Physical Education; By Muscular Exercise

Luther Halsey Gulick

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PREFACE

The material in this little book grew up gradually through the exigencies of a lecture course on the Philosophy of Exercise. The subject-matter appeared in the " Y. M. C. A. Athletic League Letter" in 1899-1900.

The range of topics discussed indicates my indebtedness to many persons. My first impulses toward working out my own thought on the subject came from my instructor, Dr. Dudley Allen Sargent, of Harvard University. The direction of my study was largely influenced for years by Dr. E. M. Hartwell, then of Johns Hopkins. To the inspiration of President G. Stanley Hall I owe the biologic point of view. To Dr. Wm. T. Harris I owe my first thought in regard to the relation of exercise to the vegetative processes. To Dr. T. M. Balliet, Superintendent of Schools, I also owe much. I do not wish to saddle these gentlemen with the responsibility for these ideas, for many of them are my own.

If I have succeeded in my endeavor this book will be of service to those who wish a general view of the subject, whether for use in medicine or education.

L. H. G.

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2. In relation to the development of the individual in structure and function.

3. In relation to general somatic vigor. Somatic vigor is the essence of that power of resistance which the organism shows to the invasion o: disease. It is well known that the power of resistance varies much in the individual from time to time; pathogenic bacteria will at one time be destroyed promptly, while at another they will gain a foothold and multiply.

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PHYSICAL EDUCATION BY MUSCULAR EXERCISE

CHAPTER I

EXERCISE AND DEVELOPMENT

General Aim. Exercise and Evolution. City and Exercise. Occupation. Schools. Balance between Neural and Muscular Expenditure. Special Classes. Exercise in Accordance with Function. Physiology of Exercise: Effect on the Muscle-cell; Effect on the Body as a Whole; Special Effects of Muscular Exercise; Position during Exercise; Physiologic Load. Neurologic Considerations: Moderate and Excessive Exercise; Physical Exercise and Cerebral Development of the Brain; Fatigue; Co-operation among Contiguous Nerve-centers; Muscular Contraction and Psychic Activity. Limits of Specialization in Exercise; Somatic Harmony; Competition. Dosage of Exercise.

General Aim

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Disease must be avoided by the prevention of inoculation; but, what is of equal importance, it must be averted by the maintenance of such bodily vigor that the maximum of resistance will be offered by the organism itself.

Special Considerations.–The physician has three questions to answer about muscular exercise: 1. What specific exercises will be effective in given pathologic states?

Under this head I discuss nothing here. It is my province to examine the general effects of exercise together with the detailed effects of specific exercises and sports. The application of these effects to the treatment of disease will be found elsewhere in this volume (Part I, Section II).

2. What character and quantity of exercise are needed for the growing organism, to insure balanced development? Physicians must pass upon the claims of various systems of gymnastics that are offered for adoption by schools, as well as upon the necessity for, and the character of, work outside of school. It is hoped that the data given will be sufficient for full and intelligent answers to these questions.

3. What exercises are best adapted under various conditions, such as age, sex, and the like, to render most active the general somatic life of the individual? This question I hope to answer with some degree of definiteness.

I am aware that some of the more important conclusions here set forth are not in accord with the accepted doctrines of many teachers of physical training; yet these views will be seen to have their justification both in clinical experience and in biologic science. While I shall in the main confine my work to conclusions and their practical application, certain preliminary considerations need to be stated, to form a rational basis for the practical directions that follow.

