RESEARCHES IN CROSS-EDUCATION

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(Second Series)

BY

WALTER W. DAVIS.

Further experiments on the effects of practice in voluntary movements have been made since the publication of my first paper on the subject.[1]

I. TRANSFERENCE OF PRACTICE EFFECTS.

Experiments with the maximum grip of the hand were begun in March, 1900. An oval spring dynamometer of the usual form was employed. The dynamometer test is not one of endurance, but of strength. To make a good record requires a strong impulse for only a moment of time.

Fifty subjects were secured—25 men and 25 women, all students or instructors at Iowa College, Grinnell, Iowa. The maximum pressure that each could exert on the dynamometer was determined for both right and left hands. To avoid the variation due to fatigue, the records were taken in the order *R*, *L*, *L*, *R*, and then an average taken of *R*, *R*, and of *L*, *L*. These average records were called the initial records for right and left hands. After the initial records were secured, practice was begun and extended over a period of three weeks, the subject exercising his grip four times per week. At the end of the practice final records were taken in precisely the same manner as at the initial test. The difference between the two records gave the amount of gain.

Great care was observed to have all the conditions of the initial and final tests precisely the same. Four points were carefully watched. 1. The dynamometer was placed in the hand face downward. This prevented the subject from seeing his own record, and there was no danger of the fingers stopping the progress of the pointer. 2. The instrument was carefully placed so that the pressure was exerted in a line perpendicular to the long axis. 3. One side of the dynamometer was placed in the crease of the second joint of the fingers, so that when it was gripped it pressed against the second row of phalanges. 4. Care was exercised to prevent the subject from pressing the hand or arm against the body.

The initial and final tests and the daily practice occurred at the same time of the day and as nearly as possible under exactly the same condi-

[1] DAVIS, *Researches in cross-education*, Stud. Yale Psych. Lab., 1898 VI 6.

tions. The practice consisted in gripping the dynamometer 10 times on each occasion, with intervals of 2 or 3 seconds of rest after each grip.

The subjects were divided into five groups. These groups with the method and manner of practice are shown in Table I.

TABLE I.

Kind of practice by the subjects.

Subjects.	Method of practice.	Imstrument used.	Hand practiced.
Group I.	Vigorous.	Dynamometer.	Right.
Group II.	Light.	Dynamometer.	Right.
Group III.	Light.	Dynamometer.	Left.
Group IV.	Light.	Cylindrical stick.	Right.
Group V.	Light.	Dynamometer.	Right and left.

TABLE II.

Characteristics of the Subjects: Men.

Serial number.	Age.	Group. (See Table I.)	Previous training.	Temperament.
1	27	I		nervous.
2	23	II		phlegmatic.
3	23	III	track athletics.	phlegmatic.
4	22	IV	track athletics.	motor.
5	22	V	baseball.	motor.
6	22	I		phlegmatic.
7	22	II		nervous.
7½	22	III	track athletics.	phlegmatic.
8	21	IV		motor-phlegmatic.
9	20	V	general athletics.	phlegmatic.
10	20	I		motor.
11	20	II	general athletics.	phlegmatic.
12	19	III	track athletics.	nervous.
13	19	IV		phlegmatic.
14	19	V		nervous.
15	19	I		phlegmatic.
16	18	II		phlegmatic.
17	18	III		phlegmatic.
18	18	IV		nervous.
19	18	V		motor.
20	18	I		phlegmatic.
21	18	II		nervous.
22	21	III	track athletics.	nervous.
23	27	V	general athletics.	motor.
24	19	II	track athletics.	motor.
25	24	IV	lifting weights.	nervous.

Those subjects who practiced vigorously made 10 efforts daily, using the maximum strength at every effort. Those who practiced lightly

made 10 efforts using from about $\frac{3}{5}$ to $\frac{4}{5}$ of the maximum strength. The cylindrical stick was 3 inches long by 1 inch in diameter. Those subjects who practiced with both right and left hands made 5 efforts with each hand on each day.

In order that the influence of age might not affect the results sought, the subjects were distributed by fives among the groups as shown in Tables II. and III. By such a distribution the average ages of all the groups were nearly the same.

TABLE III.

Characteristics of the subjects: Women.

