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Hydrotherapy in orthopedics

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HYDROTHERAPY IN ORTHOPEDICS

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INTRODUCTION

Hydrotherapy, in the usual sense, refers to the use of water in the treatment of disease. In this paper we shall imply a limitation of that broad application of the term. We shall have in mind the use of water only as an external agent for conveying various therapeutic elements to the body surface, and for resisting movements of the body, as well as supporting the body in opposition to the force of gravity.

No specific term seems to be widely adopted which implies such use of water. However, the suggestive compound words, "hydrogymnastics,"[10] "hydrokinesitherapy,"[18] and the like appear not infrequently in the literature. Since these do not cover all the uses of the hydrotherapeutic tub and pool, the term "hydrotherapy" shall be used in this paper carrying the implications indicated above.

"Hydrotherapy," as will be shown, is in its early stages of development. We feel sure that as it becomes more firmly established on sound principles of physiology, as more hospitals install its peculiar type of apparatus, and as the technique of administration is better understood by the profession, it will fill an important place in the practice of Orthopedics.

CHAPTER I

HISTORY

"Man from his advent has daily experienced the beneficent action of water. Instinctively he drank when thirsty, washed when unclean, and bathed when tired and heated. The knowledge that water is essential to the maintenance of life was among the first of all human acquirements. The relation of vegetation to water and the cleansing action of the rain, streams, and seas must have been recognized even by the earliest forms of human intelligence. Primitive man felt the need of water, saw its wide dominion in the world, wondered, perhaps, at the mysterious forces which dictate its form and motion, and in his dawning imagination endowed it with preternatural powers.

"Symbolism characterizes all primitive mental expression. It was therefore natural that man should use water, not merely when ministering to his bodily cleanliness, but also when striving to convey ideas of moral purification. As late as the beginning of the Christian era we find this application of water even among the cultured Romans. Pontius Pilate, when he wished to disclaim guilt and responsibility for

the Crucifixion, called for water and washed his hands before the comprehending eyes of the clamoring mob.

"Analogous use of water entered into spiritual matters. Today Hindus still seek grace by bathing in their sacred streams; Mohammedans perform extensive ablutions as an essential preliminary to prayer; Jews wash in prescribed fashion at fixed periods in order to conform to the law; and Christians are sprinkled with, or immersed in, water to wash them from the stain of 'original sin' in the sacrament of baptism.

"This symbolic use naturally led to the inclusion among religious practices of the application of water in the treatment of mere bodily ailments. So hydrotherapy developed under sacred auspices, and the use of water as a healing agent acquired the dignity of a religious ceremony. Waters from sources distributed over the greater part of the Old World gained more or less local reputations for special efficacy. Sometimes a natural peculiarity lent awe to these waters and served to strengthen faith in their remedial powers. The periodic filling of the well of Bethesda in Jerusalem and the annual rise of the Nile are typical examples of such peculiarities. The moment of the appearance of these unique phenomena signified to the

faithful that the endowed waters had then attained the climax of their curative powers.

"In some instances the special attributes of the water were disclosed by revelation or by happy experience to the pious. To some sources was given a specific virtue; thus, the famous well of St. Triduana and the waters of Siloam were efficacious in eye diseases; lepers were made clean in the Jordan; abdominal diseases were healed at the well of St. Gingolph; and madness, sterility, and most other afflictions were cured by waters from appropriate sources. The Jordan, the Nile, the Ganges, the well at Emmaus, and a few other holy waters possessed such wondrous powers that they acted practically as panaceas.

"The waters of Bethesda now rise almost unheeded; the pious blind no longer seek the once all-powerful well of St. Triduana; and, except among the adherents of the Greek Church, faith in the properties of the sacred waters of the Jordan is almost dead. As the popularity of one source ebbed that of another rose. In our own times to the well at the Grotto of Lourdes, near the Pyrenees, and that of St. Winifred at Holywell, in Wales, seem to have been transferred many of the marvelous properties which centuries ago were vested in the holy places of the Orient. From these wells

wonderful cures are daily reported by eminent physicians whose belief in the verity of the phenomena they record is above suspicion and beyond question.#

"Although substances of greater potency, but of less traditional and spiritual force, have had their day and now are irretrievably forgotten, water has preserved throughout the ages its reputation as a remedial agent, owing largely to this fostering by religious bodies of faith in hydrotherapy.

"The rudely material benefits of bathing were early appreciated. So widespread in ancient times was the custom of bathing that the Greeks and Lacedaemonians had not only private but public baths. Alexander the Great is recorded to have marveled at the magnificence of the baths of the conquered Darius. But the apostles of bathing were the Romans. The Romans elevated bathing to a cult. The splendor of their baths is a salient feature of their civilization. In the Roman conquests a bath was built as soon as the barbarians gave the invaders a moment's leisure. The more settled the new colony the more ornate was the

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#"The modus operandi of these cures may be just as satisfactorily explained in other ways, and, moreover, the cures can be performed in many other ways."--Editor.[1]

bath. Elaborate descriptions of these early baths and interminable dissertations upon bathing survive in the writings of many of the ancient authors, particularly Pliny, Seneca, and Juvenal. The use of water alone was not fashionable even in the humblest baths. Oils, perfumes, spices, and other adjuvants enhanced the aesthetic pleasures of these institutions. Together with bathing the Romans associated massage and physical exercises. The untrammeled license which characterized many of the public baths of the Romans brought bathing under the ban of the reforming zeal of the early Christian Fathers and perhaps conduced to the not overscrupulous cleanliness which sometimes served to eke out the penance of the pious anchorites who retired into desert places, and to the strikingly insignificant role which water plays in the ritualistic practices of the Christian church.

"The Roman influence upon bathing is accentuated in our period partly because the Romans were so prodigal in their bathing resources, but mainly because our civilization is in direct succession to theirs. But knowledge of the cardinal uses of water probably dates from the dawn of man. The ancient Egyptians, Picts, Celts, Turks, Moroccans, Japs, Indians, and Mexicans all used

forms of vapor baths. Besides baths of water--ice, vapor, hot, cold, river, spring, well, and sea water--other media such as sand, mud, peat, wine, milk, and even blood were used.

"The therapeutic use of water by physicians is as old as the art of medicine. Hippocrates was hardly an enthusiast for baths, but he advocated them under certain conditions in several of his writings. Celsus praised house baths but was reticent about the use of mineral waters. Aretaeus of Cappadocia, Athenaeus, and Rufus of Ephesus wrote at length upon the merits of certain thermal baths. Agathinus was the apostel of cold baths. Galen said little of baths. Fallopius alluded to the diseases which may be benefited by the water at Lesbos, Mitylene, and other places. Antyllus, Oribasius, Aetius, Paul of Aegina, Caelius Aurelianus, and countless others through the ages lauded the uses of water. To enumerate the physicians who have practiced water treatment would be merely to catalog the fathers of medicine. But until the scientific renaissance of the last century the properties and actions of water remained clouded in superstition and empiricism. The pioneer work of Winternitz, Brutenbach, Baruch, Thayer,

and others has now definitely established the physiological principles upon which the action of water depends. Out of the chaos a certain amount of order and system has been evolved; a rational basis for the therapeutic employment of water has been defined; and the science of hydrotherapy, which deals with the action of water upon the human body, has been erected."[1]

Considering, then, the comparatively recent development of systematic, carefully supervised underwater exercises--the development of the hydrogymnasium, let us say--we find it specifically dated by no individual. Olsen states, "It is difficult to say who discovered the new procedure of giving medical gymnastic exercises under water, but Dr. C. L. Lowman, in 1924 was among the first, if not the first, to use the treatment for infantile paralysis, of which he is recognized as the leading authority."[18]

Hansson ascribes its introduction to several contemporaries. "It was during the third decade (1920-30) that we saw the introduction of underwater exercises. Dr. Lowman in Los Angeles has developed many of the scientific points connected with this treatment, Dr. Hubbard at Warm Springs, Georgia, backed by Governor Roosevelt, of New York State, has helped to popularize

hydrogymnastics, and Dr. Childs, of Port Jefferson, Long Island, is another pioneer in this form of treatment."[10]

Lovett, however, in pre-War years was employing the warm tub and the salt bath in the treatment of poliomyelitis as follows: "At this period (cessation of tenderness) a warm bath is generally of benefit because the bouyancy of the water diminishes the weight of the limbs and permits motion which is not possible out of water because the limbs are thus supported. The addition to the bath of sea salt of course increases the specific gravity of the water. Immersion in a bath is not desirable during the first two or three weeks of the paralysis but may be used before tenderness has wholly gone, the patient being lifted into the bath on a sheet."[2]

Lowman places the origin of underwater treatments far back in medical history. "The treatment of various types of illness in pools originated probably centuries ago, for we read in the bible of the sick being thus treated. It has also long been known that paralytic patients could move with less effort in the water because of its bouyancy. Many physicians have used small tanks and bath tubs for a number of years for this purpose."[14]

It is apparent, then, that the general principles of underwater exercises have been employed by physicians for centuries, but only within the past two decades have exercises been carefully supervised and correlated with the basic sciences.

CHAPTER II

PROPERTIES OF WATER

"A brief outline of the properties of water is essential to a clear understanding of its uses. Its distribution is universal. It exists in and can readily be transformed into solid, liquid, or gaseous form.

"Under ordinary atmospheric pressure, at the temperature of 0° C. it becomes ice; between 0° and 100° C. it is liquid; above 100° C. it exists as steam. In changing from fluid to ice a remarkable absorption of heat takes place: if a kilogram of water at 0° C. and a kilogram of water at 79° C. be mixed the resulting mixture has a temperature of 39.5° C.; but if a kilogram of ice at 0° C. be added to a kilogram of water at 79° C., the ice disappears and two kilos of water with a temperature of 0° C. remain. This heat absorption explains the great efficacy of ice baths in bringing about a lowering of temperature in cases of fever.

"Similarly in passing from liquid to steam a tremendous amount of heat is rendered latent; hence allowing water to evaporate from a surface is one of

the best means to produce cooling.

"Further, water has a great capacity for absorbing heat; thirty-one times as much heat is required to raise one unit of water through one degree of temperature as is required to raise one unit of platinum one degree.

"Water cools relatively slowly. It is therefore invaluable as a medium for abstracting heat, for storing heat, and for applying heat. Its utility as a thermal agent is further enhanced by the ease with which its temperature can be measured, regulated, and controlled. As a fluid it mixes with solids to form pastes, the consistency of which can be altered at will; it also permeates most textures, so that its application can be restricted or adapted at will to any surface.

"Water can readily be applied with varying and regulated pressure.

"When water holds a small amount of a salt in solution it is one of the best of the electrical conductors and can be used to insure intimate contact between the body and electrodes, or a bath may be arranged in a circuit, through which faradic or galvanic currents may be passed. When currents are passed through aqueous solutions decomposition or electrolysis of the solution occurs.

"Thus, the constant current decomposes water into hydrogen and oxygen. The elements at the moment of liberation from their compounds are said to be nascent. The action of the nascent elements produced by such electrolysis is relatively powerful and is utilized in certain forms of baths.

"Water is thus an ideal medium for the application of cold and heat, electricity and pressure, owing to the simplicity, precision, and rapidity with which these physical forces can through it be controlled. Its power in combating disease depends almost solely on its property as a medium."[1]

CHAPTER III

PHYSIOLOGY

The "physiological action" of water "when a medium, is essentially that of the physical force which it is conveying. We shall, therefore,...briefly consider the various actions of heat, cold, pressure, and electricity upon the body.

"Some areas of the skin have certain definite nervous relations to the viscera.