Exercise and Evolution.–Those conditions under which the body was given its present size, shape, and structure are in general the conditions adapted to maintaining the fullest functional activity. During the unnumbered years of evolutionary time, muscular exercise in labor, war, or the chase has been one of the major elements of human experience. Upon neuromuscular ability the race has depended for survival, even when its ancestors were in a condition of development yet more elementary than that of savage life. A biologist, having brought to him a human body and being asked for a statement of its functions from an examination of the structure, would say that both in form and function the organism must have been adapted to a life of considerable muscular exertion; that this appeared, first, from the proportions of the muscular system; that the lungs as well as the heart indicated far more capacity than would be needed for a life exclusively or even largely sedentary; and, finally, that the nervous system was designed predominantly for

EFFECT OF CIVILIZATION ON MUSCULAR DEVELOPMENT. 3 the initiation or control of muscular movements. The health of such an organism depends upon the balanced co-operation of all its parts. These parts have become adjusted to a certain general balance in the activities of the nutritive, neural, and muscular tissues. No argument is necessary to the evolutionist to show that the necessity for muscular exercise has been constant and predominant throughout the whole history of the life of the species; that it has been so constant and so large a factor in adjustment to the total environment as to have had a chief share in determining the character of the organism itself; and that those conditions which have been decisive in determining the form and functions of the organism are the conditions in which it functionates the best.

The argument for muscular exercise from the standpoint of evolution is thus the strongest that can be presented. The environment of the organism cannot be changed in other respects with impunity. Man has become adapted to breathing air of a certain approximate constitution, and he is at his best in this environment. He has become measurably able to carry his environment with him with reference, for instance, to temperature, and somewhat with reference to light; but the general fact remains that perfect adaptation to environment is most definitely related to health.

City and Exercise.–Man has by conscious direction so utilized artificial coverings as to be able to maintain a certain thermic environment in spite of variations in the natural temperature of the atmosphere. The time is rapidly approaching when he must generally take as consciously. under his direction the matter of muscular exercise, because the process of civilization is taking away from him those natural demands for muscular exercise which have been its efficient cause during the ages of evolution. The conditions of human life in civilized countries have changed more since the development of the steam-engine than they had for thousands of years previously. In the United States the proportion of steam power to manual labor is represented by a steam-engine of nj horse-power to every male adult inhabitant. The bulk of the heavy work in the civilized world is done by machinery and not by human muscles. There is still a good deal of muscular work performed, but it is decreasing rapidly. It is least among the most civilized peoples, and among these peoples is least among the most civilized classes. The management of machinery demands not muscular force, but muscular skill and intelligence.

Occupation.–In connection with this specialization, there have arisen a whole group of so-called diseases of occupation, some of these related definitely to the specialization itself–such as writers cramp.

In the handling of machinery the tendency is to have individuals make comparatively few movements many times. The more general activities of early farm life called for a far more varied set of muscular movements. For example, personal experience on the farm for a short period embraced the following forms of exercise: driving the cows home and milking them, caring for horses and stables, sharpening tools, handling hay and grain with pitchfork, driving a horse-rake, digging potatoes, cleansing large milk cans, making wooden handles for tools, dishwashing, building rail fence, chopping wood, helping with cross-cut saw (two men), working on a threshing-machine, hoeing weeds in a potato patch, husking corn, sawing wood with a buck-saw, repairing in woodwork, helping to build a stone fence, digging out woodchucks, hunting gray squirrels, and a multitude of minor exertions that slip the memory. Let these activities be compared with those of the mill operative who "tends a machine" of some kind, or with those of the salesman in a store, or the clerk in a bank, and the contrast becomes evident.

Finally, it is to be remembered that the process of urbanization is a progressive one, needing continually greater attention from the physician. In 1790 considerably less than 4 per cent, of the population of the United States lived in cities and villages. A general comparison with the present condition is hardly fair because of the immense tracts of sparsely settled country that have been acquired since then; but in spite of this, the census of 1900 (Abstract of Census, page 38) shows that only 59.8 per cent, of the population are now classified as living in country districts. The change from 96 per cent, to 59.8 per cent, in one hundred and ten years is instructive. The lesson is still more dramatically told by a study of the urban growth in some of the more stable eastern States Massachusetts has only 8.5 per cent, in country districts, Connecticut

25.1 per cent., New Jersey 29.4 per cent., New York 27.1 per cent., Rhode Island 5 per cent.

