

*Kellogg, J. H.*  
MODERN MEDICINE LIBRARY, No. 2. June, 1896. Issued Monthly.  
Subscription Price, \$1.00 per annum.

The Value  
OF  
STRENGTH  
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IN THE  
Prescription of Exercise.

*B-1193*



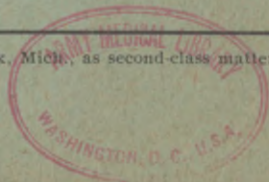
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BY J. H. KELLOGG, M. D.,

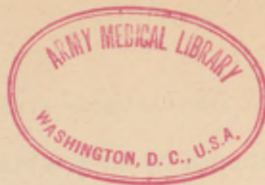
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MODERN MEDICINE PUB. CO., Battle Creek, Mich.

Entered at the Post-office in Battle Creek, Mich., as second-class matter.







# THE VALUE OF STRENGTH TESTS IN THE PRESCRIPTION OF EXERCISE,

AND A

COMPARATIVE STUDY OF THE STRENGTH OF INDIVIDUAL  
GROUPS OF MUSCLES, AND OF HOMOLOGOUS  
MUSCLES, IN MEN AND IN WOMEN.<sup>1</sup>

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BY J. H. KELLOGG, M. D.,

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It will doubtless be admitted by all who have undertaken to make a scientific application of exercise as a means of physical development, that the dosage of exercise, or, in other words, the preparation of a day's order, or program, is a question which gives to the trainer more perplexity, and one concerning which he is more often in doubt, than any other subject relating to physical training.

Some twenty years ago, in taking charge of an institution for the treatment of chronic invalids, I was at once confronted by this difficulty, in attempting to make a practical application of exercise as a therapeutic means. It will be readily recognized that the adjustment of the amount of muscular work to be done to the condition of the subject, is a matter of much greater difficulty when dealing with invalids than in dealing with that class of persons who usually come under the care of the physical director, owing to the greater degree of muscular asymmetry which is commonly encountered in invalid adults. In fact, it is a very rare exception to find among adults a person whose habits of life have not been such as to allow important muscular groups to fall into a state of idleness.

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<sup>1</sup> Read before the meeting of the American Association for the Advancement of Physical Education, New York, April 26, 1895.

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This is well attested by the fact that such deformities as hollow chest, round shoulders, prominent abdomen, curvature of the spine, forward carriage of the head, and similar abnormalities are so prevalent that the majority of men and women who have reached the age of forty years or over, furnish illustrations of one or more of these defects. Among chronic invalids especially, it is exceptional to find a person who does not present asymmetry in some of the forms which I have shown in a series of outline studies of the human figure, presented elsewhere.<sup>2</sup>

I made use of the usual methods of anthropometry, exercising the greatest care in taking my measurements, only to be disconcerted by the fact that patients not infrequently decreased in measurement while gaining in strength, or were discouraged by making little or no change in their dimensions, notwithstanding hard and persevering efforts in the gymnasium.

I soon discovered that measurements are of very little value indeed in dealing with adult invalids, however useful they may be in the management of the physical training of growing boys and girls and undeveloped youths. I learned that quality, rather than quantity, of muscle was the important thing in dealing with adults—at least invalid adults. Through the assistance of Professor Sargent, I possessed myself of all the various forms of dynamometers which had been constructed for use in testing the strength of the muscles of the human body. I found, however, that these dynamometers had so little range of adaptability that only a few muscular groups could be studied by their aid; and, finding myself daily embarrassed in consequence of my inability to meet the requirements of my patients, and being unable to avoid most unhappy blunders in my exercise prescriptions, in sheer despair I sought to devise some accurate means for testing the strength, which could be adapted to the principal muscular groups of the body.

After seven or eight years of experimentation, I succeeded in perfecting a dynamometer by means of which the strength of every important group of muscles of an individual can be

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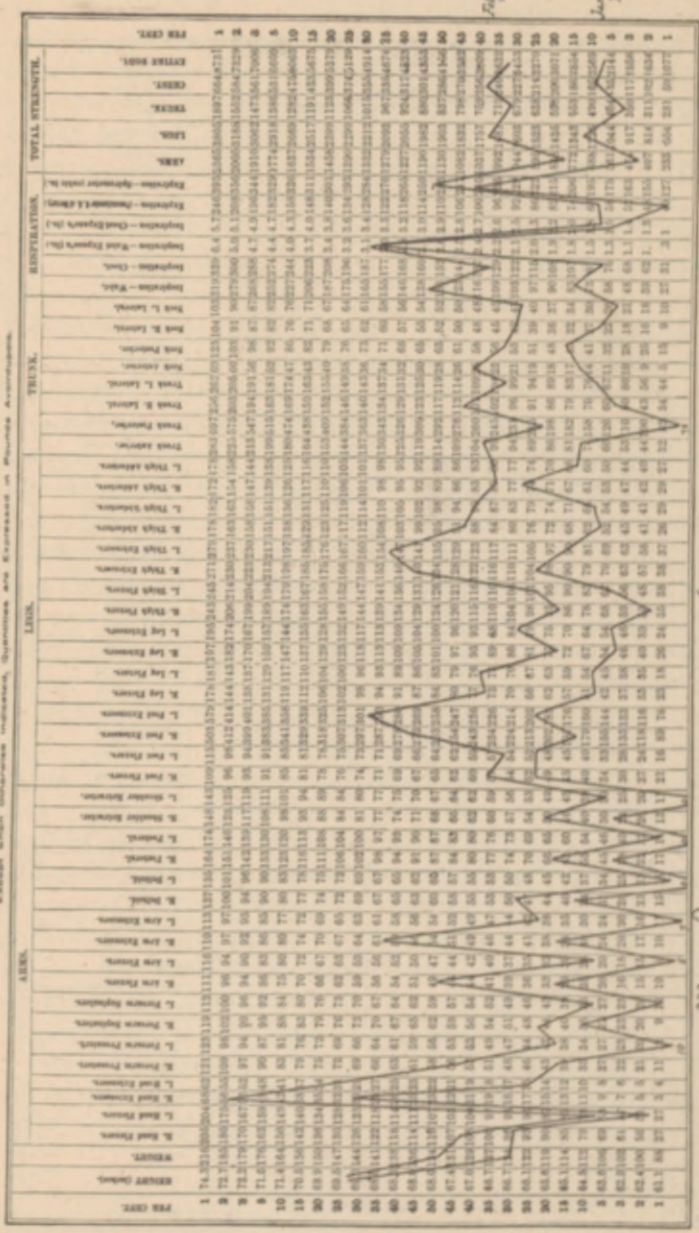
<sup>2</sup> "Outline Studies of the Human Figure, Comprising 118 Figures, which Embody the Results of Several Thousand Observations, Embracing Studies of a Number of Different Civilized and Uncivilized Races."



# — PHYSICAL CHART —

Arranged from the results obtained in testing the strength of the individual groups of muscles in 600 MEN, by means of a Universal Electromyogram, made and controlled under the direction of J. B. KEILMANN, M. D., Superintendent of the Institution and Hospital, Battle Creek, Michigan.

EXERCISES: ARM, LEG, TRUNK, RESPIRATORY, EYE, EAR, NOSE, THROAT, LARYNX, PHARYNX, GLOTTIS, PALATE, UTERUS, VAGINA, RECTUM, ANUS, PERINEUM, GENITALS, SKIN, SKELETON, AND ARTICULATIONS.



Original Measurements of *Wm. O. ...* Taken January, 1910, at *St. ...*  
 Reprinted from *Journal of the American Medical Association*, Vol. 1, p. 1000, 1910.

## CHART II.

tested. This instrument I have elsewhere described, and have one here for exhibition. By means of this apparatus, the strength of each of the following muscular groups may be accurately determined: For the upper extremities, hand flexors and extensors, forearm pronators and supinators, arm flexors and extensors, deltoid, latissimus dorsi, pectorals, and shoulder retractors; for the lower extremities, foot flexors and extensors, leg flexors and extensors, thigh flexors and extensors, thigh abductors and adductors; for the trunk, anterior, posterior, and right and left lateral muscular groups; for the neck, anterior, posterior, and right and left lateral muscles; for the thorax, the force of waist and chest expansion. Expiration and inspiration are also measured by means of Waldenburg's pneumatometer.

I have worked out a definite mode for testing each group of muscles. This method is followed with care in each test made. The general principle which I have followed is that the resistance of the dynamometer should be applied at the distal end of the bone which is operated upon by the group of muscles under examination, and in such a manner as to give the muscle an opportunity to act to the best advantage, at the same time isolating its action from that of other groups which might vitiate the results obtained.

