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原 著

Loaded Pendular Exercise for Shoulder Muscle Relaxation: An Electromyographic Finding*

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Abstract

Patients with stiff and painful shoulder condition are usually instructed to carry out Codman's pendular exercise while grasping a dumbbell or iron, hence it is known as the 'iron exercise'. It is hypothesised that the weight of such a load stretches the contracted soft tissues of the shoulder joint, together with voluntary relaxation of its muscles. The question arose: By grasping a load, would not contraction of the forearm and hand muscles facilitate contraction of the shoulder muscles, negating the purpose? A comparison was made of the integrated electromyographic (IEMG) activities of the right deltoid and infraspinatus muscles when performing pendular exercise with a 2-kilogramme weighted band at the wrist (WB pattern) and the same exercise grasping a 2-kilogramme dumbbell (DG pattern). IEMG activity of these muscles was also compared according to the plane of pendular movement. The subjects were 15 healthy male student physiotherapists acting as their own control. Significantly greater IEMG activity was obtained for all the muscles in the DG than in the WB pattern. As for the plane of movement, sagittal plane swinging caused least IEMG activity in the middle deltoid, while transverse plane swinging and clockwise circumduction caused least in the anterior deltoid. The greatest IEMG activity recorded for all the movements was in the infraspinatus muscle. The results of this investigation suggest that wearing a weighted band and limiting pendular movement to sagittal and transverse plane swinging, eliminating circumduction, may promote less contractile activity in the shoulder muscles when performing pendular exercise.

Key words Pendular exercise, Shoulder muscles, Integrated electromyography

Pendular exercise has traditionally been used for shoulder mobilisation since E. A. Codman first described it in 1934[1] and it is intended to be a purely passive treatment of the shoulder[2,3]. R. W. Sperry modified the stooped posture in his experiment by inclining the upper body and resting one hand on the edge of the table (Fig. 1)[4]. Since then, this position has commonly been adopted by the physiotherapist administering Codman's pendular exercise in the clinic. In general, this position is much easier to maintain than the classical Codman position in which the feet are placed together, and the trunk is strongly flexed at the hips with both arms hanging down (Fig. 2). In pendular exercise the shoul-

* 肩関節周囲筋弛緩のための重りつき振子運動:筋電図学的所見

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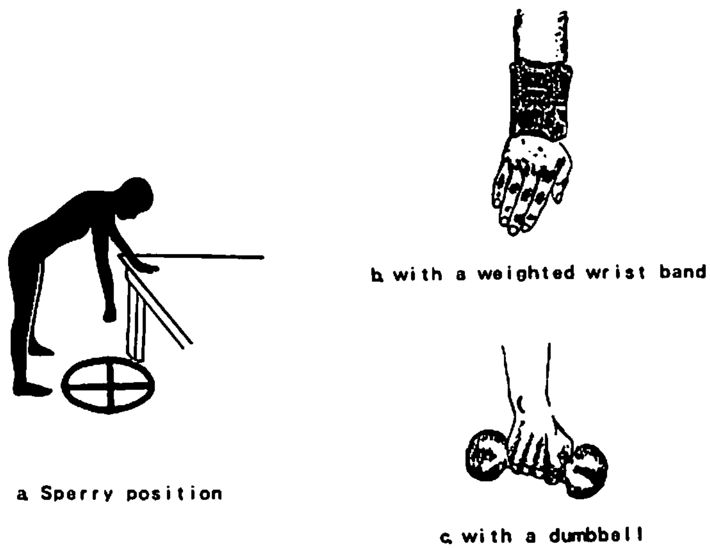

Fig. 1. Sperry position (modified from Hellebrandt, *et al*[6]) and type of loading during the experiment.

der joint is moved passively through the sagittal and transverse planes and circumduction arc by the forces of gravity and through the momentum created by the body swaying. There is a similar exercise to this in prone lying recommended by Chandler[1], but it is rarely used because of its inherent impracticality.

Pendular exercise is used for patients with any stiff and painful shoulder condition, such as frozen shoulder syndrome. Such patients are instructed to carry out this exercise by grasping a 0.5- to 3-kilogramme (kg) sandbag or dumbbell. In addition, they are often recommended to grasp an iron when practising this exercise at home, hence, in Japan, it is known as the 'iron exercise'. The purpose of loading the upper limb is to add traction to the dependent arm and momentum to the pendular cycle, thereby supposedly inducing voluntary relaxation of the shoulder muscles.

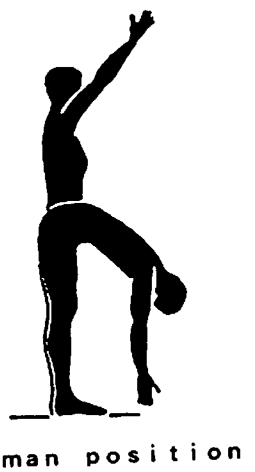

Fig. 2. Codman position (from Hellebrandt, *et al*[6]).

