Sensitivities in grip exercise on simultaneous measurement of weight discrimination task and EMG recording

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We measured the sensitivities in grip exercise for weight discrimination task and for EMG recording simultaneously. Subjects had to choose one of two weights that were a standard weight and one of nine test weights, respectively (Two-Alternative-Forced Choice: 2AFC). The EMG signals were obtained from the flexor-digitorum-superficialis muscle at the dominant forearm in the weight discrimination task. In order to compare the sensitivities in weight discrimination task directly with that in EMG recording, we used *d'* as an index according to the signal detection theory. The results showed that the *d'* in the weight discrimination task between standard weight and test weight (5.0 kg) was 2.12 and that in the EMG recording was 1.20. The *d'* in the weight discrimination task was significantly larger than that in the EMG recording ($p<0.03$,Wilcoxon signed-rank test). We conclude that the weight discrimination task could be a good measurement as well as the EMG recording to evaluate the condition of muscle.

Key words: *Weight discrimination task, Two-Alternative-Forced Choice, EMG, Grip exercise*

Introduction

Every movement of the body has to be correct for force, speed, and position. These aspects of movement are continuously ascended to the central nervous system by receptors sensitive to the position, posture, equilibrium, and internal conditions of the body. The heaviness perception is one of the most important perceptions when we manipulate an object, and has been well investigated using the weight discrimination task in psychology. For example, a just-noticeable difference, which is the smallest perceivable difference in weight, is proportional to the total weight of the object. This is well known as Weber's law and Weber-Fechner's law, which represents the relation between the magnitude of physical stimulus and the magnitude of psychological sense in human being. On the other hand, an electrical activity of muscle obtained by an electromyogram (EMG) recording is often used to evaluate a condition of muscle. It is well known that integrated EMG (iEMG) during isometric contraction is strongly associated with the level of muscle force (Lawrence & Deluca, 1983, Moritani & de Vries, 1978, Maier & Hepp-Reymond, 1995). Although both the weight discrimination task and the EMG recording reflect the muscle condition, no attempt has been made to compare sensitivities for weight discrimination task and for EMG recording.

In this study we measured the sensitivities in grip exercise for weight discrimination task and for EMG recording simultaneously.

Methods

Eight healthy university students (3 females, 5 males; age 23.6 ± 1.7 years; mean ± SD) participated. Informed consent was obtained from all-volunteers for the study. One subject was left-handed according to his writing and exercising behavior. None of them had a previous history of neurological illness and special training relating to grip exercise. In the pre-experiment, maximal grip forces were measured for 2 times (force 48.7 ± 8.1 kg; male 40.6 ± 13.2 kg, female 27.0 ± 6.2 kg). Subjects sat on a chair and their dominant hand was placed on a grip exercise apparatus attached by a wire cable to a weight adjuster (Fig.1). The weight adjuster was blind to subjects. Subjects took an enough rest between each session.

Weight discrimination task and EMG recording were measured simultaneously in grip exercise. The experimenter controlled weight adjuster connected with the grip part. Subjects grasped the grip part and held it for four seconds using the dominant hand. Under the constant method, weights were lifted successively in pairs and compared with respect to heaviness. We used one standard weight (4.6 kg) and nine test weights, 3, 3.8, 4.2, 4.4, 4.6, 4.8, 5, 5.4 and 6.2 kg. Each test consists of 20 trials. The presentation order of the combination was pseudo-randomly prearranged. Subjects attempted to memorize the first heaviness (s1). Then, subjects attempted to memorize the second heaviness (s2). Experimenter announced the question "Which weight was heavier, the first or the second one?" Finally, each subject had to answer that they judged the heavier weight by comparing the first and the second grip exercise (Two-Alternative-Forced Choice: 2AFC).