The accompanying physical charts (Charts I and II) are reduced copies of those which I use for recording the condition of the muscular system of my patients. These charts are constructed on a percental plan somewhat similar to that followed by Professor Seaver in his anthropometric chart. In making these charts, based upon the examination of six hundred men and a like number of women, the figures obtained for each group of muscles were arranged in a column in regular order from the highest down to the lowest. The average of 50 per cent of those found in the middle column was obtained, and put down in the center of the corresponding column on my chart. Forty-five per cent, reaching 5 per cent above the upper level of the middle 50 per cent, were next added together, the average found, and the result placed in the same column, just above the previous result. Forty per cent, 35 per cent, and so on down to 1 per cent of the numbers above

the middle, were cut out in like manner, the averages found, and the results properly placed. Proceeding in a similar manner, the figures were obtained for the lower half of the column. By treating the data obtained for each group of muscles in the body in this manner, I have obtained a chart upon which I can make a graphic representation of the strength of the body, just as bodily dimensions have heretofore been graphically represented upon anthropometric charts and tables.

At the right-hand side of the chart are arranged columns for the totals of the arms, legs, trunk, chest, and the entire body, so as to bring under the eye at a single glance both the relative and the actual strength of the principal divisions of the body.

I have also prepared two other sets of tables, one based upon the examination of two hundred healthy men between twenty and thirty years of age, the other upon the data obtained from testing an equal number of women of the same age. This chart differs from the other chiefly in that the figures start at a higher level. In transferring the graphic representation of a person's muscular strength from one of these tables to another, I find that the characteristic features, although slightly modified, always remain the same.

As a further test of the value of the chart, I have platted the figures obtained for the various groups of muscles, and find that excellent curves are made. In the case of the left foot flexors, for example, an almost absolutely perfect binomial curve is obtained. The best test, however, for the value of this method of obtaining a basis for a prescription for exercise, is the fact that it meets in a most admirable manner the purposes for which it was designed.

The data afforded furnish exact information concerning the capacity of each of the principal groups of muscles in the body. Knowing the capacity of each muscle, it is easy to proportion the work in such a manner as to secure symmetry of development. My plan for accomplishing this is as follows:—

Taking 300,000 foot-pounds, 1-6 of a full day's work, as the proper daily amount of exercise for a man whose total strength capacity is 10,000 pounds, corresponding very nearly

to the greatest capacity shown upon my table prepared from two hundred young men in vigorous health, I have undertaken to establish a definite relation between the strength capacity and the total amount of work to be performed. This is accomplished by simply dividing the total amount of work done by the total capacity of the muscles; that is, 1,800,000 is divided by 10,000, giving 180. In other words, for each pound of capacity, the muscles are capable of doing 180 foot-pounds of work daily, an interesting physiological fact thus for the first time determined. One sixth of 180 is 30. Hence it is clear that in a symmetrically developed man, with a total strength capacity of 10,000 pounds, each muscle, in order to do its proportion of the 300,000 foot-pounds prescribed, must do work to the amount of 30 times its lifting capacity represented in foot-pounds. It is only necessary, then, in order to ascertain the exact amount of work to be done by each group of muscles at each level, to multiply by 30 the figures of each column of the chart.

I have made a careful approximate calculation of the amount of work done in each exercise or set of exercises, with each apparatus in the gymnasium under my supervision. It is necessary to know the strength of the medicine as well as the needs of the patient. Knowing the amount of work required for each individual and for each set of muscles, and also the result obtained from each exercise, it is easy to construct tables of exercise exactly adapted to any capacity. I have arranged ten series of such tables, or day's orders, five for each of the two charts.

In making a prescription for exercise, I first note the total capacity of the individual, and then write down a number indicating the day's order which would secure for an individual of the given capacity, the proper amount of work. Then, glancing over the chart, I note the low points, and check or underscore each of these, which indicates to the assistant who superintends the exercise in the gymnasium that the work is to be doubled on all such points, so as to secure to the weak muscles such rapid development and growth as will enable them to overtake the rest of the muscles, and thus restore muscular symmetry. In practice, I find that this method never results

in giving to a muscle more than a full day's work, and consequently there is no danger of injury resulting from this doubling of the amount of work to be done by the weak muscles. In case of complete paralysis of the muscle, it is of course necessary at the beginning to administer the exercise by electrical or mechanical means.

As a rule, I find it sufficient, for practical purposes, to divide the series of total capacities represented upon my table into five groups, instead of making a distinct schedule of work at each of the levels indicated by the several quantities representing total muscular capacity.

The ratio which I have established between the muscular capacity and the day's work is probably too small for those in vigorous health; but I find it well suited to the class of persons coming under my observation, who are mostly invalids or semi-invalids. The man who is in training, and desires to develop his whole body to its highest capacity, should be required to execute a full day's work,— 1,800,000 foot-pounds, or even more. In arranging a day's order of exercises, due account is of course taken of the work done in walking, running, and similar exercises which may be made a part of the program.

The patient does not undertake the first day to do all the exercises prescribed in the series, but gradually takes them up from day to day as he learns them, and becomes able to do them; and by the end of two or three weeks, he is expected to have thoroughly mastered all the exercises given him, and to have become able to take each day all that is directed in his prescription. At the end of a month, another chart is made, the changes noted, and a new prescription prepared according to the requirements. It is a matter of frequent observation that the points which at the first examination are lowest on the chart, are so improved by the specific exercise directed to these particularly weak muscles that they become the highest ones upon the second chart.

The advantages of this mode of studying the condition of the muscular system, and the great change which may be effected by a precise and definite prescription for exercise, in combination with massage and manual and mechanical Swed-

ish movements, are well shown in Chart I, which represents the muscular condition of a young woman at three different dates; respectively, April 6, May 2, and Sept. 1, 1892. The great irregularities of the first tracing, and the low levels reached by many of the arm groups of muscles, with the low level of the total strength, indicate a very weak and unsymmetrical development at the beginning. The young woman was stooped, round shouldered, hollow chested, pale, anemic, and possessed of very little vigor. Less than a month later, when the second tracing was taken, the patient had made a gain of nearly 800 pounds in total strength, the greater part of the gain having been made in the arms, which in the beginning were very much weaker than the legs, but which by special attention had become proportionately stronger than the legs. The chest had also gained even more than the arms, so that this portion of the muscular system was slightly in the ascendancy. At this time another prescription was made, the effects of which appear in the further improvement shown by the test made September 1. By comparison of the totals, it will be seen that the asymmetry had largely disappeared.

No person is ever found whose chart gives a perfectly straight line; but the nearer the approach to a straight line across the chart, the more perfect, of course, the symmetry.

At the time of the last test, September 1, this unsymmetrical, feeble young woman would certainly have been pronounced one of more than average vigor and of excellent symmetry. She carried herself erect, her chest had become full, and the respiratory movements deeper, and the whole body shared in the increase in physical vigor and stamina acquired by the muscular system.

By means of this method, it is possible to obtain exact knowledge respecting the requirements of each individual case. Possessed of this, it is not difficult to make a prescription which will be exactly adapted to the wants of the patient. It is possible to make in less than a minute's time, a prescription which is more perfectly adapted to the needs of the individual examined, than could be made by the most elaborate study and the consumption of any amount of time, without the aid of the accurate data obtained by this method.

One of the charts herewith presented, that of Mr. A. (Chart II), shows the value of this mode of investigation in the diagnosis of morbid conditions affecting the motor system. The patient was suffering from paresis of the left arm. This would be apparent from the chart alone, without other evidence, as will be readily seen. The dynamometer picks out the particular groups of muscles which are affected by paresis, or paralysis, and thus gives important indications respecting the location of the central lesion, of which the paralysis is merely a symptom. This chart also shows, in a most interesting manner, the value of the dynamometer as a means of indicating the progress made by a paretic patient under treatment.

Another advantage in this mode of studying the motor apparatus is the fact that the dynamometer tests not only the muscles, but the nerves and nerve centers as well, so that it is a precise measure of the condition of the individual's motor apparatus. It is a true measure of the dynamic energy of the body, and shows the actual ability of the individual to manifest energy through his muscular system as a whole, and through each particular part of it. The tape line merely gives the dimensions of a man,—it tells nothing as to whether he is alive or dead. The dynamometer gives us an accurate description of the living, active man. The chart obtained by means of a dynamometer enables the physical director to make a precise prescription for exercise without even seeing the subject, whereas the data furnished by the measurements of the tape line may relate to a man who is dead, or so completely paralyzed that all forms and degrees of exercise are alike impossible; so that without the aid of the dynamometer, anthropometry is a most unreliable guide and almost altogether useless, unless the subject is before the director, who, even then, is obliged to depend upon his intuitions and experience in arranging a program for gymnastic work, rather than upon the indications of the tape line.

