THE RELATION OF STRENGTH TO FLEXIBILITY IN THE HANDS OF MEN AND CHILDREN.

It is commonly supposed that this relation is an inverse one. For the purpose of determining it as well as studying the strength and flexibility of the hands of children of different ages, the writer took up the problem near the close of the year's work at Clark University. Results thus far obtained can have a general value only, but for the purpose of gathering criticisms and suggestions for a more elaborate study, they are reported now.

It is thought that not only this relation, but that a definite knowledge of the strength flexibility and voluntary control of the hand have bearings on physical and manual training, writing and drawing.

Twenty men, twenty-two boys, and eleven girls have served as subjects. Fourteen of the men are university students; two, members of the faculty; one, the clerk of the university; and three, workmen at the university, men past middle life.

The children were pupils in one of the Worcester first primary schools. Their ages range from 6 years to 7½ years. They were all acquainted with the writer, having served him as subjects in a previous study. The strength of the hand was tested by gripping a "Salter" dynamometer; the degree to which voluntary movement of the joints could be made was measured by protractors modified for the purpose. In getting the grip of the hand several trials, alternating the hands, were permitted. The best results are taken. With at least 50 per cent. of the subjects the second efforts showed a loss with one hand and a gain with the other. Third trials rarely gave any gain.

Tables showing grip of hands in nearest five pounds:

		70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
20 men.	R't	1	0	0	0	0	6	3	0	2	2	2	1	2	0	0	0	1
	L't	0	0	3	1	5	3	2	0	1	2	0	1	0	1	1	1	0
		5 10 15 20 25 30																
22 boys.	R't	0	2	10	8	1	1											
	L't	1	5	8	7	1	0											
11 girls.	R't	0	1	4	6	0	0											
	L't	1	5	3	2	0	0											

No one showed exactly equal strength of hands. Generally the right hand is the stronger.

Differences between the strength of the hands range from three to twenty-one pounds.

The weakest right-hand grip was by the oldest man; with his left hand he gripped ninety-five. He is not left-handed.

The best right and left-hand grips were made by students.

Comparing the right and left hands of each man, there is greater

flexibility of the weaker hand in thirteen instances. This is true of fourteen of the boys and seven of the girls.

Comparing stronger with weaker individuals, the weaker ones have more flexible hands in a few cases only.

The width of the hands was taken at the metacarpophalangeal joints, with these results:

	Cm's.	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.3
Men.	{ Right	0	0	0	2	0	1	2	5	1	3	1	1	1	1	1	1
	{ Left	1	0	1	3	4	0	0	4	0	2	0	1	2	2	0	0
	Cm's.	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	
Boys.	{ Right	0	0	1	1	0	3	3	3	2	1	3	3	3	1	1	
	{ Left	2	0	1	0	0	2	2	4	3	1	1	2	2	0	2	
Girls.	{ Right	0	0	1	0	1	2	2	3	1	0	0	0	0	1	0	
	{ Left	1	0	1	0	1	0	2	4	2	0	0	0	0	0	0	

Nine of the men, fourteen of the boys and five of the girls showed greater strength in the wider hand.

The right hand was as wide as the left in four cases among the men, six of the boys, and four of the girls.

The greatest difference between the right and left hand in the same individual was for the men 7 mm., for the children 5. Listing the widths in order of the strength of each of the hands, the total of the widths of the stronger ten of the men slightly exceeds that of the weaker. The total of the widths of the right hands slightly exceeds that of the left.

A similar arrangement for the boys gives the same results.

The length of the large finger was taken on each hand. In a number of cases with both men and children, it was difficult to get the measurement quite satisfactorily. Hence I give them as grouped in the nearest half cm.