Taketomi and associate[5] found that the deltoid and latissimus dorsi muscles of one healthy individual produced almost no electrical activity during forward/backward swinging of the arm in a stooped position compared to those of a patient with frozen shoulder syndrome. It is, however, unclear whether the pendular exercise was carried out grasping a 1 to 2 kg dumbbell or with a wrist band of the same weight. In addition, the number of subjects was rather small in that experiment.

Hellebrandt and associates[6] compared in detail electromyographic activity of the shoulder muscles during pendular exercise in the Codman, Sperry and Chandler positions under three experimental conditions: they were 1) no loading of the upper limb at its distal end; 2) grasping a five-pound or two-and-a-quarter-kg dumbbell; and 3) carrying an equivalent weight suspended from a wrist cuff. They found that the latter elicited least electromyographic activity. However, pendular movement was actively initiated in all the groups. Although the difference in the contractile activities of the shoulder muscles was clearly demonstrated on the electromyograms, its statistical significance was never computed. Thus, the purpose of our investigation was to compare and statistically analyse the state of shoulder muscle relaxation via electromyographic activities when grasping a dumbbell or when wearing a weighted wrist band during passive pendular movement created by the body swaying.

Method

Electromyographic instrumentation

Integrated electromyographic (IEMG) activities were measured by using a type 1205D electromyogram and a type 1310 integrator (NEC San-ei Instruments, Ltd, 12-1, Okubo 1, Shinjuku, Tokyo 160), of which the latter had the advantage of quantifying the overall muscular activity which was an aggregation of action potentials. These IEMG amplitudes indicated a linear correlation to the muscle tension generated[7,8,9].

The following muscles were selected for IEMG measurement: the anterior, middle and posterior fibres of the right deltoid and the right infraspinatus muscles (Fig. 3)[10]. We excluded the rotator cuff muscles which would have necessitated further use of needle electrodes. A pair of one-centimetre (cm) in diameter surface electrodes in a bipolar lead system was applied over the belly of these muscles. They were placed parallel to the muscle fibres, three cms apart from each other, and secured to the skin by a piece of tape. The reference electrode was applied over the biceps brachii. The electrode placement was preceded by abrasion of the skin surface with an alcohol swab to reduce its impedance. The speed of the recording paper was set at one cm per second and meaurements were taken for five seconds. In this way, five consecutive 1-second integrals of electrical activity were obtained.

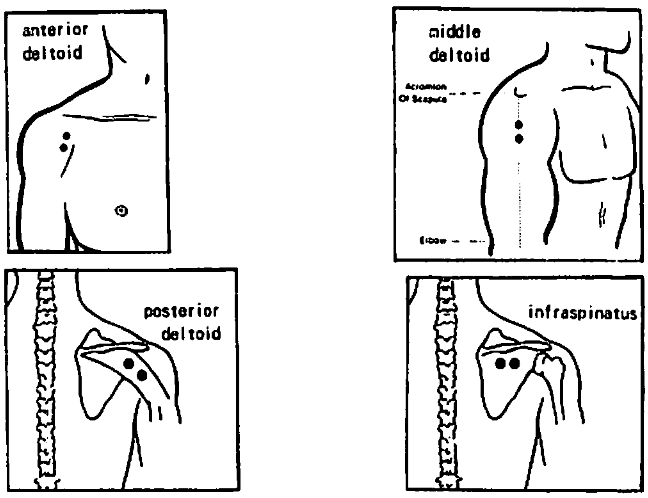

Fig. 3. Electrode placement for the deltoid and infraspinatus muscles (from Basmajian[10]).

Subjects and testing procedures

The subjects of this study were fifteen healthy male student physiotherapists with no noticeable defects in musculoskeletal function. The mean age of the subjects was 23.1, ranging from 19 to 30 years old.

The subject was instructed regarding the nature of the method and instrumentation of the experiment and given several trials to become familiar with the patterns of the pendular movement. During the experiment, he was asked to stoop 80 to 90 degrees and to rest his left hand on the table with elbow extended, and to let his right arm hang downwards in a relaxed position (Fig. 1a). The subject swung his right arm in three motions: forwards/backwards, sideways and in clockwise circumduction. A circle on the floor 50 cms in diameter served as a guide for the movement with a circumference as wide as the practised subject could make it. In addition, we placed two 50-cm cross markers inside the circle and the subject was asked to swing his arm within the diameter of the circle and in line with the cross markers (Fig. 1a). The subject carried out the sequence of movement while wearing a 2-kg weighted band at the wrist (Fig. 1b), which was termed as the wrist-band-wearing (WB) pattern and then the same movement grasping a 2-kg dumbbell in his right hand (Fig. 1c), which was termed as the dumbbell-grasping (DG) pattern. Each subject acted as his own control and the sequence of the two patterns was randomised.