After several years' use of my dynamometer and the charts which it has enabled me to prepare, I am so thoroughly dependent upon these means of directing the gymnastic work of my patients that I should be quite at a loss to know how to prescribe for them without this or some other equally good means of exact diagnosis.

A most interesting line of research which the dynamometer has enabled me to undertake, is a comparative study of the muscular system in men and women. The studies of this subject heretofore made, have been chiefly based upon the results obtained by the use of the tape line, which, as has already been remarked, are practically valueless, and always misleading. A few studies have been made by Quetelet and others, based upon such incomplete tests as the strength of the grasp of the hand, the weight which can be dragged over a level surface, etc.; but the facts presented have been so fragmentary as to be of little practical value.

In my personal studies by the aid of the dynamometer, the principal comparisons which have been made are as follows, the figures given (Table I, columns I-XIII) being based upon the study of two hundred healthy men between the ages of eighteen and thirty years, and an equal number of healthy women of the same ages:—

1. A comparative table of the actual strength of each of the several groups of muscles, and of all the muscles of each of the principal divisions of the body, in the average man and the average woman.

2. The relative strength of each group of the muscles, and of each division of the body, and also of the total muscular strength, as compared with the average weight of the body.

3. The strength of each group of muscles, of the muscles of each of the principal divisions of the body, and of the total strength of the body compared with the average height in inches.

4. The strength of each group of muscles, and of the muscles of each of the principal divisions of the body, as compared with the total strength.

5. The strength of each group of muscles (right and left together) as compared with the strength of the corresponding division of the body.

6. The strength of the muscles of the left side of the body as compared with those of the right side of the body.

7. The strength of each group of muscles, of the muscles of each division of the body, and the total strength, in women, as compared with the same in men.

8. The strength of each group of muscles as compared with the antagonizing group.

TABLE I.

A COMPARATIVE STUDY OF THE STRENGTH OF THE VARIOUS GROUPS OF MUSCLES IN THE HUMAN BODY, BASED UPON THE DATA OBTAINED BY DR. KELLGOG'S DYNAMOMETER.