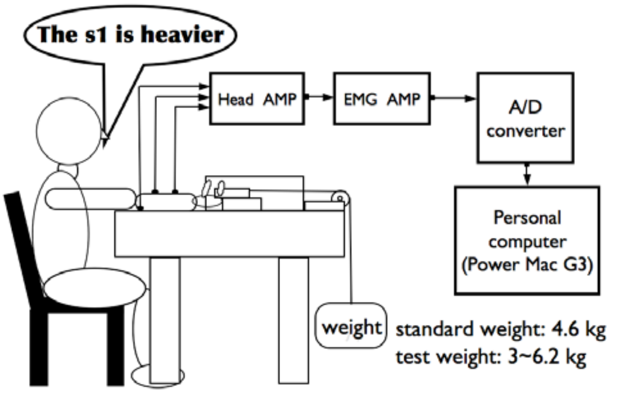

Figure 1: A schematic drawing of the experimental system.

The EMG recordings were made using Ag/AgCl surface electrodes with a diameter of 0.9 cm, fixed over the dominant flexor-digitorum-superficialis muscle in the weight discrimination task. The EMG signals were amplified by Neuropack ∑(NIHON KODEN) with a bandwidth of 10 Hz to 1 kHz, digitized at the sampling rate of 2 kHz (Maclab, AD Instruments). A reference electrode was placed over the wrist joint. The iEMG was caluculated by full wave rectification for 2 seconds during sustaining isometric contraction. All possible error factors (fatigue, muscle length and contraction speed) were controlled.

In order to compare the sensitivities in weight discrimination task directly with that in EMG recording, we used *d'* as an index according to the signal detection theory.

Results & Discussion

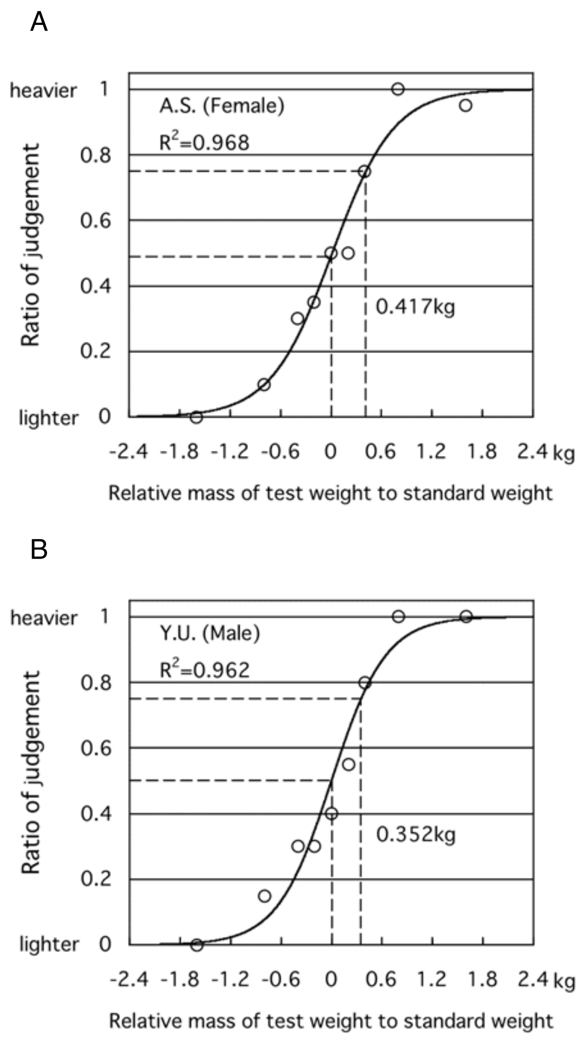

Figure 2: Relationships between ratio of judgement and relative mass of test weights to the standard weight from typical examples. Curving line in the figure was fitted by logistic function. A: Typical example of female. B: Typical example of male. The JND was 0.382 kg and 0.402 kg from fitting curve, respectively.

