THE INFLUENCE OF EXERCISE ON GROWTH.

By HENRY G. BEYER, M. D., Ph. D.,
SURGEON, UNITED STATES NAVY.

The effects produced by exercise on the human body may be divided into immediate and remote, subjective and objective, ponderable and imponderable, permanent and temporary, real and imaginary.

The principal immediate, subjective, and temporary effect of almost all forms of exercise is a general feeling of well-being. It is quite immaterial whether the exercise which is being indulged in consists in walking, running, bicycle or horseback riding, playing football or lawn tennis, rowing in a shell, or doing gymnasium work of any kind, while in the midst of it, and while the supply of those substances in which our energy is stored up in the muscles is still equal to the demand or before breathlessness puts a stop to the enjoyment of our work, we invariably experience a certain sense of exhilaration, which must be actually felt in order to be properly appreciated. This fact also explains in a way the quite peculiar and often even startling enthusiasm of a great many people for the particular form of exercise during the taking of which they first experienced this feeling.

As an immediate direct consequence also of almost all forms of exercise, it is perfectly true that we sleep better and think clearer; we react, discriminate, and associate ideas quicker; we see, hear, and taste more distinctly; the functions of the skin and kidneys are increased; digestion and assimilation are greatly improved; the expansion of our lungs is greater and the contractions of the heart are stronger, blood pressure being slightly increased; and, finally, all the muscles, both voluntary and involuntary, contract more quickly and with greater effectiveness. Such effects as these have been abundantly recorded.

Now, whatever may be the more scientific explanations in detail which physical and chemical physiology and psychology have to offer for this temporary simultaneous increase in the functions of all these different organs and tissues, resulting from vigorous exercise of any kind, it remains an interesting fact. An increased supply of oxygen in the capillaries, together with a more rapid and abundant outflow of the products of wear and waste than takes place under the conditions of rest, seem to constitute the common primary cause of it all. The condition may perhaps not inaptly be compared with the simple shifting of the lighted candle from the normal atmosphere into one of oxygen. As the candle burns with greater brilliancy, as its wick is consumed more completely, and combustion is more thorough when in an atmosphere of oxygen than it would be if merely surrounded by ordinary air, so also during exercise must all those chemical processes be improved and quickened upon which depend not only the quality but also the quantity of the functions of the different cells of the body whenever brought in contact, as is the case during exercise, with an amount of oxygen from two to seven times greater, for a given time, than under conditions of rest, and when, furthermore, the products of such increased combustion are carried off so much more rapidly than is the case under normal conditions.

Such general effects as these, directly traceable to almost any form of vigorous exercise, are simple matters of daily experience, and every one of us has, no doubt, experienced and verified them frequently.

It is, however, quite different with regard to some of the more remote, objective, and permanent effects of exercise. The methods that must be employed in order to ascertain and define these precisely and with sufficient scientific accuracy, so as to make them absolutely convincing, must be more carefully chosen than has been done heretofore, and must rest upon a more substantial basis than do those that usually suffice for the determination of the effects of a merely subjective and temporary character.

Thus, for instance, it is not deemed sufficient to note or record

the various increases or changes in several different dimensions that take place during or after a course of exercises taken in a gymnasium in the cases of a number of persons, and which changes are usually determined by two sets of measurements taken before the course begins and after it is ended, for in the various increases or changes noted after this manner are contained not only those values that *may* be due to the exercise performed, but also those that *must* be due to the natural growth and development, and which are quite naturally expected to occur during the period of life occupied by the persons who are the subjects of such observations, as well as by the time occupied by the observations themselves.

In order, therefore, to determine exactly what increment of height, weight, lung capacity, or strength is due to exercise, we must first of all know what the amount of normal growth in these dimensions is that is expected to take place during such time as was occupied by the exercise and for the same period of life.

In other words, the absolute annual growth values for each and all the different dimensions must first of all be worked out before we can possibly deduce those values which may result from a certain given amount of exercise and before, it would seem, we had any very valuable reason or right at all to talk of the effects on growth and development of any particular form or system of exercises.