		8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5
20 men.	{ Right	1	0	0	0	0	3	4	3	7	2
	{ Left	1	0	0	0	0	6	3	5	5	0
		6.5	7.0	7.5	8.0	8.5					
22 boys.	{ Right	0	7	10	4	1					
	{ Left	2	7	7	6	0					
		6.5	7.0	7.5	8.0						
11 girls.	{ Right	1	1	7	2						
	{ Left	1	2	6	2						

In the remaining tables results for the boys and girls are given together, since there do not appear, from the limited data, material differences between them.

The flexibility of the wrist in degrees for the men is as follows:

MEN.

	Degrees	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Right wrist	{ Forward	1	1	0	0	0	1	1	2	3	2	4	3	1	0	1
	{ Backward	0	0	0	0	1	3	4	4	1	2	2	1	2	0	0
Left wrist	{ Forward	0	0	1	0	1	0	1	1	3	4	1	3	5	0	0
	{ Backward	0	0	0	0	0	2	1	2	6	4	3	2	0	0	0

CHILDREN.

	Degrees	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Right wrist	Forward	1	0	0	0	2	0	6	3	4	7	7	2	1	0
	Backward	1	0	0	0	1	1	4	2	5	10	4	5	1	0
Left wrist	Forward	0	0	0	1	0	2	2	2	4	9	5	6	1	1
	Backward	0	0	0	1	1	0	2	1	4	13	8	2	1	0

The flexibility of the metacarpophalangeal knuckles of the men is shown in the following table :

	Degrees	60	65	70	75	80	85	90	95	100	105	110
Right	Index	1	0	4	3	2	3	6	0	1	0	0
	Middle	0	1	0	2	3	4	7	1	1	1	0
	Ring	0	0	0	1	3	6	5	1	3	1	0
	Little	0	1	1	0	0	3	7	4	2	0	2
Left	Index	0	1	4	5	0	5	2	3	0	0	0
	Middle	0	1	2	1	2	6	4	2	2	0	0
	Ring	0	1	1	1	2	7	4	3	1	0	0
	Little	0	1	1	2	0	8	1	4	2	1	0

Table showing same for the children :

	Degrees	50	55	60	65	70	75	80	85	90	95	100	105
Right	Index	1	0	2	5	6	10	2	5	0	2	0	0
	Middle	0	0	2	2	2	8	8	9	0	1	0	1
	Ring	0	0	1	1	5	11	8	7	0	0	0	1
	Little	0	0	2	3	4	8	7	9	0	0	0	1
Left	Index	0	0	3	2	10	5	9	3	1	1	0	0
	Middle	0	0	2	1	6	7	10	5	1	1	0	0
	Ring	0	0	2	2	7	11	6	3	1	0	0	0
	Little	1	0	2	2	5	11	4	6	2	0	0	0

The table for the men shows less flexibility of the index finger than of the others. The larger numbers for the left hand are, excepting the index knuckle, grouped from 85° to 95°. In the right hand it is from 70° to 90°, excepting the little finger.

The results are somewhat similar for the children, few going over 85°, and the large numbers being divided between 70, 75, 80 and 85 degrees.

Tables for flexibility of first interphalangeal joints :

MEN.

	Degrees	85	90	95	100	105	110	115	120	125
Right	Index	1	1	3	3	8	0	3	0	1
	Middle	0	2	2	3	6	3	3	1	0
	Ring	0	0	2	2	3	6	6	1	0
	Little	0	2	2	5	6	2	3	0	0
Left	Index	0	5	1	4	4	2	3	0	1
	Middle	0	2	1	4	7	3	2	0	1
	Ring	0	0	3	0	6	3	7	0	1
	Little	0	3	1	4	7	3	1	0	1

CHILDREN.