Data analysis

The difference in the average IEMG amplitude between the WB and DG patterns was analysed by the Student's t-test. This test was also employed to compute the average IEMG amplitude for the planes of pendular movement. The level of significance was set at 0.05. The null hypothesis was that there would be no difference in the electrical activity of the muscles in either the WB and DG patterns, nor for the planes of pendular movement.

Results

A typical recording of electrical activity for the posterior deltoid muscle is demonstrated in Fig. 4 which shows at the top the pattern of the electromyogram and on the bottom the pattern of the IEMG; the left half is the pattern produced by pendular movement with the weighted band and the right half the pattern with the dumbbell. As is obviously apparent, the

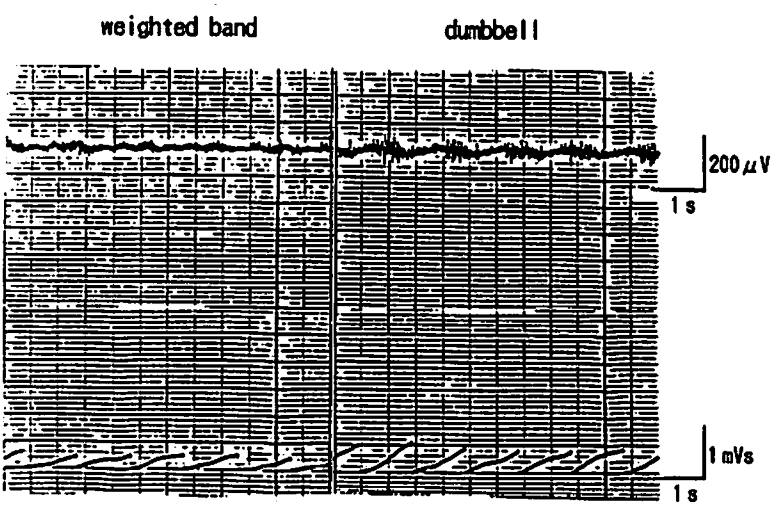

Fig. 4. EMG and IEMG recording for the posterior deltoid muscle.

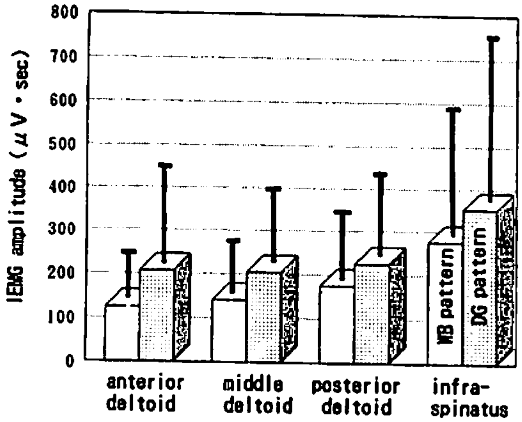

Fig. 5. Electromyographic activity and standard deviations (line above the blocks) during the WB and DG patterns.

electrical activity was greater in the DG pattern than in the WB pattern.

Figure 5 created from values in Table 1 shows electrical acitivity of the shoulder muscles tested according to the type of loading. As is seen in the bar graph, IEMG activity of the shoulder muscles was significantly greater in the DG pattern than in the WB pattern. In both patterns, however, the infraspinatus showed the greatest amplitude. Electrical activity was not evident in some subjects' muscles, which resulted in larger standard deviations than expected.

In Fig. 6 created from values in Table 2 the bar graph shows the amount of IEMG amplitude produced in the four separate muscles according to the direction of pendular movement. The bar on the left is the amount produced by sagittal swinging, the centre bar by transverse plane swinging and the bar on the right by circumduction, respectively. As is seen, the IEMG amplitude for the anterior deltoid was significantly greater for circum-

Table 1. Mean (SD) IEMG amplitude in the WB and DG patterns (μV • sec)

Muscles		WB Pattern	DG Pattern	p
	anterior	123.6±115.8	206.7±242.9	<.01
DELTOID	middle	140.7±134.8	204.4±194.1	<.05
	posterior	173.8±160.8	224.4±205.7	<.01
INFRASPINATUS		275.6±322.4	352.4±403.7	<.01

Table 2. Mean (SD) IEMG amplitude for the plane of movement (μV • sec)