Serial number.	Age.	Group. (See Table I.)	Previous training.	Temperament.
26	25	I	1 year.	nervous-motor.
27	22	II	4 years.	phlegmatic.
28	22	III	2 "	nervous-motor.
29	21	IV	2 "	motor-phlegmatic.
30	21	V	1 year.	moderately phlegmatic.
31	20	I	2 years.	phlegmatic.
32	20	I	2 "	nervous.
33	20	III	1 year.	moderately phlegmatic.
34	20	IV	1 "	nervous-motor.
35	20	V	3 years.	nervous-motor.
36	19	I	2 "	motor-phlegmatic.
37	19	II	2 "	nervous.
38	19	III	1 year.	motor.
39	19	IV	2 years.	phlegmatic.
40	18	V	2 "	nervous-motor.
41	19	I	1 year.	nervous.
42	19	II	1 "	motor-phlegmatic.
43	18	III	4 years.	motor.
44	19	IV	1 year.	nervous-motor.
45	17	V	3 years.	motor.
46	17	I	1 year.	phlegmatic.
47	25	V	7 years.	motor.
48		II		nervous-motor.
49	21	III	2 years.	nervous.
50	24	IV	2 "	phlegmatic.

The previous training for the men and women was determined differently in the two cases. In Table III. the length of the period of physical training was reckoned from the number of years each subject had spent in the gymnasium in actual required class work, such work being compulsory except for seniors in the college. Since gymnasium work had not been required heretofore of men, it was necessary to set a different standard for them. This standard was proficiency in athletic sports.

The factors of the grip that affect the strength of the pressure on the dynamometer are very complex even in one individual. Factors which favorably affect the pressure in a certain person may be entirely counteracted by factors which affect the pressure unfavorably. In another subject the factors may oppose each other in an entirely different fashion. When many conditions that are favorable to the strength of pressure are present in one person we then expect that person to make a good record of strength.

For convenience we have classified all factors as either, (*a*) those that are not affected by a short period of practice such as that during which our investigation was carried on, or (*b*) those that may be affected by such practice. The first four factors belong to the former group, the others to the latter one.

1. *Effect of length of hand.*—This factor is of some importance. The longer the hand the longer must be the levers on which the muscles pull and consequently the greater the strength that may be exerted on the dynamometer. This factor may be almost entirely counteracted by others, as is evidenced in the case of the men in Table IV. The importance of this factor is shown quite clearly in the case of the women.

TABLE IV.

Length of hands as a factor in dynamometric pressure.

	Men:		Women:	
	Shortest hands.	Longest hands.	Shortest hands.	Longest hands.
Average length in mm.	186.3	200.1	166.8	180.2
Average pressure in kg.	48.1	48.2	26.0	30.3

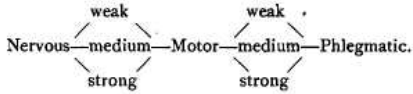
To construct Table IV. the hands of all the subjects were measured with a measuring stick; the distance was measured from the primary crease on the front of the wrist to the end of the middle finger. The result 186.3^{mm} represents the average length of the 10 shortest hands among the men, 200.1^{mm} the average length of the 10 longest, all of the subjects being taken into account in one or the other class. In the case of the men, those who had short hands seem to have possessed other qualities that counteracted the disadvantage of the short hand. There was an altogether different arrangement of favorable and unfavorable factors in the case of the women. Of course, the number of measurements taken was too small to make any very important generalizations.

2. *Effect of length of forearm.*—MILLER[1] has found a definite relation between the length and the strength of the forearm.

[1] MILLER, *Relations of length and strength in the forearm*, Pub. of the Univ. of Penn., 1900 IV 153.

3. *Effect of muscular development of the hand and arm.*—However important the part that this factor plays in the amount of the pressure, it is not probable that it was affected by the short practice of this experiment. It has been pretty clearly demonstrated too in this investigation that the test under consideration is not nearly so much one of muscular power as it is one of mental power.

4. *Effect of temperament.*—GALEN'S universally adopted classification of the temperaments into choleric, melancholic, sanguine and phlegmatic was not followed. For several reasons a different classification was more suitable to our needs. Since it was our purpose to discover the readiness of the subject to respond to practice (considering exercise as a stimulus, and development of motor ability as the response to this stimulus), our needs were subserved better by a classification based fundamentally on the ability to respond quickly to a given stimulus, and not by one based on both the strength and quickness of the response. An outline of such a classification is presented as follows:



The nervous temperament reacts quickly to a stimulus; this reaction may be either weak, medium or strong. The phlegmatic temperament reacts slowly; this reaction may be either weak, medium or strong. The motor temperament stands midway between the nervous and phlegmatic, if we consider time of reaction as the chief element in classification. The motor subject's reaction may be either weak, medium or strong. This classification makes strength of reaction a secondary consideration and quickness of reaction the primary consideration.

