0.95.
When comparing F-wave waveforms with a CC of 0.95, recognize almost matching

## Conclusion

In summary, CC of 0.95 is effective for ensuring consistency between visual judgment and CC data using Excel software. In future F-wave waveform analysis research, a CC of 0.95 should be used to judge the same waveform. We feel that waveform analysis can be used to treat physical disabilities and can be used for objective evaluation of the effect of physical therapy. Excel software is easy to use and is cost-effective.

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