| NAMES OF THE GROUPS OF MUSCLES TESTED, COMPRISING ALL THE PRINCIPAL GROUPS OF VOLUNTARY MUSCLES, EXCEPT WHEN OTHERWISE STATED, THE FIGURES GIVEN RELATE TO THE COMBINED STRENGTH OF THE RIGHT AND LEFT GROUPS IN POUNDS. | MEN.       |       | WOMEN. |       | The actual strength of each group of muscles, and of the muscles found in each of the principal divisions of the body. | The strength of each group of muscles, and of the muscles of each division of the body, in women, as comp. with men. |       |       | The relative strength of each group of muscles, of the muscles of each division of the body, and of the entire body, as compared with the average weight of the body. |        | The strength of each group of muscles, of the muscles of each of the principal divisions of the body, and the total strength of the body, comp. with av. height in inches. |       | The strength of each group of muscles, and of the muscles of each of the principal divisions of the body, as compared with that of the whole body. |       | The strength of each group of muscles, (right and left together) as compared with the strength of the corresponding division of the body. |       | The strength of the muscles of the left side of the body as compared with the muscles of the right side of the body. |       | The actual strength of each group of muscles, and of each division of the body, in tall men and short men. |       | Muscular strength of short men compared with that of tall men. |     | The actual strength of each group of muscles, and each division of the body, in tall women and short women. |  | Muscular strength of short women compared with that of tall women. |  | Relative differences in muscular development between men and women of equal height (65 inches). |  | The muscular strength of women 65 inches in height compared with men of the same height. |  |
|--|------------|-------|--------|-------|--|--|-------|-------|---|--------|--|-------|--|-------|---|-------|--|-------|--|-------|--|-----|---|--|--|--|---|--|--|--|
|  | I          | II    | III    | IV    |  | V  | VI    | VII   | VIII  | IX     | X  | XI    | XII  | XIII  | XIV   | XV    | XVI  | XVII  | XVIII  | XIX   | XX   | XXI | XXII  |  |  |  |   |  |  |  |
| Hand Flexors.....  | 249.       | 125.  | .50    | 1.80  | 1.07   | 3.67   | 1.98  | .018  | .047  | 1.63   | .169   | .97   | .95  | 258   | 214   | .83   | 137  | .86   | .331   | 137   | .41  |     |   |  |  |  |   |  |  |  |
| Hand Extensors.....  | 54.        | 29.   | .53    | .39   | .24  | .79  | .46   | .010  | .011  | .036   | .039   | .93   | .95  | 65    | 54  | .57   | 38   | .87   | .64  | 43    | .67  |     |   |  |  |  |   |  |  |  |
| Forearm Supinators.....  | 143.       | 57.   | .39    | 1.03  | .48  | 2.11   | .90   | .028  | .021  | .094   | .077   | .96   | .96  | 122   | 117   | .96   | 67   | .82   | .124   | 67    | .54  |     |   |  |  |  |   |  |  |  |
| Forearm Pronators.....   | 134.       | 57.   | .42    | .96   | .48  | 1.97   | .90   | .026  | .021  | .088   | .077   | .97   | .96  | 140   | 116   | .83   | 68   | .85   | .118   | 58    | .58  |     |   |  |  |  |   |  |  |  |
| Arm Flexors.....   | 139.       | 48.   | .40    | .86   | .41  | 1.77   | .76   | .023  | .017  | .078   | .065   | .97   | 1.00   | 125   | 113   | .90   | 61   | .93   | .136   | 62    | .49  |     |   |  |  |  |   |  |  |  |
| Arm Extensors.....   | 137.       | 53.   | .41    | .91   | .45  | 1.87   | .84   | .024  | .019  | .076   | .072   | .98   | .96  | 113   | 113   | 1.00  | 62   | .90   | .119   | 64    | .54  |     |   |  |  |  |   |  |  |  |
| Latissimus Dorsi.....  | 185.       | 99.   | .55    | 1.33  | .85  | 2.74   | 1.57  | .036  | .036  | 1.22   | .134   | .99   | .98  | 127   | 128   | 1.01  | 75   | .91   | .140   | 70    | .50  |     |   |  |  |  |   |  |  |  |
| Deltoïd.....   | 140.       | 71.   | .50    | 1.00  | .60  | 2.06   | 1.12  | .027  | .026  | .090   | .096   | .97   | .97  | 127   | 128   | 1.01  | 68   | .91   | .140   | 70    | .50  |     |   |  |  |  |   |  |  |  |
| Pectoral.....  | 209.       | 102.  | .48    | 1.30  | .87  | 3.08   | 1.70  | .037  | .037  | 1.37   | .138   | .97   | .96  | 200   | 168   | .84   | 90   | 1.11  | .192   | 100   | .52  |     |   |  |  |  |   |  |  |  |
| Shoulder Retractors.....   | 160.       | 95.   | .59    | 1.15  | .81  | 2.36   | 1.51  | .031  | .035  | 1.05   | 1.29   | 1.00  | 1.02   | 184   | 156   | .85   | 100  | .95   | .161   | 95    | .59  |     |   |  |  |  |   |  |  |  |
| Foot Extensors.....  | 614.       | 364.  | .59    | 4.41  | 3.11   | 9.07   | 5.79  | .018  | .018  | 1.33   | .271   | .99   | .99  | 160   | 139   | .81   | 103  | .93   | .492   | 308   | .63  |     |   |  |  |  |   |  |  |  |
| Foot Flexors.....  | 145.       | 89.   | .61    | 1.04  | .76  | 2.14   | 1.41  | .028  | .032  | .064   | .067   | .99   | 1.02   | 160   | 160   | 1.02  | 182  | .92   | .175   | 109   | .62  |     |   |  |  |  |   |  |  |  |
| Leg Extensors.....   | 200.       | 116.  | .58    | 1.44  | .99  | 2.95   | 1.84  | .030  | .042  | .088   | .088   | .98   | 1.00   | 197   | 197   | .99   | 169  | .80   | .140   | 175   | .50  |     |   |  |  |  |   |  |  |  |
| Leg Flexors.....   | 237.       | 123.  | .51    | 1.05  | 1.05   | 3.50   | 1.95  | .045  | .045  | 1.04   | .093   | .97   | 1.02   | 233   | 214   | .92   | 125  | .92   | .125   | 124   | .55  |     |   |  |  |  |   |  |  |  |
| Thigh Flexors.....   | 303.       | 179.  | .59    | 2.10  | 1.52   | 4.47   | 2.84  | .058  | .065  | 1.34   | .136   | 1.02  | .96  | 280   | 263   | .94   | 163  | .94   | .113   | 162   | .52  |     |   |  |  |  |   |  |  |  |
| Thigh Extensors.....   | 330.       | 174.  | .52    | 2.30  | 1.49   | 4.87   | 2.76  | .064  | .064  | 1.45   | .131   | 1.01  | 1.00   | 351   | 276   | .79   | 159  | .91   | .302   | 159   | .53  |     |   |  |  |  |   |  |  |  |
| Thigh Abductors.....   | 206.       | 135.  | .65    | 1.40  | 1.15   | 3.04   | 1.45  | .039  | .049  | .091   | .102   | 1.00  | .98  | 203   | 188   | .93   | 146  | .93   | .194   | 140   | .72  |     |   |  |  |  |   |  |  |  |
| Thigh Adductors.....   | 297.       | 142.  | .62    | 1.63  | 1.21   | 3.35   | 2.25  | .044  | .052  | 1.00   | .107   | 1.02  | 1.00   | 244   | 207   | .85   | 128  | .92   | .214   | 129   | .60  |     |   |  |  |  |   |  |  |  |
| Trunk Anterior.....  | 139.       | 73.   | .73    | 1.00  | .62  | 2.05   | 1.16  | .025  | .027  | .133   | .141   | 1.00  | 1.00   | 130   | 121   | .93   | 66   | .92   | .123   | 123   | .68  |     |   |  |  |  |   |  |  |  |
| Trunk Posterior.....   | 380.       | 173.  | .45    | 2.79  | 1.47   | 5.61   | 2.75  | .073  | .063  | .364   | .335   | .97   | 4.42   | 332   | 315   | .65   | 139  | 1.07  | .146   | 145   | .40  |     |   |  |  |  |   |  |  |  |
| Trunk Lateral—R. and L.....  | 287.       | 154.  | .54    | 2.06  | 1.31   | 4.23   | 2.44  | .055  | .056  | 2.75   | .298   | .99   | .97  | 248   | 266   | 1.07  | 146  | .94   | .146   | 138   | .58  |     |   |  |  |  |   |  |  |  |
| Neck Anterior.....   | 75.        | 35.   | .19.   | .25   | .16  | .51  | .30   | .007  | .007  | .034   | .037   | .47   | .51  | 38    | 34  | .89   | 23   | .91   | .34  | 23    | .68  |     |   |  |  |  |   |  |  |  |
| Neck Posterior.....  | 75.        | 37.   | .49    | .54   | .31  | 1.10   | .58   | .014  | .013  | .072   | .071   | .97   | .97  | 70    | 71  | 1.01  | 39   | .92   | .70  | 39    | .56  |     |   |  |  |  |   |  |  |  |
| Neck Lateral—R. and L.....   | 196.       | 90.   | .47    | 1.23  | .67  | 2.54   | 1.25  | .024  | .022  | 1.29   | .476   | 1.00  | 1.00   | 112   | 116   | 1.04  | 64   | .94   | .113   | 60    | .53  |     |   |  |  |  |   |  |  |  |
| Inspiration—Wrist.....   | 172.       | 79.   | .45    | 1.23  | .67  | 2.54   | 1.25  | .024  | .022  | 1.29   | .476   | 1.00  | 1.00   | 159   | 135   | .85   | 74   | .99   | .140   | 78    | .56  |     |   |  |  |  |   |  |  |  |
| Inspiration—Chest.....   | 190.       | 85.   | .44    | 1.36  | .72  | 2.95   | 1.35  | .037  | .031  | 1.519  | .512   | 1.00  | 1.00   | 177   | 151   | .85   | 88   | .93   | .163   | 87    | .53  |     |   |  |  |  |   |  |  |  |
| Inspiration—Pneumometer.....   | .9         | .4    | .006   | .006  | .003   | .013   | .006  | .0002 | .0001   | .0025  | .0024  | ..... | .....  | ..... | .....   | ..... | .....  | ..... | .....  | ..... | .....  |     |   |  |  |  |   |  |  |  |
| Expiration—Pneumometer.....  | 2.6        | 1.4   | .54    | .019  | .038   | .022   | .022  | .0005 | .0005   | .00721 | .0084  | ..... | .....  | ..... | .....   | ..... | .....  | ..... | .....  | ..... | .....  |     |   |  |  |  |   |  |  |  |
| Arms   | Right..... | 770.  | 373.   | .48   | 5.54   | 3.19   | 11.38 | .148  | .136  | 5.93   | .507   | .98   | .97  | 684   | 601   | .68   | 360  | .98   | 1.1  | 323   | .61  |     |   |  |  |  |   |  |  |  |
| Left.....  | 751.       | 363.  | .48    | 5.40  | 3.10   | 11.09  | 5.77  | .145  | .132  | 5.77   | .507   | .98   | .97  | 679   | 589   | .87   | 353  | .90   | 1.2  | 318   | .55  |     |   |  |  |  |   |  |  |  |
| Both.....  | 1321.      | 736.  | .48    | 10.94 | 6.29   | 22.47  | 11.70 | .293  | .268  | 11.54  | .507   | .98   | .97  | 1363  | 1190  | .87   | 715  | .90   | 1.270  | 708   | .56  |     |   |  |  |  |   |  |  |  |
| Legs   | Right..... | 1131. | 663.   | .58   | 8.13   | 5.66   | 16.70 | .218  | .242  | 5.501  | .501   | 1.00  | 1.00   | 1134  | 987   | .87   | 626  | .92   | 1.009  | 618   | .61  |     |   |  |  |  |   |  |  |  |
| Left.....  | 1131.      | 659.  | .58    | 8.13  | 5.63   | 16.70  | 10.48 | .218  | .241  | 5.50   | .501   | 1.00  | .99  | 1100  | 934   | .87   | 628  | .90   | 1.007  | 618   | .61  |     |   |  |  |  |   |  |  |  |
| Both.....  | 1131.      | 659.  | .58    | 8.13  | 5.63   | 16.70  | 10.48 | .218  | .241  | 5.50   | .501   | 1.00  | .99  | 1100  | 934   | .87   | 628  | .90   | 1.007  | 618   | .61  |     |   |  |  |  |   |  |  |  |
| Trunk  | Right..... | 1042. | 516.   | .49   | 7.50   | 4.41   | 15.39 | .201  | .188  | 1.00   | .188   | 1.00  | 1.00   | 918   | 859   | .87   | 477  | .97   | .942   | 476   | .51  |     |   |  |  |  |   |  |  |  |
| Left.....  | 1042.      | 516.  | .49    | 7.50  | 4.41   | 15.39  | 2.64  | .071  | .061  | 1.00   | .188   | 1.00  | 1.00   | 918   | 859   | .87   | 477  | .97   | .942   | 476   | .51  |     |   |  |  |  |   |  |  |  |
| Both.....  | 1407.      | 1042. | .48    | 10.13 | 5.83   | 20.80  | 5.41  | .071  | .061  | 2.00   | .376   | 1.00  | 1.00   | 1257  | 1246  | .99   | 940  | .98   | 1.246  | 642   | .52  |     |   |  |  |  |   |  |  |  |
| Chest and Trunk.....   | 1407.      | 682.  | .48    | 10.13 | 5.83   | 20.80  | 10.84 | .271  | .249  | 2.00   | .376   | 1.00  | 1.00   | 1257  | 1246  | .99   | 940  | .98   | 1.246  | 642   | .52  |     |   |  |  |  |   |  |  |  |
| Body.....  | 5190.      | 2740. | .53    | 37.34 | 23.42  | 76.68  | 43.56 | ..... | .....   | .....  | .....  | ..... | .....  | 4854  | 4377  | .90   | 2969   | .92   | 4532   | 2586  | .57  |     |   |  |  |  |   |  |  |  |

\* Compared with chest. \* Compared with both arms. \* Compared with both legs. \* Trunk anterior compared with trunk posterior. \* Neck anterior compared with neck posterior.

9. The strength of the muscles of the arms as compared with the homologous, or corresponding, muscles of the legs.

10. A study of the muscular strength of men as compared with that of women of the same height.

11. A study of the muscular strength in short men and short women as compared respectively with that of tall men and tall women.

In the accompanying table (Table I) will be found the figures indicating the principal of these relations, which are made more evident by the accompanying series of graphic diagrams.

*The Relative Strength of the Various Groups of Muscles.*—

In Table II the figures which indicate the strength of each individual group of muscles for the average man and the average woman, are arranged in the order of their relative strength. It will be observed that the order in the two columns is not the same. Interesting differences and facts, a few only of which will be mentioned here, occur at many points:—

1. One of the most curious facts noted is that the foot extensors, or calf muscles, in the average woman, have a strength almost exactly equal to that of the left arm.