Now, normal-growth tables and curves in several dimensions of children of both sexes, and from the sixth to the eighteenth year of age, have been worked out by Bowditch* and Porter.† From the ages of sixteen to twenty-two years such tables and curves have furthermore been calculated and published from the records of 4,537 naval cadets.‡ It would, therefore, seem that we are in possession of a certain amount of valuable statistical material covering a period of normal growth from the sixth to the twenty-second

* The Growth of Children. *Twenty-second Annual Report of the State Board of Health of Massachusetts.*

† The Growth of St. Louis Children. *Trans. Academy of Sciences, St. Louis*, vol. vi, No. 12.

‡ The Growth of United States Naval Cadets. *Proceedings U. S. Naval Inst.*, vol. xxi, No. 2.

year of age, and which material is well calculated to serve the above-mentioned purposes.

The values of the absolute annual growth that are shown in these tables represent, of course, the averages for the number of subjects that were available for measurement between the different years. The figures given under the different percentile grades are likewise only average values. These average values naturally tell us nothing about the peculiarities in growth that are, without doubt, inherent in distinct types, but which it was impossible to eliminate and to study separately. Since, however, it may well be taken for granted that the racial composition of a nation changes but slowly, these average values may be expected to stand in a constant ratio to other averages derived from the same nation or parts of it, and consequently they may be safely employed for purposes of comparison with values derived by the same methods and obtained from identical sources. At any rate, these values, although perhaps not absolutely true, are the best that it is possible to obtain with the means at present at our command. Pure types of man in these modern times are the exception rather than the rule, and no country with a modern civilization exists which is free from composite types. So, then, while we freely and frankly admit that our averages are far from representing the American types, and while the growth curves constructed from them can not be true for every individual included in these averages, they may safely be pronounced true for the great majority of them, and consequently they are and must be comparable as such, if not to individuals, at least to averages derived by similar methods and from identical sources.

One of our objects is to utilize these averages for the purpose of showing whether or no our method of physical training which was introduced at the Naval Academy about three years ago has an influence on the growth of naval cadets as regards height, weight, lung capacity, and general strength over and above that method which was in vogue before that time.

To this end we began about three years ago collecting data somewhat as follows: Every cadet entering the Academy was accu-

rately measured, all the measurements being taken the latter part of September of each year. The gymnastic work during October and November consists mainly in a daily setting-up drill, and from December 1st to the last of March a regular systematic course in gymnasium work, leading from the lightest calisthenic exercises very gradually up to heavy gymnastics and apparatus work, is gone through with. The work is done in the form of drills, five times a week, beginning at 4.15 P. M. and lasting three quarters of an hour each. All the exercises have been carefully selected and arranged according to physiological principles, and the drills take place under my personal supervision. Special exercises are also taken by those of the cadets in whom previous examination revealed the existence of special defects as regards symmetry, so that it may be said that during the first six months, the only time during which gymnastic exercises are made compulsory at the Academy, such exercises are administered on the proper principles and under due and proper supervision.

The last of March all those of the cadets who have not dropped out of my original list by resignation or dismissal from the service are re-examined, and the results of such examinations are recorded, as was done in the first examination. The difference between the first and second examinations, it may be fairly assumed, is made up of the values of the absolute semi-annual growth in height, etc., plus that amount which is due to gymnastic exercise, other conditions of life being equal for all the cadets under observation and those from which the normal averages had been worked out, and with which alone we propose to compare our gymnasium averages.

The ages of the cadets entering the Academy vary from sixteen to twenty years, the average during the last four years having steadily remained at eighteen. We have then a period of growth to deal with which covers four years—namely, from sixteen to twenty years. Dividing now my one hundred and eighty-eight observations that have so far accumulated, and arranging them according to age, multiplying, furthermore, by two these semi-annual values obtained, thus converting them into annual ones, they are ready for being compared with the tables giving the normal annual

absolute growth in the same dimensions, and which were calculated from 4,537 cadets of previous years.