"An organ may be reflexly influenced through a particular area of skin, and affections of organs may reflexly influence special skin areas. Our knowledge of these areas we owe to Head and Mackenzie, and it enables us so to guide and restrict our operations that by the simple bloodless procedures of hydrotherapy we can influence viscera with as much certainty as if we were exposing them by a surgical operation.

"The skin, however, besides being an organ of sensibility, has also secretory, excretory, and heat-regulating functions. These are subservient to nervous and vascular control. A stimulation of a cutaneous secretory nerve induces an increased flow of sweat and a local increase in the blood supply. An increase in the blood supply usually involves an increased sweat

secretion. The heat regulation of the body is largely attained through the skin. In overproduction of heat by excessive muscular action, or in exposure to excessive external heat, the cutaneous capillaries dilate, and sweating increases; the evaporation of the sweat from the skin absorbs much of the surplus heat from the body. If exposed to cold the cutaneous vessels contract and sweating diminishes; the body heat is thus conserved. Urea, xanthin, and other decomposition products of protein metabolism may be demonstrated in the sweat; the sweat glands, just like nearly all glands, have a vital selective affinity for certain substances circulating in their blood supply.

"But as the secretory, heat-regulating, and excretory mechanisms are merely outward evidences of vascular and nervous activities we shall first consider the action upon these activities of each of the physical forces utilized in hydrotherapy.

"Physical agents such as cold act mainly by virtue of their irritant properties. Within certain limits of intensity a stimulus to the skin produces similar effects, whether it be caused by chemical or physical action. Weak cutaneous irritants narrow the arterioles and raise the blood-pressure; the increased peripheral resistance thus produced causes the heart to contract

more rapidly. On the contrary, intense cutaneous irritants fatigue and paralyze the normally existing innervation of the blood-vessels and produce a relaxation and dilatation of the peripheral arterioles with diminution of pressure; at the same time the inhibitory action of the pneumogastric slows and intensifies the cardiac contraction, and, when excessive, may produce death by vagus tetanus.

"Cold.--The application of cold is perceived with varying delicacy on different parts of the skin. The local and general disturbances are dependent upon the degree and duration of the cold employed and the extent of the area to which it is applied; that is, to the intensity of the stimulus. Long-continued application of severe cold deleteriously affects the vitality of the tissues to a degree depending upon the resistance of the tissue exposed. And when the cold is severe, besides the coldness, a pain element is noticeable in the sensation.

"The application of sudden cold produces first a sharp inspiration, next a pause, and then a long expiration which is followed by frequent and shallow breathing. This reaction is the basis of one of the best known and most efficient methods of resuscitation of the still-born; indeed, it is alleged to be an essential

stimulus to the establishment of respiration at birth. In breech presentations, in which a premature onset of respiration might be attended by fatal consequences to the child, accoucheurs carefully swathe the extruded limbs in warm clothes. The effect of cold is not confined to the respiratory mechanism; consciousness is stimulated by its application, as may be seen in the awakening of the dormant attention of hysterics, and in the sobering of the drunk, by cold affusions. Cold is one of the most powerful nerve stimulants we possess.

"Owing to the stimulation of the cutaneous nerves the voluntary and involuntary muscles are influenced. Investigations by means of Mosso's ergograph have proved conclusively that cold is able to increase enormously the resistance of muscle to fatigue, and also to restore the efficiency for work to muscle which is already fatigued. A slight increase in the tonicity of voluntary muscle is produced. And in involuntary muscle the stimulation is evident in 'goose skin,' and in shivering.

"The contraction of the cutaneous vessels diminishes the skin secretion, increases the blood-pressure in the vessels of the deeper structures, and stimulates their vital processes. One well-known consequence of this elevated blood-pressure is diuresis. The increased blood-pressure, the increased force and frequency of the

heart's action and the increased blood supply to the kidney all tend to enhance the diuretic action of cold.

"Cold baths produce a leukocytosis which persists at least for one and a half hours. Some observers have found an increase also of red cells.

"In order to obtain a cold stimulus, temperatures sensibly lower than 92° F. must be employed. If the cold be slight, the effect does not proceed beyond the stage of arteriole constriction, enhanced cardiac and respiratory action, and increased muscle tone. And these consequences are in variable degree transient. The vasoconstriction is followed soon by vasodilatation; but the beneficial effect upon the heart and the general musculature is more persistent. While in the cold bath, when the cold is mild, or after emerging, if it be less mild, the cutaneous blood-vessels dilate, the skin reddens, a pleasurable sensation of warmth ensues, and a feeling of general well-being prevails. Such is the 'reaction' to the cold bath. To elicit it in the sick great care is necessary to temper the stimulus to the patient's strength. The shock produced by the cold must not be too severe.

"Heat.--As already stated, the initial effect of all forms of physical stimuli is essentially the same; hence the action of heat is not directly inverse to that of cold. All stimuli produce initially vaso-

constriction, but whereas with cold this effect tends to be maintained, with heat it is immediately superseded by vasodilatation which persists as long as the heat. Owing to the vascular dilatation the skin reddens, a sensation of warmth prevails, sweating increases, and the deeper structures are depleted somewhat of their blood. The increase of the cutaneous blood sheet promotes radiation, the evaporation of the excess of sweat renders latent a vast amount of heat, and the concomitant increased frequency of respiration abstracts much heat in the larger volume of expired air and water vapor; hence, all these factors tend to cause a fall of temperature. If the whole body be immersed in a bath of a temperature higher than 98.4° F. the body temperature may rise somewhat.

"The relatively anemic condition induced in the viscera minimizes their activities and thus heat tends to act as a general sedative. Also, the direct action of heat upon the sensory nerves is pleasurable and soothing. The sedative influence of heat is invaluable in abolishing convulsive seizures due to tonic conditions in children. The warm bath is the surest, safest, and simplest sedative for the irritable nervous system of infancy.

"The effects of heat and of cold on respiration appear to be somewhat similar; each produces at first a sharp inspiration; next a pause, and then a long expiration which is followed by frequent and shallow breathing.

"On the other hand, hot baths diminish the power of muscular work, unless at the same time mechanical stimuli such as douches and massage are employed; but even with these adjuvants the increase in efficiency is always less than under the influence of cold applications.

"Roughly speaking, therefore we may regard the action of cold as tonic, of heat as sedative.

"In addition to its use as a medium for applying physical agents, water is of great service as a solvent. It is the most universal of all solvents, the vehicle for the administration of all soluble drugs.

"Water is given to remove in solution or in suspension noxious material, not only from the surface of the body, but also from its apertures and the cavities into which these apertures open. The bladder, uterus, rectum, colon, and stomach are all subject to its cleansing action.

"The principle of osmosis has been applied by Sir Almroth Wright, the distinguished Irish bacteriologist, to the treatment of septic gunshot wounds. Antiseptics generally are protoplasmic poisons. The best antiseptics are those which are highly destructive to the protoplasm of bacteria and relatively harmless to the healthy human cell.

"Antiseptics, however, are almost invariably additional destructive agents menacing the life of the damaged cells in the wound. After careful observation of the unfortunate effect of antiseptics upon wounds arising in modern war, Wright discarded antiseptics in favor of the bland and uniformly beneficent saline solution. Saline solutions wash wounds free from all uncleanness, exudate, debris and surface organisms; dissolve, dilute and disperse toxins, and by osmosis mechanically relieve cells of their diffusible noxious contents. The natural resistance of the tissues is thus greatly reenforced and the optimal conditions for local repair are ensured. The brilliant results already achieved by Wright with this method of treating septic wounds make this new application of hydrotherapy one of the most important advances in surgery of our time."[1]

Discussing the use of hydrotherapy in the treatment of arthritis, Currence observes, "The hot bath increases the pulse rate; after a brief initial rise, the blood pressure is slightly lowered. It produces a definite increase in the number of capillaries in the nail bed visible under a capillary microscope. With lessened capillary stagnation, there is an increased volume of circulating blood. It produces a diuretic effect with greater concentration in the urine. Stimulation of peristalsis frequently produces copious bowel movements. There is better ventilation of the lungs; carbon dioxide is washed out of the lungs and also escapes from the body in the urine and sweat. It tends to improve the sub-oxidation and impaired circulation which furnish a fertile soil for disease in the joints.

"By the increase of metabolism, other organic acids together with phosphates and sulphates also are eliminated, and a relative alkalosis is induced. Diaphoresis is stimulated and there is a loss in weight, which, however, is only temporary.

"Certain hot baths produce a reaction similar to that following injection of a fairly large dose of non-specific protein, with the added advantage of being agreeable to the patient and giving relief during the

height of the reaction instead of pain. It is also capable of more frequent repetition and has the added factor of control, as the reaction may be checked at any time by stopping the treatment. If, as a result of the stimulation of the tissues by baths, foreign proteins are swept into the blood stream, a secondary reaction ensues. The absorption of the exudate is thus comparable to the injection of a foreign protein and the secondary reaction which occurs can properly be described as a protein shock reaction. These effects usually begin a few days after treatment has been instituted, and articular inflammation which may have been quiescent for months suddenly flares up necessitating rest in bed.

"With the local manifestation, there is usually considerable general disturbance characterized by a rise in temperature and malaise. As with the injection of non-specific protein, it is quite essential that the dosage of the bath be regulated, so that too severe reactions are not produced.

"Courses of baths tend to increase the basal metabolic rate. High blood sugar levels are gradually lowered and it was noted that in several cases a complicating psoriasis gradually improved.

"It is a good rule to establish that the lower the blood pressure, the lower should be the safe maximum bath temperature. Various hot baths are contraindicated in cardiac diseases, advanced arteriosclerosis, hemophilia, aneurism, functional neuroses and tabes dorsalis."[5]

The physiologic action of water and the agents it may convey to the body surface has been discussed. We shall now consider some important aspects of muscle physiology relating to the restoration of function to muscle.

Normal Muscle

"The electric response which is intimately connected with the mechanical reaction is expressed by the curve of the action current. The greater the tension of the muscle and the less shortening of the fiber is permitted by the arrangement of the experiment, that is the more the muscle acts under isometric conditions, the higher will be the action current curve. There is also, normally, an interrelation between the mechanical response and the heat production of the muscle during contraction. The most outstanding chemical effect of contraction is the accumulation of lactic acid which involves an increasing demand of oxygen usage in order to burn up lactic acid into its end products--oxygen

and carbon dioxide. The rate of accumulation of lactic acid during exercise in the normal muscle is known and with it the amount of oxygen necessary for its combustion. We know that in severe exercise the formation of lactic acid may reach the value of 3 g/sec.

"From the intake of oxygen and output of carbon dioxide, the energy consumed can be established and brought in comparison with the amount of visible work. A ratio of efficiency can then be expressed in terms of relationship between the oxygen expenditure and the amount of realizable work, and so we arrive at a standard of normal efficiency for most of the ordinary occupations, and locomotor acts, including walking, running, etc.

"Under pathological conditions we find considerable deviations from the standard efficiency index. For instance in the limp of the bilateral congenital hip dislocation, or the ankylosed hip, so much motion is wasted by the oscillations of the center of gravity, the shifts and tilts of the body, that the ratio between muscular effort and actual work of propulsion is often not one-half of the normal.

"Now, when the primary causes of the wasteful gait are overcome, for instance, by reduction of the dislocation, it is up to physical therapy to evolve a scheme of locomotion commensurate with the muscle material at hand, which approaches normal function.

"A rearrangement of the muscle activity by re-education of the single muscle or muscle group or by changing of the plan of the muscle play is possible and very often practicable. It is the aim of rational muscle reeducation to find ways by which the reorganization of the locomotor complexes is effected.