2. The anterior muscles of the neck, in both men and women, have about half the strength of the posterior.

3. The hand flexors in men have just twice the strength of the arm flexors; in women, the hand flexors are nearly three times as strong as the arm flexors.

4. The anterior muscles of the trunk, the deltoid, the forearm supinators, and the foot flexors have almost equal strength in man; in woman, the forearm supinators, forearm pronators, and the lateral muscles of the neck may be similarly grouped.

5. In man, the forearm supinators are considerably stronger than the pronators, whereas in women they are of equal strength, although much weaker than in men, these muscles being, in the average man, 2 1-2 times as strong as in the average woman.

6. In man, again, the thigh abductors and the pectorals have almost the same strength capacity; in woman, a similar



parallel exists between the leg extensors and the hand flexors, and another group is found in the muscles of the back, the thigh extensors, and the thigh flexors, which are in the average woman almost exactly equal in strength capacity.

7. In man, the latissimus dorsi and the muscles which move the upper chest in inspiration, are equal in strength; while in woman a similar parallel exists between the latissimus dorsi, the pectorals, and the shoulder retractors.

8. The inspiratory powers of the waist and chest are practically equal in woman; while in man the inspiratory power of the chest is perceptibly greater than that of the waist, although in each case the respiratory strength in man is double or more than double that of woman. This fact demonstrates the fallacy of the idea that restriction of the waist is a means of giving woman a superiority in upper chest development, and so acting as a preventive of pulmonary disease. Men, without waist constriction, have greater relative strength in the upper chest than have women.

9. The total strength of inspiration (chest) is, in women, just 1-8 that of the total for the chest and trunk.

10. The strength of one leg is almost exactly equal, in woman, to the strength of the chest and trunk; in man, the total for the chest and trunk is considerably greater than that for either leg.

11. The waist-expanding capacity is almost exactly 1-2 that of the total for the two sides of the trunk, in woman.

12. The thigh extensors in man have a capacity more than six times that of the hand extensors; while the foot extensors have a capacity almost exactly twelve times that of the hand extensors, and double that of the thigh flexors.

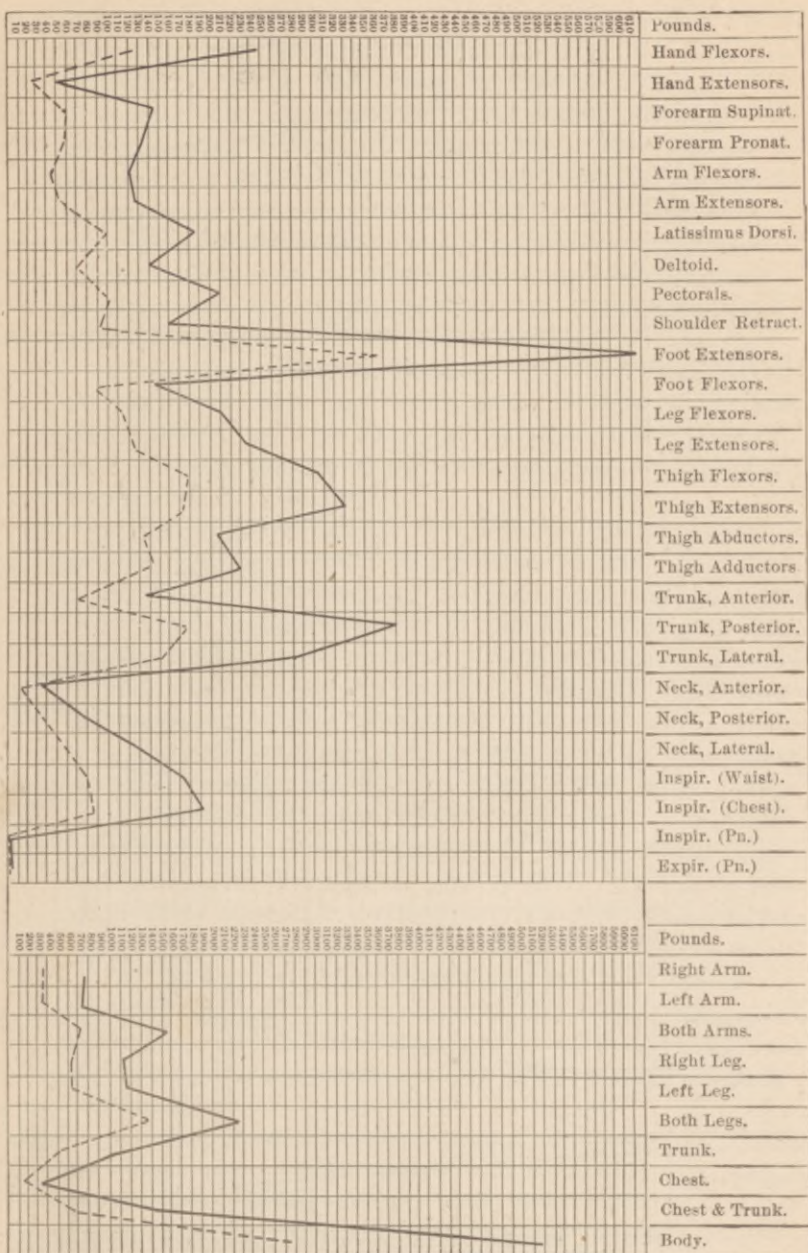
13. The strength of the arm extensors, in man, is almost exactly 1-12 that of the entire arm.

14. The strength of the deltoid is, in woman, almost exactly 1-2 that of the homologous muscles,—the thigh abductors.

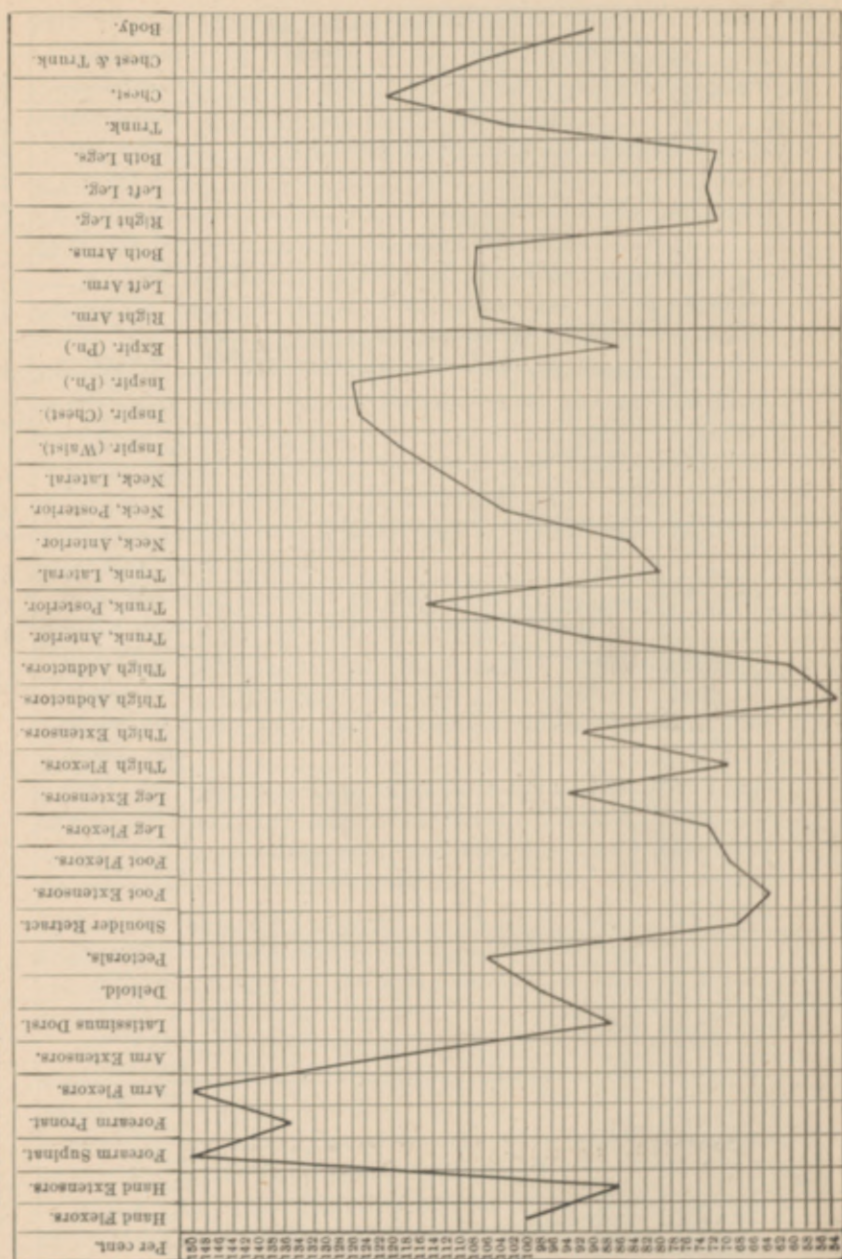
15. The lateral muscles of the neck have half the strength of the hand flexors, in both men and women.