So far as height alone is concerned, I am in the fortunate position of being able to make a still more valuable comparison. Being in possession of the complete annual records of the heights of one hundred and eighty-six cadets for the ages of from sixteen to twenty-two years, I was able to produce a table according to the individualizing method, and which, therefore, is of far greater value than the one obtained by means of the generalizing method, in spite of the numbers in the latter being much larger.

The possession of these two tables, both showing the normal amount of growth in height, but derived according to different methods, enables me not only to compare them both with those obtained from the gymnasium records, but also to test, in a measure, the comparative value of the two above-mentioned methods by which the two tables showing the normal values were produced. In comparing these two tables with each other, the first thing that will be noticed is that the distribution of the annual growth values is very different in the two; but when we add these values together in each table separately, their respective sums are absolutely identical, being in both sixty-nine respectively. I am therefore inclined to believe that the sums in each and both are correct as applying to the material in hand. Moreover, the fact that the distribution of the values in the table produced by the individualizing method is so much nearer the truth and to nature than that shown in the other table proves conclusively that the individualizing method is the only one that will ever give us the correct values of the absolute annual growth that occurs between any two successive years of life. On examining the figures representing the averages derived from the individual records of one hundred and eighty-six cadets, and comparing them with those obtained from one hundred and eighty-eight cadets that were under observation in the gymnasium, a very striking similarity with regard to the distribution of the annual growth values may be noticed at once.

These two tables, graphically represented, would show two nearly

parallel lines, a circumstance arguing strongly in favour of the conclusions drawn from a comparison made between them.

It would appear from these figures that a positive increase in height may be attained through properly systematized gymnastic exercise, when administered between the years sixteen and twenty, amounting to 26·6 millimetres over and above that which may be expected to take place without such exercise. (See Table I.) The largest amount of gain in height occurs between sixteen and seventeen years, being 38 millimetres, or 10 millimetres more than the normal increase. This is in perfect accord with the laws of growth, for it is well known that the younger a person the greater also are his chances for growth, and it would seem a most natural inference to make that any agent influencing growth favourably would likewise have its best chance to assert itself at that time. For the remaining years, or from seventeen to twenty-one, a surplus of about 4 millimetres is steadily gained over the normal values.

It is perhaps not altogether superfluous to mention here that all the cadets before coming to me for their first measurements have had at least one month's setting-up drill, swimming, and infantry drill. About one half of their number entering during the month of June have, of course, had these same drills for a much longer time. All of them have, furthermore, passed a satisfactory physical examination before a board of experienced medical examiners. The material on which these examinations or observations were made may be safely accepted as normally developed and well set up at the time of their first examination by me.

TABLE I.—*Height.*

		AVERAGE INCREASE IN MM. BETWEEN THE YEARS					
		16–17.	17–18.	18–19.	19–20.	20–21.	Total.
1	From records of 4,537 * naval cadets, normal values.....	28	6	15	19	1·0	69·0
2	From records of 186 continuous individual cadets, normal values.	28	20	12	7	2·0	69·0
3	From records of 188 cadets influenced by gymnasium exercise.	38	24	16	11	6·6	95·6

* In this number are included several hundred who left but the records of one examination; they were afterward rejected in the mental examination, and, consequently, never became cadets.

The total amount of increase in height to be deduced from the adjoining table being 26·6 millimetres, or a little more than one inch, is, perhaps, not quite up to the true gain in this dimension, but rather a little below it, our normal standard having been obtained from naval cadets whose training at the Academy as well as on board ship implies an amount of exercise over and above that which is implied in the education of the average individual at either the high school or college, and from the effects of which it was, of course, impossible to disentangle our normal averages.

Now, a gain in height of one inch during four years of systematic exercise may perhaps not seem a very great reward for the time spent. On further thought, however, it is of the greatest importance when applied to an entire nation or race, whose very existence may depend on the physical resources and strength of its individual members, as it sometimes does even among the most civilized. The struggle for existence, in the physical sense of that term, has not yet come to an end, and modern civilization, instead of preparing for this end, seems, on the contrary, to be preparing man for still greater and graver struggles in the near future than he has had to encounter in the past.

