Nagoya J. Health, Physical Fitness, Sports Vol. 9, No. 1 (March 1986)

Comparison of force patterns between elastic and rigid dumbbell in arm exercise

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A new stick-shaped dumbbell made of elastic materials was developed. This elastic dumbbell (ED) was 51.5 cm long, 2.0 kg in weight and has an diameter of 4.0 cm. Force patterns produced during repetitive arm exercise with ED as well as with a rigid dumbbell (RD) of the same weight and diameter as ED were investigated. The center part of each dumbbell was attached to the bottom of the force transducer (load cell). A handle was fixed to the top of the load cell. A subject was asked to grip the handle and to lift the load cell repeatedly at the following tempos; 77, 116, 154, 193 and 231 times per minute. These tempos corresponded to 50, 75, 100, 125 and 150 % of the frequency of resonance of ED, respectively. Force was continuously recorded by a pen oscillograph. Angle of elbow joint was displayed on oscilloscope to regulate the amplitude of movement. At tempo 77 and 116, peak force value (PFV) of both dumbbells were almost the same. After the peak, the force of ED was found to be at higher level than that of RD. At tempo 154, PFV of ED was 1.6 times as high as that of RD, which might be explained by resonance. At tempo 193 and 231, PFV of ED were smaller than that of RD. From these characteristics of force curve of ED, it was suggested that larger force could be exerted in wider range of joint angle in strength training with ED than with RD.

Barbells and dumbbells have been traditionally used for strength training. They are usually made of rigid materials without elasticity, such as iron and lead. Therefore, in exercises with barbells or dumbbells in hands, human joint movements are often restricted in a certain range of movement, because of preventing muscles and tendons from receiving injuries. If these so-called "free weights" have some elasticity, strength training could be taken with more natural movements of the extrimities. From such conception, an elastic dumbbell was developed in Japan. Our previous study[2] suggested that impulsive force of elastic dumbbell at sudden stop was smaller than that of rigid one. And it was reported that pattern of reaction force received from rigid free weight in repetitive movements was related to repetitive rate.[1),3] As for an elastic dumbbell, however, its dynamic characteristics in repetitive exercises are not known.

The purpose of the present study was to investigate dynamic characteristics of the elastic dumbbell in repetitive arm exercises by comparing with rigid one.

Materials and Methods

The elastic dumbbell used for this study (developed by Argo Japan company, see Figure 1) was a stick-shaped one, which was 51.5 cm long, 4 cm in diameter and 2 kg in weight. Its surface was

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made of rubber, and inside were combined lead or wooden tablets which were 3.5 cm in diameter and 1 cm in height. A rigid dumbbell which had the same weight and diameter as elastic one was also used.

The center part of dumbbell was attached to the bottom of a force transeducer (load cell, Kyowa LT-F) through a load attachment which weighed 0.5 kg. An acceleration transeducer (accelerometer, Kyowa AS-10B) was attached to the top of the load cell, and also a handle was fixed. Thus, the force-measurement set was made, which consisted of handle, load cell, accelerometer, load attachment and dumbbell.

A subject was asked to grip the handle and to lift the set repeatedly at 5 different tempos; 77, 116, 154, 193 and 231 times per minute. It was known from the previous experiment that this elastic dumbbell caused resonance at tempo of 154 times per minute. Therefore, these different tempos corresponded to 50, 75, 100, 125 and 150 percents of the tempo of resonance. Angle of elbow joint obtained by an electrogoniometer was monitored on a screen of oscilloscope. The subject was asked to regulate the range of movement of elbow joint by watching the goniogram. The range of movements was made smaller according to tempo in order to enable the subject to perform the movement even at faster tempos. Force, acceleration, and angle of elbow joint were recorded simultaneously on a pen recorder (San-ei 8K11) and a data recorder (Sony FE-35A).

In order to obtain average curve at each tempo, records of force, acceleration and angle of elbow joint in 4 successive cycles were picked up and superposed at the point of maximal elbow extention in each cycle.