Many other interesting comparisons might be made, especially those which relate to the strength of each group of mus-

GRAPHIC I.—A GRAPHIC REPRESENTATION OF THE ACTUAL AND COMPARATIVE STRENGTH OF EACH OF THE PRINCIPAL GROUPS OF MUSCLES IN THE AVERAGE MAN AND THE AVERAGE WOMAN. MAN ———; WOMAN - - - - -.



GRAPHIC II.—GRAPHIC REPRESENTATION OF THE RELATION OF THE DIFFERENCE BETWEEN THE STRENGTH OF EACH GROUP OF MUSCLES IN THE AVERAGE MAN, AS COMPARED WITH THOSE OF THE AVERAGE WOMAN, TAKING THE STRENGTH OF THE MUSCLES IN WOMAN AS UNITY.



cles as compared with the whole body. This is graphically shown in one of the diagrams referred to.

*The Strength of Each Group of Muscles in the Average Woman as Compared with the Corresponding Group in the Average Man.*—(Table I, column III.) By referring to Graphic I, in which is shown the actual strength of each group of muscles in the average woman as compared with the corresponding group in the average man, the strength of man being taken as unity, it will be seen at once that the strength of the average woman falls far below that of the average man. A few comparisons will be found interesting:—

1. The thigh abductors, the group which is relatively strongest in women, have less than 2-3 the strength of the corresponding group in the average man; while the total strength of the average woman is but a trifle more than half that of the average man (53 per cent).

2. The following groups of muscles in woman possess a relative strength of more than 1-2 that in man: Latissimus dorsi, shoulder retractors, foot flexors and extensors, leg and thigh flexors and extensors, thigh abductors, thigh adductors, anterior trunk muscles, lateral trunk muscles, anterior muscles of the neck, muscles of expiration, as measured by the pneumatometer, and the leg muscles as a whole.

3. The following groups of muscles have, in the average woman, a relative strength of less than 1-2 that in the average man: Forearm pronators, forearm supinators, arm flexors, arm extensors, pectorals, muscles of inspiration, and the total for the muscles of the arms. The muscles of the arm, especially those of the forearm and those which act upon the forearm, are relatively the weakest muscles in the average woman.

4. The reasons for the unusual weakness of certain groups of muscles in women, are, in some instances at least, quite apparent. The weakness of the arm muscles is explained by the fact that women engage less than do men in laborious employments.

5. The legs are relatively stronger than the arms in women for the reason that the amount of exertion by the legs is more nearly equal in the two sexes than in the case of the arms. The greater strength of the thigh flexors is, perhaps,

due to the fact that the bones of the legs are, in women, shorter than in men, so that the muscles acting upon the thigh have a better leverage than in men. The same reason will hold good for the thigh abductors and adductors, which are relatively the strongest muscles possessed by the average woman. The greater width of hips perhaps affords another anatomical advantage to the muscles of the thigh in women.

These observations are entirely in harmony with the interesting fact pointed out by Quetelet and Sargent, that the thigh is not only proportionately, but actually, larger in women than in men. The thigh is found to be relatively larger even in girls of twelve, and in girls of fifteen it is two inches larger than in boys of the same age. Increase in the size of the thigh is, in fact, one of the very first of all the sexual characteristics of a physical nature which appears as the girl approaches puberty. It is interesting to note that the results obtained by the dynamometer entirely coincide in this particular with those noted by anthropometry.

Heretofore, there has been no means of knowing whether the larger thighs of women were the result of a greater proportionate development of the muscles, or simply a greater accumulation of adipose tissue. It is probable that both peculiarities in structure are present, but the dynamometer has clearly shown that the thighs in women are not only larger, but proportionately stronger, as compared with other muscles, than in men. As compared with men, the abductors are stronger in women of equal height than in the average woman, the relation being 72 per cent for the former, as compared with 65 per cent for the latter.

Many of the facts already noted, and others, are made more clear by reference to Graphic II.

6. The muscles which are relatively weakest in women are the forearm pronators and supinators, and the arm flexors. The latter muscles are 2 1-2 times stronger in men.

7. A very marked superiority in favor of men is also noticeable in the muscles concerned in respiration.

The inspiratory strength of the waist and that of the chest, both as measured with the dynamometer and with the manometer, or pneumatometer, are relatively much weaker in

women than in men, the disparity being : For waist inspiration, 1.18 ; chest inspiration, 1.24 ; and inspiration as measured by the pneumatometer, 1.25 ; or respectively, 2 1-5, 2 1-4, and 2 1-4 times greater strength for corresponding parts concerned in inspiration in man than in woman.

8. It is worthy of note, on the other hand, that the disparity in the case of expiratory strength, as measured by the manometer, is not so great, being only 86 per cent, or 1 6-7 times as great in man as in woman, the latter being unity. The explanation of this weakness of the inspiratory power in woman is clearly to be found in the impediment to inspiration afforded by the conventional mode of dress among civilized nations, and the resulting deterioration in muscular structures. It is quite safe to predict that such a deficiency would not be found to exist in the case of savage women.

The obstacle existing in regard to inspiration does not exist in relation to expiration, since the constriction of the clothing would assist, rather than interfere with, expiration. If it be argued that the hindrance to inspiration presented by tight clothing ought to act as a sort of gymnastics and discipline of the respiratory muscles, whereby they would acquire greater strength, it is only necessary to say in reply that one of the best established principles in relation to muscular development, is the fact that long-continued and unrelenting opposition to muscular movement finally results in the tiring out and disabling of a muscle, rather than in its superior development. This is clearly seen in various forms of spinal curvature, as well as in other acquired deformities.

9. The total for the chest falls at a point nearly as high as that for inspiration, the difference amounting to 1.20 in favor of the average man, indicating a total strength of the chest in the average man 2 1-5 times that of the average woman.

10. Another prominent point of weakness in woman is found in the muscles of the back, which are in the average man 2 1-5 times stronger than in the average woman.

We have here one explanation of the constant complaint heard from women, of tired back. This undeveloped condition of the muscles of the trunk, particularly those of the

back, may well be due to the constriction of corsets and tight skirt bands, and the consequent inability, as well as neglect, to make free use of the muscles of this portion of the body.

11. The pectoral muscles are also notably weak in woman, which quite agrees with the weak inspiratory power of the chest previously referred to.

A number of other interesting facts will be learned by a careful study of Table I. These are more clearly shown in the graphic diagrams opposite page 12. A few points may be briefly mentioned, as follows:—

*Relation of Strength to Height and Weight in Men and Women.*—Without going into all the relations of strength to height and weight which we have traced out, and which are based on the figures given in Table I, columns IV to VII, attention is called to the following as of especial interest:—

1. The strength of the average woman, in comparison with her weight, is less than 2-3 that of the average man, as compared with his weight.

2. The strength of the average woman, in comparison with her height, is only 4-7 that of the average man.

3. The total strength of the average woman as compared with the total strength of the average man is .53. The weight of the average woman as compared with that of the average man is .86. The height of the average woman as compared with that of the average man is .92. It thus appears that the average woman, while less than the average man in height, is still more inferior in weight, and presents a still higher degree of inferiority in strength. A comparative study of men and women between forty and fifty years of age would possibly show women to be somewhat less inferior in weight.

The full significance of these facts is recognized only when they are considered in connection with the law that weight increases with the cube of the height, whereas muscular strength increases only in proportion to the square of the height. This principle gives the shorter individual an advantage over the taller, so that while, according to this law, we might expect to find women weaker than men, they should not be weaker than men in proportion to their height.

To make this point clearer, let us take an example: The average strength of 12 men, each 70 inches in height, was found to be 5483 lbs. The average strength of 14 men, each 65 inches in height, was found to be 4653 lbs. The calculated strength of the men, compared with that of the average man, is found to be exactly 5425 lbs.,—only 58 lbs. less than the actual strength observed.