Schools.–Another process that is rendering conscious attention to muscular exercise necessary is the growth in school population, and the increase in the length of time during which children go to school. In 1840, out of a total population of 17,069,453, there was a school population of 2,025,565, or ii per cent. In 1890, out of a total population of 62,622,250, there was a school population of 14,768,965, or 23 per cent. The normal life of the child is one of steady activity during the waking hours. We are taking away for five hours a day a large part of this activity. It will be shown further on that exercise is fundamentally related to growth, so that the harmfulness of this lessening of exercise by school limitations during the early years of life is readily seen. Not only

EFFECT OF CIVILIZATION ON MUSCULAR DEVELOPMENT. 5 is muscular exercise decreased by school life, but pressure is brought to bear to increase the attention to psychic things. Thus, there is a coincident decrease in muscular expenditure and an increase in lines that are purely neural.

Intercommunication.–There are further factors that are changing the balance between the neural and muscular expenditures of the body; for instance, in modern life the growth of the news-communicating agencies, shown not only in the tremendous increase in the postal service, but in the development of the telegraph, the telephone, and the daily press. Two kinds of results may be traced to these sources: 1. A vast increase in the amount of business done in a given time, without any decrease in the necessary expenditure of thought. That the modern business man accomplishes a vastly greater quantity of business than his ancestors did in the same length of time is as evident to those who are familiar with modern conditions as it is impossible to set forth statistically.

2. News-communicating agencies bring us into contact with the whole world as never before, and thus emotion, which is a peculiarly exhausting form of psychic activity, is stimulated. The daily press deluges our minds with the tragic occurrences of the world. Then, again, the development of city life diminishes the amount of sunshine that the average individual will get, and in most cases also the quantity of fresh air. The tremendous growth in the use of drugs affecting the nervous system reflects a corresponding increase in disorders of that system. The increase in womens diseases with the progress of civilization, and the decrease in the muscular work of women, are more than mere coincidence, as is shown by the comparatively robust health of women who do regular physical work; even when it is carried on to the extent found among female acrobats working in circuses, we still find great health and vigor, contrasting markedly with the health of women whose lives have but little of muscular activity. Attention has frequently been called to the inferiority of stock born and bred in the conditions of city life. This was first pointed out by Rousseau, and has been since stated repeatedly. It appears that the city is a sort of biologic furnace which in the course of three or four generations pretty thoroughly burns up vitality, and that the addition of country stock is essential for the perpetuation of family life in the city.

General Results.–All these differences coincident with civilization and the development of the city are disturbing the balance of expenditure between the neural and muscular systems. In muscular exercise there is the neural element, but in mental and emotional activity there is not the muscular. The result is a new balance in the total activity of the body, a different environment with reference to activity from that which the organism is adapted to, or has previously had.

Special Classes.–Let us now note a little more in detail the different classes in the city with reference to their physical activity. The workers in factories and shops, handling machinery for approximately ten hours a day, make an immense number of movements of a more or less uniform character. The clerical classes–bookkeepers, stenographers, salesmen–have considerable walking to do, handling goods, going on errands, and the like. Most of them do no work that involves deep breathing or quickening of the circulation. Their muscles do not have a physiologic amount of labor from one months end to another, except the small muscles involved in writing or similar occupations. We find them as a class with sunken chests, small arms, more or less round-shouldered, and with but little physical endurance or muscular strength. The cardiac muscle is not specially vigorous. Business men lead lives that are largely sedentary. The burden of their work is done at the desk. Such men are often fat, with protuberant abdomens. They have even less muscular labor to perform than the clerical class. Women who work in factories have already been considered. Women who do domestic service have sufficient muscular activity of varied character, and so far as this element is concerned nothing is needed. Mistresses of households, while they are about a great deal, do so little work involving activity of the large groups of muscles that these muscles are rarely in a condition of normal vigor. Manual laborers in a community are comparatively healthy.

The object of the discussion so far is to show that in civilized communities the environment that has been making during untold ages for the present shape and functions of the human body has so changed that the normal requirements of daily life for muscular activity are insufficient to keep the organism in that condition of vigor necessary to the best health; and hence that to maintain the body in conditions of health and vigor, conscious attention to this factor of environment is of increasing necessity.

