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APPARATUS AND METHOD FOR DETERMINATION OF ISOMETRIC MUSCLE STRENGTH IN MAN

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ABSTRACT. New equipment for determination of isometric muscle strength by use of strain gauge dynamometers has been designed. Even severely handicapped persons can easily and conveniently be placed in the apparatus. Adaptation of the measuring devices to the individual length of the trunk and extremities is easily achieved.

For convenience as well as simplicity, isometric force instead of dynamic force has usually been measured in determination of muscle strength in men. This is justified, as experimental evidence shows a good correlation between these two parameters (Asmussen et al., 1965).

During the last 10–15 years different techniques for muscle testing have been developed. The following principles, among others, have been applied: mechanical balance dynamometers, cable tension technique, hydraulic systems, pneumatic methods and strain gauge dynamometers. Surveys of the literature are given, including the papers by Hunsicker & Donelly, 1955; Asmussen et al., 1959; Tornvall, 1963 and Hettinger, 1966. Bäcklund & Nordgren (1968) recently designed a device where the muscle strength was measured by means of pressure inducers.

The methods have mainly been constructed for measuring muscle strength in healthy persons. In order to find a device which for clinical purposes would fulfill reasonable requirements of standardization and accuracy we felt it necessary to construct an aparatus to meet the following demands:

1. Convenience in placing even severely handicapped persons in the test apparatus.
2. Possibility of testing the most important large muscle groups.
3. Adequate standardization of positions and fixation of different joints at examination.
4. Possibilities for rapid adaptation of the apparatus to the length of the person's trunk and extremities.
5. Simplicity of the testing procedure with a peripherally placed strain gauge unit connected to a central recording instrument.
6. Satisfactory characteristics of the measuring device including linear response.
7. Good constancy of the measuring capacity lasting for years.
8. Recording of forces by direct reading as well as by writing instruments.

APPARATUS

Stands

The apparatus includes two stands for fixation of different joints in standardized positions. One part is constructed as a chair, which permits even severely handicapped persons to be moved easily from the wheelchair to the stand (Fig. 1). Units are attached on the chair for measuring of the strength of the extension muscles of the knee and the strength in plantar flexion and extension. The chair is easily moved on wheels and can be firmly attached to the other stand which has measuring units for elbow flexion and extension (Fig. 2) as well as for the strength of the handgrip (Fig. 3). The stand is also equipped with units for measuring of the strength of neck and trunk muscles as well as units for testing of the flexors of the knee.

INSTRUMENTAL EQUIPMENT

Strain gauge equipment has been chosen, consisting of 5 measuring units connected with a

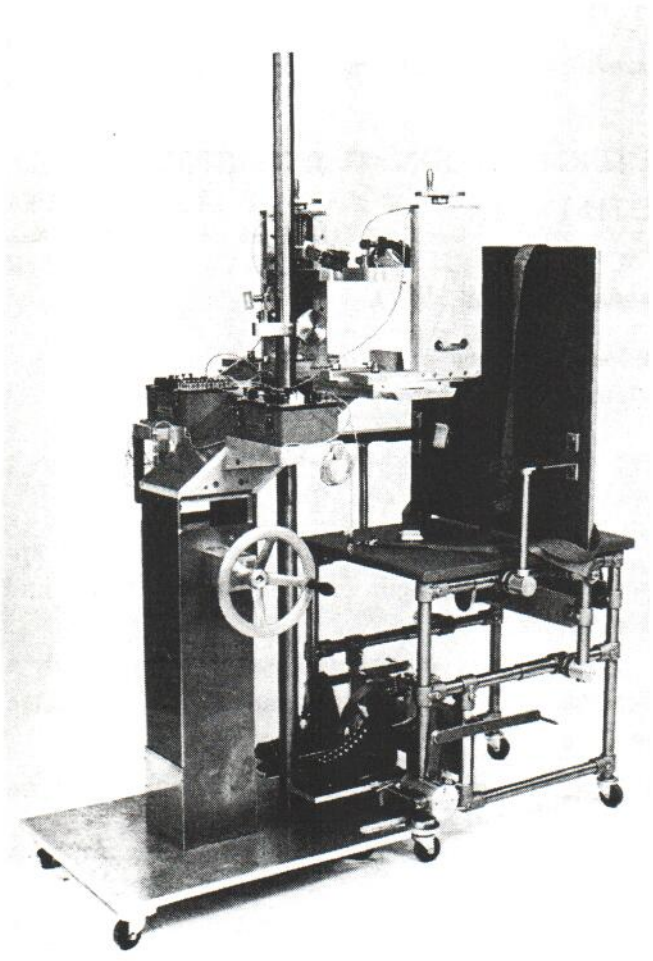

Fig. 1. Apparatus for determination of muscle strength. The patient is placed in position with the chair separated from the stand and the elbow-rest removed. When the muscle strength is being measured the chair is rigidly attached to the stand. The height and width of the seat and the measuring devices on the stand can be modified in order to permit standardization of the examination for the various motor groups.

special coupling and balancing unit (Budd SB-1) to a central Wheatstone bridge and amplifier (Budd P-350). This is coupled to a potentiometer writer (Servogor type BE 511).

