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Skill Evaluation Method Based on Variability of Antagonism Power of EMG

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ABSTRACT

We can more effectively take the physical skills of individual people into consideration from various points of view when we focus on evaluating their skills while exercising. We can focus on their maximum levels of speed and power, their smoothness through a series of exercises, their instantaneous force, repeatability, and their adjustability to agitation or obstacles such as circumjacent people or nature. A lot of exercise skills can relatively and easily be quantitatively evaluated by carefully analyzing the results and performance.

However, it is difficult to evaluate the "repeatability" aspect, which is only one of exercise skill, when judging its degree from only viewing the given exercise. An example of a physical exercise process that can contribute stable results would need to be equivalent to a "skill" such as hitting a home run each time. We believe that the acquisition of a given skill is very useful in fields such as physical training. Therefore, we examined the repeatability aspect from this point of view.

We also used an antagonism power index calculated using EMG to achieve such purposes. The index represents any adjustments made in the output power from the muscles. I thought that the adjust function of the output power of the muscles would be very useful when evaluating the exercise skills of a given individual. The antagonism power was calculated using the quasi-muscular tension and a skeletal muscle model consisting of one joint and two muscles. We also made a comparison between the unskilled state and a skilled state. As a result, the differences in exercise skill appeared to be antagonism power. Therefore, we thought that antagonism power was effective enough for creating a new exercise skill evaluation index that we define in this paper.

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Categories and Subject Descriptors

F.1.1 [Models of Computation]: Computability theory; H.1.2 [User/Machine Systems]: Human information processing

General Terms

Verification

Keywords

EMG, proficiency, antagonism power, skill, exercise

1. INTRODUCTION

It is very difficult to make an objectively judgment from the evaluation results of physical exercise. Generally, an exercise can be quantitatively and easily evaluated using the results and performance. However, we believe that such evaluations and the actual level of skill of each person have different meanings. The results from evaluating a given exercise appear as results of the mutual effect of the associated organs in a series of exercises.

We call the unity of several associated organs in support of an act a "skill" [4]. For example, it is possible to hit pay dirt "by chance" when doing an exercise such as darts. Similarly, for an exercise such as baseball, it is possible to hit a home run with using proper form. In this way, a skill can't be judged by sampling only a single trial when it consists of a series of exercises. Therefore, we believe the process involved with a given physical exercise that contributes stable results should be equivalent to a "skill". In fact a "performance" is also raised by a "skill".

In this instance, we have to observe the physical exercise process to observe a given skill. One method of doing this is using EMG. EMG is the electrical signal observed on the surface of the skin where the muscle was used, meaning the movement of the muscle is known from the signal. There

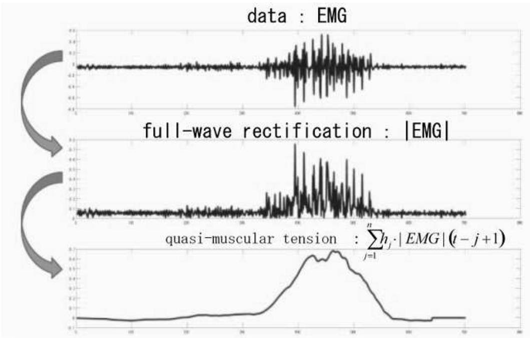

Figure 1: Calculated process of quasi-muscular tension (Second-order low-pass filter after moving average and full-wave rectification)

have been a lot of studies about exercise evaluations using EMG [7][5]. However, most of these studies use specialized exercises. That is, most of these studies research the unique technique involved with each exercise.

It would be extremely difficult, in this case, to determine the unique techniques of all exercises. However, it is possible that there may be a skill process that is common to most exercises. There may also be an evaluation index that can be used equally for most exercises. If this is true, we believe an effective skill raising technique could be created. Therefore, as a first step to our study, we examined the exercise evaluation index that could evaluate the difference between the unskilled state and a skilled state.

2. METHOD

2.1 Analysis

We defined the "antagonism power" for an exercise skill evaluation index, and used it in this study. That is, the index is extracted from the power of the antagonist, and it is generated using two models: quasi-muscular tension and a joint model.

First, as a precondition to explain quasi-muscular tension, we assumed the surface EMG to be directly proportional to the muscular tension. We calculated the quasi-muscular tension using a second-order low-pass filter after moving average and full-wave rectification. EMG using a second-order low-pass filter is sufficiently for describing the relationship between the muscle action potential signal and muscular tension. This was shown in a neurophysiological study [3]Schmidt:Motor. In addition, Akazawa et al. previously measured the levels of muscle tension from EMG using a second-order low-pass filter [1]. Figure 1 shows the calculated process of quasi-muscular tension using EMG.

The second model was a skeletal muscle model consisting of one joint and two muscles. This means the two muscles control the movement of the joint. Figure 2 shows the skeletal muscle model we used.

This time, we used these models and calculated the "antagonism power" and then evaluated it.