FUNCTION MAKES STRUCTURE

This, the well-worn formula of the evolutionist, may be applied in two directions. First, it implies that to produce any given effect upon the structure of the organism, we should institute exercises that are calculated to achieve the desired perfection of structure. Secondly,

EXERCISE IN ACCORDANCE WITH FUNCTION 7 it implies that except under certain pathologic conditions, the kind of exercise best adapted to produce the balanced and healthful development of the body as a whole or of its parts is, in the main, the kind of exercise for which the part exercised is best adapted.

The first point needs hardly more than the statement. Leaving out of account pathologic cases, if the heart is to be increased in structure we prescribe gradually progressive exercises that make a greater demand on the heart, with the result that it is gradually built up to meet this increased demand. Upon this is founded the special work of Oertel, Schott, and others. If the muscles of the upper extremities seem to be deficient in size, we prescribe exercise that demands the functioning of these muscles, and we expect the function to be the indirect agency that shall produce growth and structure. If we find the muscles of the back of a growing girl flabby and poorly nourished, with the spine in the early stage of scoliosis, the first indication is to increase the power and efficiency of the faulty muscles. This is accomplished by increasing the function of the parts, and the structure rapidly follows the function. This general law applies not only to the development of muscle-tissue, but to other tissues as well. It has been shown that the bones of both horses and men that do work in which power is demanded have a heavier specific gravity and a greater density of structure than the bones of those engaged in less laborious occupations.

The second application of this formula is that the body as a whole, and each of its parts, is best exercised in accordance with its natural function. The far-reaching character of this principle is not easily seen at first glance. The upper extremity is obviously adapted for the handling of objects. The great range of movements allowed by the shoulder-joint as contrasted with the hip-joint, the structure of the forearm as compared with the leg, allowing not only flexion and extension, but pronation and supination in the arm, the more delicate structure of the hand, the independence of the phalanges, the more differentiated nerve-supply to the muscular tissue–all point to a difference in function in these two organs: the lower extremity as a whole being adapted for power, the upper extremity for varied action, delicacy, quickness of movement, and the like. It is true that the upper extremity may be trained so that the weight of the body shall be handled by it alone for considerable periods. This is done by performers on the horizontal bar, the German horse, rings, and the trapeze; but it is a departure from the normal function of the arms and results in limitation of the movements at the shoulder-joint, the stiffening of the ligaments of the hand, and general perversion of function. On the other hand, it is possible to train the legs to exer cises of great skill and delicacy; jugglers who learn to handle objects with their feet while lying on their backs accomplish this result; but in neither case are the results worth the labor expended. They are not in line with the natural functions of the organs, and the best development of each part of the organism is related to its natural function. Our aim should be not to see what each part can be trained to do, but to get each part into its normal condition. The body can be trained to do and to endure many things that are not only useless, but harmful. Because a man can learn to walk on his hands is no sufficient argument for men to adopt that mode of locomotion; because the shoulder-joint can be made to resemble somewhat the hip-joint is no reason why it should be made to do so; so that, excepting conditions dependent upon pathologic states, it may be safely said as a general proposition that the exercise of the body as a whole, and of its parts in particular, should be related to the natural functions of the part.

Vis naturae.–With normal heredity and normal environment the individual will develop a balanced organism. The constant tendency of the organism is to develop along suitable lines. Upon the germ plasm is written the law of development of the individual. Environment may hinder or accelerate this development: if it is one-sided or otherwise perverted, the results will be abnormal, but the essential character of the protoplasm cannot be altered. This fact is of supreme importance in the physical education of the young. It has been customary to measure the various parts with great exactness, and then to attempt to prescribe exercise that shall meet the specific needs of each part, as shown by its deviation from the average of the species. Theoretic reasoning as well as experience shows that such work is generally useless. What is needed in normal cases is to supply normal conditions of food, rest, exercise, sleep, and the like. That which is a perfectly symmetric body for one person will not be so for another. When the deviations from the average are so marked as to be pathologic, or when there is specific disease that must be combated, the conditions are somewhat different. What are now referred to are the smaller differences, which are entirely normal. For instance, the fact that the left arm is a quarter or even half an inch less in girth than the right arm is not a matter for special consideration. If both arms be given vigorous work, they will become equal not only in measurement but in power as well. This I have repeatedly demonstrated upon both the growing and the full-grown organism. It is commonly said that the girth of the neck and of the flexed upper arm and of the calf should be the same, and some have spent much time in the endeavor to secure such measurements; but more basal than such arti-