Figures 2 and 3 show the relationships between ratio of judgement and relative mass of test weights to the standard weight. Data were fitted by a logistic function that was represented as a curve in each panel. Just noticeable difference (JND) of weight was defined as the relative mass that was obtained from the ratio of 75 percentage of correct judgement. The JND represents a sensitivity of heaviness perception. When the JND is small the sensitivity is high whereas when the JND is large the sensitivity is low. We found a ratio of judgement as a function of relative mass of test weights to the standard weight was almost the same among subjects. There was no significant difference in JND between female and male. The JND was 0.395 ± 0.049 for all subjects, 0.402 ± 0.056 kg for 5 male and 0.382 ± 0.045 kg for 3 female (mean, SE). Intensively, although there was a remarkable difference in maximal grip force among subjects, the JND for all subjects were proportional to the test weight. The points were fitted by psychometric function that is well known as the Weber-Fechner's law.

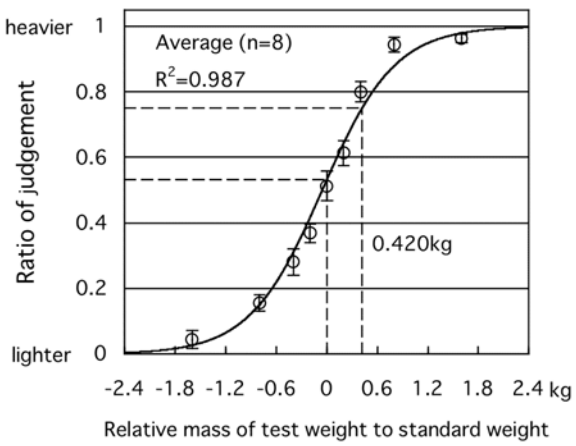

Figure 3: A relationship between a ratio of judgement and a relative mass of test weights to the standard weight. The curve line in the panel was fitted by a logistic function. The JND was 0.420 kg.

Figures 4 and 5 show the relationships between a normalized iEMG and a relative mass of test weights to the standard weight. The iEMG linearly increased with increasing the mass of test weights for all subjects. The monotonic increase of iEMG is consistent with previous reports (Lawrence & Deluca, 1983, Moritani & de Vries, 1978, Maier & Hepp-Reymond, 1995). The monotonic increasing iEMG, could be explained by a fascilitation of the firing rate of each motor unit and by an increase of the number of motor unit. The correlation coefficient between normalized iEMG and the relative mass of test weight to standard weight was 0.975 (p<0.001).

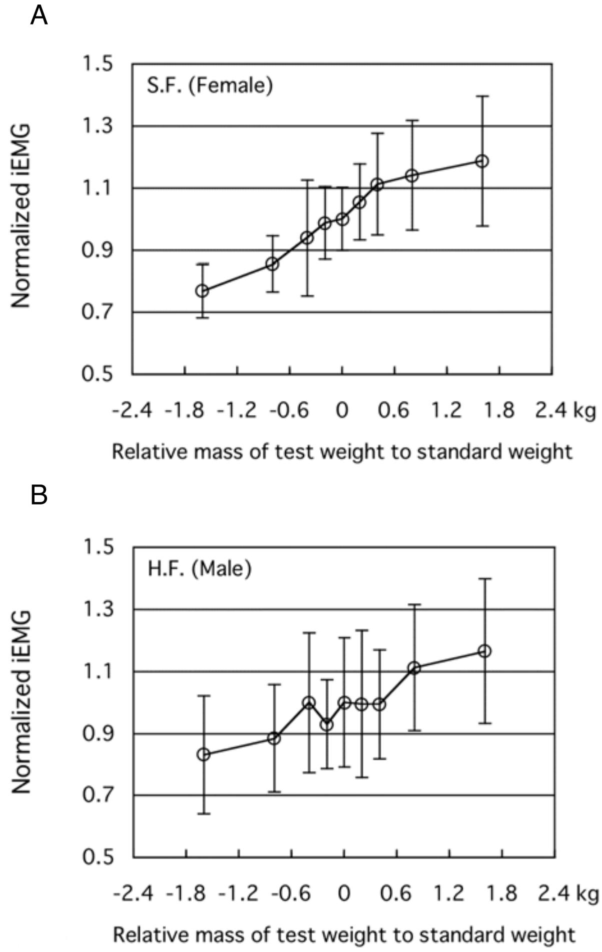

Figure 4: A relationships between a normalized iEMG and a relative mass of test weight to standard weight in typical examples. The plotted data show the mean and standard deviation from 20 trials. A: Typical example of female. B: Typical example of male.