Pathological Fatigue

"From the biochemical point of view, fatigue may be defined as an accumulation of lactic acid to a point at which the normal functional contraction of the muscle fiber is inhibited. Because the removal of the lactic acid by the blood stream is an essential factor in preventing this accumulation, it is above all things necessary in preventing fatigue that the circulation be intact. The blood fed muscle may be stimulated every six seconds indefinitely without fatigue because of the excess of oxygen, the amount of which is raised during the period of recovery sometimes ten to fifteen times its resting value.

"This surplus oxygen keeps pace with the production of lactic acid if no undue accumulation takes place. In moderate exercises there is a steady level of lactic acid, and since oxydation is proportionately increased,

also, the oxygen again falls to its normal level. But in violent exercise the accumulation is more rapid until the fatigue threshold is reached. The excess oxygen intake can take care only of a small part of the lactic acid by oxidation; therefore, after violent exercise, the increase of oxygen keeps on during the resting period, that is, the oxygen debt incurred during the exercise period is paid off during the period of rest. The anatomical site of fatigue is around the endplates of the individual muscle fibers, but the fatigue products may diffuse through the whole muscle.

"To understand fatigue, we must remember that prolonged contractions are only made possible by an arrangement of rotational activity of the individual constituents of a group of muscles. According to Sherrington's law, each muscle fiber contracts at maximum. Only by the alternate rotation of the different muscle fiber groups is it possible that a sustained contraction may be obtained. It is interesting from the viewpoint of the practical physiotherapist that there is an innervational factor of fatigue based upon the plurisegmental innervation of the muscle from the spinal cord. When one spinal root is stimulated to exhaustion the muscle still responds perfectly to stimulation of the other; the fatigue products are confined

to the group of endplates supplied by the same root. On the other hand, when circulation is obliterated or impeded a diffusion of fatigue products throughout the muscles takes place and complete exhaustion results.

"From the viewpoint of physiotherapy, therefore, the greatest single local factor to overcome and prevent fatigue is the restitution of the normal circulation of the muscle.

"How can all this mass of evidence coming from the laboratory be put to practical use in physiotherapy?

"So far as the fatigue is concerned, it means that the application of

1. Rest
2. Relaxation, and
3. Re-establishment of the normal blood circulation of the muscle are the three principal therapeutic measures. The effect of fatigue upon the mechanical response may be shown by the behavior of the poliomyelitic muscle which had been subjected to stretching.

"The threshold of fatigue of the paretic muscle is extremely low and efforts which otherwise appear entirely insignificant may lead to very considerable degrees of fatigue and exhaustion.

"The excess of tone during the earlier stages of

fatigue and the subsequent development of clonic tremors are further phenomena which are significant in the application of physiotherapeutic measures. A healthy muscle is characterized by a marked degree of recuperability. In certain muscular affections, such as progressive muscular dystrophy, fatigue occurs very readily, but recovery also takes place promptly. In other conditions, particularly in peripheral and poliomyelitic paralysis, in which the threshold of fatigue is very low, recuperation, on the other hand, is extremely slow.

"There is a distinction between the training of the musculature in isometric and isotonic contraction. In the former, the muscle is not allowed to shorten but during the contraction the tension constantly increases; whereas in isotonic contraction the muscle shortens and performs actual mechanical work under more or less constant tension. In isometric contraction all chemical energy is converted into heat and no visual work occurs; on the other hand, in isotonic contraction, mechanical work is accomplished, but because of several factors, such as incomplete shortening, premature relaxation, and internal friction, the work accomplished is incomplete; it only amounts to one-third of the theoretical maximum work.

"These facts shed some light on the practice of resistant dynamic exercises which are of such paramount importance in mechanical reeducation of muscles. So far as exercises, carried out under restraint, are concerned, we must remember that an optimum length of the muscle exists, and that the greater the initial distension or stretching, the greater, in general, is the isometric tension developed. This, however, is only true to a certain point. When the resistance increases beyond this, then further distension of the muscle tends to decrease the energy of contraction. This is important in passive exercises. The method of passive stretching of a shortened muscle by plaster cast or braces, if carried out beyond a certain point of resistance, impairs the efficiency of the muscle. In contraction, either free or against resistance, efficiency increases the more prolonged or the slower the contraction, but, in general, we find that the maximum efficiency of contraction is obtained when the latter lasts about 1½ seconds. In contraction slower than this, the efficiency falls slowly. The natural efficiency of the muscle has been found to be about 26 per cent.

"If we apply the isotonic contraction, that is, that in which the muscle is allowed to shorten, the

efficiency of the muscle is greater because in this type of contraction the muscle draws upon sources of energy not utilizable in resisted contraction. For the choice of position in which to start exercises, it is well to know that the maximum of contractile power is reached when the muscle has a length of 1.4 to 1.5 times its natural length. This is usually the case in the extreme joint position; for instance, in the extreme extension of the elbow, the biceps assumes this length in comparison to its relaxed natural length.

"For the avoidance of fatigue during exercise the following experimental facts are of importance:

"Earlier signs of fatigue are revealed by changes in the action current curves, leading to the picture of clonic contraction. The low threshold of fatigue is to be considered in planning and administering exercises. That recovery from fatigue is slow in paretic muscles has been mentioned. It must be complete before exercises are taken up again. It seems that in muscles fatigued entirely from local biochemical changes, recovery is speedier than in neuromuscular fatigue, especially if the circulation is otherwise intact."[19]

CHAPTER IV

HYDROTHERAPY APPLIED

In the foregoing chapter the aims of physical therapy in the treatment of motor disturbances were clearly defined by Steindler[19]:

1. Reorganization of the locomotor complexes.
2. Prevention of fatigue by restitution of normal circulation of the muscle.

In this chapter we shall consider the merits of hydrotherapy in these respects, as well as in the treatment of other affections met in the practice of Orthopedics.

Elsom says, "Exercise, properly graded and intelligently directed, is profound in its therapeutic effects, but generally not sufficiently appreciated by the members of the medical profession. I regard specific forms of exercise, active and passive, as an important and integral agency in physical therapy. We do not appreciate, perhaps, the large and vital part the muscles play in metabolic processes and in the human economy. Physical activity in reasonable and adequate amount promotes vigor, efficiency, health, happiness, skill and coordination. Inactivity, on the other hand, results in deterioration, atrophy, disturbances of bodily functions, and hence impairment of general health.

"Exercise, of course, accelerates the circulatory process. Nature accomplishes its healing effect by bathing the injured or diseased parts in the nutritive fluids of the body. When the blood stream diminishes, repair and nutrition are correspondingly reduced. Thus exercise is a profound regulator of nutrition; therefore it seems reasonable that in many abnormal conditions exercise should be prescribed, and with accuracy as to kind, amount, degree, and frequency of administration.

"Exercise for therapeutic purposes should be given rather slowly, steadily, and purposefully, with a brief period of rest between individual muscular contractions. This is a far better method than short, jerky movements which the patient is apt to make if improperly instructed. Further, muscular effort should be made to carry the joint which is being treated through the largest excursion that may be possible; at least the greatest extent of movement which may be done without great pain. This type of exercise, performed by the patient alone, we call <u>active</u> exercise; it is usually the most beneficial form. <u>Passive</u> exercise consists of movements performed on the patient by an operator. The force exerted in the passive movement of a joint may be very slight, or great, according to the condition of the

part being treated. As a rule, the application of heat in some form is desirable before the beginning of either active or passive exercise.

"Assistive exercise is that type in which the patient is not quite able to move a joint to the desired extent, and is assisted more or less by the operator. This type is especially beneficial in the various forms of paralysis. Resistive exercise is given to advantage when the muscles are fairly strong; the operator offers manual resistance to movements, supplying a heavier load against the voluntary muscular action of the patient. Muscular strength and development is secured best in this way. The resistance may be slight or heavy according to the strength of the patient; but no muscle should be pushed to its maximum ability. Each exercise should be well within the capacity of the individual performer."[8]

With these points in mind we come to an evaluation of underwater exercises in orthopedic problems. Lowman says, "The chief values of pool treatment are, first, the greater ease and freedom of movement in painful and neuritic conditions, as in the acute stage of poliomyelitis. Better handling of painful joints and easier development of weakened muscles is one of its

marked benefits. Secondly, it is excellent as a post-operative procedure following tendon transplants and plastic joint surgery, and as an early follow-up measure in fractures and osteotomies in which movement is desired to stimulate function and structure without the danger incident to weight bearing. Thirdly, the maximum degree of enjoyment and interest is obtainable. Fourthly, the hydropathic effect on the nervous and circulatory systems through the skin is of value. Finally, the general psychophysiologic benefit of improved morale is obtained thereby."[14]

"From a general standpoint the value of the pool lies in the high degree of enthusiasm and interest that is aroused in the patients. They can hardly wait till the next day for treatment and any who ever have been in the water before their affliction look forward with keen anticipation to the time when they can start.

"We find that these, as any other emotions, call for expression and as expression is always evidenced by motion, it requires no urging or further stimulus to action. This interest does not flag and the fact is that when these children finally get so that they can swim they are elated, because at last they can do something that others can do. Their helplessness becomes

less acute, they work with renewed effort and interest and the change from the tiresome bed to the pool is a welcome relief."[17]

Gaenslen states that, "The advantages of underwater exercises are that (1) the buoyancy of water eliminates gravity and (2) the warmth of the water relaxes the muscles and accelerates the blood flow. The steady, gentle resistance of the water is readily overcome even by feeble muscles. The degree of resistance varies with the speed of motion."[9]

Olsen advocates hydrotherapy for the following reasons, and adds a list of some of the affections that have been benefited by underwater exercise.

"Underwater therapeutic exercise is the treatment of choice for the chronic stage of anterior poliomyelitis and various spastic and flaccid paralyses. It is also an excellent therapy for many crippling and disabling disorders such as chronic arthritis and for some traumatic conditions. Convalescence from certain exhausting diseases is hastened by hydrogymnastics.

"The chief advantage of this new treatment is the combined immersion and the buoyancy of water which allows muscular movement and the use of limbs under water that elsewhere would be impossible.

"Among the diseases and disorders that have been

successfully treated by underwater therapy may be mentioned:

1. Poliomyelitis, especially in the chronic stages, and after operation.
2. Spastic paralysis.
3. Flaccid paralysis.
4. Multiple sclerosis.
5. Chronic arthritis.
6. Paralysis from fractured spine.
7. Congenital hip dislocations following reduction.
8. Spinal fusion cases for Pott's disease.
9. Fractures.
10. Various bone and joint plasties.
11. Hip, knee and other arthrodesias.
12. Certain postoperative cases.
13. Osteotomies.
14. Bone grafts.
15. Scoliosis and other curvatures of the spine.
16. Faulty postures."[18]

Lowman believes that, "The commonest misconception regarding this physical therapy modality seems to be that it is the treatment of paralysis by 'swimming'.... The objection to this is two-fold. In the first place muscle reeducation under water is not swimming. Certain movements of the free floating type...are employed, but the purpose is not to teach swimming.

"The chief reason for objecting, however, is the danger of swimming instructors getting the idea that they are competent to treat paralytic and other types of cases in the water. The result is that the untrained and the unscrupulous take such patients into the water when it is often too cold, and give them swimming strokes

which usually strengthen muscles already strong...and increase the tendency to contracture or their over-action against weakened opponents.... This increase of pleasurable activity of a recreational character may be given but it is at the expense of increasing the deformity.