The measuring units, except for that for plantar flexion and extension, have standard dimensions ($8 \times 32 \times 60$ mm), with a narrowing at the middle part of the steel. Strain gauge units (Budd type C 6–12 A, coupled in half bridge) are glued on the measuring steels (Fagersta steel K-825) and then calibrated against known weights. These measuring units, as mentioned, are attached to the stands and connected to padded leather straps or other arrangements for transmission of the forces developed.

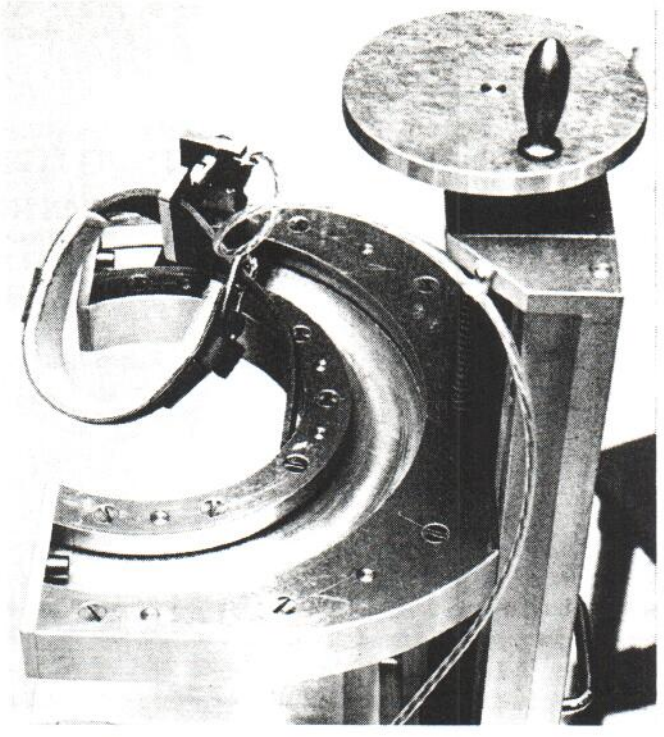

Fig. 2. Device for measuring isometric contraction of flexion and extension of the elbow: With the wrist inserted into the cuff, the strain-gauge element can be moved proximally (extension) or distally (flexion) along the semicircular track.

PROCEDURE

The person is placed in the stand, in the standardized position. He is given thorough information, and the importance of maximal contractions is stressed. He is asked to avoid jerks and other "trick movements". In connection with vocational

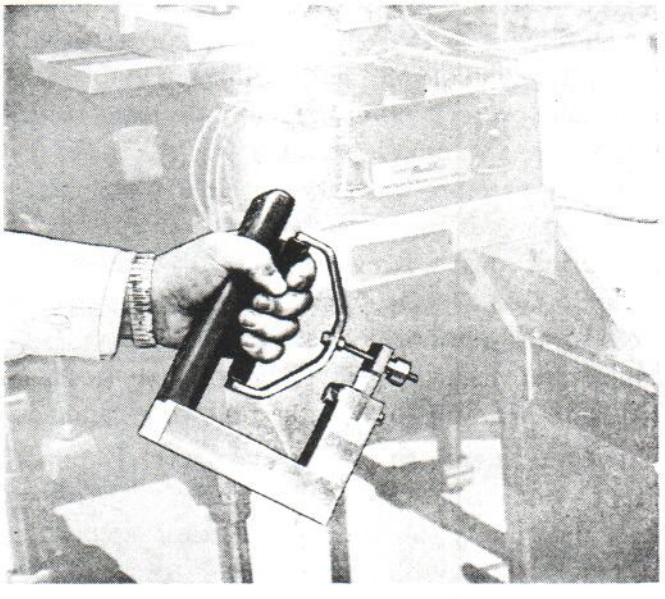

Fig. 3. Device for measuring isometric contraction of the hand grip.

