1952

A study of normal and abnormal motor development in infants (An approach to muscle testing of infants)

https://hdl.handle.net/2144/22547
Boston University
BOGTON UNIVERSITY

SCHOOL OF EDUCATION

Service Paper

A STUDY OF NORMAL AND ABNORMAL MOTOR DEVELOPMENT
IN INFANTS

(AN APPROACH TO MUSCLE TESTING OF INFANTS)

Submitted by

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(B.S., Boston University, 1946)

In Partial Fulfillment of Requirements for
the Degree of Master of Education

1952
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PART I
CHAPTER I

INTRODUCTION

The aim of this study was originally and primarily to clarify in the writer's mind some of the problems encountered during the past eight years in work as a physical therapist at the Children's Medical Center (Children's Hospital) in Boston, Massachusetts.

Children from all parts of this country and from many foreign lands are brought to this hospital. Anxious parents come from near and far to find out what is "wrong" with their youngsters; they hope that something can be done to make them well and normal like other children.

Children with fractures, sprains, dislocations and wounds are admitted daily to emergency wards; the neurological and neuro-surgical services deal with diseases of the neuromotor and neurosensory mechanism, such as cerebral paralysis, encephalitis, and transverse myelitis. The orthopaedic outpatient department handles countless cases of peripheral nerve lesions, congenital and post-traumatic deformities and deviations from normal development. The posture clinic sees children with uncomplicated posture problems only and others who have severely deformed backs due to structural scoliosis. There are also specialized wards where only one type of disease is treated, such as the cardio-vascular, the leukemia, the poliomyelitis units and many others.

Children seen in any of these departments frequently are referred to the Physical Therapy Department which operates in the outpatient
department as well as on all the hospital wards. The children are referred there for diagnostic tests as well as for purposes of treatment.

For the sake of illustration of a child's first visit to the hospital let us take the case of a two-year old boy whose parents have noticed that he walks with a limp. After the medical and social history has been recorded, the doctor examines the child. Obviously, the schedule of a very busy outpatient department will not allow him to give each child the detailed sensory and muscle examination which serves as a basis for the diagnosis is the child's abnormal gait due to muscle weakness, some deficiency of bones or joints, cerebral injury or other factors. The doctor, therefore, refers the child to the physical therapy department for more specialized tests; then -- using the results as a basis for further examinations -- he decides whether the child should be admitted to the hospital wards for further study or treatment, or be advised to return for treatment to the outpatient department.

Obviously, the scope of the problems thus referred to the physical therapy department is a wide one; the tests on which the medical staff relies to a great extent when making a diagnosis and in prescribing specific forms of treatment have to be very reliable. Inaccurate tests would be most confusing and misleading. Physical therapists, therefore, are required to have several years of practical experience, working under close supervision, before they are qualified to give muscle examinations and tests of motor performance.

It is beyond the scope of this paper to describe in detail the numerous tests employed for such a muscle examination. They have been
used and standardized not only throughout the United States but almost identical procedures have been employed in foreign countries.

Dr. Robert W. Lovett and Janet B. Merrill of the Children's Hospital were the originators of these manual tests, which were later revised by Dr. Arthur Legg and Miss Merrill.

Throughout the years several mechanical tests have been devised for measuring muscle function and strength objectively, but it has always been found that while it was technically possible to measure normal muscle strength by various spring balance machines, it is difficult to conceive of a machine which would be able to account for changes in the patient's position during the test, to detect substitution of muscles other than those to be tested, and to analyze complex motor patterns due to abnormal conditions. Only a trained eye can detect and interpret differences in the types of muscle weakness due to nerve involvement, disuse atrophy, pain, fatigue or incoordination. The result of the manual test expresses not only the examiner's evaluation of the functional strength of the muscle but also the observations and frequently an analysis and interpretation of anatomical, physiological and neurological symptoms encountered during the examination.