"Also the impression that pool work is chiefly for patients with paralysis should be corrected. My early demonstration of its value in the treatment of both acute and chronic poliomyelitis probably led to the emphasis on this aspect of its use. However, a great variety of conditions are amenable to its use. There is an erroneous idea in some minds that this modality can be administered by employes having no special training, or that a nurse or anyone who can swim might be a suitable technician. It happens that the reverse is just the case.

"A simple knowledge of kinetics is not sufficient by any means to qualify a technician. The teacher should have an extensive knowledge of abnormal kinesiology and the pathologic aspects of her cases; a good personality; a thorough acquaintance with all the pedagogic tricks needed in teaching and a knowledge of the limitations of this modality--its indications, contraindications and technique.

"I find that the commonest error, made by even our trained technicians, is the tendency to over work the patient. Nothing is so deceptive as work in the water. It is very fatiguing, especially to the weak and afflicted. The gravity load being removed, the parts move more easily through a greater arc and this freedom is misleading and makes actual grading of the amount of movement to be used quite difficult.... Periods as short as five to ten minutes are all that patients with severe involvement can stand.

"Many laymen believe that the influence on paralytic and other ailments is due to some inherent potency or active principle in the water. This idea probably has gained ground because of the use of natural hot springs in some places for work of this sort.... The value of underwater gymnastics, however, is one of physics and not of chemistry.

"Another point is the confusion of the recreational and reeducational features. Technically, it is not sound clinical or physiologic treatment to mix the two as is done in some pools. The play factor has no place in the schedule during the stage of concentrated muscle training. The latter is regulatory and disciplinary in character and is actually mental and muscular effort, or work, and not play.... The constant effort of the technician must be directed toward getting definite,

deliberate motor response to command by purpose and direction--not by indirection--even though that is better than none at all.

"To me it seems highly inconsistent, during the stage of actual technical muscle training, when an effort at stimulating the muscles to maximal exertion is made, to attempt prescribed and carefully graded dosage of exercise of paralyzed or impaired muscles and then at any time during the day to allow free recreational swimming, or play, without the protection of braces to the weakened muscles. If the latter activity, unsupervised is to be allowed on a play basis of free response to emotional impulses and desires, of what use is a carefully laid out plan of graded supervised muscle training? If work in the water under a cautious technician who allows only slow, deliberate movements is fatiguing, what must happen to the affected muscles in the unsupervised activity? The very condition of the handicapped paralytic patient requires him to make greater effort to accomplish his movements. Hence, to compensate his sense of inferiority he will be too persistent in his attempts and become fatigued or else over-develop existing normal or overactive muscle groups. This tends to favor deformity.

"If swimming is to be allowed the patient with poliomyelitis, and even the patient with bad posture should be most carefully supervised and only those strokes that are corrective be allowed. This, however, is far from being free pool play. In any case it should not occur on the same day as actual muscle training treatments."[17]

"While swimming strokes are used and taught as a definite part of the muscle reeducation program, they are always adapted to the special need. For instance, in deltoid paralysis, the active stroke is out and up which propels the body in the reverse direction from that of the usual one.... It must be remembered... that the cripple in swimming, as in walking, desires progression and will use any musculature available to attain that end. Consequently the use of muscles already strong, without supervision, would do more harm than good."[16]

"I should like to sound a note of warning to technicians regarding the handling of frail individuals even in reasonably warm pools. The danger of chilling the skin must not be overlooked because of the bad effect on the general well being of the patient, especially if he has a kidney lesion. I have noted

that quite a high percentage of patients with early acute poliomyelitis show a nephritis of varying grades--sometimes only slight, and sometimes one that takes several weeks to clear up.... It is advisable to cover the patient with a large, hot bath towel or blanket immediately after he leaves the pool.... It is also well to have a hot air blower in the dressing room which can be directed against the body, and not only assist in drying but prevent chilling.

"It is advisable for the patient to take a rest period immediately after the pool treatment because of its fatiguing effect, and particularly as it is easier to take a nap at this time. This is valuable in nervous and high strung patients--spastic patients, choreic patients and hypertense children in general."[17]

In the hydrogymnastic pool at the Orthopedic Hospital School in Los Angeles, Lowman finds, "...the optimum temperature for most cases to range from 88° to 91° F. The spastic group including all hyperactive cases require a higher temperature--from 95° to 100°, in which better relaxation and coordination is obtained. Warmer water than used in regular swimming pools is necessary because these frail, inactive children chill more readily than the normal, and, furthermore, weak

muscles cannot function well when cold. With the added precaution of watching the length of treatment, no bad reaction from chilling has been noted in any cases during the year the pool has been used. Ten to thirty minutes is the average time for all except a few of the more rugged and old chronic cases, in whom the more vigorous development of trunk muscles is desired. In the older chronic poliomyelitis cases the children with leg involvement say they are steadier because of the treatments, which is due to increased tone and power of gluteals, quadratus lumborum and lower back muscles.

"The sequence of treatment is: first, the fear of water is overcome; second, every one is taught to breathe properly; third, each one is taught to float both prone and supine; fourth, emphasis is added to the work of the parts involved--leg or arm, hands or feet, as indicated."[16]

"When the Orthopedic Hospital in Los Angeles began to use the underwater exercises as a physio-therapeutic modality in 1924 our primary interest was fixed on the treatment of poliomyelitis. The effort was confined to chronic cases at first, but as a light epidemic brought us a few acute cases, we included them. Gradually as we appreciated the value of the work in

the water we became braver, until we commenced this phase of treatment right after quarantine, as early as the end of the fourth week even while pain, muscle neuritis and spasm existed. We were impressed very early with the value of such treatments for other types of cases. We desired especially to get the operated poliomyelitis cases back on the water treatment and began to study ways and means of doing so. We noted in handling poliomyelitis in the acute stage, that the limitation of movement from pain and spasm was much less when attempted in the water. We concluded that earlier movement of operated parts would be possible without the production of joint pain and muscle spasm, and thus insure a much wider margin of safety when so handled. This proved to be true.

Spinal fusion

"In spinal fusion cases for Pott's disease, scoliosis, fractures, etc., the back was held firmly in water-proof splints, the patient gently moved from bed to guerney, thence to the hydrogymnasium, lifted from the dressing room table, carried out to the pool and lowered into the water by the electric traveling hoist. Partly supported on a submerged inclined plinth, the legs could be gently exercised, thus stimulating

the general metabolism and raising the tone of the leg and pelvic muscles. It is especially important in such cases to improve the tone of abdominal, low back and gluteal groups. It can be done in this way without spinal movement and does not jeopardize the healing of the grafted area. Such treatment can be instituted by the eighth or ninth week. Otherwise it would be necessary to wait three or four weeks longer before very much physical therapy, other than massage to legs, or sun or light therapy, could be safely used.

Congenital hip

"Following the method of DeNuce, of Bordeaux, who uses walking in the water after reduction of congenital dislocation of hips, we elaborated a similar follow-up for hips after operative as well as closed reductions, beginning with the lying position on the plinth and later in free floating positions. The chief movements given are strong, active abduction and hip extension, with ankle and knee bending, but limited hip joint flexion. After two or three weeks of this, walking in shoulder depth water, began. At first we use crutches, later discarding them, and the legs are used widely abducted in what we term the 'straddle walk'. About the same routine is followed for all joint and

bone plastics, arthroplasties, shelf operations, bone grafts, hip and knee arthrodeses, etc.

"The most trying time to the surgeon, of course, is from eight to ten weeks after operation, while bone repair or regeneration, is taking place and the motions involved in walking, plus the danger of slips, falls or sudden application of muscle power to regain balance and prevent falling, are likely to undo what he has labored so hard to accomplish. This long period of inactivity, while waiting for wound healing, lessening of pain and spasm, and bone repair naturally promotes not only atrophy, but circulatory stasis both of which retard the process of healing. Thus if this period can be shortened, recovery is hastened, hospitalization time reduced and expense lessened.

"For instance, after a hip arthroplasty or shelf operation for congenital dislocation of hip, the patient by the method mentioned above, may be placed in the water without bending or pain, the body floated to position on the plinth, and active movements of the part commenced. The only rules to observe are: (1) Do not produce pain; (2) Use only active motion of the affected joints within a painless arc.

"Of course, in addition to this, movements of all other unaffected parts are stressed to begin with,

because the patients morale and general tone need building up after the shock of such large surgical procedures, and the long period in bed in splints or casts, awaiting the joyful day when he will have his turn in the pool. His chief fear is of pain in the operated area, so when the technician directs his attention to the exercises for the unaffected parts, this is overcome. The production of inhibitory spasm so common to all efforts of motion in bed does not occur, and he does not realize that during the movements of other parts quite a good deal of motion of short range takes place in the operated joint.

"Next in sequence are specific exercise for the foot and knee of the affected leg, which force blood and lymph to and fro through the operated region from the muscle action below. Very definite deliberate and forceful movements of foot, ankle and knee are given by the technician in order to force the patient to concentrate his attention on these parts, and keep it away from the hip. Thus the inhibitory reflex spasm so detrimental to physical therapeutic progress is avoided.

"Passive motion (of the affected part) has but little place in the treatment or handling of bone and joint cases.

"We consider that by avoiding this spasm, and the earlier and safer attempts at active motion, such as we made in the water, we have succeeded in cutting down the convalescent period in the hospital at least 15 to 25 per cent--or an average of perhaps two weeks. At an average cost of $6.00 daily for the hospital, if it is a charity case, or more than that in instances where a special nurse is employed for a private patient, the amount saved the hospital in a year may be considerable."[15]

"Congenital and other hip joint conditions are handled with increasing satisfaction, especially because of the lessening of fear of movement after casts are removed and motion instituted. The terrifying apprehensiveness shown by these cases after the long imprisonment in casts for fracture, traumatic epiphysitis or congenital hip is one of the most obstinate factors militating against the reestablishment of function, with which the physiotherapist and surgeon have to contend."[16]

Tendon Transplants

"Because of the absence of gravity load, due to bouyant support of the part by the water, tendon transplants can be activated with greater safety, through

a somewhat greater range under water than is usually obtained in the bed or on the gymnasium table. The effect of this earlier activation guards against adhesions around the transplant and makes for better results in a shorter time. Where weight bearing is desired, but is rather dangerous (because there is no way of knowing exactly how much weight the patient really puts on the affected leg, even with crutches), this method affords a definite dosage, and is one of the most valuable parts of the treatment. This is effected by having the first standing and walking efforts made in water about four feet six inches deep, which will average about to the axillae on most patients. At this depth, only about one-eighth to one-sixth of the body weight is actually transmitted to the sore joint, bone braft or fracture line in the leg.

"Stepping in place, at first holding to the railing and then walking across the deep end of the pool with crutches, allows the legs to go through the complete short range used in these movements, thereby reestablishing neuromuscular control, and stimulating all metabolic processes according to the law that function and structure are interdependent. As soon as it is safe and advisable the patient moves up toward the shallower depths, thus

cautiously increasing the weight dosage. At the same time, by the increase of joint range and muscle function, by other exercises on the plinth, or in free floating positions, greater physiologic response is gained. The fear of falling does not exist, but even so the patient is told not to worry, because if he loses his balance and falls over no harm is likely to occur because there is no shock or strain to the part in the water.

"In this connection, may I point out that the method which we instituted in our very first pool, of having the physical therapist in the water with the patient, is a great advantage, not only to give assistance and moral support, but to hold and guide the part during its exercises. This could not be done, were small or deep tanks used and she had to stand outside the tank and give instructions."[15]

Fractures

"Any local treatment or manipulation around the site of a fracture was usually taboo in the last generation or two. Splints and casts were usually applied and the limb kept as nearly immobile as possible for six or eight weeks. At the end of this treatment there was obvious atrophy of muscles within the neighborhood of the fracture, and usually a very

considerable ankylosis of nearby joints. After the healing of the fracture, much time had to be spent in attempts at restoration of the function of joints and muscles, and recovery was much delayed. Today the treatment by physical means has been a distinct improvement in lessening the period of disability. By means of careful massage, the application of heat, and gentle movement of surrounding joints, the healing process is hastened, callus formation is stimulated, and the muscles and joints are more quickly brought back to normal function.