Throughout these observations it was clearly shown * that the taller a cadet was at the beginning, the greater also was the amount of weight and strength that was gained by the exercise he was made to perform. It was invariably observed in every series of observations that those of the cadets whose gain in total strength was over one hundred kilos were also taller and heavier than those whose gain in this respect fell below one hundred. An increase in height, therefore, means a corresponding increase in weight as well as strength. Consequently we incline to the opinion that height is the most important consideration in an investigation of this character, and any agent that influences growth in height in man influences growth in bone. Growth in height practically ends at the age of twenty-one years, while weight and strength may be increased al-

* See *Reports of the Surgeon General to the Secretary of the Navy* for the years 1893, 1894, and 1895.

most indefinitely and to a much later age, and when we speak of the growth of man in a general sense we always imply growth in height.

Both Bowditch and Porter have shown that the period of the most rapid growth for boys occurs between the ages of thirteen and fifteen. Our observations begin with boys of sixteen years of age, a time when the period of the most rapid growth for the average boy has passed. Now if, as is clearly shown by our table, it is possible to add one inch to our height by means of systematic exercise after the age of sixteen, the inference is rendered very probable that we could add still more to it if such exercise were applied earlier. This must be equally true for growth in the other dimensions.

TABLE II.—*Weight.*

		MEAN INCREASE IN KILOS BETWEEN THE YEARS					
		16–17.	17–18.	18–19.	19–20.	20–21.	Total.
1	Records of 4,537 naval cadets, normal values	3·6	3·2	2·4	0·7	0·2	10·1
2	Records of 188 observations in gymnasium.....	8·8	6·6	6·6	6·6	6·4	35·0

Examining the figures presented in the second table, we find that a very decided increase in weight has taken place, which increase is due to exercise. The amount of increase is greatest between the years sixteen and seventeen, just as was the case with regard to height, but, unlike what was observed in the table of the heights, the various additions of weight due to exercise remain practically uniform for each year from the seventeenth to the twenty-first.

The sum of 35 kilos, or about 77 pounds, is therefore considered a much larger proportionate amount of increase for weight than was noticed with regard to height. This shows well how much easier growth in weight is influenced by exercise than is height. Weight, on the other hand, is likewise easily and quickly lost. Height, once attained, is rarely, if ever, lost again.

The figures in Table III show clearly that an increase in lung capacity has occurred above the normal amount between each year

from the sixteenth to the twenty-first. The respective annual values are steadily diminishing from the sixteenth to the twenty-first year in both the normal records and those obtained in the gymnasium; they stand, therefore, in a more constant ratio to the various values presented in the table of the heights than to those given in the table of the weights, which remain practically uniform from the seventeenth year on to the twenty-first.

TABLE III.—*Lung Capacity.*

		MEAN INCREASE IN LITRES BETWEEN THE YEARS					
		16–17.	17–18.	18–19.	19–20.	20–21.	Total.
1	Records of 4,537 cadets, normal values.....	0·250	0·167	0·152	0·083	.....	0·652
2	Records of 188 observations in gymnasium.....	0·658	0·540	0·462	0·376	0·340	2·374

This must be regarded as an observation of some importance, since it has a bearing on the "vital index" of Demeny, or the ratio of lung capacity to weight $\left(\frac{LC}{W}\right)$. A high vital index is deemed an attribute of perfect training. In order to attain a high vital index, the lung capacity must show a greater proportionate increase than the weight, for the greater the capacity of the lungs and the less the weight of a person, the higher will be this index. Thus, for example, the mean vital index, calculated from the records of 4,537 cadets, was found to be 0·077 at the age of twenty-three years, which is considered a very high index.