In order to compare the sensitivity in weight discrimination task directly with that in EMG recording, we used *d'* as an index according to the signal detection theory. We attempted to find a difference in *d'* between weight discrimination task with EMG recording by the Wilcoxon signed-rank test. Figure 6 showed the *d'* obtained in each condition for weight discrimination task (black bars) and for EMG recording (white bars), respectively. The error bar in the panel represents a standard error. The *d'* was 2.12 for the weight discrimination task and 1.20 for the EMG recording. We found a significant difference in *d'* between the weight discrimination task and the EMG recording (p<0.03).

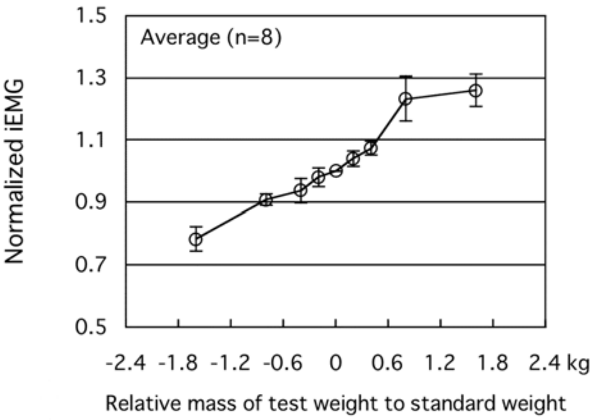

Figure 5: A relationship between a ratio of normalized iEMG and a relative mass of test weight to standard weight.

The reason why the *d'* in weight discrimination task was greater than that in EMG recording could be a difference in information between two measurements. The *d'* in weight discrimination task was determined from variety kinds of information: haptic information, muscle information, tendon information, and efferent information. On the other hand, the *d'* in EMG was determined only from a few muscles. The *d'* in EMG will be better when we increase a number of muscles measured.

These results indicated that the weight discrimination task could be a good measurement as well as the EMG recording to evaluate the condition of muscle.

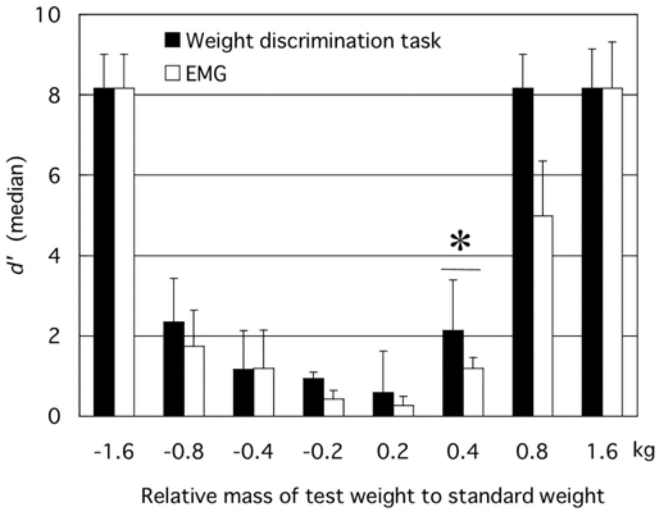

Figure 6: The *d'* obtained from each test weight in weight discrimination task and EMG recording. Median and standard error are shown. The *d'* in weight discrimination task was significantly larger than the *d'* in EMG between weights of standard weight and 5.0 kg (Wilcoxon signed-rank test, $p<0.03$).

References

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