Plane of Movement	DELTOID anterior	DELTOID middle	DELTOID posterior	INFRASPINATUS
Sagittal	168.0±193.3	87.0±103.0	160.0±168.8	329.3±402.8
Transverse	117.3±89.5	162.7±125.5	190.7±156.5	284.0±310.7
Circumduction	210.0±253.2	265.3±209.0	246.7±217.5	328.7±380.4

Table 3. Student's *t*-test for the plane of movement

Plane of Movement	DELTOID anterior	DELTOID middle	DELTOID posterior	INFRA-SPINATUS
Sagittal vs. Transverse	NS	<.01	NS	NS
Sagittal vs. Circumduction	NS	<.001	<.01	NS
Transverse vs. Circumduction	<.05	<.001	<.05	NS

NS : non-significant

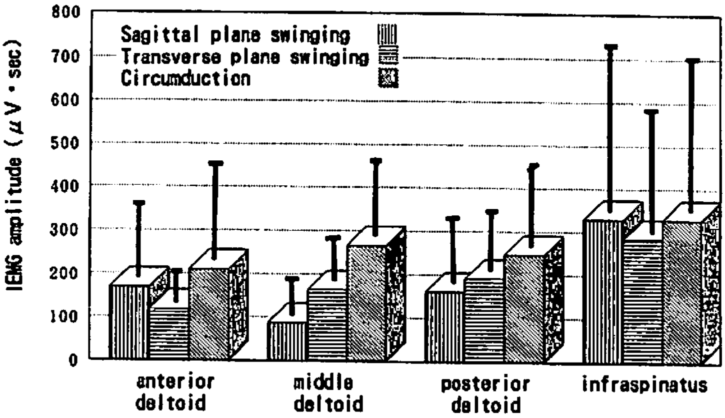

Fig. 6. Electromyographic activity and standard deviations (line above the blocks) for the plane of pendular movement.

duction than in transverse plane swinging, but there was no statistically significant difference among the planes of movement (Table 3). For the middle deltoid the greatest IEMG amplitude was in circumduction, followed by that of transverse plane swinging and the smallest amplitude was in sagittal plane swinging, all of which were statistically significant (Table 3). For the posterior deltoid the IEMG amplitude was significantly greater for circumduction than in transverse and sagittal plane swinging, but there was no statistically significant difference between that of sagittal and transverse plane swinging (Table 3). Finally, for the infraspinatus there was no statistically significant difference among the planes of movement (Table 3).

Discussion

Despite prior practice to the experiment, complete relaxation of the shoulder muscles was not achieved. The majority of subjects in the WB and DG patterns demonstrated electrical activity which was in agreement with Hellebrandt's report. This may have been due to the following reasons; 1) the 2-kg weight was too heavy a load for the glenohumeral articulation, causing protective contraction of the shoulder muscles; 2) in spite of the instruction of initiating passive pendular movement by body swaying, the subject unintentionally initiated active contraction of the shoulder muscles; 3) the contraction of the forearm and hand muscles by grasping the dumbbell caused overflow of nerve impulses into the shoulder muscles, resulting in increased tone of these while swinging the arm; and 4) increased psychological tension on the subjects' part possibly caused co-contraction of the shoulder muscles. However, the amount of electrical activity elicited was significantly less in the WB pattern than in the DG pattern. Thus, relaxation of the shoulder muscles may be best achieved by pendular exercise with a passive initiation of movement, and by wearing a wrist band of a suitable weight, preferably around 2 kgs, because it was found to be the most favoured load our subjects chose before the experiment.

Uyeda[11] reported that zero loading and loading with a 1-, 2-, or 3-kg sandbag attached to the distal end of the forearm in normal upright individuals without swinging the arm elicited no electrical activity of the shoulder muscles. In contrast, dynamic loading in our experiment clearly demonstrated electrical activity. Therefore, it may be suggested that, in order to relax the shoulder muscles, static loading alone in a stooped position may have an advantage over Codman's pendular exercise, especially for patients with frozen shoulder syndrome in the acute and subacute stages when pain and protective spasm of the shoulder muscles are the main symptoms[12][13][14].

The plane of pendular movement seems to cause a variance in electrical activity of these muscles. The least electrical activity demonstrated was in sagittal and transverse plane swinging. In other words, the easiest movements to produce with body swaying appear to be along these two planes. In contrast, the most difficult movement for the body to perform seems to be the circular movement of the arm.

In conclusion, pendular exercise should be carried out by; 1) loading the arm distally with a weighted wrist band; and 2) swinging the arm only in the sagittal and transverse planes. This conclusion, however, cannot be applied uniformly because, in this study, the results demonstrated large standard deviation. Furthermore, our study was somewhat limited because we used young healthy volunteer subjects for the experiment. Our findings, therefore, may not be extrapolated directly to patients. Further research will be required to find out the amount of IEMG activity in the shoulder muscles during pendular exercise without loading the arm.

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