FROM THE DEPARTMENT OF PHYSICAL MEDICINE, LUND, SWEDEN
(HEAD: H. BRODIN, M.D.)

EVALUATION OF TWO METHODS FOR INCREASING MUSCLE STRENGTH

By

H. BRODIN

"Recovery of function depends ultimately on the muscles. Muscle power is the key to success".—*E. A. Nicoll*, cit. *R. Watson-Jones:* Fractures and Joint Injuries, 1946, p. 858.

Isotonic-concentric muscle exercise against increasing resistance according to *DeLorme* (1945) and *DeLorme & Watkins* (1951) has been widely accepted as an effective method for muscle development.

Asmussen (1949) found that dynamic exercise produced roughly the same increase in muscle strength as static exercise. *Hettinger et al.* (1953) showed that static exercise can improve muscle strength considerably.

Which of the two methods (isotonic-concentric and isometric) is the more efficacious, is debatable. *Liberson et al.* (1958) found isometric training to give much better results than isotonic-concentric exercises. *Bonde Petersen* (1960), on the other hand, found isotonic-concentric exercises to produce better results. A third training method, isotonic-eccentric exercises produced no increase in muscle strength with certainty.

PROBLEM

In comparing the two methods under consideration, the diseases and injuries of the subjects or their age and sex, their bodybuild or mental make-up have never been considered. Neither has the type of muscles to be exercised been taken into account (e.g. flexors-extensors, muscles for maintenance of posture-muscles of locomotion). Before approaching such special aspects of the problem, it was considered expedient first to form an opinion of any differences in the results when the subjects are left to themselves to do the exercises.

In other words, the purpose was to find out whether the isotonic-

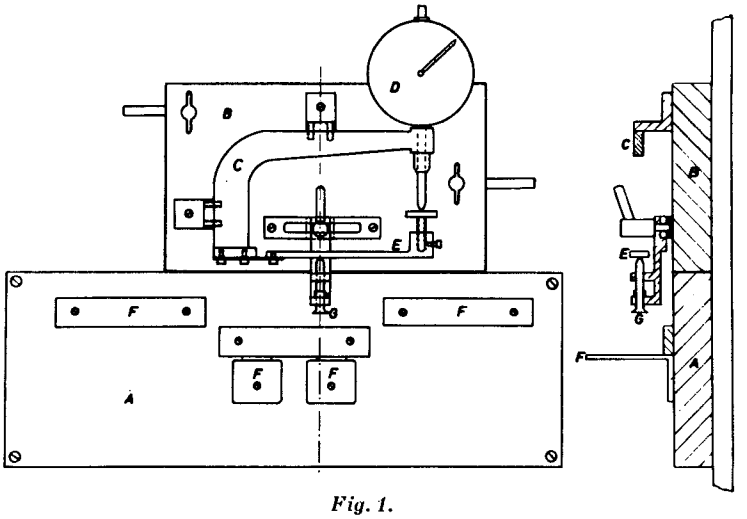

Fig. 1.

Apparatus for isometric measurement of the strength of M. abductor dig. V. A metal arm C is fixed to a plate B adjustably amounted on plate A. At the end of C is a dial D. To the other end of C is fastened a spring integrally connected with a lever E. The forearm of the subject rests on the support A, the hand to be tested is placed against the support F, and the key G is adjusted to abut upon the ulnar edge of the distal interphalangeal joint of the small finger. Movements of the key G are transmitted via the lever E to the dial D.

concentric exercises were superior to the isometric under experimental conditions simulating those under which such exercises must, as a rule, be performed by patients.

MATERIAL

M. abductor digiti V of the right hand (left hand if left-handed) was selected for the trial. This muscle is a mover and used rather little in daily life. Its strength is usually small, but can be increased considerably by both static and isotonic-concentric exercise (*Liberson et al.* 1958).

Female physical therapy students, aged 18–28 (average 21–22), were selected for the trial.

The group used for evaluation of *isometric* training consisted of 41 students and a control group of 41 other students. The design and use of the apparatus employed for testing strength is given in Figs. 1 and 2.