Muscle grading based on Legg and Merrill's work uses gravity and resistance as measures for evaluation of strength. The following grades are used:

1. Gone -- no contraction felt.

2. Trace -- muscle can be felt to tighten, but cannot produce movement.

3. Poor -- produces movement with gravity eliminated, but cannot function against gravity.

4. Fair -- can raise part against gravity.

5. Good -- can raise part against outside resistance as well as against gravity.

6. Normal -- can overcome a greater amount of resistance than a 'good' muscle.

Ratings of additional "plus" or "minus" are used for finer gradations. All the muscles listed in Table 1 and 2 are tested and rated according to the above key. Range of joint motion is expressed in numerical value of degrees; any restriction from the normal range is recorded. Muscle tone is described as well as presence of spasm, fibrillations and tremor. Fixed deformities are described and abnormal motor patterns are noted.

Obviously, this type of manual muscle testing requires not only a great deal of experience on the part of the examiner, but also cooperation on the part of the patient. Older children rarely present a problem in this respect; they usually go through the motions and exercises the way they are asked to.

Testing of children under the age of two, however, presents a very different problem. These infants, naturally, do not understand what is wanted of them and, therefore, cannot be expected to go through a series
of test positions and movements. They often react quite strongly to the new and strange surroundings, to the unknown faces and the people in white uniforms. They are frequently so upset that they will not play with the toys offered to them. Nevertheless, the physical therapist has to give a thorough analysis of the baby's muscle function and motor performance; all too frequently is she compelled to do this within a very short period of time. She will, therefore, have to find and employ other types of technique than the ones used for the appraisal of motor behavior in adults or older children.

This study attempts to present some methods and techniques found helpful in testing muscle strength and function and in differentiating various patterns of motor development in infancy. No claim is made as to the originality of many of these methods and techniques as such. Frequently, the same basic positions and factors of gravity and resistance that are used for older patients, have been used for the evaluation of infants, too. They were adapted, however, to the infant's capacities and the results were interpreted in terms of an infant's behavior at various age levels.

Some types of stimulation, such as stroking, tickling, sudden changes of position, and so on, have been used and described in the medical literature; such tests have been devised, however, for the evaluation of neurologic disorders. No evidence could be found that


they had been applied with the intention to elicit, observe and evaluate motion and muscular contractions which could not be obtained by other means; nor that the results of this type of stimulation had been interpreted in terms of muscle strength and motor patterns.

Besides using these more or less known methods of stimulations, several additional techniques were tried out during this investigation, which to the best of knowledge are new.

Two questions might arise, however; one, whether motions obtained by such methods of stimulation can be considered "true" movements, that is, movements comparable to or equal to voluntary motion; and, second, whether the strength of muscular contractions during such reflex activities can be rated on the same scale as are voluntary movements.

A number of specialists in neurology, neuroanatomy and orthopaedics (Dr. William Behrenberg, Dr. Randolph Byers, Dr. William T. Green, all of Children's Medical Center, and Dr. Paul Jossmann, Valleyhead Hospital, Concord, Massachusetts) when queried on this subject, agreed that such a method and approach to the evaluation of motor behavior in infancy was permissible and justifiable. Since this study was started about three years ago, the results of muscle examinations obtained by such types of stimulation have been accepted concomitantly with observation and tests of voluntary motion by the medical staff of the hospital.

It must be kept in mind that it is the primary objective of such muscle tests to determine whether a given muscle is working or not. If the desired motion is performed, it has been shown that the muscle itself possesses a given amount of contractible strength. The interpretation of
why there may be response to one type of stimulus (e.g., sensory) and possibly not to another one (e.g., visual) must be left to the doctor. (See the case described on page 2).

On the theoretical side, it may be argued that although it generally has been assumed that during early infancy the cerebrum does not participate in the control of motion, some scientists do not completely accept this point of view. Ford, in defense of a newer theory, states that "the cranial and spinal segments and the special sense organs are capable of functional activity" and that while many reflexes are transmitted through simple spinal arcs "others are very complex involving the nervous mechanisms of the brain-stem and labyrinths".

Obviously, from a point of view of the total behavior of the infant and its interpretation a distinction should be made; it should also be recorded whether the movement was an active voluntary one or obtained by reflex stimulation.

The following case may serve as illustration as to how the results of a muscle examination can be interpreted and evaluated from different points of view and for different purposes.