Applying the same rule in a comparison of men and women, the following result was obtained: The average strength of 25 men having an average height of 69 inches was found to be 4810 lbs.; the average strength of 34 women, 64 inches in height, was found to be 2652 lbs. The calculated strength of a woman 64 inches in height, obtained by the same rule, and taking the average strength of 25 men 69 inches in height as a basis, is 4130 lbs. By this we see that, applying the ratio of the square of the height as a means of determining the strength for a person of given height, women fall far short of the strength they should possess, the deficiency in the above case being 1478 lbs. In other words, the strength of woman is only 64 per cent of what it should be, as compared with man.

An actual comparison of men and women of the same height brought out the deficiency still more clearly. The average strength of 19 healthy women between the ages of eighteen and thirty years, 65 inches in height, was found to be 2660 lbs.; the average strength of 14 healthy men of the same age and the same height, was found to be 4653 lbs.

We find in these observations an interesting confirmation of the correctness of the principle that the strength of two persons of different heights will be in direct ratio to the squares of their heights. It also appears that the actual facts, as observed by the comparison of the average strength of a large number of men and women of equal height, agree very closely with those shown by calculation, since the 19 women with an average strength of 2660 lbs. should have had an average strength equal to that of the 14 men, whereas they fell short 1993 lbs., or 43 per cent. According to this, the strength of the average woman is 57 per cent that of the average man of the same height.

4. The strongest single group of muscles in the body in relation to body weight is the foot extensor group, which, in

men, lifts 4.4 times the weight of the body, and in women, 3.1 times the weight of the body.

5. The following groups of muscles in the average man (the muscles of both sides being included) are capable of lifting the entire weight of the body or more: Hand flexors, forearm supinators, deltoid, latissimus dorsi, pectoral, shoulder retractors, foot flexors, foot extensors, leg flexors, leg extensors, thigh flexors, thigh extensors, thigh abductors, thigh adductors, trunk anterior, trunk posterior, trunk lateral, inspiration (waist), inspiration (chest).

6. In women, the hand flexors, foot extensors, leg extensors, thigh flexors, thigh extensors, thigh abductors, thigh adductors, trunk posterior, and trunk lateral are each able to sustain a weight equal to that of the body.

7. Those muscles which are able to lift a weight equal to that of the body in men but not in women, are the following: Forearm supinators, deltoid, latissimus dorsi, pectorals, shoulder retractors, foot flexors, leg flexors, trunk anterior, inspiration (waist), inspiration (chest).

8. It is interesting to note that the strength of each division of the body is more than sufficient to lift the entire body; even the smallest total found—that for the chest in women—is able to lift  $1\frac{1}{4}$  times the body weight. The highest total for a division of the body—that for the legs—indicates, in men, a strength 16 times that required to lift the body weight. The arms in men are able to lift 11 times the weight of the body, while the muscles of the chest and trunk combined are, in men, capable of lifting 10 times the body weight.

9. The foot extensors are, in men, a little less than fifty per cent stronger than in women, when compared with the body weight, although the flexors are but a little more than 1-3 stronger in men than in women.

10. The strength of the inspiratory muscles as compared with the body weight in men, is nearly twice that of women.

11. The lateral muscles of the neck have a strength, in relation to the weight of the body, nearly double that of the same muscles in women, a fact which is readily explained by the greater size of the head in men.

12. The back muscles are stronger in men, in proportion

to total strength, doubtless in consequence of the heavier arms, shoulders, and head which these muscles are required to sustain.

*Relation of Strength to Height.*—In this relation, special interest attaches to the following figures, which express the number of pounds lifted for each inch in height:—

1. For men: arms, 22.5; legs, 33.4; trunk, 15.4; chest, 5.4; entire body, 76.7.

For women: arms, 11.7; legs, 21; trunk, 8.2; chest, 2.6; entire body, 43.6.

2. The strongest group of muscles in the body, in relation to height, is the foot extensors, which are able to lift a little more than 9 pounds for each inch in height, in men, and 5.78 pounds for each inch in height, in women.

*Relative Strength of Flexor and Extensor Muscles.*—(Table III.) It is evident that in order that bodily movements should be well balanced, the opposing muscles must be endowed with proportionate strength. With this fact in mind, the following comparisons are interesting:—

TABLE III.

RELATIVE STRENGTH OF OPPOSING MUSCULAR GROUPS IN MEN AND WOMEN.

(The group first mentioned is taken as unity.)

| MUSCULAR GROUPS.                         | Men. | Women. |
|--|------|--------|
| Hand: Flexors — Extensors.....           | 4.61 | 4.31   |
| Forearm: Supinators — Pronators.....     | 1.07 | 1.00   |
| Arm: Flexors — Extensors.....            | .74  | .91    |
| Latissimus Dorsi — Deltoid.....          | 1.32 | 1.39   |
| Pectorals — Shoulder Retractors.....     | 1.31 | 1.07   |
| Foot: Extensors — Flexors.....           | 4.23 | 4.09   |
| Leg: Flexors — Extensors.....            | .84  | .94    |
| Thigh: Flexors — Extensors.....          | .92  | 1.03   |
| Thigh: Abductors — Adductors.....        | .91  | .95    |
| Trunk: Anterior — Posterior.....         | .37  | .42    |
| Trunk: Right Lateral — Left Lateral..... | 1.00 | 1.00   |
| Neck: Anterior — Posterior.....          | .47  | .51    |
| Neck: Right Lateral — Left Lateral.....  | 1.00 | 1.00   |
| Inspiration — Expiration.....            | .35  | .29    |
| Arms: Flexors — Extensors.....           | 1.47 | 1.41   |
| Legs: Flexors — Extensors.....           | 1.41 | 1.50   |
| Trunk: Flexors — Extensors.....          | .58  | .63    |
| Entire Body: Flexors — Extensors.....    | 1.18 | 1.22   |

1. In the comparison of the relative strength of the flexor and extensor muscles, it is found that the greatest difference between the strength of the flexors and extensors exists in the case of the hand, in which, in men, the flexors have more than 4 1-2 times the strength of the extensors.

2. In the lower extremities, the foot extensors (corresponding anatomically to the hand flexors) are 4 times as strong as the opposing muscles.

3. The pronators and supinators of the arm are very closely balanced, as are also the arm flexors and extensors.

4. The latissimus dorsi is 1-3 stronger than the deltoid, and the pectorals are about 2-5 stronger than the shoulder retractors.

5. The leg flexors and extensors, thigh flexors and extensors, and thigh abductors and adductors, are very closely balanced.

6. The anterior trunk muscles are only 2-5 as strong as the posterior; the muscles of the right and left side are of nearly equal strength.

7. The anterior neck muscles have a little less than 1-2 the strength of the posterior muscles; while the lateral muscles of the neck are of equal strength.

This relation of the anterior and posterior muscles of the trunk and neck is evidently the result of the greater work imposed upon the posterior muscles of the neck and trunk in sustaining the head and body.

8. The force of inspiration is but 1-3 that of expiration, as shown by the pneumatometer; but with this statement must be considered the fact that the expiratory muscles have the assistance of the elasticity of the chest walls and of the lungs, which oppose inspiration, but aid expiration.

9. Coming to the totals, we find the muscles of the arms and legs standing upon a nearly equal footing. The flexors of the arms are a little more than 50 per cent stronger than the extensors, while the flexors of the legs are slightly less than 1-2 stronger. In the trunk the extensors are stronger than the flexors, the flexors having a strength of only 60 per cent that of the extensors.

10. Considering the entire body, the flexors are in men 20 and in women 25 per cent stronger than the extensors.

These facts are interesting from a physiological standpoint, though the cause has not been fully determined. It is probable, however, that it is to be found in the greater amount of work which, as a rule, is imposed upon the flexors.

In comparing the figures for men and women, it is observed that they run remarkably close together, so that the above remarks, which are based chiefly upon the figures obtained for the average man, apply with almost equal exactness to the average woman. Practically, the only differences are the following:—

11. In men, the forearm supinators are a little stronger than the pronators.

*The Strength of Each Group of Muscles, and of Each Division of the Body, as Compared with the Whole Body.*—(Table I, columns VIII and IX.) The most prominent point brought out by this comparison is the fact that the strength of even the strongest group of muscles in the body—the foot extensors, the muscles of the calf—is small when compared with the total for the entire body.

1. The strength of the foot extensors is, in man, about 12 per cent, or 1-8 of the total strength.

2. Next in order are the muscles of the back, which have a capacity of .073 that of the body, or a little less than 1-14 of the total strength—about 1-2 the strength of the foot extensors.

3. The hand flexors have a strength of nearly 1-20 that of the body.

4. The lowest point, with the exception of expiration and inspiration, as measured by the pneumatometer, is reached by the neck anterior, the capacity of which is only .7 per cent of the total for the entire body.