The series used for evaluation of *isotonic-concentric* training consisted of 44 students and 41 other students as controls. The apparatus used for training and measurement of the strength is described in Figs. 3 and 4.

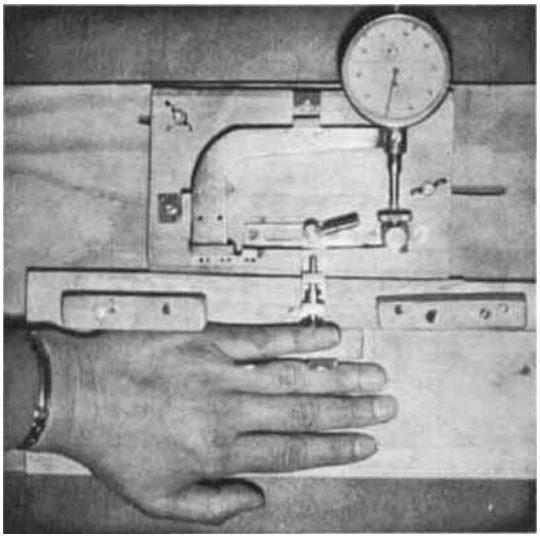

Fig. 2.
Subject with hand in apparatus illustrated in Fig. 1.

METHOD

Gallagher et al. (1949) found it necessary for the subjects to get accustomed to the apparatus for measurement of strength before the recordings became reliable. All the persons taking part in the present investigation were therefore given about a week to use the apparatus before the investigation proper was started.

During this time, the method was explained to the participants who were also given instructions individually. They were informed that the purpose of the trial was to study the efficacy of the method. Since *Wright* (1959) observed considerable variations in grip strength at different times of the day, all exercise (and measurement) was done at the same hour of the day. The subjects trained 5 days a week for 8 weeks.

One group trained during the 1959–1960 term, the other during 1960–1961. All the director of the trial did, was to arrange for the students to have time for the trial at a given time every day.

This was the only reminder they were given of the trial. During measurement of the muscle strength, however, both the experimental group and the control group were stimulated to exert their utmost.

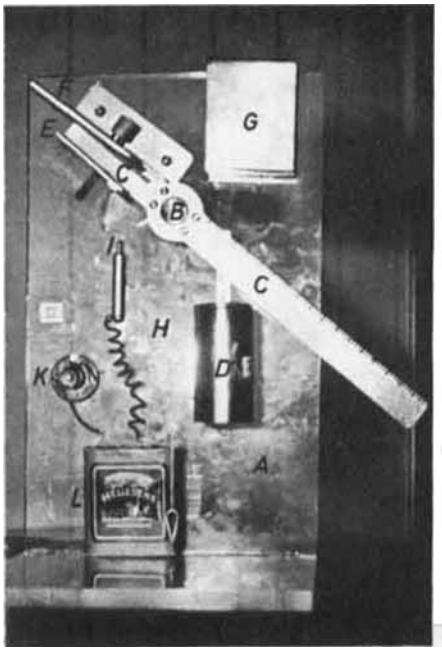

Fig. 3. *Fig. 4.*

Fig. 3. Apparatus for isotonic measurement of strength of M. abductor dig. V man. On a frame A is mounted a horizontal pivot B carrying a balanced lever C. A weight D of 750 g. is suspended from one of the deep indentations in one arm of the lever. The indentations are 0.25 cm. apart. Along the other arm of the lever is a plate E, against which the small finger is pressed. The hand is supported by an adjustable plate F and a support G. Under the elbow is placed a support of such a height that the forearm, hand and fingers are in a straight line. See Fig. 4. The dorso-volar axis of the metacarpo-phalangeal joint of the small finger can be fairly accurately determined by palpation. Judging from roentgenographs of the joint in different degrees of abduction, the axis is stationary during the movement of abduction. The axis of the joint is placed over the pivot B of the lever with the aid of the plumb-line through B (the weighted thread H).—The small finger is placed against and parallel to the lever. When the lever is pressed horizontal, it closes the circuit at I and lights the lamp K. The source of energy is the battery L.—The distance from the pivot B to the point of suspension of the weight D is proportional to the force that must be applied to the plate E to maintain the lever horizontal. One centimetre of this distance is called a unit of strength.