A four months old baby was brought to the clinic because his mother had noticed that the child did not seem to use the right arm and hand "the way other babies do". A muscle examination was requested in order to determine function and muscle strength of this extremity. On first examination the baby lay with both arms at his sides, not moving.

either of them voluntarily. When a toy was held out to him, he made only a slight attempt at reaching for it with his left arm. Only after a prolonged examination was it possible to record that the muscle strength in the left upper extremity was normal for a child of his age. The right arm and hand responded only partially to several types of stimuli described later in this paper (such as stroking, tickling, restraining, and so on). Thus it was shown that several muscles of the arm and hand were very weak and not at a functional level.

During the muscle examination, it was also noted that the child seemed to react emotionally and socially below his age level; it was also observed that the mother did not take very much interest in the child.

This muscle examination was only one step in the long series of tests, examinations and investigations which followed in order to diagnose this baby's case. The orthopaedic doctor will examine the infant's bones, joints and muscles clinically and by X-rays to determine whether the paralysis is due to injury before, during or after birth; the neurologist may test the infant's sensory reactions by means of neurological or electrical tests to differentiate between upper and lower motor neuron involvement; the psychologist or psychiatrist may evaluate the infant in terms of his mental age and inquire into the emotional and social factors which might have retarded not only his mental but possibly also his physical development. The previous muscle examination, however, had given all these specialists several basic facts, namely that the child had good muscle power in his left extremity — although he did not
use it to full advantage -- and that he actually had very weak muscles in his right arm. According to the findings of the muscle test, a brachial plexus injury was a possible diagnosis. Had it been found during examination that both arms were involved, or that there was additional weakness in a lower extremity, this diagnosis would have been ruled out.

The material on various types of stimulation in this paper is partially new; the data on range of joint motion in infancy are believed to be original; also, only scattered and a scant amount of information and few descriptions of abnormal motor patterns and motor behavior at this early age level were found in the literature.

Needless to say, however, there is a vast amount of excellent material and information available dealing with the motor development of normal infants and in regard to gross motor patterns, such as creeping, sitting and walking. But the description and interpretation of these activities are based primarily on maturational and psychological concepts of development; they do not deal in detail with the anatomical, neurological and physiological aspects per se. For work in a children's hospital where the majority of children deviates from the normal, the need for such more minute evaluation of motor behavior was evident.

The material and data on motor development presented by authorities in the field of child development, such as Gesell, McGraw and others, have been used and quoted here with the intention of giving, first, a graphic description of the mechanics of normal motor behavior, and, then, to analyze this behavior from the point of muscle function; furthermore,
it is contrasted with types of motor behavior which are considered abnormal.

The description and analysis of abnormal motor development are based on experience and careful observation of 75 infants up to the age of two years who were seen at the Children's Hospital. All these infants -- afflicted with various types of motor disabilities -- were given partial or complete muscle tests; their muscle strength and functions and their motor behavior was recorded, analyzed and compared with the motor activities of normal children of the same age. Some of the children were only seen once or a very few times during or after the muscle examination in the outpatient department; in these cases the findings of the muscle test and their interpretation was later compared with the findings and diagnosis established by the medical staff. Most of the infants used for this study were under observation for longer periods of time while admitted to the hospital wards.

Obviously, no claim could be made that this study is of any statistical value or that it could be used to establish norms for testing muscle strength and motor performance of infants. It is simply meant to give a description of some of the characteristics of certain phases of muscle function and motor behavior which were found to be either normal or abnormal and of some ways and means which helped to make such a distinction possible. This paper will have accomplished its purpose if it can be of any help to those less fortunate colleagues, who do not have the opportunity to study a great number of infants and if it should inspire them to continue this type of investigation.
CHAPTER II

"NORMAL" OR "ABNORMAL" MOTOR DEVELOPMENT

In order to determine whether the motor development of an infant is normal or not, we will have to consider first what is meant by the term "normal" in this particular connection. "Normal", according to Webster, means "conformed to a type, standard or regular form". Thus it becomes obvious that the term "normal" can be used only where a comparison with "a type" or "standard" is possible. However, no such "type", "standard", or "regular form" exists in the pattern of human development. There is a continuous, constantly fluctuating process; there can be no standardization of the growing human organism. Possibly, "normal" can be accepted as equivalent for the "average", with the understanding that what falls above and below it may -- to varying degrees -- still be normal for the individual.