PHYSIOLOGY OF EXERCISE 9 ficial conception of symmetry is the standard of development contained in the germ plasm of each person. If vigorous all-round exercises produce such measurements in the individual, they are then the best for that individual. If not, the endeavor to secure them is prejudicial rather than helpful. In subjects of so-called nervous temperament, with long, rather slender bones and small joints, the muscular proportions differ from those in whom opposite conditions obtain, and the attempt by means of artificial standards to force individuals of these two types into the same physical form is most unwise. We may demand similar functions from the bodies of the two, but the proportions of the body will take care of themselves. It is our business to furnish a suitable environment and demand the normal functions. Natural tendencies may then be depended upon to render the structure normal, or at least to give it that type best adapted for the life of the individual.

PHYSIOLOGY OF EXERCISE

The contraction of a single muscle involves three major elements: activity in the motor center, a nerve-current to the muscle, contraction of muscle-fibers. Let us note the general effect of exercise in these three divisions.

Effect upon the Muscle-cell.–The contraction of the muscle-substance is accomplished by a mechanism as yet beyond ultimate analysis. Energy is expended. Some of the highly complex cell-constituents are broken down and extruded. The cell at once proceeds to absorb from the surrounding plasma additional food materials, particularly carbohydrates and oxygen. Thus, muscular activity results in the constant change of some of the essential elements of the muscle-cell itself, which is kept in a state of increased efficiency proportionate to its use. Both the number and the size of muscle-cells are increased by exercise. The sar-colemma appears to be slightly increased in strength. The growth in this, the fibrous part of the muscle, is well shown in the toughness of muscles taken from animals that are heavily worked as compared with those that are not so worked, or with the flesh from animals that have never been worked hard; the fibers being coarser and heavier, the tendons thicker and less yielding, the whole muscle firmer.

General Effects of Muscular Exercise

The absorption by the muscle-cells of oxygen and carbohydrates from the blood plasma has immediate and ultimate effects upon the body as a whole. When muscular energy is expended, the blood is altered in constitution. Such blood flowing through the respiratory center in considerable quantities causes increased respiratory movements. All the muscles of respiration are thus brought into immediate and often vigorous action, even the accessory muscles being called on promptly when there is particular need of rapidly augmenting the oxygen supply. The blood circulating through the lungs makes up its oxygen tension, the added activity of respiration changes the air in the lungs, with the result that during exercise the percentage of oxygen in the lungs is greater than usual. The contraction of the muscular fibers squeezes the lymph-vessels and the smaller veins so that blood and lymph are pressed onward toward the heart. This, together with stimulation of the centers governing circulation in the medulla, causes increased cardiac activity. The quickening and deepening of respiration also are effective in the aspiration of the thorax. By these various means the circulation of the blood is at once markedly stimulated, and the arteries supplying the muscles exercised are immediately somewhat dilated. We thus have a completely adjusted mechanism for augmenting food-supply and eliminating waste. The muscle-cell eliminates the products of combustion in the form of carbon dioxid and of urea or some of its antecedents. These are carried away by the circulation, which is now accelerated, the carbon dioxid being eliminated by the lungs, the urea by the kidneys. The greater consumption by the cell of carbohydrates and proteids affects the organism in ways that are somewhat analogous to the enlarged need of oxygen, but instead of causing oxygen hunger there is produced hunger for food. Through the influence again of the vasomotor system, the whole digestive tract comes eventually into a state of heightened activity, in part owing to the increased blood-supply, but chiefly to direct neural stimulation. The consciousness of hunger is more marked, and gradually the normal individual will be led to eat more food as certainly and as definitely as he is prompted to breathe more air. A third group of activities is due to the heat evolved by the rapid combustion in the muscles. This is kept down by the dilatation of the superficial arteries and capillaries which increases surface radiation. At the same time the sweat-glands are influenced through the sympathetic nervous system to operate with more or less vigor, throwing sweat upon the skin. The evaporation of this sweat cools the body, and is a potent factor in preventing the rise of the body-temperature. Thus, through muscular exercise, the function of respiration, circulation, nutrition, and excretion are all profoundly affected, and the heat-controlling mechanisms of the skin and sweat-glands are stimulated to greater action.