*The Strength of Each Group of Muscles (right and left) as Compared with the Strength of the Corresponding Division.*—(Table I, columns X and XI.) 1. The strength of the foot extensors is a little more than 1-4 the total for the legs.

2. The strength of the muscles of the back is more than 1-3 the strength of the entire trunk, exclusive of the chest.

3. The relative strength is found to be greater, in women, in the hand flexors, the hand extensors, the deltoid, the latis-

simus dorsi; the pectorals, and the shoulder retractors, as compared with the total for the arms. The foot extensors, the foot flexors, the thigh flexors, and the thigh abductors and adductors are also stronger in relation to the total for the legs, than in men. The anterior and lateral muscles of the trunk show a similar superiority; also the neck anterior muscles. It should be remembered, however, that in the total strength of the trunk muscles, the average woman is much inferior to the average man.

*Strength of the Muscles of the Left Side of the Body as Compared with Those of the Right Side.*—(Table I, columns XII and XIII.) In a symmetrically developed man, the muscles of the right and left sides should be found of equal strength, but the unequal training of the average man gives the right side of the body an advantage in the case of nearly every group.

1. In only three instances do the muscles of the left side exceed those of the right side, in the average man; viz., the thigh flexors, thigh extensors, and thigh adductors. Why the thigh flexors, extensors, and adductors should, in the average man, be stronger upon the left side than upon the right, is a question which I have not been able to settle. I have, however, for many years made this observation, and it is clearly shown in the average measurements made in more than one thousand men. It has occurred to me that, while we are right handed, we have a tendency to left-leggedness, and my observations certainly seem to justify this idea, although the totals for the right and left legs are found to be exactly the same, a marked deficiency of the flexors and extensors of the left leg, as compared with the right, serving to counterbalance the excessive development of the thigh flexors, extensors, and adductors.

2. In the average woman, as in the average man, the left side is ahead of the right at three points. Curiously, however, none of these points coincide with the corresponding points in men. The points of left-side superiority in women are found in the shoulder retractors, foot flexors, and leg extensors.

3. In women, there is a greater degree of asymmetry, as regards bilateral development, than in men. The total strength

of the left side of the body, in men, is 99 per cent that of the right side, so that the two sides of the body are very nearly balanced. In women, the total strength of the left side, as compared with the right, is a little less, or 98.6 per cent. This is what we should expect from the inferiority of woman, in relation to man, in muscular development.

*Comparison of the Muscular Strength of Tall Men with That of Short Men.*—(Table I, columns XIV to XVI.) The average heights of the groups compared were respectively: for tall men (15), 71.5 inches; for short men (39), 64 inches. No height in either group varied from the average more than one half inch.

In a comparative study of tall men and short men, it was found that tall men are at nearly every point stronger than short men. The total strength capacity for a short man was found to be 90 per cent that of a tall man. At four points only are short men superior to tall men; namely, the lateral and posterior muscles of the neck, the trunk laterals, and the deltoid.

The reasons for this difference are interesting. As has long been known, the difference between the height of short men and tall men is chiefly due to the difference in the length of the legs. The arms of the short man are longer in proportion to his height than are the arms of the tall man. In view of this fact, we should expect to find the relative strength of the arms in short men greater than that of the legs. In the case of the muscles of the trunk and neck, the short man has an evident advantage over the tall man, in that his muscles have a better leverage. Both the neck and the trunk are shorter in the short man, thus giving an anatomical advantage which is apparent in the records made by the dynamometer.

*Comparison of the Muscular Strength of Tall Women with That of Short Women.*—(Table I, columns XVII to XIX.) The average heights of the two groups compared were respectively: for tall women (64), 66 inches; short women (88), 61 inches. No height in either group varied more than one half inch from the average.

In the comparison of tall women and short women, it is found that short women, while showing a total average strength

of only 92 per cent that of tall women, are ahead at three points; viz., the pectorals, posterior trunk muscles, and the muscles of inspiration (waist).

The superiority of the pectorals is a characteristic which is not shown in short men, hence is probably accidental. The greater strength of the muscles of the trunk, and also of the waist-expanding muscles, is probably due to the anatomical advantage referred to in the case of short men.

It is interesting to notice that short women, as well as short men, show a superiority at this point over taller persons of the same sex. I think the fact is more than a coincidence, and is confirmatory of the explanation above given.

*Comparison of the Muscular Strength in Men and Women of Equal Height.*—(Table I, columns XX to XXII.) In the comparison of 45 men and 45 women of equal height, the average height being 65 inches, and no individual varying more than an inch from the average height, it was found that the average woman is slightly less inferior to the average man of the same height than is the average woman when compared with the average man, without reference to height.

The figures are 57 per cent for the woman of equal height as compared with 53 per cent for the average woman. Two or three points are especially worthy of notice. The thigh adductors and thigh flexors of the woman of equal height have a relative strength slightly less than that of the average woman, the figures being respectively 60 and 62 for the adductors, and 52 and 59 for the thigh flexors.

*Comparative and Relative Strength of Homologous Muscles in Men and Women.*—(Table IV.) In this comparison the flexors of the hand are compared with the extensors of the foot, and vice versa; the deltoid with the thigh abductors; and the latissimus dorsi with the thigh adductors.

TABLE IV.

RELATIVE STRENGTH OF HOMOLOGOUS GROUPS OF MUSCLES  
IN MEN AND WOMEN.

| MUSCULAR GROUPS.                          | Men. | Women. |
|---|------|--------|
| Hand Flexors — Foot Extensors.....        | .41  | .34    |
| Hand Extensors — Foot Flexors.....        | .37  | .33    |
| Arm Flexors — Leg Flexors.....            | .60  | .41    |
| Arm Extensors — Leg Extensors.....        | .54  | .43    |
| Deltoid — Thigh Abductors.....            | .68  | .53    |
| Latissimus Dorsi — Thigh Adductors.....   | .81  | .70    |
| Forearms — Legs.....                      | .76  | .59    |
| Arms and Shoulders — Thighs and Hips..... | .63  | .54    |
| Total Arms — Total Legs.....              | .67  | .56    |

This table presents the following interesting facts respecting the relative strength of homologous muscles:—

1. The hand flexors and hand extensors have each, in men, a strength about 2-5, and in women about 1-3, that of the corresponding muscles of the legs.

2. The arm flexors have, in men, 3-5, and in women, 2-5, the strength of the leg flexors.

3. The total for the arms is, in men, almost exactly 2-3 the total for the legs, and in women, a little more than 1-2.

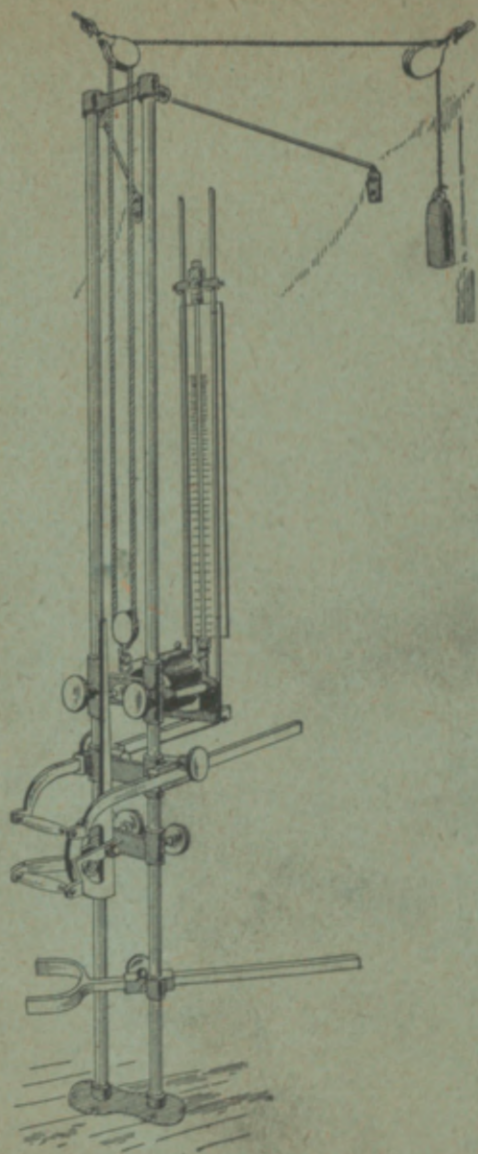
4. The forearm has, in men, 3-4 the strength of the lower leg; in women, 3-5.

5. The upper arm and shoulder have 3-5 the strength of the thigh and hip, in man; a trifle more than 1-2 in women.

It will readily appear that by aid of the data obtained with the dynamometer an almost infinite number of relations may be traced out.







THE AUTHOR'S UNIVERSAL DYNAMOMETER.