Standards for weight, height, "mental age", and so on, are still widely used to compare a child's status in a given area with that of a group of the same age; however, in the past few years increasing evidence has been presented to the effect that physical and mental development are not only influenced by hereditary factors and that both vary greatly according to environmental circumstances but that each child has his own individual growth pattern which does not lend itself to comparison with an average or a group. What is important is not to know how, at a given age, a child compares e.g. in motor achievement with other children of the same age, but whether his motor development
progresses in the right direction, or whether there is a decrease in acceleration, or even no progress at all. Therefore, a knowledge of the basic pattern of motor behavior has to be combined with the observation of the trend of development in order to estimate the rate and tempo of development of the infant in health as well as in disease.

Certain types of diseases of the central nervous system (such as cerebral paralysis, brain tumors, spina bifida, hydrocephalus, and so on) are almost certain to retard and permanently injure a child's motor development. Other disturbances caused by nutritional and metabolic deficiencies, peripheral nerve injuries or infectious diseases, may only temporarily retard motor development. Lack of experiences, e.g. as caused by sensory deprivations in case of blindness and deafness, certainly may delay a child's development; insufficient outside stimulation frequently is the cause for failure to perform motor activities to be expected at a certain age level. According to Gesell,

"Disease, defects or damage that impair the integrity of the organism deflect the normal currents of development. Normal equipment includes normal developmental potentials, normal receptors and normal effectors. Loss of impairment of vision, hearing, touch or proprioception, the most important receptors, interferes seriously with the acquisition and integration of normal experience and with the development of appropriate responsive behavior...."

According to Kennard, there is another factor which would make it rather difficult to decide whether motor development proceeds according


to the expected rate and pattern; he claims that movements in early infancy are not mediated by the cerebral cortex and, therefore, injury to motor areas may not be expressed by loss of motion until the infant has reached an age at which truly voluntary motion may be expected.

Thus, symptoms caused by injury to the pyramidal tract, e.g. hemiplegia and spasticity, would become apparent only later -- at the time when these structures had matured sufficiently to function under normal conditions. In support of this theory, Kennard states that "the absence of cortical motor areas is not accompanied by any marked and noticeable motor deficit in the infant before complex skilled motor activity has developed," and that "spasticity begins to appear much later than paresis, possibly at the time when there is functional organization of certain subcortical pathways".

The clinical evidence in the group of infants observed in this study, however, gives rise to the belief that, in contrast to the theory presented above, it is frequently possible to determine the location, the character and the extent of motor loss before the age at which voluntary action can be expected. It may not always be possible to determine whether the infant innervates and uses all individual muscles or muscle groups properly; but if he does not use them at all, the functioning antagonistic muscle groups are likely to undergo structural changes which will result in shortening and contractures.

A normal baby who is not old enough yet to reach out for objects and, therefore, keeps his elbows flexed most of the time, certainly differs from the baby who keeps his elbows flexed all the time because

of non-functioning elbow extensors. While the former possesses a complete passive range of elbow extension, the latter soon will have only a limited range in this direction; this tightness would not be due to spasticity of the elbow flexors but rather to secondary changes of muscle tone in this group. This example emphasizes the importance of not only observing carefully the type and pattern of active motion in infancy, but also of watching passive range of joint motion and the nature of the limitation.

By using the developmental norms, Gesell, after having tested a great number of normal children, has been able to make qualitative and quantitative comparisons of those children who do not follow the "normal" -- that is, the average -- pattern of development; again, as borne out before, retardation in itself at a certain level of development is considered less important than the rate at which this retardation occurs, i.e. whether it is increasing or decreasing. According to Gesell, this "Developmental Quotient" (D.Q. = Chronological Age \times 100),

\[ \frac{\text{Maturity Age}}{\text{Chronological Age}} \times 100 \]

"...represents the proportion of normal development that is present at any given age...It furnishes a rough index of the current rate of development...It is an analytical tool, a diagnostic indicator, which consistently limits itself to the problem of maturity status..."