From a physiological point of view, nothing would appear more rational or more desirable than to acquire a proportionate addition to our lung area for every pound of increase in muscular substance which we gain during the exercise which we take. Comparing now the figures presented in Tables II and III, respectively, it will be noticed, while the various additions to weight (not necessarily all muscular substance, of course) between two successive years remain practically uniform in amount, that the corresponding additions to lung capacity show a uniform and steady decline from the beginning

to the end. The ratio between these two items, in other words, as represented by the figures in the two tables, would indicate a steady and continued decrease in the value of the vital index directly due and traceable to the quality of the exercise which was performed.

If, therefore, the significance of this vital index as a criterion of good training is maintained, then our system of physical training would clearly have the fault of adding on too much weight. I would not be willing to admit the other alternative—namely, that the development of the lung capacity was in any way neglected or its importance underestimated. On the contrary, all possible means of training and instruction are employed to develop the lung capacity to the greatest possible extent. Thus, for example, after this observation was made for the first time, more running was practised than had been done the year previous; but still the results remained obstinately the same, and the vital index invariably became smaller in those of the cadets who had gained both weight and strength in amount far above the average. This was noticed and expressed in my first publication on the subject,* and has since been noticed to recur every year with regularity.

I was then, and am now, a firm believer in the value of this index, because it is based upon sound physiological principles and because of the high authority from whom it has emanated.

If the results obtained from our method of training show a decrease in the index, which results are contrary to the expectations, we should be inclined first to look for the fault in our methods of training rather than to question the validity of this index as a test of the condition of training.

It is likely, or at least more than merely possible, that we may here touch one of the more vital points in connection with the whole subject of physical training. If, for instance, we admit, as I think we must, that an increase in muscular strength is necessarily accompanied with a proportionate increase in the weight of our muscles, whether this ratio is a decreasing one or not; if, furthermore, this increase in weight be out of proportion to the simultaneous increase

* See *Surgeon General's Report to the Secretary of the Navy*, 1893, p. 155.

in the lung capacity, and, consequently, result in a decrease in the vital index—it is, as mentioned before, more than merely possible that a person's capacity for carrying both strength and weight has been reached to the fullest extent consistent with the most perfect health of that person.

If by further researches this supposition could be proved as correct, we should be in possession of a most valuable means for determining the weight and strength capacity for every person undergoing physical training. We should then, moreover, be in possession of a simple means by which we might pronounce judgment that is worthy of the name on the comparative merits of the different so-called "systems" of gymnastics in vogue, thus forever putting an end to that everlasting war of words that has been waged about them for very nearly one hundred years without making us any wiser.

TABLE IV.—*Total Strength.**

		MEAN INCREASE IN KILOS BETWEEN THE YEARS					
		16–17.	17–18.	18–19.	19–20.	20–21.	Total.
1	Records of 605 cadets, normal values.....	39	56	43	69	61	268
2	Records of 188 observations in gymnasium.....	266	200	236	230	244	1176

The foregoing Table IV shows plainly that exercise is followed by a very large increase in muscular strength. Advancing years, at least within the limits of those presented by the table, seem to make no difference in the amount of gain in strength, as is the case with the other items treated of in this paper. The average annual increase in total strength that was calculated from six hundred and five cadets for the years from sixteen to twenty-one is 55·6 kilos; that due to gymnasium exercise is 235 kilos, exceeding the normal nearly five times. Indeed, the increase in strength following exercise which is systematized and well regulated is generally so rapid and occurs with such great regularity that it has long since ceased to astonish

* For an explanation of what is meant by "total strength," the reader is referred to an article in the *Amer. Jour. of the Med. Sciences*, September, 1894—Football and the Physique of its Devotees, etc., by H. G. Beyer.

me, and I firmly believe that the now so wonderful performances of most of our "strong men" are well within the reach of the majority of healthy men, if such performances were a serious enough part of their ambition to make them do the exercises necessary to develop them. Nothing, in fact, seems to be more natural to our composition and organization than to immediately provide an increased supply of strength in answer to an increased demand made upon it through the performance of muscular work. This is true not only for the period of normal growth which comes to an end at the age of twenty-one years, but also for that period which reaches well into middle life.