Special Effects of Muscular Exercise.–Let us now examine somewhat more in detail certain special features of bodily exercise.

SPECIAL EFFECTS OF MUSCULAR EXERCISE II

Every muscle tends to contract, even during rest. This is due to two causes: the elasticity of muscle-tissue, and a certain amount of stimulation that is constantly being sent to the muscle. The tension is greater when the muscle is healthy and when its proper nerve-center is in normal state, than when other conditions obtain. Again, the strength of this contraction varies directly as the strength of the muscle; thus, when the pectorals are developed out of proportion to the trapezius and other muscles, the normal pull of the pectorals will overbalance the pull of the trapezius and rhomboidei, with the result that the shoulders will be drawn forward. When the flexors of the fingers are developed far more than the extensors, the fingers will hang in a semiflexed position. The tendency of much of the gymnastics of the heavy type performed on gymnastic apparatus is to develop the flexors not only of the arms, but of the trunk, more than the extensors, with the result not only that the hand is nearly contracted when at rest, the elbow hanging partially flexed, but the shoulders are drawn forward, the spine is bent, and the ribs are depressed by the action of the recti and the two obliques. In order to preserve the balance of power between the flexors and extensors of the arms, and particularly of the trunk, it is necessary to give approximately twice as much work to the extensors as to the flexors. Thus, in doing work with the pulley-weight apparatus, a person should spend approximately twice as much time facing the apparatus as with the back to it.

Muscles and ligaments tend to assume the position during rest that they occupy during exercise. If, for instance, the muscles of the forearm are exercised vigorously in a contracted position, as they are in rowing, when the man is through rowing his fingers will stay almost flexed; and if he rows day after day for a good while, only with difficulty can the fingers be wholly extended. The muscles that contract the fingers have overbalanced the extensor muscles, and are holding these fingers in the flexed condition. On the other hand, the back of a coal-heaver is an illustration of muscles that are stretched, and at the same time strong. The coal-heaver has developed a powerful back, but he has used his back in the bent condition, so that while he has great masses of muscle upon his back, it is difficult for him to straighten himself, and after some years of such work he cannot do so at all. The parts have become so accustomed to the bent position that they retain it permanently.

Thus, the position taken during exercise is of the greatest importance. If a person: takes pulley-weight exercise with the spine in a forward position, the ribs depressed, and the chest flat, that very exercise will tend to make this position a permanent one; and yet this is exactly the position that uninstructed individuals commonly take in gymnasiums when doing pulley-weight work. Again, work on the parallel bars, particularly the bent-arm work, is usually taken with the spine flexed, and with the ribs in a depressed condition, the pectorals being in active contraction, as are also the muscles of the abdomen. The tendency is to perpetuate in the individual the form held during the exercise. We are all familiar with those who have done a great deal of such parallel bar work, and have observed the flatness of their chests in spite of the large development of the greater pectorals.