Although these individual patterns and trends in the child's development have to be taken into consideration, it cannot be denied that motor development still proceeds in an orderly, integrated way, although it cannot always be compared with the development of another

\footnote{A. Gesell and C. Armstrude, \textit{op. cit.}}
child. Gesell \footnote{Gesell, How A Baby Grows, Harper and Brothers, 1945.} expresses this thought well when he says: "Babies pass through similar stages of growth, but not on the same time table. Each child has his own growth schedule even though the order of stages was much alike...."

There is not only a sequence in the development of motor development but there is also a definite continuousness. There are no sudden surprises; development is rather like a chain where one link connects with the next. If one link is broken, the connection will be disturbed. At first, the simultaneous development of various functions and activities frequently seems unrelated; but in a later stage, it becomes apparent that there actually existed a sequence and reciprocity.

There is one pattern of development which can almost uniformly be observed in any child; motor control and development start with the head, progresses to arms, hands and trunk successively and only later includes the lower extremities. Biologists call this the cephalo-caudal (head to tail) development, a development which occurs alike in animals and human beings. This is the reason that sucking is one of the first activities, that the legs -- at birth -- are shorter than the arms, and that the infant, while already engaging in several activities of the arms, does not stand or walk until a few months later. A disturbance in this primary pattern of development should always give rise to suspicion of some irregularity in the child's development.

In the transverse plane, development progresses latero-ventrally.
and in the limbs proximo-distally. Abramson points out that this method of growth is of phylogenetical importance because,

"The head is the most primitive portion of the body and is, therefore, precocious in development, whereas the trunk is perhaps a secondary acquisition arising as an extension of the primitive head region. Anteroposterior development thus leads to definite formation of a head and centralization of the nervous system, the front end of which becomes enhanced in importance and forms a brain, which assumes a dominant influence over the more caudal segments."

Summing up, one may say that in the light of the reported experience a distinction can be made even in early infancy between a well functioning motor apparatus and a deficient mechanism.

CHAPTER III
MATURATION AND LEARNING

Working in the field of child development one is bound -- at one
time or other -- to come up against the complex problem of the impact
of growth and maturation on "learning".

It would be beyond the scope of this paper to take up all aspects
of this controversial question. What can be done in this study is to
summarize a number of theories set forth by acknowledged authorities in
this field and to consider the possibility of applying such theories to
the understanding of motor development of handicapped infants.

To be sure, maturation and learning are not two separate problems.
They are merely two aspects of one developmental process. Nevertheless,
many authors have tried to separate the two interconnected questions in
terms of the nature-nurture controversy.

Gesell, in opposition to the school of Watson's behaviorism which
contended that the hereditary endowment of the individual is limited and
the hereditary units of behavior can be identified by structural and
physiological correlates, has supplied the term "maturation" to child
psychology. Largely based on the result of practical experiments on
twins, he came to the conclusion that changes can be observed in a
growing infant which cannot be explained in terms of trial and error
learning or conditioning theories. "The nervous system grows according
to its own intrinsic pattern and thereby establishes the primary forms
of behavior. These forms are not determined by stimulation from the outside world. Experience has nothing specifically to do with them, and there is no conclusive evidence that practice and exercise even hasten the actual appearance of types of reactions like climbing and tower building... The time of appearance is fundamentally determined by the ripeness of the neural structures; Gesell states.

Although it is generally conceded that sharp lines of distinction cannot be drawn between what constitutes maturation and learning per se, it has been assumed that if changes in behavior are due to the factors of growth and development of structure they are attributed to maturation; if changes in behavior are caused by environmental influences, then they are attributed to the process of learning.

Gesell and Thompson claim that while it may not be desirable to draw a marked line, such a distinction may still be necessary "in order to facilitate intellectualizing and manipulating of concepts and phenomena". Other psychologists, in contrast, believe that there exists such close interrelationship between the two processes that learning is always accompanied by anatomical changes in the central nervous system. Carmichael states:

1/A. Gesell and C. Amatruda, op. cit.

2/A. Gesell and Thompson, "Learning and Growth in Identical Twins; An Experimental Study by the Method of Co-Twin Control," General Psychology, Number VI, 1929.

3/Ibid.

"...from the moment growth has begun in the fertilized ovum until senescence or death, development consists in the alteration of existing structures and functions in an organism living in a continually changing environment. That is, it is not possible save for pragmatic reasons to say at any point that growth has stopped and learning has begun, but that the environment plays a part in all 'maturational' and maturation plays a part in all learning."