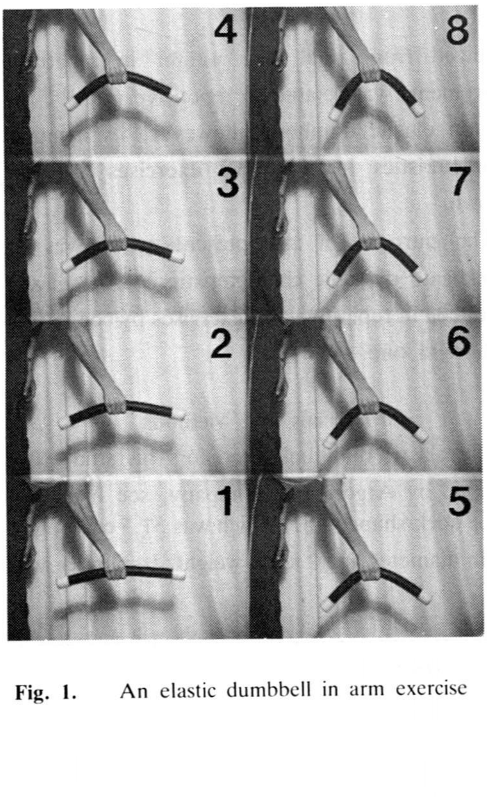

Fig. 1. An elastic dumbbell in arm exercise

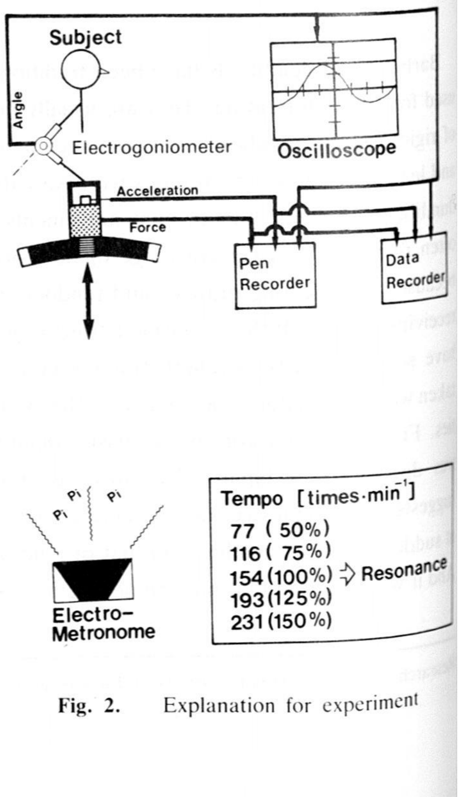

Fig. 2. Explanation for experiment

Results

Figure 3–7 show average curves obtained by using a technique of superposition at each tempo. In force (top), positive values show force pulling the load cell downward and negative values show force pushing the load cell upward. In acceleration (middle), positive values show acceleration upward and negative values show acceleration downward of load cell. The angle (bottom) expresses the flexion of elbow joint from the fully extended position.

At tempo of 77, there was little difference in acceleration and angle curve between rigid and elastic dumbell. The values of peak force were almost the same between rigid and elastic dumbbell. Force of rigid dumbbell dropped rapidly after the peak. Force of elastic dumbbell dropped more slowly. At tempo of 116, relationship of force curve between rigid and elastic dumbbell was almost the same as the case of tempo 77. At tempo of 154, which caused resonance, the peak force of elastic dumbbell came up to 1.6 times as high as that of rigid one. In elastic dumbbell, negative force was observed. At tempo of 193, the peak force in elastic dumbbell was lower and came later than that of rigid one. At tempo of 231, the results were almost the same as tempo of 193.

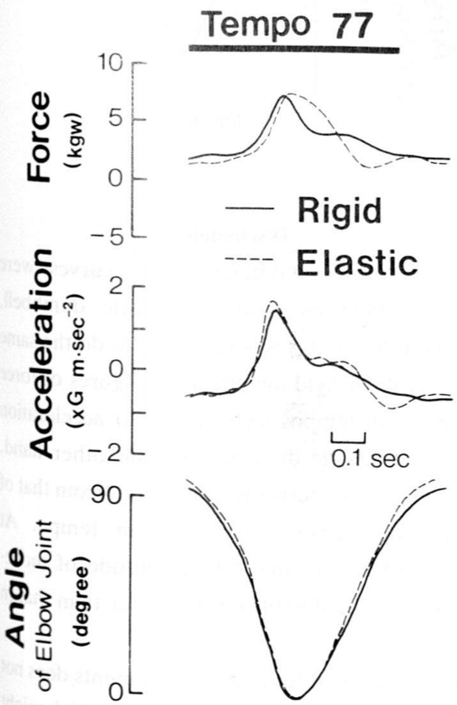

Fig. 3. Average curves at tempo of 77. Figure 4-7 are average curves at tempo of 116, 154, 193 and 231, respectively.

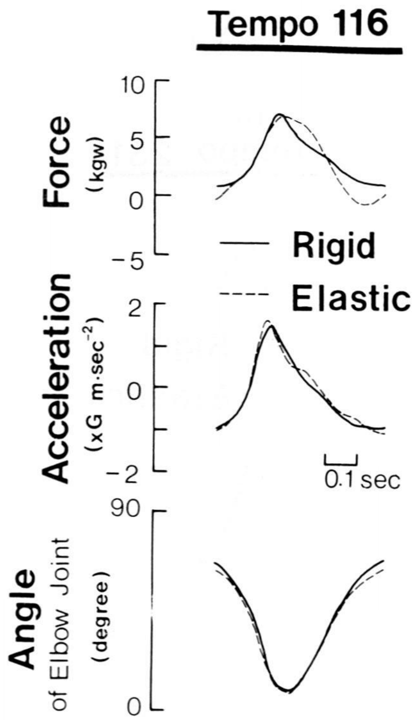

Fig. 4.