2.2 Derivation of Exercise Skill Evaluation Index

Antagonism power F is calculated using the stiffness. There

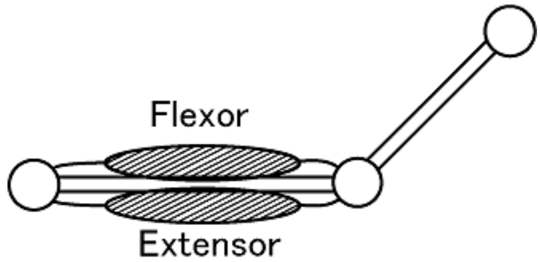

Figure 2: Skeletal muscle model consisting of one joint and two muscles

have been several studies concerning exercise skill evaluation [2]. Joint stiffness is defined by Osu et al. as the physical flexibility that decreases with any improvements in skill [6]. However, we believed that joint stiffness is not sufficient enough for evaluating an exercise. We investigated how to use a muscle that is visually difficult to evaluate. We also used the antagonism power calculated using EMG for the establishment of a new index in the training for an exercise.

Therefore, we set the parameters for obtaining the antagonism power. The computational expression of hand torque τ is

$$\tau = a_e T_e - a_f T_f. \quad (1)$$

The computational expression of the cubital joint stiffness S is

$$S = a_e T_e + a_f T_f. \quad (2)$$

The quasi-muscular tension of the biceps brachii was T_e. The quasi-muscular tension of the triceps brachii was T_f. a_e and a_f were constant. We estimated these constant values. Thereby, these constant values have several meanings that can be translated from the range of EMG to the muscular tension and movement of the muscles. The parameters were estimated using the pressure value and surface EMG, and the method for estimating the parameters used the pressure value and the level of quasi-muscular tension. The parameters were set as close to the pressure value with the quasi-muscular tension as possible using the least-square method. In this case, several indefinite elements were removed. Muscles have contraction rates and muscle lengths. These elements can be used to change the EMG-muscular tension relationships. Other elements have similar effects and include the joint angle, angular speed, and gravitational force among others. Therefore, these changes were removed by the voluntary isometric contractions.

Then, the calculated antagonism power using the hand torque τ and the cubital joint stiffness S is as follows.

$$F = S - |\tau| \quad (3)$$

The antagonism power calculated in this way has a property unlike that of the stiffness. The stiffness depends on the exercise intensity. For example, consider a golf swing. The swing advances as a release impact follow-through after raising the club. Generally, there is more strain at the moment of impact than at the moment of release. Therefore, the stiffness is necessarily growing at the moment of impact. However, we think that there are tips to determining the series of a given exercise. In other words, your weak point isn't always the moment of impact. The point may be

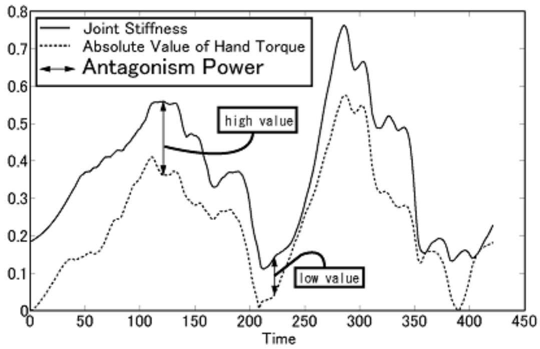

Figure 3: Mean of the antagonism power

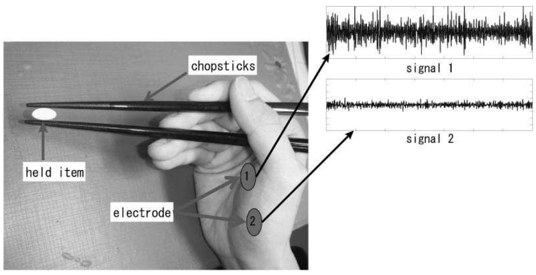

Figure 4: Experimental view (B: hold position (state that maintains the power of the finger))

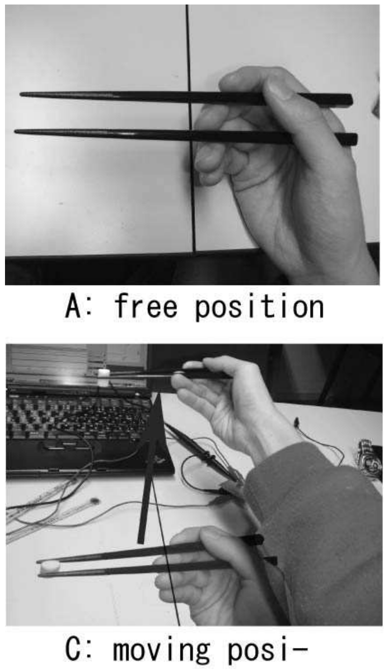

Figure 5: A: free position (state of loss of strength) C: moving position (state that coordinates power of finger while moving arm)

the moment of release, the moment of follow-through and so on. Therefore, we thought that more antagonism power than stiffness could be determined for better evaluating the exercise skill, making it easier for comparison with less dependence on the exercise intensity.