Another exponent of this theory is Sherman who tested the reflexes and primitive early motor activities of infants; he comes to the conclusion that many of the responses which are usually attributed to organic maturation are in reality products of learning. He and other investigators claim that learning occurs even prior to birth, that the early reflex motor activities in infancy actually are the result of external stimuli while in utero and that these intra-uterine motions have become learned activities at the time of birth.

Kingsley -- while basically agreeing with the principle of genetic maturational limitation -- attributes great importance to experience and the exercise of function. He summarizes the problem as follows:

"There is probably no learning activity that does not involve the muscles, for the action of muscles also plays an important, though less universally recognized part in perceiving, remembering, imagining, comprehending and thinking."

The problem of maturational and learning is closely related to the problem of myelinization of nerves. In this field of research new and

startling ideas have been put forth in recent years. It is generally agreed that myelinization of the central nervous system has to be completed before it can function in the establishment of neuromuscular skills. Nerve cells present at birth cannot function before they have matured; muscular tissue matures only later. But while it was formerly thought that function was directly dependent upon myelinization and that a nerve without myelinization could not transmit an impulse, more recent research has offered striking evidence that there exists an interaction of these two processes and that myelinization actually occurs by usage.

At birth only isolated cortical regions have undergone myelinization. It has been shown that there is not only post-natal development of synaptic and dendritic connections but that myelinization in the nerve trunk begins distally and proceeds to the cortex. Neurons are simple in structure at birth. They possess very few branches. They acquire differentiation in their bodies, in their cell processes and in their intercellular connections by use or stimulation. Langworthy also upheld the theory that myelinization may be the result of development of function rather than the cause of it. Experiments on decorticate animals showed that myelinization results and increases with the use of nervous tissue; after the cortex had been removed in these animals, one eye was covered while the other remained open during the recovery period; myelinization occurred more rapidly in the eye that was being used.

Another interesting factor in regard to myelinization is discussed

1/0. R. Langworthy, "Development of Behavior Patterns and Myelinization of the Nervous System in the Human Fetus and Infant," Contributions to Embryology, Carnegie Institution of Washington, D.C., Volume 34, Number 139-143.
in the classic research paper by Flechsig who showed that nerve tracts acquire myelin sheets in the same order in which they develop. Regions receiving myelin sheets early are the centers of lower functions, whereas areas of the higher intellectual functions undergo myelinization later. At birth the spinal cord possesses practically all its myelin constituents whereas the brain stem, the cerebellum and extensive areas of the cerebral cortex, do not possess it yet. Although there is still much discussion as to the significance of myelinization in regard to motor development, the facts suggest that there exists some relationship between early myelinization of more primitive structures and the acquisition of simple types of motor activities (phylogenetic activities) as contrasted to later myelinization of more highly organized structures and the acquisition of motor activities of a more complex nature (ontogenetic activities).

From the above discussion it becomes evident that there still exist differences of opinion regarding the nature of the learning process. However, there has been very little doubt that such processes of learning do occur in the cortex of the cerebral hemispheres, the most complex of all nerve structures. Countless experiments have employed the method of removing specific areas of the cortex, and to observe the effect of such a surgical destruction of brain areas upon the ability to learn and to retain what has been learned. It has generally been reported that such ablations caused reduction or inability to learn.

\textsuperscript{1}P. Flechsig, \textit{Die Leitungsbahnen im Gehirn und Ruckenmark des Menschen}, Engelmann, Leipzig, 1876.
Investigating this generally accepted point of view, Karl U. Smith, (Department of Psychology, University of Wisconsin) sought to find out,

"...whether the observed deficiencies in learning were the results of some integrative or learning disturbance itself or the outcome of motor and sensory defects that invariably appear when the visual, somesthetic, motor, and frontal areas of the brain are removed."

By means of a neurosurgical operation, the pathways of the corpus callosum which contains the interconnecting neurons between the two hemispheres were cut and thus isolated. Certain types of learned performances (mirror-drawing and non-visual stylus maze learning) were compared before and after the operation. According to the investigation "there was no discernible effect of the operations upon the mirror-drawing learning and mirror-drawing transfer".