"In the physical treatment of fractures, the stages of the fracture must be well considered. For convenience we may divide these stages into three; first, the acute or recent, before ossification has begun. Here muscular spasm, pain and swelling are prominent. Adhesions tend to form very rapidly, within a few days after the initial trauma; swelling is often extensive, and both swelling and adhesions affect neighboring joints. There is passive congestion and more or less ankylosis. Tendons may adhere to their sheaths, causing further limitation of movement. In the physical treatment of this stage we should endeavor to relieve pain and congestion, to promote active circulation, and to prevent the formation of adhesions. To this end, heat and massage, very light

at first, should be applied; stroking movements above and below the site of injury should be given, providing in all cases adequate support to the limb and handling the injured area with greatest caution.

"Heat treatment may be begun at once, massage after a very few days, followed by active movements of neighboring joints. A patient with Colles' fracture, for example, may move his fingers from the first, and in a day or two the elbow and shoulder. These movements need not include the whole excursion of the joints; small degrees of movement are better. In some cases, movement of the surrounding joints should be postponed until a degree of union has occurred. Active movements are preferable, because the patient himself will instinctively avoid any movement which causes pain. Passive movement may be overdone very easily, especially in the early stages of fracture. Any increase of pain or swelling after physical therapy treatment is an indication that it has been carried too far and has been too severe. In all cases, the limb should be placed in a comfortable position, supported by pillows, and in recent cases the treatment is best done while the part is in a splint or half cast, or even in a sling.

"In the second and third stages, the chief aim is to secure muscular strength as well as freedom of move-

ment.... The patient should be encouraged to make active use of the limb, without putting upon it an undue amount of strain. In the third stage the bones are quite well united, and if pronounced adhesions are present, force in the use of passive exercises may be employed. Massage should be strong and vigorous."[8]

"When spasm exists," says Lowman, "or the adjacent joints are painful and partially stiff, as the knee for instance is in fractures of the femur, or from long incarceration in splints or casts, we have found that the compressed air bubbling massage applied to such parts aids very materially in lessening the spasm, and thereby aids the treatment possibilities, allowing a greater range of motion and improvement of the mental state. We use this means a great deal in the early stage of follow-up fracture treatment. It is especially suited to nervous children because of its sensory effect and its uniqueness."[15]

Poliomyelitis

Lowman, a pioneer in hydrotherapeutic treatment of poliomyelitis victims, says, "We have started underwater treatment in these cases several weeks earlier than ever before, beginning as early as the sixth week or immediately after a reasonably safe quarantine, even while some muscle

soreness still existed. We feel...that, following the treatment in the pool, the soreness and stiffness seem to disappear more quickly. In the water the movement can be started earlier with greater range, before spasm from soreness ensues, than can be done with bed treatment. The morale of the patient is decidedly better, because the inhibitions established during the early stage of acute soreness when the child dreads handling, are more readily overcome. In the water the children rapidly relax and lose their fear and probably the sensory threshold is raised by the development of other more powerful stimuli which claim the attention.

"Under the former treatment of early splintage for physiological rest, baking, massage and muscle training were not started till soreness disappeared, the period of inaction averaging about ten to twelve weeks. The mental resistance to movement in the first four to eight weeks, plus the increased sense of comfort from lying perfectly quiet, with the added pathological diminution of function and nutrition, make an obstructive barrier which is extremely difficult to overcome. When the actual sense of feeling of motion thus becomes lost it is expecting a good deal of the small patient, especially, to abstractly 'think' the impulses down to the various muscles.

"In the water, however, the contact with it, stimulating immediate bodily movement physiologically through the myriads of tactile end organs, produces a far greater and more natural stimulus to movement, which is accomplished more readily without strain because the gravity load is removed. The children sense this more readily than when a technician carries the gravity load by lifting the part with her hand.

"During the past year we have treated ten cases of poliomyelitis in the early stages and on a basis of our experience there has been a more satisfactory degree of improvement in less time than by any previous method we have used.

"It must be remembered, however, that it does not wholly replace the regular muscle training in the gymnasium or in bed, which is decidedly more disciplinary and regulatory and should be resorted to as soon as all soreness has disappeared and muscle 'come back' is evidenced.

"In chronic or old poliomyelitis cases the pool treatment should be used for general toning up of the body as an adjunct to the regular gymnasium work, for, from the improved body control, it makes better use of arm and leg than does simple gymnasium work alone.

The most prominent result with this group, however, is the psychological effect upon the children of finding that they can begin to compete in an active sport with their more fortunate fellows and feel less 'out of it' socially."[16]

Hansson adds, "The exercises we use are the muscle re-education exercises of Dr. Lovett[2], although applied in a new medium. The treatment requires 15 minutes. The first five minutes are devoted to special exercises, such as might be given for the calf muscle for example. The next five minutes are used for general condition exercises, as for instance walking in the water; and the last five minutes the patient undergoes some applied exercise, for example, diving."[10]

In regard to the treatment of poliomyelitis, Hubbard has this to say, "Anterior poliomyelitis is an acute infectious or communicable disease caused by a specific filterable virus. This virus attacks the motor cells of the central nervous system and the result, in a large percentage of cases, is paralysis or weakness of one or more muscle groups. In the majority of cases the end result will depend upon the treatment. In the acute and early convalescent stage absolute rest is the most important. In the later stages restoration of

muscle and nerve function is obtained best by means of specially directed exercises, for each muscle group affected. These exercises can be done most effectively with less fatigue in warm water."[11]

Evaluating the underwater exercises in poliomyelitis, Hansson maintains, "...that hydrogymnastics do not take the place of the other recognized orthopedic measures in the treatment of poliomyelitis. Orthopedic operations are more important than ever before because of improved technique; braces and other supports are necessary. At the Hospital for Ruptured and Crippled we still use the dry gymnasium, and also the low tension electric currents. Hydrogymnastic treatment, however, is the important part in the rehabilitation of residual paralysis in poliomyelitis."[10]

Hernia

"In most cases of hernia," says Elsom, "there is found to be a weakness of the abdominal muscles, especially the internal and external oblique, which are concerned in the formation of the inguinal ring. The recti muscles, which are commonly used in abdominal exercises are not so important from a corrective point of view. Therefore the movements which twist the body from side to side, side-bending movements and the like are most valuable.

"A patient convalescent from a herniotomy may hasten his recovery by mild exercises of rotation of the trunk and pelvis, with or without resistance. The operator may place his hand on the shoulder of a supine patient and offer varying degrees of resistance, while the patient tries to turn his body, shoulder, and pelvis first in one direction and then in another.... Many forms of exercise may be taken while the patient is lying on his back. These forms are often desirable in some post-operative cases, because of the lessened strain on the heart in the recumbent position. Active movements of raising the knees to the chest, with or without resistance, leg-raising and spreading, the so-called 'bicycle' movement, raising and rotating the legs, are all good. Simpler and less disturbing exercises consist of voluntary contractions and relaxations of the abdominal muscles, with a kind of pumping movement, which is in reality a form of abdominal massage stimulating the viscera and increasing the circulation, both arterial and venous. Simple blowing movements, as if blowing up a rubber bladder, involve considerable exercise to the abdominal muscles, and are useful in strengthening these organs when indicated postoperatively."[8]

Judging from the good results obtained by other men in improving muscle tone by hydrotherapeutic measures it is reasonable to expect similar results should this means be employed postoperatively as indicated above.

Arthritis

Currence believes, "The classification of arthritis into atrophic and hypertrophic forms is probably the best means to eliminate confusion. Hot baths constitute a most valuable form of treatment in both types.

"Hydrotherapy has been used with varying success in arthritic and rheumatic affections since the dark ages. Its curative value was not appreciated because of the empiric manner in which it was frequently utilized. The occasional failure of medication to satisfactorily control arthritic states has often forced sufferers to seek aid from non-medical groups. Lack of knowledge and the unsatisfactory application of such knowledge is accountable for the present situation.

"Hydrotherapy is an effective therapeutic measure capable of producing beneficial results more striking than the average medication now in vogue. Just as the pharmacological action of a drug is determined prior to its use, so should the specific value of hydrotherapy procedures be known and applied.

"I am not advocating that hydrotherapy should be used as the sole remedial agent. Diet, medication, colonic irrigations, endocrine therapy, vaccines, foreign proteins, electrotherapy, massage, passive and active motion, mechanotherapy, and occupational therapy may also be employed when indicated. In general, the induction of various degrees of hyperpyrexia is the most desired effect of baths in rheumatic disease.

"Hot Tub Baths. In order to prevent a reflex vasoconstriction of the capillaries, the bath is started with a water temperature of 96 to 99° F., and over a period of 5 to 10 minutes, the temperature of the water is gradually increased to 101 to 106° F., with the duration ranging from 3 to 30 minutes. Subsequent to this, the patient rises slowly or is lifted from the tub, and after being placed on a couch, is either wrapped in a warm sheet and blanket and allowed to cool gradually, or is packed in a blanket to maintain the hyperpyrexia, as may be indicated. When a more profuse diaphoresis is desired, sipping a cup of hot tea usually proves effectual.

"Bath Medication. The addition of medicaments to the bath water is a matter of choice.... Iodine preparations for this purpose show definite absorption

and effect. Sulphur--especially the newer colloidal preparations--may be of some value. There is no doubt that concentrated salines are effective as a surface stimulant and create hyperemia, especially if friction of the skin is prescribed with the bath. The addition of an emulsion of ethereal oils with salts will produce a marked surface stimulation and induce a higher fever. When such medicaments are added, care must be taken to prevent splashing into the eyes or ears, and the axillae, neck and groin should be protected by an application of vaseline prior to the bath. If it is desired to follow the tub bath with a pack, the fever will be maintained at a higher level than if this surface stimulus had not been produced.

"For all heat procedures involving the whole or a large part of the body, it is important to guard against the patient catching cold on account of the cutaneous hyperemia. A brief cold application prevents or lessens this danger. The normal capacity of the cutaneous vessels of responding to external cold temperatures by prompt contraction is noted. The feeling of fatigue often following heat applications is counteracted by brief cold water application or an alcohol rub. The temperature of the treatment room must also be observed and should be sufficiently warm to avoid

chilling.

"In the hypertrophic cases it is usually preferable to use less strenuous baths and to give them daily over a period of 2 to 4 weeks. These cases almost always are given temporary, and occasionally permanent, relief. These courses may be repeated after an interval of several weeks, and sometimes shorter courses suffice to maintain the improvement obtained. A similar course of treatment is often of great value in cases of chronic myositis and of neuritis.

"In gout, after the acute symptoms are under control, a similar course of baths will greatly hasten recovery. The gouty patient will usually do well with slightly higher bath temperatures.

"In the atrophic cases, courses of treatments must be carefully individualized. The more strenuous forms of hot baths which produce a fever of 101 to 103° F. given 2 or 3 times a week, produce striking results. In these cases, care must be exercised not to enervate the patient. Also, the frequency of strenuous hydrotherapy must not be sufficient to disturb the acid base equilibrium of the body, as this type of bath tends to produce an alkalosis.