Fig. 4. Position of hand in apparatus shown in Fig. 3. A mark on the back of the hand indicates the dorso-volar axis of the small finger.

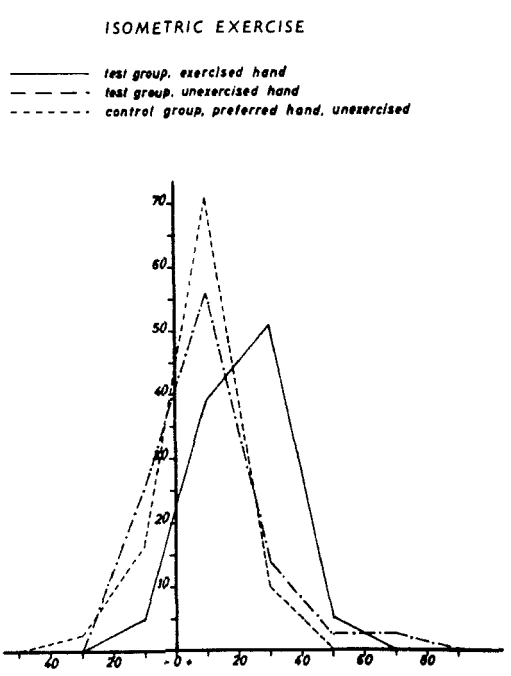

Fig. 5.
Result of isometric training. Abscissa: Percentual increase in strength during period of exercise. Ordinate: Percentual distribution of material.

A. *Isometric training.*

The apparatus (Figs. 1 and 2) for measurement of strength was calibrated both immediately before the first and immediately before the last measurements.

During exercise, the students worked in pairs. One fixed the other's right (or left for left-handed subjects) hand and fingers against a horizontal, stable surface (seat of chair or the like). For 6 seconds (same time as that used by *Liberson et al.* 1958) maximum static exercise was performed by the abductor of the small finger of the fixed hand. Both members of each pair performed the exercise on each occasion.

B. *Isotonic-concentric training.*

The apparatus shown in Figs. 3 and 4 was used for training and for measurement of the strength. The recommendations of *DeLorme et al.* (1951) were observed. Before training was started, once a week during the training period and at the end of the training, 10 RM (Repetition

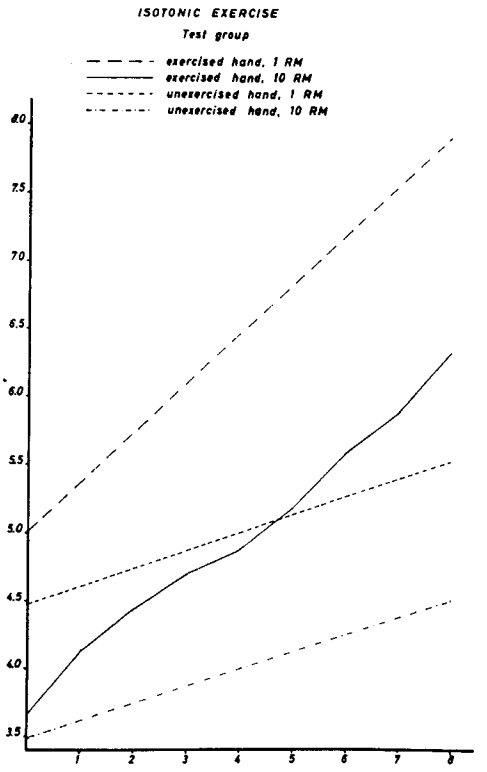

Fig. 6.

Survey of results of isotonic exercise. Abscissa: Duration of exercise in weeks. Ordinate: Mean strength for entire series (Units of strength: see legend to Fig. 3).

Maximum) was determined i.e. the resistance that could be overcome 10 times in succession but not more.

At the beginning and end of the training period, determinations were made of 1 RM in the experimental group, i.e. the resistance that could be overcome once only. At the same time measurements were made of 10 RM and 1 RM in the control group.

The students worked in 5 subgroups of 8–9, selected at random.