The process of learning these activities with the preferred hand first and then with the non-preferred hand, were studied next.

The author comes to the conclusion that; (1) "there is no specific or generalized integrative neural mechanism of the cortex explicitly essential for learning and related functions, which may be rendered seriously inoperative by injury to intracortical association pathways; and (2) the neural integrative functions of the cortex in learning are therefore closely bound to the specific reactive and psychophysical mechanisms of the sensory and motor projection areas of the brain and are apparently inseparable from the processes underlying reactive and psychophysical aspects of behavior."

Although it may seem at first that the above discussion is strictly theoretical, far removed from any practical and clinical application, nevertheless it should be of greatest interest to anybody concerned with the practical aspects of the mechanism of learning. One could ask: In the case of a cortical lesion, is the patient being deprived of the tools of learning or is he deprived of the proper use of these tools? Or to be more specific: Can we hope to train or re-train a patient with a cortical lesion by emphasizing the development of his tools (the sensory-motor mechanism)? Or, shall we believe those scientists who claim that cerebral injury inevitably leads to a lowered level of organization, to decreased retention and capacity for learning and that these defects cannot be overcome through time or training.

Certainly, from the clinical observations made during this study, it can be stated that the apparent development of motor function can be encouraged and will be hastened by training and transfer of existing capacities. This fact can be observed readily in a hospital where infants are not only confined to bed for longer periods of time, but in addition frequently restrained in their physical activities. When later restored to their freedom of movement, these infants do not always engage in motor activities according to their age, although processes of maturation took place during this period of confinement. They frequently have to go through the previous stages of motor development which they had missed; however, they may advance now at a somewhat faster rate. With all his motor functions fully developed, an adult who loses his skill in an activity and is unable to perform it for sometime will
rnelearn it quickly once he can engage in it again. On the other hand, a child's impairment not only handicaps him in the performance and function at the time of incapacitation, but it also retards further learning and acquisition of new skills and activities. Previous growth and previous learning are inseparately intertwined; retardation thus accumulates, unless steps are taken to ascertain that the child uses fully his capacities for learning through activities which are appropriate to his maturational level. Motor activities may have to be adapted to the handicapped child's needs and his present ability to use them.

Referring to the previous theoretical discussion of function and learning, there should be special emphasis on activities which afford experiences in the area of sensory-motor activities. To give but a few suggestions: If a baby cannot use his arms or hands to grasp objects, he may be encouraged to touch, manipulate and explore them with other parts of his body, such as face, feet or toes. If he is not allowed to bear weight at least, he should be given ample opportunity to engage in activities, such as kicking his legs, rolling over, crawling and creeping. The result will be not only an increase in strength and function in the parts of the body thus exercised, but also a transfer of learning from the exercised to the non-exercised parts.

Research has demonstrated quite conclusively that some amount of transfer occurs when similar activities are learned. This is illustrated by the effect of practice with the right hand upon later learning by the left hand; after a practice period for the right and left hand, the
practice was continued by the right hand only; the left hand, without further training, nevertheless continued to improve. Investigating the problem of bilateral transfer, Wieg measured not only transfer from right hand to left hand and vice versa but also from left hand to left foot, from right foot to left foot and from left foot to left hand. The author's findings -- although based on only a small number of cases -- suggests a saving in speed and in errors after having practiced a transfer limb.

Experiences accumulated during the last World War, when amputees were trained in occupational and recreational activities with their unimpaired limb first, showed that they later learned the identical activities with their protheses better and in a shorter time than they did without previous training.

Certainly, one could debate the various aspects responsible for such transfer phenomena, the factor of experience gained in the first activity and re-applied in the second activity, or the influence of a problem solving attitude. Another interpretation is possible on the basis of the holistic theory of Goldstein who maintains that learning of a motor activity is never confined to a definite anatomical structure but that it is always a total reaction of the organism to the demands of the environment.

Goldstein also denies that a real restitution is possible, once


damage to the central nervous system has occurred. He claims that apparent recovery is really a readjustment on the part of the damaged organism in order to get along without the former function. He says, "A true recovery of function comes only as a result of restoration of the anatomical substratum or, under exceedingly rare and limited conditions, by a tedious relearning with the help of a remnant of the substratum which participated in the original function."