"Continuous baths are of particular value in conditions of excessive pain, and when measures of a strenuous nature are contraindicated. Patients are

placed in a tub, preferably on a hammock, and are allowed to remain from one to three hours at a temperature of 99 to 99.5° F. This temperature is slightly higher than ordinarily used in a continuous bath, but it is usually necessary because arthritics with lowered skin temperature do not tolerate cooler temperatures. A pronounced sedative effect is produced and great relief is often accomplished when other measures have failed. This may be given daily or even twice daily, according to the patient's reaction.

"The use of pools is of great value. The temperature in the pools may vary according to the purpose indicated, ranging from 99 to 101° F. A definite tonic effect with great relief of pain is often achieved. Pools are excellent for free exercise, graduated movements, re-education of muscles, and manipulation by masseurs. Under efficient supervision, patients may spend many beneficial hours in pools.

"I have found local hydrotherapy of value in acute rheumatic fever. In acute stages of gout, hot applications alternating with light alcohol packs give some relief.

"Arthritis cases are...amenable to regular daily institutional care and treatment. In fact, in seem-

ingly hopeless cases, when all other measures have failed, hydrotherapy will often restore their comfort and return the patients to useful life.

"Although the best results with hydrotherapy are obtained when the patient is under institutional regime, hydrotherapy has the advantage in that effective courses of treatment may be utilized for ambulant cases or at the patient's home, without interfering with such other treatment the physician may consider indicated."[5]

The Saltpool

Brockway reports eleven cases of osteomyelitis treated in the warm salt water pool. He observes, "Theoretically, the principles of treatment seem sound and by actual practice the method has given worthwhile results. It is particularly suited to those cases where the osteomyelitic process involves the joint or is in close proximity to the joint.

"This method of treatment embodies and makes use of definite well recognized principles in the treatment of infection and joint regeneration, namely:

(1) Adequate drainage and immobilization. After the acute stage absolute rest is not maintained but after the first month the plaster cast is removed and the patient immobilized in bed by light traction, by splints, or by bi-valved casts. Daily pool treatment

is then started, but even this is comparative rest, since motions in the pool are performed with a minimum of effort. No effort is exerted by the patient in getting in and out of the pool, since this work is done by an overhead electric traveling hoist with the patient lying on a stretcher.

(2) Past experience in the treatment of suppurative arthritis has proven the proposition that physiological stimulation of a joint is the best means of insuring maximum return of motion in a diseased joint and regeneration of joint structure. This principle is made use of in the salt water pool treatment without jeopardizing the cardinal principle of rest.

(3) The salt solution being extremely hypertonic, drainage of the infected tissue is accelerated because the difference in osmotic pressure existing between the solution and the body fluids causes an outflow of the latter from the diseased area.

(4) Active movement in the water avoids the production of inhibitory spasm from pain or fear of pain as is usually produced by other forms of physiotherapy and muscle reeducation movements.

(5) The treatment is soothing and is enjoyed by the patient as compared with spending months of inactivity in ill-smelling casts."[4]

Lowman advocates use of the saltpool "In cases with draining sinuses or open wounds...such as tuberculous hip cases, Pott's disease, osteomyelitis or simply surgical wounds that are sluggish in skin closure.... This pool contains about 2100 gallons of water, into which 500 pounds of sea salt and 200 pounds of magnesium sulphate are dissolved.# This strength of brine does not tolerate germs, as it is a hypertonic solution, in which organisms cannot live long. Many cases of osteomyelitis that have become surgically clean, with the saucerized area filled with granulations, can be helped by mild exercising in the salt water. The patients are apt to be pale and thin from the long standing infection; they may have spent months in casts and have had repeated operations, and the respite and enjoyment of this type of treatment may help materially in building them up."[15]

In brief, underwater exercise offers resistance increasing with the speed of motion[9] and at the same time supports the body, permitting free motion in any direction without the strain of weight bearing.[14] Careful regulation of the temperature of the water can

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#1 lb. sea salt/4 gal. of water; 1 lb. mag. sulph./10 gal. of water.

produce relaxation of muscles[9], increase the local blood supply, and exert a sedative action on the patient.[1] Thus, weak muscles acting in this medium are resisted only as they increase their strength and speed of motion, and can therefore be exercised earlier than by any other means.[16] Spasm is reduced, blood supply is enhanced, and recuperation following exercise is promoted by the decreased irritability of the patient.

By the addition of salt to the bath hypertonic solutions[15] may be prepared which increase the specific gravity of the water[2] and inhibit bacterial growth in draining and slow-closing wounds.[15]

The proper place of this mode of treatment should be appreciated. It does not replace, but is an important adjunct to, other recognized orthopedic measures.[10]

CHAPTER V

EXAMINATION OF MUSCLE FUNCTION

"It has been quite generally accepted that muscle reeducation, as applied particularly to paralysis cases, is of very decided value in treatment.... Other things are done to the patient; this he does himself, and in doing it he activates the whole psychomotor mechanism involved in active muscle function.

"The degree of ultimate success of our surgical treatment of paralysis cases will be evidenced by the degree of care and the intelligent handling of both preoperative and postoperative phases, or, in other words, the physiotherapeutic stage.

"In this phase of the treatment it is essential that the technician be one as thoroughly trained and competent as it is possible under the circumstances to obtain for any given case, for, unless one is definitely certain that every bit of functional improvement has been obtained by the technician, how can one determine which of several operative steps to apply when the time for surgical interference is decided upon? In fact, the question of when to operate is often determined by the report of the physical therapist, as is also the choice of procedures.

"Consequently, if the amount and degree of motor response in a given case is such an important factor it becomes necessary to understand the element involved in obtaining response. The amount of comeback in any given case depends partly on the pathological condition existing, partly on the mental ability of the patient in accepting, teaching and developing power of concentration and action, and also partly on the ability of the physical therapist in recognizing and overcoming any obstacles presented which delay or prevent return of function. One must know the degree of actual residual paralysis in any and all muscle groups in order to prescribe the proper surgical procedures. The question of when this can be ascertained is more or less variable and of all the factors involved in arriving at a decision, the consideration of whether or not the technician has thoroughly mastered the psychological as well as the physiological details, is not the least. The qualifications and capabilities of the person conducting the muscle reeducation needs some check or measurement in order to determine how stable and uniform his results are and what degree of dependence can be placed upon his report in a given case.

"We have found at the Orthopedic Hospital School Clinic, as well as in private practice, that an adequate

system of measurement and recording of motor responses makes for accuracy in determining surgical procedures based on these records. It also tends to develop the technicians handling the cases, and makes them realize more fully how really valuable and important a contribution their particular work is to the success of the clinic. Time must be conserved in a busy clinic, and when one has to trace back through a mass of typewritten data to obtain the original record and then pick out the progress recorded at different dates for comparison, one's eye cannot take in at a glance enough to arrive at a quick conclusion. It is extremely important to note the degree of improvement as well as the length of time passed in obtaining it, in order to decide whether to go on with the reeducational work or to operate.

"By having one person only make the muscle analysis for the record once a month, the element of personal equation involved is ruled out and differences of response at different times can be more accurately explained. We have used a scale familiar to many, composed of nine gradations, estimating muscle movement, effect on gravity as evidenced by joint movement, and muscle action against both gravity and resistance load.

The following table with abbreviation and numerical equivalent explains these points:

Inactive	IA	0	No appreciable motion
Action weak. . .	AW	1	Definite muscle contraction #
Fair minus . . .	FM	2	Definite muscle action without much influence on the joint.
Fair	F	3	Well defined action almost up to movement of the joint.
Fair plus . . .	FP	4	Beginning action of joints but not against gravity or enough to overcome friction of table.
Good minus . . .	GM	5	Beginning action against gravity or friction.
Good	G	6	Well defined control over gravity or friction.
Good plus . . .	GP	7	Beginning power against added resistance.
Normal minus . .	NM	8	Increase against resistance but not quite normal.
Normal	N	9	Normal

Between IA and AW is fibrillation or questionable contraction.

"It was found after several years of recording by using the abbreviations in columns on either side of a printed list of joint movements, that as the record became fuller it took longer to figure out the comparisons and form conclusions as to the amount of progress made. We consequently adopted the method of recording by numerical equivalents, which greatly expedited the facility of judging progress. The first column in our present chart shows both the abbreviation and number while the subsequent columns have only the

numeral. Each column is dated above and shows the initials of the one making the test. In this way tests by the physical therapist can be compared with those of the surgeon, or trained technician, and a check obtained upon the abilities of clinicians, internes, students or any one training for this work.

"On Chart I, made July, 1925, to May, 1927, one is immediately struck with the rapid return of power in the thigh groups, as the eye notes quickly, for instance, thigh flexion through progression of 3, 6, 7, 8, 9. Still more valuable is the glance at the right knee showing a gain from very weak to nearly normal. One concludes at once that the comeback is going to be favorable. The adduction register at Point 6 nearly balances with abduction at Point 7. Thus, deformity in either of these planes is hardly to be expected from muscle imbalance. As one notes that high numbers prevail at the end-reading on all muscles controlling action at the hip joint, one says at once, 'no operation indicated.' Study of the foot and ankle section shows that, on the whole, the right foot is weaker than the left. Everters are more active than inverters, but both are extremely weak. Note that progress has for the first three months or so begun to indicate the future probabilities as the knee and thigh are in good

CHART I
MUSCLE TESTS

Right																			
SR 5/12/27	SR 2/12/27	SR 11/11/26	SR 8/9/26	SR 5/7/26	SR 4/7/26	SR 1/22/26	SR 11/13/25	CLL 7/22/25			CLL 7/22/25	SR 11/13/25	SR 9/27/26	SR 4/7/26	SR 5/7/26	SR 8/9/26	SR 11/11/26	SR 2/12/27	SR 5/12/27
Thigh																			
9	9	9	9-	9	9	9	9	8	NM	Ext.	NM	8	9	9	9	9	9	9	9	9
8	8	8	8	9	8	7	6	3	F	Flex.	GP	7	8	8	9	9	9	9	9	9
9	8	8	8-	7	7	7	7	7	GP	Abd.	NM	8	7	8	8	8	8	8	8	9
8	9	9	9-	9	8	8	8	6	G	Add.	G	6	9	8	8	9	9	9	9	9
9	8	8	8	8	8	7	7	7	GP	Ext. Rot.	GP	7	8	8	9	8	8	9	9	9
9	8	8	8	8	9	7	7	3	F	Int. Rot.	NM	8	8	8	9	8	9	9	9	9
Knee																			
9-	9	9	9	9	7	8	8	4	FP	Flex.	N	9	9	9	9	9	9	9	9	9
9-	8	8	8	9	8	8	8	3	F	Ext.	NM	8	9	9	9	9	9	9	9	9
Foot & Ankle																			
7	6	6	6	6	6	5	4	2	FM	Flex.	FP	4	7		8	8	8	8	8	9
3	3	3-	3*	5	5	5	2	0		Ant. Tib.		0	1		5	7	6	6	6	*
9	9	10	9	9	9	9	9	8	NM	Ext.	GP	7	9		9	9	9	9	9	9
3	2	2	2	4	4	4	2	3	F	Inver.	GM	5	9		9	9	8	8	8	9
9	8	8	8	8	8	7	3	2	FM	Ever.	GM	5	9		9	9	9	9	9	9
Toe																			
9	9	9	9	8	8	7	6	9	N	Flex.	N	9	9		9	9	9	9	9	9
5	5	5	6-	6	7*	6	6	9	N	Ext.	N	9	9		9	9	9	9	9	9
8	6	6	7	8	8	8	7	9	N	E.P.H.	N	9	9		9	9	9	9	9	9

*REMARKS: April 7, 1926. Little to ext. 3; Posterior delt. still weaker than middle and anterior. August 8, 1926. See note on progress card. May 12, 1927. Left anterior tibial 7 when holding but never works with dorsal flexion unless foot is held in inversion and will not work independent of E.P.H.

condition and one sees that alignment and foot stabilization are all that will be needed to make this leg brace-free. Note the later record and this prognosis seems about correct, i.e., the right foot shows that throughout the whole period the Achilles has continued more powerful than the dorsiflexors and the evertors progressively overcome the inverters, so, stabilization with transplantation of the peroneus to the inside of the foot and the extensor proprius hallucis, which has always been strong, back to the metatarsals, is indicated. At once you may ask, 'Why stabilize by arthrodesis when there is much evidence of good musculature?' There are three reasons: (1) Weakness of the opposite foot, (2) sufficient imbalance in right foot muscles to indicate worse deformity than there would be with weaker muscles, and (3) too much insecurity over the subastragaloid joint.

