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WITH WHAT DEGREE OF PRECISION CAN VOLUNTARY STATIC MUSCLE FORCE BE REPEATED?

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ABSTRACT. The aim of this investigation was to get an apprehension of the capacity of repeating voluntarily exerted static forces in a row without visual feed-back in three situations viz. two-hand-lift, foot pedal press and thigh-raise. Seven subjects participated. It seems that the degree of precision is approximately a little below 10 %.

Key words: Biomechanics, ergonomics, motor control, motor program, voluntary forces

Everyone who has ever lifted or carried a load knows from experience fairly accurately how much force that should be applied the next time she/he has to lift or carry the same load. Voluntarily exerted forces, as well as voluntary movements, are to a large extent carried out automatically. As a rule, the actions are conscious only at the time they are initiated. They are then completed automatically and become conscious only if the effect of the force or movement is not as intended or something unforeseen occurs.

The purpose of the present study was to obtain some idea of the precision with which a voluntarily exerted force can be repeated, when the only clue available in force application is the subjective experience from previous performances of the same nature. Vision was of no help to the subjects because no recording instruments could be seen by them. The forces under investigation were applied in two familiar situations, viz. a two-hand lift and an operation of a foot pedal, and in one unfamiliar situation, viz. pressing the thigh against a resistance in attempted flexion of the hip joint in sitting position, an experiment I here call "thigh-raise". The forces in the three studies were static.

METHOD

The subjects were 6 women and 1 man, all Department employees. All participated in the two-hand lift experiment and the foot pedal experiment. Six took part in the thigh-raise experiment. None of them suffered from somatic or mental infermity that could influence the test results. They were well motivated and aware of the objective of the study. They had plenty of time to become acquainted with the experimental procedure and to assume a suitable body position. The experiments were conducted under the most favourable circumstances in a quiet laboratory room, in order to minimize distractions and allowing the subjects to concentrate on their tasks.

As it was important that each subject who took part in this study should determine and decide for herself/himself how much force she/he would need or like to use, a number of test runs were made before the individual experiments were started. The idea was to determine the force that each individual subject thought that she/he would be able to maintain constantly during 7 trials in a row within a total period of 1 min. It was estimated that the duration of the force during each trial would be 2 sec. This time limit would avoid jerking and thrusting and, at the same time, eliminate the possibility of correcting (changing) the force after it had once been initiated. The peak on the recorded force curve should be approximately 1 sec after force initiation. If the ascending curve showed an even progress without dips or breaks this was interpreted to indicate that there had been no force corrections (changes).

If and when a subject felt, that the force exerted in any particular trial was not what she/he had intended it to be, the experiment was done all over again as it was absolutely necessary that the subject should feel that the same force had been exerted in each trial. When the subject felt convinced of this and the experiment had been properly carried out as prescribed one two-hand experiment, one foot-pedal experiment and one thigh-raise experiment per subject were sufficient.

A modified Darcus dynamometer (Carlsöö, 1972) was used to measure forces, and a Honeywell Visicorder to do the recording.

Two-hand lift

A rough wooden beam, 4×6×60 cm, was attached to the dynamometer handle. A metal handle was screwed onto the beam at each end, about 4 cm from the end of the beam (Fig. 1). These handles were 12 cm long and 2.8 cm in diameter. The test participants stood in a comfortable upright position with the handles on level with the crista iliaca. The task for the subject was to lift the beam 7 times using the same force each time, viz. the amount of force that she/he had selected as described above. The lifts were carried out at 10 sec interval. Since each lift took 2 sec, this gave the subject a rest pause of 8 sec between each lift.

Table I. *Results of the measurements of precision in the three experiments*

For each subject the exerted forces in the seven trials (in kg), the mean value, standard deviation (SD) and the SD in percentage of the mean (SD%), i.e. the coefficient of variation are given. Moreover the average precision of the whole group, i.e. means of all SD and SD% values respectively (See further in the text)

	Force exerted in trial no.									
Subject	1	2	3	4	5	6	7	Mean	SD	SD%
Two-hand lift										
A	27.0	26.5	27.5	30.0	31.0	29.5	30.0	28.9	1.82	6.3
B	20.5	20.5	17.0	19.5	18.0	20.5	22.0	19.5	1.70	8.6
C	14.5	13.5	10.5	15.0	12.0	12.5	13.5	13.1	1.54	11.8
D	25.0	24.5	21.0	25.0	25.0	25.5	23.0	24.1	1.60	6.6
E	32.0	32.0	35.0	35.5	36.0	34.5	38.5	34.7	2.31	6.6
F	28.5	25.5	24.5	26.5	20.5	21.5	24.5	24.5	2.77	11.3
G	29.5	32.5	23.0	27.5	29.0	30.0	36.5	29.7	*4.17*	*14.0*
Average precision of the whole group									2.44	9.3
Foot-pedal pressure										
Subject	1	2	3	4	5	6	7	Mean	SD	SD%
A	12.5	13.0	14.9	13.5	14.0	14.0	13.0	13.6	0.81	6.0
B	12.4	12.2	13.0	12.6	14.0	12.4	14.0	12.9	0.76	5.9
C	23.0	23.5	24.5	24.5	26.0	20.0	22.5	23.4	1.90	8.1
D	15.0	14.5	12.5	13.0	14.5	14.0	15.5	14.1	1.07	7.6
E	16.7	13.5	16.7	18.2	20.2	18.9	18.0	17.5	2.13	12.2
G	20.0	18.0	20.0	22.0	22.0	20.0	25.0	21.0	*2.24*	*10.6*
Average precision of the whole group									1.61	*8.4*
Thigh raise										
Subject	1	2	3	4	5	6	7	Mean	SD	SD%
A	5.6	5.7	5.9	6.1	6.1	5.5	6.4	5.9	0.32	5.4
B	5.3	5.0	5.3	5.0	4.9	5.0	5.5	5.1	0.22	4.3
C	8.0	6.4	7.2	6.0	6.8	7.2	8.0	7.1	0.78	10.7
D	12.0	12.0	13.0	12.5	11.0	11.0	11.5	11.9	0.75	6.3
E	6.4	7.3	7.0	6.8	7.5	7.5	7.5	7.1	0.43	6.0
F	7.1	7.2	6.6	7.3	7.4	7.9	7.7	7.3	0.42	5.8
G	4.0	4.4	4.3	4.1	3.4	4.0	3.7	4.0	*0.34*	*8.6*
Average precision of the whole group									0.50	*6.7*