The general effects of exercise are in relation to the number of footpounds of work performed. By the general effects of exercise are meant the effects upon the heart, lungs, digestive organs, nervous system, and general cell-metabolism. We shall not here consider the effects of extended attention, or concentration of mind; that will come later on. We are now considering merely the general effects of exercise upon the body. I may extend my index-finger as many times as possible, until I am thoroughly exhausted, without producing any great effect upon my heart, lungs, or digestive organs; although I may produce an effect upon my nervous system from the exhaustion that would supervene from excessive work. The exercise of so small a muscle has comparatively little effect upon the great organic functions of the body. The amount of mental effort put into the exercise does not appear to be directly related to the activity of the heart and lungs. If I stoop down and raise myself I am not at all fatigued, but I have done that which has an immediate effect upon the body as a whole. The heart is increased in action from five to twenty beats in the minute, and the breathing is accelerated, even by a single movement of this character; there has been comparatively little nervous, but a great deal of muscular, expenditure. Such an effort might be equal to a hundred foot-pounds of energy, whereas the most vigorous effort of my will might not suffice to perform a hundred foot-pounds of work by the contraction of the small muscle referred to before–the extensor indicis. In seeking, then, the general effects of exercise upon the body, we must exercise those groups of muscles with which it is easiest to perform large amounts of work. These are obviously the great muscular groups of the body–the flexors and extensors of the thigh, and the muscles of the back, abdomen, and shoulders. These five groups include by far the strongest muscles in the body. Upon their exercise we must chiefly depend for effect upon the vital organs. Exercise of the muscles of the forearm and upper arm is somewhat effective; but so much inferior are these muscles in size

EXERCISE AND CIRCULATION 13 and power to the other muscles referred to, that great reliance cannot be placed upon them. When muscles contract, we can foretell to a nicety how much effect there will be upon the heart and lungs, if we know the number of foot-pounds of energy to be expended. This is our most valuable criterion. Because of their greater natural capacity for skill, as well as because of the more showy character of their work, it is common in gymnasiums to find chief attention given to the development of the arm muscles. The fallacy of this is easily seen.

Physiologic Load.–There is a load for each muscle, and for each group of muscles, under which it can do its maximum of work. This we call its physiologic load. It is the load under which the greatest effect can be produced upon the organism. If the element of time is considered, the load must be altered to correspond. There is thus a physiologic load for each muscle for each length of time. It has been demonstrated that muscle will contract more vigorously and effectively when it is pulling a certain load than it will when contracting free; thus, the advantage of working against a weight of some kind. This weight can usually be the weight of the body in some form or another, except in the case of the arms, which are not well adapted to handling the weight of the body. For the arms we use apparatus in order to bring about this contraction under a load; and the longer the exercise is to last, the lighter we make the load. It is not sufficient that we shall contract the upper arm so many times; it must contract under a given load in order to secure the proper physiologic result.

Exercise a Factor in Promoting the Circulation of Fluids in the Body.–In this respect it is second only to the contraction of the heart. In the great muscle-groups of the body the lymph circulation is chiefly carried on by the contraction of the muscles. These press upon the lymph-spaces and urge the lymph on. The circulation of blood, as well as of lymph, in the abdominal organs is accelerated by exercise and by deep breathing. When the diaphragm makes large excursions, the abdominal organs are alternately pressed upon and released. The valves in the large veins are so arranged that the fluids can only go in one direction. Thus, it is clear that the relation of deep breathing to the circulation of blood in these organs is intimate. This indicates the great limitations imposed upon the health of the abdominal organs by anything that restricts the breathing, and one of the reasons why deep breathing is so effective in bringing about a state of vigor in the whole organism. Deep breathing seems to increase the freedom with which the return flow of the blood from the head is effected. This Verhaps is not a major effect, but it certainly should be reckoned with.

The quantity of oxygen absorbed–that is, taken from the air of the lungs into the blood plasma and into the hemoglobin–varies in proportion to the need of oxygen in the body far more than in proportion to the quantity of air inhaled and exhaled at each breath. One may by deliberate effort breathe with rapidity and amplitude. The result is that the air in the lungs is more free from carbon dioxid than is usual. This, however, will not raise the oxygen absorption in the body. The oxygen tension in the blood plasma remains measurably constant. The way to increase oxygen absorption by the tissues is to do work that increases the breaking-down of oxygen compounds. Thus, there is more demand created for oxygen, deep breathing results, and this deep breathing is effective in the promotion of oxygen absorption. We thus see the fallacy of expecting to rejuvenate the tissues of the body by voluntary deep breathing. Such deep breathing may have useful effect in strengthening the accessory muscles of respiration; or by means of the wide excursions of the diaphragm moving back and forth the abdominal contents and thus affecting the vigor of these organs; but its usefulness is not primarily related to increased absorption of oxygen.