"The second chart, a condensation of a fuller clinical chart, shows the line-up for about twenty-one months and shows the muscle group relations and the foundations upon which we must base our judgment as to the next stage of treatment, i.e., the surgical. At a glance one sees that the right leg is satisfactory except in the foot where the relation of eversion to

CHART II
MUSCLE TESTS

Right					Left			
				Thigh				
SR 6/29/27	SR 1/15/27	SR 2/22/26	SR 9/15/25		SR 9/15/25	SR 2/22/26	SR 1/15/27	SR 6/29/27
9		9	5	Ext.		9		9
9	9	7	5	Flex.	4	4	4+	4
9	8	7	5	Abd.	4-	5	7	9
9	9	9	4	Add.	4-	4		3+
9	9	9	6	Ext. Rot.	8	7	9	9
8	9	7	2	Int. Rot.	4	4	6	7
				Knee				
8	7	5*	5	Flex.		5*	6*	7
9	9	8	6	Ext.		4*	4	3+
				Foot & Ankle				
8	7	5	0	Flex.	4	7	8	9
4	2	1	*	Ant. Tib.	1	2	6	7
9	8	6		Ext.	9	9	9	9
4	5	4	0	Inver.	7	7	9	9
9	9	6	4	Ever.	9	9	9	9
				Toe				
6	7	5	5	Flex.	4	9	9	
9	8	7	0	Ext.	6	9	9	
7	8	4+	0	E.P.H.	7	9	9	

*REMARKS: September 15, 1925. Heel cords contracted, especially right. Hamstrings contracted. February 22, 1926. Limited range of motion to knee so hamstrings will not become overactive. Left knee at first and second tests could not move patella by pull of quadriceps tendon; now has a strong pull. January 15, 1927. Left knee flexion assisted by gastrocnemius and tensor fasciae good on left in assisting knee flexion. June 29, 1927. Left thigh adduction with gravity and friction and thigh flexion ruled out is 5.

to inversion and extension to dorsiflexion is so disproportionate that stabilization will be necessary, but also that combined with a transplant a brace-free leg will be expected. The left thigh is seen to have been improved but not throughout. The flexor weakness represented by 4 means future difficulty in stair climbing. The extensor 9, however, allays any anxiety as regards standing, as long as we note that with flexors grading 7 against quadriceps 3 we can make a biceps-to-patella transplantation. This will assure a reasonably stable leg, further confirmed by noting the grading of foot muscles which are all strong. From the findings of the chart, even though one did not see the patient, the future course and prognosis of the case can be determined with a good degree of certainty.

"The possibility of getting at least a reasonably good idea of the status of a case by simply a glance at such a chart, is enhanced by a photograph of the case as originally presented.

"Differences in grading muscular power can be noted and changes may be accounted for by the condition of the patient at the time, and fatigue, excitement, cold muscles, etc., may all be allowed for. Allowance must also be made for the personal equation which usually accounts for at least a variance of one degree. Pref-

erably the same persons should make all the tests, and the longer they do this the more reliable they become and the more dependence the surgeon can place upon their findings in deciding upon reconstructive procedures." [13]

"We are also developing a system of cork floats, which will give us a possibility of measuring the amount of actual strength which the muscles are exerting in certain movements. Knowing the coefficient of buoyancy of the water, we can measure the lifting power of any piece of cork by a scale, in accordance with its size. These floats of various sizes are numbered and have webbing loops through which a hand or a foot can be thrust, and when the patient submerges them we know exactly the number of pounds of muscle pull that is being exerted." [14]

Charts similar to those presented above were kindly forwarded by L. W. Hubbard of the Georgia Warm Springs Foundation. They are included here because of their completeness.[20]

Steindler, at Iowa City, uses still another method. He checks "the effect of muscle training by recording the increasing efficiency of the locomotor act. In pathological locomotion, casual observation gives only very inaccurate ideas of efficiency.

CHART III

KEY TO MUSCLE TEST

(Georgia Warm Springs Foundation)

Normal	N	- Muscle can complete arc of motion against gravity with a great deal of resistance.
Good	G	- Muscle can complete arc of motion against gravity with some resistance.
Fair	F	- Muscle can complete arc of motion against gravity (no resistance).
Poor	P	- Muscle can not complete arc of motion against gravity.
Trace	Tr	- Muscle can be felt to contract but no motion seen.
Gone	or O	- Muscle cannot be seen or felt to contract.

CHART IV (Georgia Warm Springs Foundation)

NO. NAME MUSCLE TEST SHEET AGE DIAGNOSIS DATE OF ONSET

	Cannot Walk,	Walks Unaided,	With Braces,	Left,	Right,	Crutches,	Canes,	Corset.
Date								
Date								
Date								
Date								
Characteristic gait								
Date								
Date								
Date								
Date								

LEFT	TRUNK AND LEGS	RIGHT
	Facial	
	Neck	
	Back	
Upper	Anterior abdominals	Upper
Lower	" "	Lower
	Lateral abdominals	
	Gluteus maximus	
	Ilio psoas	
	Sartorius	
	Tensor fasciae latae	
	Hip abductors	
	Hip adductors	
	Inward rotators	
	Outward rotators	
	Quadriceps	
Inner	Hamstrings	Inner
Outer	"	Outer
	Gastrocnemius	
	Anterior tibial	
	Posterior tibial	
	Peroneals	
	Extensor longus digitorum	
	Extensor brevis digitorum	
	Extensor proprius hallucis	
1	Flexor longus digitorum	1
2	" " "	2
3	" " "	3
4	" " "	4
1	Flexor brevis digitorum	1
2	" " "	2
3	" " "	3
4	" " "	4
	Flexor lumbricales	
	Flexor longus hallucis	
	Flexor brevis hallucis	

MEASUREMENTS
Calf
Thigh
Length

CONTRACTURES AND DEFORMITIES
Hip
Knee
Ankle
Toes
Scoliosis

LEFT ARM	NAME	RIGHT ARM
Anterior	Deltoid	Anterior
Middle	"	Middle
Posterior	"	Posterior
Upper	Trapezius	Upper
Middle	"	Middle
Lower	"	Lower
	Serratus magnus	
	Rhomboids	
	Latissimus dorsi	
Clavicular	Pectoralis Major	Clavicular
Sternal	" "	Sternal
	Outward rotators	
	Inward rotators	
	Biceps	
	Brachioradialis	
	Triceps	
	Supinator brevis	
	Pronators	
Ulnar	Wrist flexors	Ulnar
Radial	" "	Radial
Ulnar	Wrist extensors	Ulnar
Radial	" "	Radial
1 Profundus	**Finger flexors**	Profundus 1
2 "	" " "	" 2
3 "	" " "	" 3
4 "	" " "	" 4
1 Sublimus	" "	Sublimus 1
2 "	" " "	" 2
3 "	" " "	" 3
4 "	" " "	" 4
1	Finger extensors	1
2	" "	2
3	" "	3
4	" "	4
1	Lumbricales	1
2	"	2
3	"	3
4	"	4
1	Dorsal interossei	1
2	" "	2
3	" "	3
4	" "	4
	Abductor minimi digiti	
1	Palmar interossei	1
2	" "	2
3	" "	3
	Abductor brevis pollicis	
	Adductor pollicis	
	Flexor longus pollicis	
	Flexor brevis pollicis	
	Opponens pollicis	
	Extensor longus pollicis	
	Extensor brevis pollicis	
	Extensor ossis metacarpi pollicis	
CONTRACTURES AND DEFORMITIES		
	Shoulder	
	Elbow	
	Wrist	
	Fingers	

More exact information of the expenditure of the motion can be obtained by measuring first the metabolic changes, especially the excess oxygen intake, and then by comparing it with the output of actual mechanical work. In this way we arrive at an efficiency index of the locomotor act. For instance, in cases of congenital dislocation of the hip, we found the expenditure, or cost, to be several times that of the normal gait, and the 'efficiency' correspondingly less. So, we can measure the effect of muscle educational treatment, alone, or combined with operative methods. Another, more simple method of measuring the value of muscle training in terms of efficiency is to correlate standard motions to the speed in which they are carried out, assuming that the actual metabolic cost increases with the slowness of motion. We have made use of this plan, particularly in muscle education of the upper extremity, both in spastic and in paralytic cases. The increase in speed denotes gain in accuracy and precision of motion." [19]

CHAPTER VI

EQUIPMENT

In planning pool construction for the sole purpose of giving under water exercises to orthopedic patients, probably no one has given more attention to detail than has Lowman. He points out that, "The size and shape of a pool will be influenced to a great extent in existing institutions by the space available for its installation. In institutions under construction and those in prospect, ample space should be allowed, if this modality is to be added to the physical therapeutic equipment.

"A convenient size would be from 12 to 15 feet wide and from 20 to 25 feet long.... Too large a pool is not economical in upkeep and frequent changing of water might prove expensive."[14] The shallow end should be a little less than 3 feet deep and the deep end not over 4'6". No pool should be less than 10' long and 8' wide since free movements of patient and technician would be hampered in a smaller pool.

"The slope of the pool floor in a length of from 20 to 25', between the depths given, is about the appropriate inclination.... The surface of the bottom...

should be rough and not of slippery tile.

"In a pool the size and shape mentioned, 2 or 3 patients can be kept busy, but if more serious and localized concentration of attention is required, a curtain can be drawn across one section of the pool shutting them off from the disturbing presence of others.

"Another essential physical feature is the placement of a pool.... A pool should be so placed that there will be ample space to pass around at least on two or three sides of it and it should be in a room with high enough ceiling to allow proper ventilation with facilities for the escape of the moist hot air which will arise from a heated pool. If necessary, suction fans should be installed. When placed outdoors, a pool should be sheltered from the wind and have plenty of sun exposure. It is best surrounded by a wall in order that outside influences may not distract the attention of the patient. It is most essential in muscle reeducation technique to maintain discipline and concentration.

"Dressing rooms should be placed conveniently.... Many patients with poliomyelitis have mild kidney lesions, and chilling of the skin is consequently

detrimental.

"Floors should all be inclined at the proper position for drainage....

"Sufficient time should be spent on the table in the dressing room after the treatment to allow the patient to recuperate. It must be reemphasized that water gymnastics are more fatiguing than most technicians realize, and those patients who are not sent directly back to bed, such as ambulatory patients, should have an opportunity for a nominal amount of rest before beginning other activity, and particularly for allowing their skin temperature to become normal before passing outdoors into colder air. Where possible, cots in a sunny nook are a valuable adjunct.

"At the entrance to the pool, foot baths should be provided so that patients and technicians can step directly from these into the main pool. This will reduce contamination of the water caused by a person stepping from a dusty or soiled floor into it.