The direction of antagonism power is opposite to the desire direction. That is, it sets up the output power of the muscles. We researched the relations between antagonism power and the skills necessary for an exercise.

3. EXPERIMENT

We researched the relation between the skills necessary for an exercise and the antagonism power. We confirmed the level of antagonism power necessary for determining any differences emerging for different exercise skills.

3.1 Experiment Environment

This time, we conducted experimental tests using chopsticks, for both the dominant and non-dominant hands. The subject was 24-years-old and right-handed. Figurereffigure:Experimental view is an overall view of the experimental environment. In this way, they picked-up a bean-sized object using chopsticks and held it. This exercise represents activities involving increases in isometric work because they don't excite muscular contraction.

The target muscles are the short extensor and short flexor muscles of the thumb that affect its flexure and extension movements. They placed electrodes on the hand as shown in Figure 4 to measure the EMG of the two muscles. The surface EMG was measured using a bipolar lead and the disk electrodes. In addition, the measured sampling frequency was 4 kHz using differential amplification circuits. They also used textile-net as a body ground to remove noise. Furthermore, the sampling frequency of the EMG ware was reduced to 200 Hz to smooth it out using the moving average method.

3.2 Experimental Task

We tested three conditions: the state where nothing is attained (exercise A), the state where something is acquired and maintained (exercise B), and the state where something is acquired and the arm is extended (exercise C). Figure 4 shows exercise B. In addition, Figure 5 shows exercise A and exercise C. They conducted these three kinds of experimental exercise tests using the right and left hands (dominant and non-dominant hand).

The dominant hand represents that the skill has already been mastered skill and the non-dominant hand represents the non-skill hand. The exercises (A, B, & C) were conducted to represent the levels of difficulty for each hand.

4. RESULTS

Figure 6 shows the antagonism power for all exercises for each hand and every level of difficulty. The horizontal axis is the time and displays the exercise being maintained for 3.5 seconds. The antagonism power was normalized when using the estimated moment arm.

Figure 7 shows Equation 6, which was calculated for each hand and each level of difficulty. This means that the standard deviation S of data x was calculated. In this case, *sample* is the number of trial samples and *num* is the num-

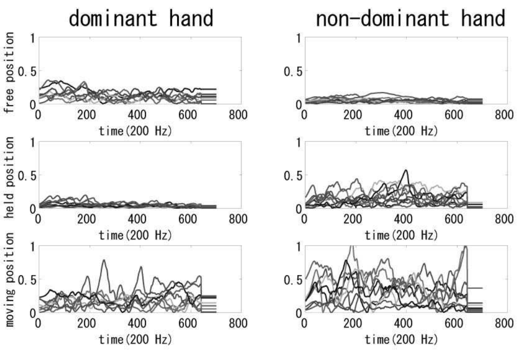

Figure 6: Plot of all data (left column: dominant hand, right column: non-dominant hand, top row: free position, middle row: held position, bottom row: moving position)

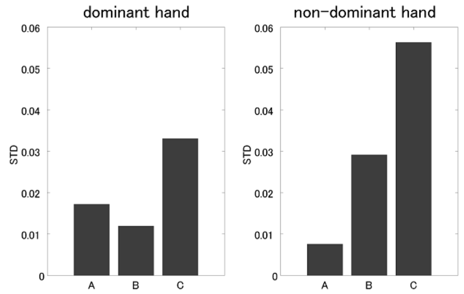

Figure 7: STD of antagonism power of dominant and non-dominant hands (A: free position, B: held position, and C: moving position)

ber of trials.

$$\hat{s} = \{\frac{1}{sample - 1}\sum_{i=1}^{sample}(x_i - \bar{x})^2\}^{\frac{1}{2}} \quad (4)$$

$$\bar{x} = \frac{1}{sample}\sum_{i=1}^{sample} x_i \quad (5)$$

$$S = \{\frac{1}{num - 1}\sum_{j=1}^{num}(\hat{s}_j - \bar{\hat{s}})^2\}^{\frac{1}{2}} \quad (6)$$

$$\bar{\hat{s}} = \frac{1}{num}\sum_{j=1}^{num}\hat{s}_j \quad (7)$$

The following results were attained from these data. Very little difference could be determined for either hand in Exercise A. A big difference was not observed between exercises A and B for the dominant hand. However, for the non-dominant hand, a clear increase phenomenon appeared for all the exercises. In addition, there were a lot of ups and downs in antagonism power in the trial when there was a big standard deviation.

5. CONCLUSIONS

We found that a difference appeared in the variability of the antagonism power based on the differences in exercise skill. The antagonism power continued to be a low value when the level of exercise was high in the case of simple exercises like holding an item with chopsticks. However, it was high even for simple exercises when the level of exercise skill was low. In addition, we confirmed that the power could be adjusted by the antagonism power when the variability of the antagonism power was large.

That is, it is basically unnecessary to make adjustments due to the antagonism power because an appropriate and stable level of power can be maintained when the level of the exercise is high. However, we think that when level of the exercise is low, adjustments based on the antagonism power are necessary because an appropriate and stable level of power is difficult to maintain.

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