The daily exercises consisted of 10 contractions against the resistance 2/3 of 10 RM and 10 contractions against the resistance 1/1 10 RM.

RESULTS

A. *Isometric training.*

The results are summarized in Fig. 5. The mean strength of abduction of the small finger of the hand exercised was 1107 g. (830–1530 g.)

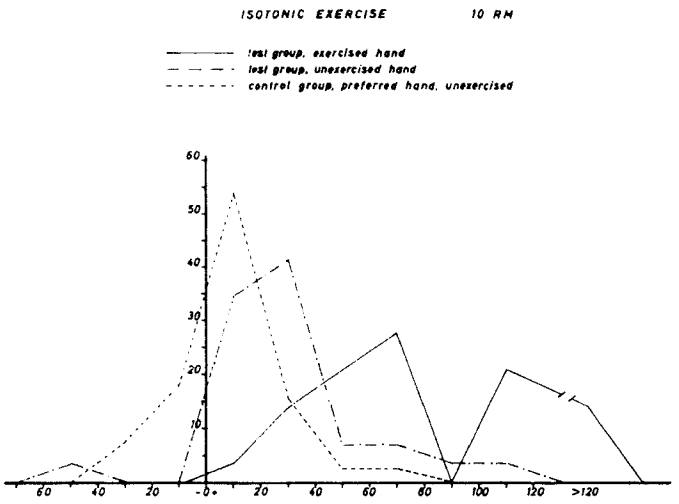

Fig. 7.

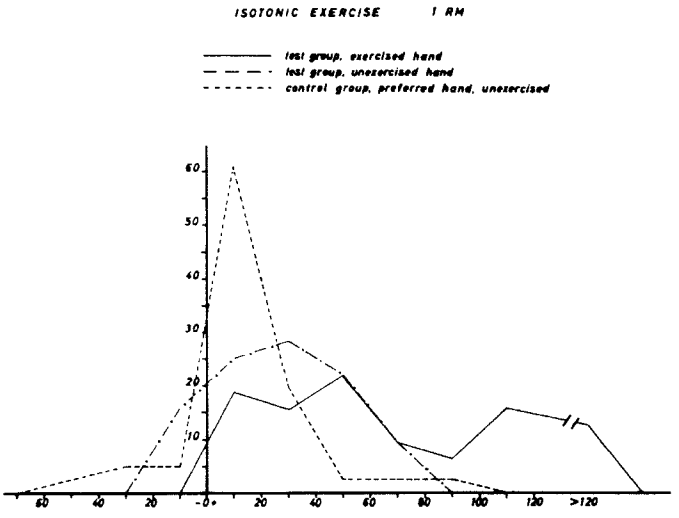

Fig. 8.

Figs. 7–8.
Result of isotonic exercise given in values for 10 RM and 1 RM. Abscissa: Percentage increase during 8 weeks' exercise. Ordinate: Percentual distribution of material.

before training. After training, the strength had increased by 216 ± 47 g. corresponding to about 20 %. In 2 cases, there was an increase of 40 % and in 2 cases a decrease of 5 % and 1.3 %, respectively. The strength of the unexercised abductor of the small finger before training

was, on an average, 1126 g. (850–1550 g.). During training, the strength increased by 106 ± 46 g. corresponding to about 9 %.

In the control groups the initial values for the better hand was, on the average, 1117 g. (850–1500 g.) and for the other hand 1048 g. (760–1620 g.). During the experimental period, the strength increased by 62 ± 33 g. and 106 ± 44 g., respectively.

Statistical analysis of the data showed that the increase in the strength of the muscle trained was significant. But the increase in strength of the abductor of the small finger of the untrained hand was not significant.

B. *Isotonic-concentric exercise.*

The results are summarized in Fig. 6 and in detail in Figs. 7 and 8. (Definition of units of strength is given in the legend to Fig. 3).

I. *10 RM-values* for the trained hand increased from 3.65 units (2.0–5.5) to 6.32 units (3.5–9.25), i.e. 2.67 units and 73 %. The difference was significant ($p < 1$ %). The corresponding values for the untrained hand were 3.48 units (2.0–5.0) to 4.50 units (2.25–7.0). The increase of 1.02 units corresponded to 29 % and was significant.