There is a question whether the nervous person does not as a matter of fact react more weakly than the phlegmatic one. To throw some light on this point, the average grip was determined for all the men classified as phlegmatic. The same was done with the records of the motor and nervous subjects. The average results are given in Table V.

TABLE V.

Relation of strength of grip to temperament.

Number of subjects.		Temperament.	Aver. grip in kg.
Men.	10	phlegmatic.	49.7
	6	motor.	49.6
	6	nervous.	43.3
Women.	7	phlegmatic.	30.3
	14	motor.	28.9
	4	nervous.	22.5

The table shows that the phlegmatic subjects in this particular group of individuals are slightly stronger than the motor subjects and considerably stronger than the nervous subjects. The fact is especially noticeable among the women. The fact noted, however, does not prove that the phlegmatic temperament *per se* is stronger than the nervous or the motor; nor would it be even though the results obtained here should be substantiated by similar ones secured from a large number of observations. There are several factors that tend to counteract, in the nervous type, any inherent power that it might have for the exertion of great strength. These are the mechanical factors that we have enumerated above.

In the first place the nervous person is smaller, generally speaking, than the phlegmatic person. This fact accounts in a measure for his being nervous; for the whole mass of muscles to be controlled being so much smaller, innervation is accomplished much more quickly. The hands are smaller and shorter, the forearm shorter, and hence the subject is placed at considerable disadvantage. Moreover, this disadvantage increases in more than arithmetical proportion, as the result of one factor at least, namely, the shortness of the hand. When the dynamometer just fits the hand and when the muscles and levers work in just the right arrangement, a good record is expected. But when the hand is so small that the pull must be made with the first phalanges rather than with the second, a tremendous disadvantage is met with, and there is a much smaller record.

This theory is strengthened by a comparison of the length of hand for men and women with their respective dynamometric records. Table VI. shows this comparison. While in length the women's hands averaged 89.7% that of the men's their strength was only 58.7% as great. The difference in strength would not be so great if it were not that the leverage of the small hand is not so good.

TABLE VI.

Relative strength of men and women.

Subjects.	Aver. length of hand in mm.	Aver. pressure in kg.
Men.	193.2	48.2
Women.	173.4	28.3

Above a certain point however great length of hand is of no advantage. Reference to Table IV. makes this statement clear. The men averaging 200.1^{mm} for length of hand were very little stronger than those averaging 186.3^{mm}. The very large hand is at a disadvantage because the dynamometer is pressed on one side, now, by the third phalanges

instead of the second. Table V., too, supports this conclusion. The natural inference is that the best method of grasping the dynamometer is to place one side in the crease of the second joint so that pressure is made with the second phalanges.

It seems necessary, then, in discussing temperament, to consider all the factors enumerated above, and the problem becomes more and more complex. An effort will be made in Part II. to present a somewhat more comprehensive view of the influence of temperament on bodily strength and its relations to muscular development.

Of the factors influencing the strength of dynamometric pressure we have named four: (1) length of hand, (2) length of forearm, (3) muscular development of the hand and arm and (4) temperament. These four factors are not easily affected by a short period of practice.

5. *Coördination.*—By coördination we mean the ability to innervate a particular muscle or set of muscles so specifically that very little of the motor impulse escapes into muscles not concerned in the movement that is being performed. It is the ability to direct motor impulse; or speaking from another standpoint it is muscular control. The term is best expressed in common speech by the word "knack." This factor is much improved by practice. Athletes possess it in a greater degree than men who have not had special physical training.

6. *Stored energy.*—This must be found in two places, in the motor nerve cell and in the muscle. It must be present in the nerve cell to generate the motor impulse and in the muscle to cause the contraction. Its absence in either place would make muscular action impossible. Fatigue means simply a loss of potential energy—hence fatigue is inability to do work. The authorities are agreed that complete loss of potential energy is sustained sooner by the central nerve cells than by the peripheral organs. Hence we say that central fatigue appears before peripheral fatigue and so a protection to the muscles is afforded. Potential energy must be present in large amounts in tests requiring a maximum exertion through a long period of time.

7. *Will power or volitional power.*—Potential or reserve energy is of no use until it is changed to kinetic energy. This change is effected in all primarily conscious tests by conscious volition. One's ability to accomplish feats of strength depends, in great measure, on his power to transform the potential energy of the motor cells into the kinetic energy of the nervous impulse. In addition to this, the strength of a muscle must depend on the readiness with which the potential energy of the muscle is changed by the motor impulse into the kinetic energy of the muscular contraction.