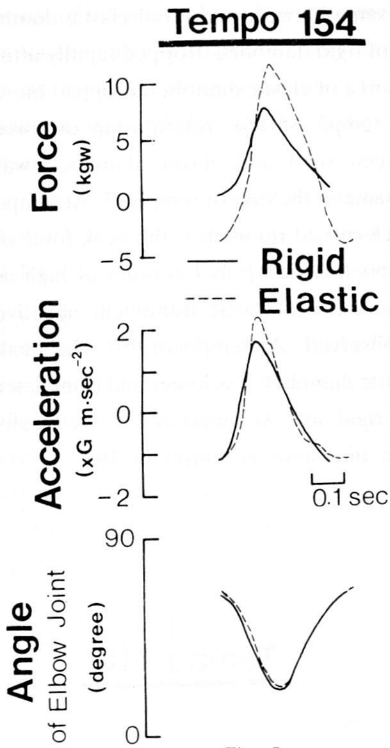

Fig. 5.

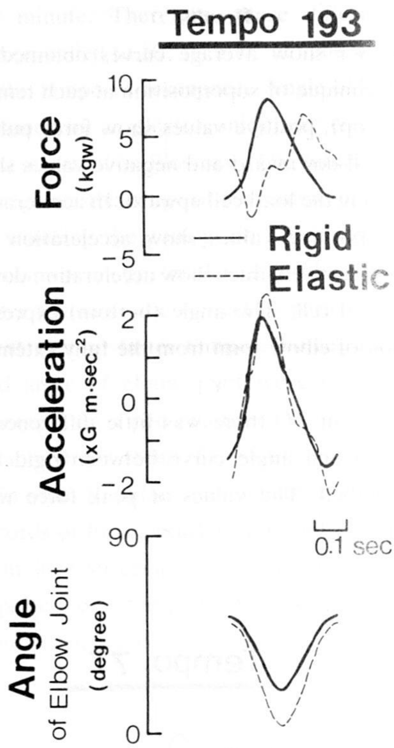

Fig. 6.

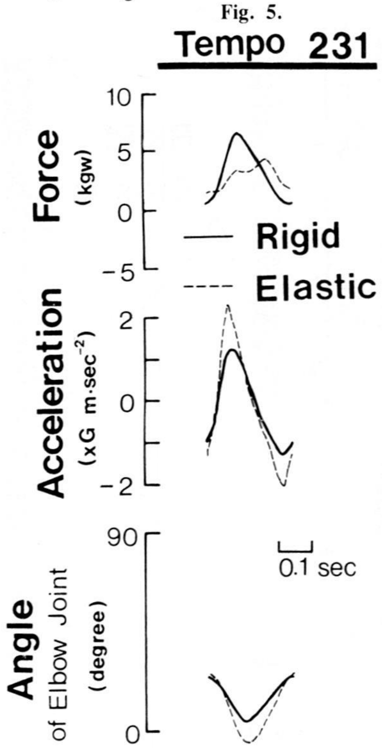

Fig. 7.

Discussion

At all tempos, different force curves were observed between rigid and elastic dumbbell, although the subject was requested to do the same movement. In rigid dumbbell, the figures of force curves at all tempos were similar to acceleration curves. In elastic dumbbell, on the other hand, patterns of force curves were different from that of acceleration curves, depending on tempo. At tempo 193 and tempo 231, magnitude of movements in elastic dumbbell was greater than that in rigid one.

However, the difference in movements does not explain the difference in force curves, which might be attributed to the dynamic characteristics of dumbbell itself.

Acceleration of load cell can be identified with that of the center part of dumbbell, which was fixed to load attachment. On the other hand, force obtained from load cell corresponds to acceleration of the center of gravity of dumbbell.

As the center of gravity of rigid dumbbell always exists in the center part of dumbbell, force changes in proportion to acceleration of load cell. In elastic dumbbell, on the other hand, it is supposed that the way of displacement of both ends might differ from that of the center part because of elasticity and that this difference might be dependent on tempo.

Therefore, acceleration of the center of gravity might be different from that of the center part in elastic dumbbell. This is why the difference in force curve could be observed between elastic and rigid dumbbell.

From these results, it was suggested that in strength training with elastic dumbbell under the tempo of resonance, larger force could be exerted in wider range of joint angle than with rigid one.

References

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(Recieved January 27, 1986)