In the control group the values for the better hand increased from 4.14 (2.0–7.5) units to 4.30 (2.0–8.0) units, corresponding to 4 %. The increase was not significant.

II. *1 RM-values* for the trained hand were at the beginning of the experiment, on the average, 5.0 (2.75–7.75) units and at the end 7.91 (4.0–11.0) units. The increase was 2.91 units, i.e., 58 % and was significant. The corresponding figures for the untrained hand were: 4.47 (2.5–7.5) units to 5.52 (3.0–8.0) units, corresponding to 1.05 units and 23.5 %. This increase was also significant.

III. *Other observations.*

a. A clear increase in strength was noted in all 5 subgroups, but one group deviated remarkably from the remainder. The increase of the 10 RM-values was 112, 84, 77, 74 and 30 %.

b. The following factors were studied and were not found to have any influence on the results of training:

1. Technical errors when the subject had become tired (pronation of the lower arm and/or ulnar abduction of wrist and/or lifting of elbow from support). Such errors were observed in 13 of the experimental groups.

2. A certain degree of absence from training. Nine of the experimental persons were absent 4–8 of the 40 exercises.

3. Inability to overcome resistance of 10 RM 10 times. Exactly half of the experimental persons could not overcome this resistance on 1–6 occasions and the remainder on 7–16 occasions.

c. The strength recorded was related to the breadth of the right femoral condyle (see *Lindegård* 1956). The dispersion of the values found for the experimental group was very wide. This argues strongly for the assumption that the subjects had not attained maximal strength of the trained muscle.

DISCUSSION

The students from both groups were healthy, they were of the same age and sex and all studying and training under uniform conditions. They had all received the same instructions. The training was standardized regarding apparatus, time of day and the influence of the director.

It may therefore be assumed that both experimental groups and their controls were strictly comparable.

The fact that members of the isometric series could not, for practical reasons, use the apparatus for measuring strength during their training was considered to have little effect on the results.

All the persons partaking in the trial had been granted about a week to get accustomed to the apparatus, and the position of the hand during the trial was exactly the same as that which they had been instructed to assume during the preparatory period.

The remarkably poor increase in strength in one of the 5 subgroups of the isotonic-concentric trial group suggests that small series can give misleading information and that such unmeasurable factors as team spirit of the group can influence the results.

The clearly better results noted for the isotonic-concentric trial group compared with the isometric group (58–73 % against about 20 %) might be ascribed to the more favourable reaction of the motor units to isotonic-concentric exercises *or* to the persons in the isometric group not having done the exercises in the proper way. The first possibility is denied by the results of *Hettinger et al.* (1953) and of *Liberson et al.* (1958).

In the isometric group the performance of the students was apparently relatively poor.

The protocols of the training offer no explanation for this poor cooperation. One might, however, imagine that the absence of movement

during training might mean an absence of valuable activating stimuli for some of the persons. The 10 RM-test every week in the isotonic-concentric group and the use of special equipment during training probably had a stimulating effect on the isometric group.

An incidental observation in the isotonic-concentric group was a clear "cross education", i.e. an increase in the strength of the M. abductor dig. V of the untrained hand.

CONCLUSION

If it is possible to choose between isometric muscle exercise according to *Hettinger et al.* (1953) and isotonic-concentric exercise according to *DeLorme* (1945), the latter should be given preference, at least if the following conditions can be satisfied:

1. The subjects (patients) and assistants are given the opportunity of getting used to the equipment.
2. The subjects (patients) perform most of the exercises with the help of friends (relatives).
3. Muscle or muscle group is a mover.

SUMMARY

85 female physical therapy students were divided into two groups for investigation of the effect of exercise on the strength of Musculus abductor dig. V man. In one of the groups the subjects performed maximal isometric exercises for 6 seconds a day. In the other group training was done by the principles of *DeLorme* (1945) (isotonic-concentric exercise against great resistance). In both groups the subjects trained 5 days a week for 8 weeks. The only stimulation was that they were reminded daily of the time of the exercise.

The isotonic-concentric training produced an increase of strength by about 65 %; isometric training by about 20 %.