"For simple construction and use indoors, a steel tank is satisfactory and may be cased outside with cement finish, and tiled inside. A cheap and simple equipment can be made by using large corrugated galvanized iron tanks with sides about 3 feet high and from 10 to 15 feet in diameter. These are inexpensive

and can be equipped with steam pipes and if necessary set at a slight inclination, so that when being cleaned the drainage will be all to one side, and they can be satisfactorily emptied with a siphon if a floor outlet cannot be placed in them.

"Filtration and sterilization deserve careful consideration. The latter is chiefly accomplished by one of two systems: that of injecting free chlorine gas into the water of the intake pipes or chlorination by means of some of the hopochlorites as salts or in solution, added continuously from a special feed line or intermittently according to the capacity and use of the pool and the laboratory tests of the water. The latter has proved less irritant and a better bactericide.

"We feel that indoors in an institution housing more or less helpless children there is an added responsibility on the trustees to avoid the use of any free gas of a dangerous type. The sentiment of my own board, since the Cleveland disaster, is strongly in favor of the hopochlorite solutions. Our pool has been used continuously for four years, having a capacity of from 5,000 to 6,000 gallons. It is chlorinated with a hypochlorite solution daily and we maintain a bacterial count as low as 50. We have had no infections at all."[14]

"Even though the water is chlorinated, the patient should be properly prepared by local bathing or a shower....before entering the pool.

"One of the reasons why technicians who remain in the water for long periods should wear rubber suits (hunter's waders) is that the bacterial load of the pool is reduced and more easily controlled. In pools used by women bathers this factor is more serious than in men's pools. One technician in the pool for eight hours is equal to 16 patients at 30 minutes each." [17]

"Copper sulphate is used as an algicide, and alum serves as a coagulant in large pools.

"For circulation of salt water, especially adapted filters using finer sand and equipped throughout with bronze fittings must be used.

"Outlets for compressed air are placed at suitable places in the pool wall from which air jets can be forced into the water against the body for its massaging and tonic effect.

"Intake and discharge outlets should be properly placed and of large size for the sake of economy in emptying time when pool water is changed.

"All submerged metal equipment should be of bronze, chrome nickel, or enamel, which are not subject to

corrosion from the chlorine. All fittings placed in the side walls should be firmly fixed in the cement and reasonably solid to allow for heavy stresses without becoming detached or cracking the tile or cement, which is likely to happen after some years of use.

"Pool furniture and apparatus is next in importance in developing successful variations of exercise. We have found that submerged plinths or tables with inclined tops have been a valuable aid to us in this respect. They allow the head and shoulders to be supported out of the water and have appropriate hand holds for fixation of the shoulder girdle, while the body floats out onto the surface of the water. In this way movements from prone, supine and side lying positions can be obtained with shoulder fixation."[14]

"For localized muscle training the patients are placed on the submerged plinths.....Perineal straps keep the body from slipping down. The head is thus held just out of water and the fear of submergence is removed. Down in the middle of the plinth is placed a row of one-inch holes, six inches apart, into which a post can be inserted for the child to straddle. It can be padded by wrapping a towel about it or may be

shaped as desired. When the post is used a little more freedom of leg movement is allowed than with the loops.

"For the use of the extensively paralyzed -- practically helpless -- cases the "Bubble Boat" has proved a godsend. It is an English surf boat supported by three large rubber balls about one foot in diameter. The bamboo frame is about five feet long and two feet wide.... Between the parallel bars are suspended two canvas slings which support the body just below the surface." [16]

"Around the side walls we have arranged a submerged hand rail 2½ inches from the wall, fastened to pins firmly set in the cement, and these are also used for localization of trunk movements by fixing the shoulder girdle from the hand hold in the prone position, or stabilizing the legs and pelvis by hooking the feet with the legs abducted behind the rod.

"A stairway leading into the water forms a useful piece of apparatus which is employed as follows: The head may rest on the step just at the water level, the body floating out into the water; the arms may be extended along this step or the elbows depressed to the step below, and extremity movements can be made from that position. The deeper steps are also useful as a

seat for sitting positions. They may be used for the "prone lying position" by having different depths in accordance with differing arm lengths in which position the hands support the body while it floats.

"A steel cable, or wire, stretched across the pool at a height of about 1 foot above the surface is useful.

"A vertical pole set in a socket forms another piece of apparatus for a type of movement in which the hand grasp holds the arms abducted and overhead in the side lying position. These movements are of value in certain types of scoliosis and also aid in the development of the lateral abdominals, latissimus dorsi and quadratus lumborum muscles, which are quite essential for walking in cases of double leg paralysis with weakness of the flexors of the thigh, it being necessary to develop the former in order that the legs carrying the added weight of the braces can be raised and thrown forward.

"Paralytic patients also require certain splintage of parts to prevent the assumption of positions of deformity and the stretching of weakened muscles. In order to keep up a continuity of treatment such as is maintained in the braces or in bed, a right angle splint for the legs, which we speak of as a "bath splint," is

made of wood with a right angle foot piece attached to either a short or a full length leg portion. This is fastened with tapes, preventing toe drop, bending of the knees and stretching of the quadriceps. Similar splints can be used for the arms if necessary. They are of double value in that, being made of wood, they assist in floating the part affected. At the same time, when efforts are made to submerge the legs the increased buoyancy makes for added resistance.

"We also use a metal form like a back brace, which is covered with rubber or shellacked and called a back splint. It is used in cases of spinal fusion for spinal curvature and allows the patient to be taken into the water in recumbency without putting gravity strain on the area recently operated on, and thus early muscular activity, which aids the nutrition of the part, is obtained without allowing the motion in the grafted area.

"The musculature of the arms and shoulder girdle can be thus developed as well as the leg and abdominal muscles. We can in this way begin movement in spinal fusion cases as early as the eighth or ninth week and hasten the possibility of solidification in the grafted

area, saving time in the early return of muscle power.

"It can readily be seen that there is just as great a possibility for variation in exercises thus applied as there is in the regular gymnasium, with the added value that in the water the patient can be allowed to move in all planes, whereas, in the gymnasium, in bed or on the table, movements are restricted to certain planes. The successful use, however, of various types of apparatus depends greatly on the resourcefulness of the technician and her knowledge of kinesiology -- not only the normal but more especially the pathologic or abnormal kinesiology, as it exists in paralytic patients or those in whom joint plastic surgery or tendon transplantation has been done. The surgeon's understanding of the prescriptive factor in ordering various types of work is also essential for the successful treatment of any given case. A surgeon should not simply place the patient in the hands of a technician and depend on her to get results. The more intelligent the prescription is, and the clearer the comprehension of the technician, the better will be the results.

"Finally, then, it can be said that the successful use of hydrogymnastic technic depends on three fac-

tors: the surgeon, the technician, and the physical equipment and limitations of the pool." [14]

In contrast to the elaborate outlay which Lowman describes, we wish to present through Blount and Elson the plans for a simpler unit, that may be installed in any hospital. Gaenslen comments that "It is doubtful whether the great sacrifices...made...to provide pool treatment are justified by the results. The ordinary tub or small home-made tank will answer very well.

"I have found the so-called Hubbard tub [3] of great help." [9]

Blount and Elson believe that "The advantages of hydrotherapy in the treatment of residual poliomyelitis have been well shown during the last few years. Adequate facilities for underwater exercises are usually lacking, however. The common bathtub is too small to allow free movement of the limbs of any but the smallest children. Large circular tubs and pools have been filled with warm water and used to advantage in muscle training and in supervised swimming. But the expense of these tanks, coupled with the necessity for considerable floor space, has made them impractical in most cases.

"Through the kindness of the inventor, Mr. Carl Hubbard of Chicago, we offer the plans of a simple and

effective tub which is in use at Madison, Wisconsin. It is made of sheet iron and mounted on legs which bring it to the proper height to avoid stooping on the part of the operator. It is of such size that the average man may be submerged and at the same time be permitted free abduction of all extremities. A minimum amount of water is required. The tub itself is not expensive, and may be set up in the ordinary home.

"There are several advantages of the peculiar shape. Without being himself in the water, the physiotherapist accurately controls the exercises in all positions. By standing in the notch, he may support the extremities without the usual backstrain, especially in exercising the deltoids and glutaei. The water is deep enough for buoyancy in all cases, but shallow enough for safety. Helpless cases are supported sufficiently to allow control of the exercises by a single operator. Introducing patients and removing them is as simple as in the case of the ordinary bathtub. With larger tubs, the handling of patients is one of the difficult problems. When patients are ready to walk alone, a large pool is obviously of benefit for swimming and walking instruction. For the finer muscle training, the Hubbard unit is still preferable. Exercises may be graded

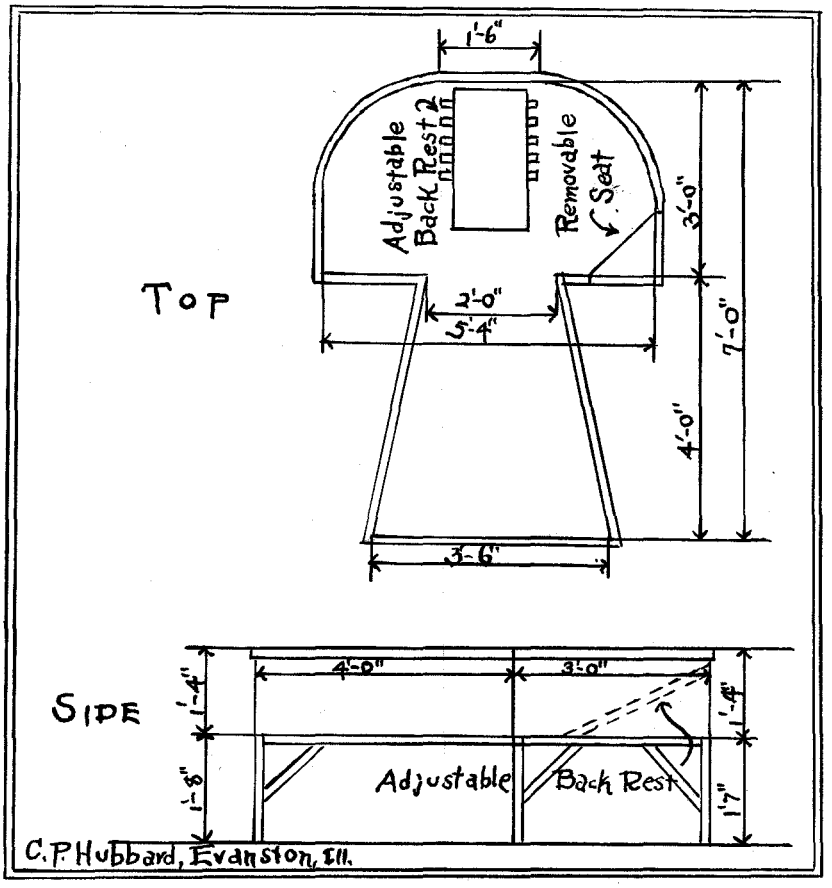

Fig. 1

A plan of the tub with dimensions

as in table work.

"In the treatment of subacute cases this tub is of particular value. The temperature of the water may be increased to stimulate circulation in the relief of primary muscle soreness, and later in the mobilization of stiff joints. Floating exercises may be started earlier than table work with no harm to the patient. The danger of overwork is lessened when the gentle support of the water is substituted for the resistance of the table top. Later, the water offers a desirable resistance to the more rapid active movements, so that the power required increases geometrically and the patient is able to move more rapidly. At this stage it may be desirable to supplement tub work with other physiotherapeutic methods."[3]

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