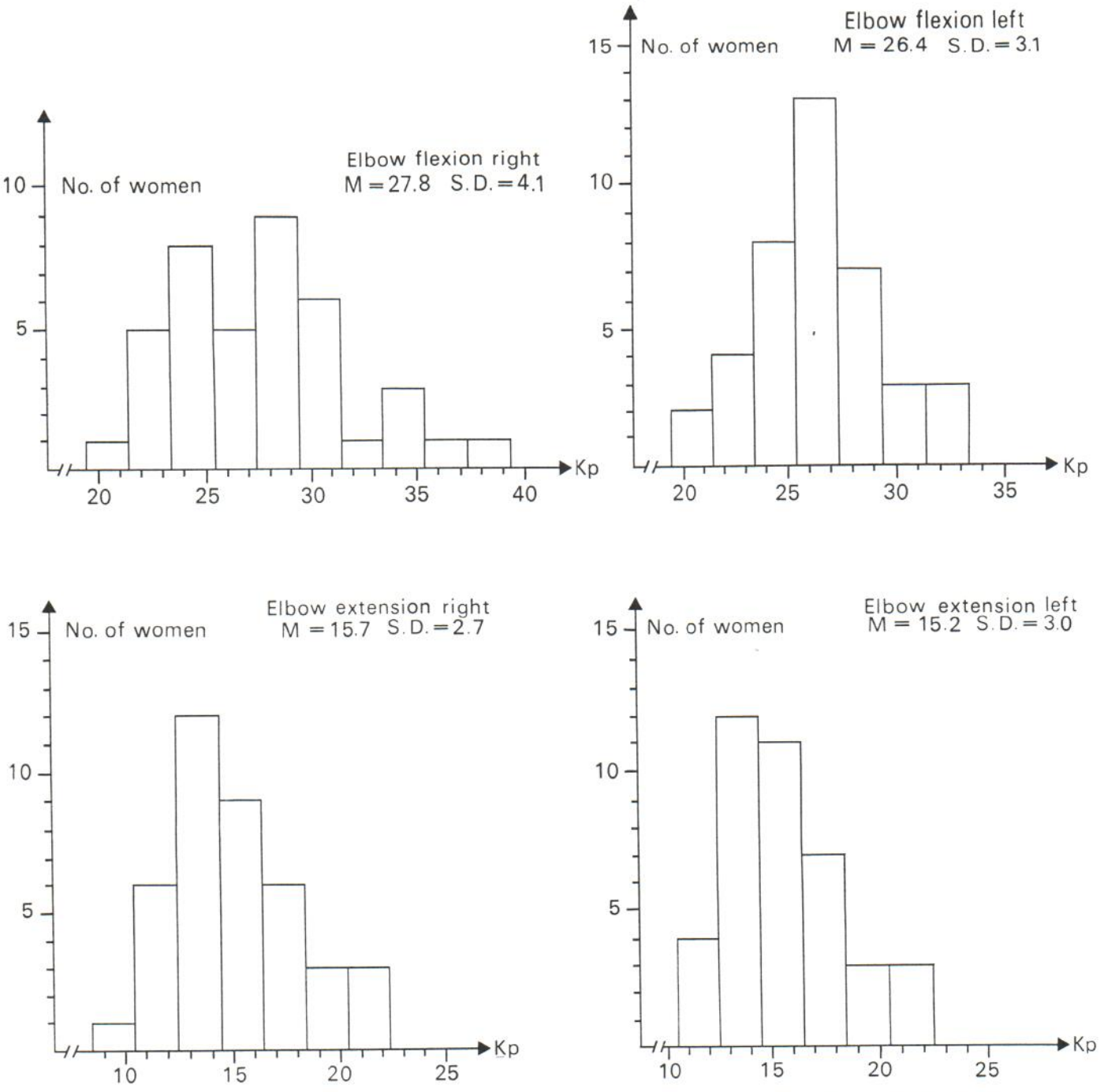

Fig. 4. Strength of elbow flexion and extension. 40 women, aged 20–22. M = Mean value. S.D. = Standard deviation. In each case we accept normal distribution on the level 0.05.

exhortation the light of a red lamp as well as the sound of a buzzer define the time and duration of the attempted movement desired. The duration amounts to 3 seconds. The individual is asked to make 3 attempts, the maximal value recorded being, by definition, used as a measure of maximum volontary isometric strength. If the maximum value is reached at the third attempt, a few further contractions are required, and the maximum value is then recorded.

The present design of the equipment thus permits the following muscle groups to be tested.

1. Handgrip bilaterally
2. Elbow flexion bilaterally
3. Elbow extension bilaterally
4. Knee flexion bilaterally
5. Knee extension bilaterally
6. Foot plantar flexion bilaterally
7. Foot dorsal flexion bilaterally
8. Neck flexion

9. Neck extension
10. Trunk dorsal flexion
11. Trunk ventral flexion.

The measuring program largely corresponds to the procedure used in earlier investigations on normal male subjects (5, 9).

MATERIAL AND RESULTS

The method has been tested on a series of healthy female physiotherapists. The practical problems, furthermore, have been studied by measurements in a group of handicapped patients. Some of the values, including means and standard deviations, are shown in Fig. 4.

DISCUSSION

The individuals tested may not be representative of the general female population of the same age. A detailed comparison with other series is therefore not motivated. As may be expected, the mean values are lower than those in a series of male conscripts, earlier investigated by Tornvall (1963). The standard deviation is however of the same order of magnitude as in earlier series. With these limited measurements, mainly in patients with paraplegia, the apparatus met the above mentioned requirements. Further studies are needed, especially in connection with physical training therapy, in order to gain a better idea of the practical value of the method.

This method as well as other methods mentioned may be considered only partially objective. The measuring results are influenced by errors on the part of the investigator as well as of the persons investigated. A closer discussion of some sources of error in connection with muscle strength determinations has been presented earlier by Tornvall (1963).

In the testing program planned at the department of rehabilitation medicine of Sahlgrenska Sjukhuset, Göteborg, the initial purpose is to study certain basic problems connected with the evaluation of different training programs in healthy volunteers. In addition, however, the method will be applied in clinical rehabilitation work.

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