The difference between the results can probably be ascribed to the assumption that isometric method is less stimulating than the isotonic-concentric procedure.

Isotonic-concentric exercises are evidently preferable if the patient is left to himself to train the muscle.

82 physical therapy students served as controls.

RESUME

85 étudiantes en thérapie physique ont été divisées en deux groupes afin d'étudier l'effet de l'exercice sur la force du muscle abducteur du petit doigt. Dans l'un de ces groupes, les sujets ont pratiqué des exercices isométriques maxima pendant 6 secondes chaque jour. Dans l'autre groupe l'entraînement a eu lieu selon les principes de Delorme (1945) (exercice isotonique-concentrique contre forte résistance). Dans leux deux groupes les sujets ont participé à l'entraînement 5 jours par semaine pendant 8 semaines. La seule émulation a été le rappel chaque jour de l'heure de l'exercice.

L'entraînement isotonique-concentrique a provoqué une augmentation de la force d'environ 65 %; l'entraînement isométrique d'environ 20 %.

La différence entre les résultats doit être attribuée probablement au fait que la méthode isométrique n'offre pas le caractre d'émulation de la méthode isotonique-concentrique.

Il convenient évidemment de choisir les exercices isotoniques-concentriques s'il est laissé au malade seul le soin de procéder à l'entraînement du muscle.

82 étudiants de thérapie physique ont servi de groupe de contrôle.

ZUSAMMENFASSUNG

85 Studenten physikalischer Behandlung wurden in zwei Gruppen eingeteilt um die Wirkung von Übung auf die Stärke des musc. abductor des 5. Fingers zu untersuchen. In einer der Gruppen führten die Teilnehmer maximale isometrische Übungen für 6 Sekunden täglich aus. In der anderen Gruppe wurden die Übungen gemäss den Prinzipien von De Lorme (1945) ausgeführt. (Isotonisch-konzentrische Übungen gegen grossen Widerstand). In beiden Gruppen übten die Teilnehmer 5 Tage wöchentlich während 8 Wochen. Der einzige Antrieb war, dass sie täglich an die Übungszeit erinnert wurden.

Die isotonisch-konzentrischen Übungen erzeugten eine Zunahme der Stärke um ungefähr 65 %, die isometrischen Übungen um ungefähr 20 %.

Die Verschiedenheit zwischen den Ergebnissen kann wahrscheinlich der Annahme zugeschrieben werden, dass die isometrische Methode weniger stimulierend als das isotonisch-konzentrische Vorgehen wirkt.

Isotonisch-konzentrische Übungen sind augenscheinlich vorzuziehen wenn der Patient beim Muskeltraining sich selbst überlassen ist.

82 Studenten physikalischer Behandlung dienten als Kontrollen.

REFERENCES

Asmussen, E.: Muskeltraening ved statisk og dynamisk arbejde. Föredrag vid 2:a lingiaden, Stockholm, 1949.

Bonde Petersen, F.: Muscle Training by Static Concentric and Eccentric Contractions. Acta Physiologica Scandinavica, *48*: 406–416, 1960.

DeLorme, T. L.: Restoration of Muscle Power by Heavy Resistance Exercises. Journ. of Bone and Joint Surgery, *27*: 645, 1945.

DeLorme, T. L. & Watkins, A. L.: Progressive Resistance Exercise. Appleton-Century-Crofts, Inc., New York, 1951.

Gallagher, J. R. & DeLorme, T. L.: The Use of the Technique of Progressive Resistance Exercise in Adolescence. Journal of Bone and Joint Surgery, *31A*: 847–858, 1949.

Hettinger, T. H. & Müller, E. A.: Muskelleistung und Muskeltraining. Arbeitsphysiologie, *15*: 111–126, 1953.

Liberson, W. T. & Asa, M. M.: Brief Isometric Exercises in S. Licht: Therapeutic Exercise, New Haven, Connecticut, 1958.

Lindegård, B.: Differential Somatology. Lunds universitets årsskrift, N.F. avd. 2, Bd. 52, nr. 5, 1956.

Wright, V.: Factors Influencing Diurnal Variation of Strength of Grip. Research Quarterly, *30*: 110–116, 1959.