Foot pedal pressure

The dynamometer handle, which was used as foot pedal was placed about 5 cm above the floor. The subject was seated in a comfortable upright position with the back supported, the left foot and right heel rested on the floor and the ball of the right foot on the pedal. Pressure on the pedal was produced by plantar flexion of the right foot. Seven pedal trials were performed in the same manner and with the same intermediate pause as in the two-hand lift experiment.

The thigh-raise experiment

The subject was seated in a comfortable upright position with the back supported, the feet flat on the floor, the hip and the knee angles about 90°. The dynamometer handle was above the right thigh about 10 cm proximal to the patella, perpendicular to the thigh and slightly in touch with it. The task of the subjects was to bend the right hip and press the thigh against the handle 7 times with the same force in accordance with the pre-arranged model.

RESULTS AND DISCUSSION

A person's awareness of its own muscular movements and muscle forces is not only of neurophysiological and psychological interest. It also has ergonomic significance. Ergonomic aspects were the reason why we began studying the ability of healthy people to control voluntary, static forces. Experiments in the present study were conducted

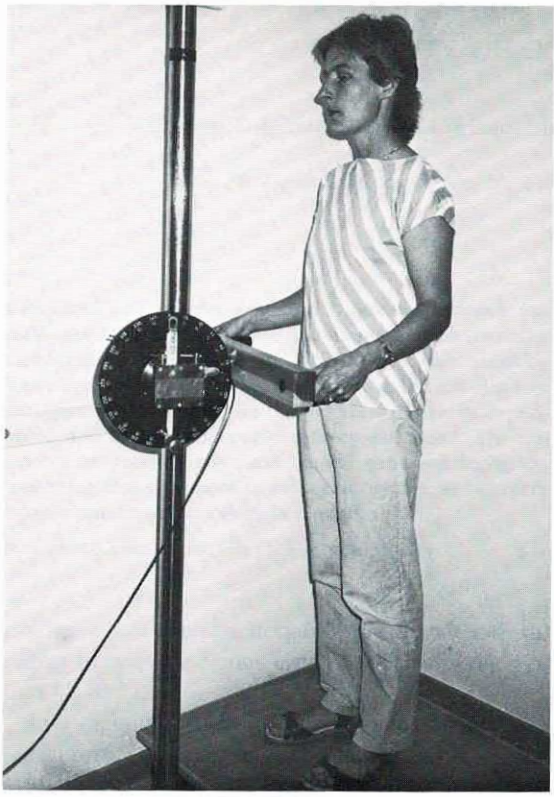

Fig. 1. Two hand lift.

under highly favourable conditions. The extent to which e.g. cold, noise and different kinds of vibration affect motor control remains to be seen.

The results of the experiment are listed in Table I which shows that no subject succeeded in accomplishing the targeted repetition. Besides the measurement values, the mean values, the standard deviations (SD) and the coefficient of variation (SD%) of each subject Table I shows the average precision of the whole group, i.e. the mean of all SD and SD% values. The group's mean deviation from the targeted repetition amounted to 9.1% for the two-hand lift, 8.7% for pedal operation and 6.7% for the thigh-raise. As will be noted, the group's precision in a rather familiar situation, i.e. the two-hand lift and operation of a foot pedal, was not greater than in the more unfamiliar and artificial thigh-raise exercise. To find out whether the precision changed during the course of the experiment all the values of trials no. 2 were compared with those of trials no. 1 and all the values of trials no. 7 were compared also with those of trials no. 1. The result of the calculation of the SD values was: in two-hand lift 1.39 and 3.01 respectively, in foot pedal pressure 1.12 and 1.58 respectively, and in thigh-raise 0.51 and 0.43 respectively. If the two-hand lift is excluded, the difference between the first trial and the seventh was not greater than between the first and the second trial. This suggests that neither objective fatigue nor subjective fatigue had any influence on the results. In the two-hand lifts, however, the difference between the first and seventh trial was greater than between the first and the second trial. According to the subjects, subjective fatigue was not the reason. The difference was probably due to the fact that the subjects performed the experiment in a standing position. This must have required more complex muscular recruitment and coordination patterns, making accurate repetition of the forces more difficult.

No obvious tendency was found in the difference between subjects' relation to age or degree of experience of a particular movement. Thus, the precision displayed by the oldest subject (A, 75 years old), was as good as the precision of the youngest subject (D, 33 years old). An experienced driver, such as subject E, accustomed to operating a foot pedal, was no more accurate in foot pedal operation than subject C who had no experience of this kind whatever.

CONCLUSION

The capacity of repeating a certain voluntary static force several times in a row with short time intervals has a degree of precision of approximately a little below 10%.

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