Effort on the part of individual muscles requires the fixation of the thorax and thus increases intrathoracic pressure. This effectively prevents the return of the blood to the veins leading into the thorax, and produces a passive congestion, which is most noticeable in the head. The staring eyeballs of a person making a vigorous effort, lasting a number of seconds, are familiar to all. The filling up of the great veins in the neck and head merely indicates the process that is going on all over the body.

Agitation of the body tends to accelerate intestinal peristalsis and hepatic circulation. This is noticed in the effect that riding a hard-trotting horse has on those of sedentary habits. For this reason running is more effective than bicycling in its effect upon the abdominal organs. Extended movements at the waist are also effective in their relation to the abdominal organs, the three factors being as already mentioned: increased peristalsis, increased circulation of contained liquids, stimulation by means of the wide excursions of the diaphragm.

Position of the Thorax and Curve of the Spine during Exercise.–When the dorsal region of the spine is flexed, the ribs are depressed, the chest is flat and the amount of space for the heart and lungs is less than when the opposite conditions obtain; the difference in the anteroposterior diameter in the two positions being often as much as three-fourths of an inch. When the trunk is thus cramped, the heart becomes embarrassed and irregular during severe exercise far more quickly than when the ribs

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Automatic and Voluntary Exercises.–Movements that are made with regularity and constant force are soon taken in charge by the lower neural centers. They are directed by the hind-brain, or possibly by the upper centers in the spinal cord. This frees not only the upper motor centers, but the seat of consciousness as well. Fatigue is more closely related to exhaustion of these upper motor centers, or even of the consciousness, than to exhaustion of the muscle-cell. Movements made automatically have far more effect upon the body in proportion to the amount of fatigue they produce than have those exercises demanding constant attention. The comparative fatigue of walking upon a smooth road and upon railroad ties placed at uneven distances is a familiar example of this principle. The automatic nerve apparatus does not become fatigued readily. The general effect upon the body, and the effects upon the muscle-cells, the digestive organs, the organs of circulation and respiration, etc., are, however, not affected by the source of the neural stimulus to muscular contraction–they are the same whether the exercises be automatic or voluntary. A typical example of a rhythmic exercise is bicycling at a moderate gait over a reasonably smooth road after one has become thoroughly familiar with riding. The somatic effect of the exercise is the same as when one is riding in a narrow track, but in the latter case constant attention is demanded and fatigue rapidly supervenes. Thus, physicians who have to do with individuals who are, as a whole, in need of muscular exercise, but who are already partially exhausted neurally, often have occasion to make large use of rhythmic exercises.

The relation between neural and muscular expenditure is not constant. Every increase in rapidity of movement calls for proportionally more neural energy than muscular energy. This is well illustrated by a person starting in the hundred-yard dash: the waiting with attention strained for the pistol-shot, and then the immense rapidity of the start, demand more neural energy many times over than does getting up the same degree of speed more slowly. It also demands, of course, more muscular energy to overcome inertia, but the neural demands are far greater in proportion than are the muscular demands. One starting a number of times in succession may become so fatigued that the hands will tremble violently when the muscles are still comparatively fresh. This is exceedingly important in the application of so-called calisthenic drills. When one wishes the individual to follow the commands of the leader the instant they are given, a far higher degree of attention is demanded than when he may follow more slowly. A teacher of gymnastics who is anxious that his class shall present a creditable appearance will constantly insist that the commands shall be followed instantly. This is unfortunate for the pupil who already has the least tendency to neural fatigue. It is harder, too, on adults or the middle-aged than on young persons, because reaction-time is slower in the former classes. After a drill or a set of exercises has been memorized so perfectly that conscious attention is no longer needed, the conditions, of course,