	Degrees	75	80	85	90	95	100	105	110	115	120
Right	Index	1	0	2	1	13	5	8	3	0	0
	Middle	0	0	0	2	13	5	10	3	0	0
	Ring	1	0	0	1	11	4	12	4	0	0
	Little	0	2	1	7	11	2	6	4	0	0
Left	Index	1	0	0	1	7	8	11	4	1	0
	Middle	0	0	0	0	9	7	10	6	0	1
	Ring	0	1	0	1	7	8	10	5	0	1
	Little	2	0	3	5	10	5	4	4	0	0

For the men 105° is the highest point, excepting the ring finger, where there are six each who reach 110° and 115°. Ten degrees less will in each case serve to indicate the "high water mark" for the children. The general flexibility of these joints is greater than any of the others.

Table showing flexibility of the second interphalangeal joints :

MEN.

	Degrees	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Right	Index	1	0	0	0	2	7	3	2	3	1	0	1	0	0
	Middle	0	0	1	1	2	5	3	3	0	3	0	0	1	1
	Ring	0	0	0	2	4	4	5	2	2	0	0	1	1	0
	Little	0	2	0	0	2	4	2	2	2	2	1	1	0	0
Left	Index	1	0	0	0	1	5	4	2	3	3	0	0	1	0
	Middle	0	0	1	0	0	3	6	1	6	0	0	1	2	0
	Ring	0	0	2	1	1	4	6	0	4	1	0	0	1	0
	Little	1	0	1	1	0	2	6	0	6	1	1	1	0	0

CHILDREN.

	Degrees	40	45	50	55	60	65	70	75	80	85	90
Right	Index	0	0	0	0	5	6	11	4	5	1	1
	Middle	0	0	0	0	2	4	14	4	5	2	2
	Ring	0	1	3	2	4	5	8	4	3	1	2
	Little	0	1	3	2	4	5	7	2	3	3	3
Left	Index	0	0	1	1	1	5	11	5	3	2	4
	Middle	0	0	1	1	0	2	9	8	4	4	4
	Ring	1	0	2	3	3	2	7	5	4	3	3
	Little	1	0	1	2	1	2	11	3	5	4	3

Table showing flexibility of the last two joints of the thumbs :

MEN.

	Degrees	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Right thumb {		0	0	0	3	3	1	3	2	3	1	2	2	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	5	2	5	4	1	0	2
Left thumb {		1	1	0	0	2	3	2	2	3	1	2	0	0	1	0	0	0
		0	0	0	0	0	1	1	0	1	1	2	6	2	1	4	1	0

CHILDREN.

	Degrees	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
Right thumb {		1	1	5	7	4	5	3	2	1	3	0	0	1	0	0
		0	0	0	0	0	1	1	3	2	7	5	7	5	1	1
Left thumb {		0	1	3	7	6	5	3	0	1	3	2	1	1	0	0
		0	0	0	0	0	0	1	1	6	7	6	3	5	1	3

The greatest spread of hands was marked out on paper and the angle made by thumb and little finger measured. The results are for the

MEN.

Degrees	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
Right {	1	0	0	0	0	6	3	0	2	2	2	1	2	0	0	0	1
Left {	0	1	0	3	1	5	3	2	0	1	2	0	1	0	0	1	0

CHILDREN.

Degrees	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
Right {	1	1	0	3	3	2	6	5	1	4	2	2	1	0	0	0
Left {	0	1	0	1	3	2	7	4	2	1	1	4	1	1	2	1

The right and left swing of the hand at the wrist was also marked out and the angle taken. The results are for the

MEN.

Degrees	45	50	55	60	65	70	75	80	85	90	95	100	105	110
Right {	2	1	1	1	1	3	0	4	3	0	3	0	1	0
Left {	0	2	1	1	1	2	4	3	2	1	0	1	1	1

CHILDREN.

Degrees	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Right {	1	0	5	4	5	6	3	3	4	0	1	0	0	0	1
Left {	0	0	7	3	4	6	3	2	2	1	1	3	1	0	0

Individual cases are of interest. This one is given in detail: J. L. is a bright boy of seven. As were each of the others he was already acquainted with the writer and was very curious to see the "new machines" as well as to show what he could do. His grip with the right hand was thirteen pounds, with the left ten. The widths of his hands were 6.1 cm. and 6.0 cm.; length of long fingers 7.2 cm. each. The forward and backward movements of the wrists were 74° and 74° for the right, 74° and 64° for the left. He closed each knuckle of the right hand 75°; the first two of the left hand 75°, and the last two 77°.

The movements of the first interphalangeal joints of the right hand were 102°, 102°, 102°, and 97°; for the left 108°, 108°, 108°, and 94°. For the second interphalangeal they were on the right hand 82°, 82°, 67°, and 67°; on the left 67°, 82°, 72°, and 72°. The right thumb measurements were 42° and 57°; the left the same. The spread of the right hand was 100°; of the left the same. The right wrist had a side movement of 60°; the left of 80°.

Flexibility of different joints shows so much variation that a better classification may be obtained by summing up the flexibility of all of these joints and tabulating results in the nearest twenty-five degrees.

RIGHT HAND.

Degrees	1200	25	50	75	1300	25	50	75	1400	25	50	75	1500	25	50	75	1600	25	50	75	1700
Men	0	0	0	1	3	1	1	1	0	0	0	3	2	2	2	0	1	1	1	0	1
Children	1	0	1	1	2	3	4	2	4	1	4	3	3	4	0	0	0	0	0	0	0

LEFT HAND.

Deg.	1200	25	50	75	1300	25	50	75	1400	25	50	75	1500	25	50	75	1600	25	50	75	1700-1875
Men	0	0	0	0	0	0	0	1	2	1	4	0	4	0	1	2	1	1	1	1	1-
Children	1	0	2	0	2	2	2	4	2	0	3	1	3	2	1	2	2	1	1	0	1-

Nearly 70 per cent. of the children and 35 per cent. of the men are below 1475° for the right hand; while for the left nearly 55 per cent. of the children and 40 per cent. of the men are below the same point. These results, as has been said, do not show any definite relation to strength of hand from individual to individual. In the majority of the cases cited, the relation suggested holds between the hands of the same individual. A small majority of all of the subjects had greater strength in the wider hands as well as greater flexibility.

For the wrist joint the men excel the children. If 65° is taken as a dividing line, 20 per cent. of the men fall below it in the forward movement of the right wrist, while nearly 50 per cent. of the children are below it. For the same movement of the left wrist, 15 per cent. of the men fall below it and $33\frac{1}{2}$ per cent. of the children.

For the metacarpophalangeal joints 85° is, with not more than 7 per cent. exception, the limit for the children, while from 35 per cent. to 50 per cent. of the men exceed the same degree. For the first interphalangeal joints 50 per cent. or more of the men reach or pass the limit of 105° , while with but one joint only, do more than 50 per cent. (17) pass this degree.

For the next joints more than 50 per cent. of the men are 65° or less. For one finger only, do the nearly 50 per cent. (16) of the children approach the same limit.

Twenty-five per cent. of the men fall below 60° in the movement of the metacarpophalangeal joint of the right thumb, while nearly 78 per cent. of the children are below the same limit. Much the same relations hold for the other joints of the thumb, except the last joint of the left thumb, where the advantage is in favor of the children.

Only 5 per cent. of the men fell below 90° in the greatest spread of the right hand, while nearly 30 per cent. of the children were below this limit. For the left hand the advantage is with the children. For the side movement of the wrists the percentage is on the side of the men. The general result of the greater voluntary control of the muscles by men leaves unexplained the difficulty which adults meet in trying to learn new movements. Habit and differences in development of the central nervous system, as well as interest and freshness, are doubtless factors to be taken into account.

I am indebted to Pres. Hall for calling my attention to this problem, and to both him and Dr. Sanford valuable suggestions in the study. Acknowledgments are due to those who have served as subjects, and to the Worcester school authorities for permission to test the children.

JOHN A. HANCOCK.