Although many investigators in the past and present have agreed with this concept of restitution, just as many have maintained throughout the years -- among them Frenz, Oden, Scheetz and Wilson -- that continued training not only can restore specific skills in a damaged organism but that almost any part of the brain can take over the functions of other parts, thus greatly facilitating recovery.

Summarizing these theories, one may say that certainly from a practical and clinical point of view there seems to be good reason for hope that a great deal can be gained by utilizing factors such as training and transfer of learning. It can only further rehabilitation and recovery if over and above what can be achieved by outside stimulation and environmental factors, nature also does its part.

1/K. Goldstein, "Über die Plastizitaet des Organismus auf Grund von Erfahrungen am nervenkranken Menschen,"


PART II

The first part of this study tried to present various principles and theories on which an evaluation of motor behavior is based.

In the following chapters the description and analysis of motor behavior will be viewed from a practical, clinical point of view. It starts with a discussion of some of the characteristic body positions which the newborn infant assumes, progresses to head, upper and lower extremities and includes the mechanics of locomotion, such as in rolling over, sitting, creeping and standing. It is, of course, realized that the appraisal of a child's motor development can be made from an overall point of view only, and that the attempted break-down into the various components of such motor activities serves only the purpose of better organization of the material.
CHAPTER I
THE NEWBORN BABY

The posture of a newborn baby is to a great extent a continuation of the intra-uterine position. Some of the characteristic positions which the newborn infant assumes are described by Dunham as follows:

"The newborn infant lies with the head held to the right or the left and resists strongly any attempt to change his position of the head.... Usually, however, the head will be turned to one side when the infant is sleeping, and it will acquire a midline position when he is crying...."

"The newborn infant lies on the back with arms and legs slightly flexed. There is normally slight outward rotation of the legs at the hips and the legs tend to assume the same position both when the infant is awake and when he is asleep.... At birth two vertebral curves are present, a dorsal and a sacral, each convex posteriorly.... The cervical and lumbar curves are not established until the infant is old enough to stand...."

This position is generally outgrown at the age of three to four weeks. At this age the tonus of the musculature is more relaxed, the infant's leg are held in a more extended position at the hips and knees. In pathological conditions, however, the typical neonatal posture persists; frequently it is an early diagnostic sign of neurological or orthopaedic defects. It is, therefore, important to examine the infant's joints and muscles by taking his extremities through a full range of motion. Dunham offers the following suggestions:


2/Ibid.
"By abducting the arm, the head of the humerus can be easily palpated in the upper axilla. Full extension of the elbows, knees, and hips is often difficult in the newborn infant, probably because the intra-uterine position is one of flexion at these joints. Flexion at the hips will be most marked in infants born by breech, and in these infants complete extension at the hips will be nearly impossible in the first three or four days. The great trochanter of the femur should be felt for on each side, and the leg should be rotated and abducted to determine whether the head of the trochanter is in the acetabulum. The contour of the buttocks and the level of the gluteal folds should be carefully noted, as any asymmetry may indicate dislocation of the hip joint. Each extremity should be handled to see that function and muscle tone are normal."

To these characteristics of a normal newborn infant may be added a few more which -- unless recognized as normal attributes -- might easily be mistaken for pathologic features.

One of the outstanding differences between the infant and the adult is the size of the baby's head in relation to the rest of his body. While the size of the head of an adult is only one seventh of his total size, a baby's head is one fourth of his total size, and usually almost as wide as his chest. As a matter of fact, the whole upper part of a newborn's body seems out of proportion to its lower extremities which appear very short. The size of the abdomen also seems to be out of proportion when compared to the rest of the body. This is attributed to the infant's liver which is proportionally twice the size of an adult liver.

A normal, healthy infant engages in very strong, active movements and vigorously kicks arms and legs around; he resists any attempt to restrain his freedom of motion. The baby's kicking movements are quite stereotyped at this early age. Usually, the legs move in the same direction; quite frequently one leg leads, the other follows. The whole
Leg participates in the kicking movement as one unit: hip, knee and foot move together. Only later, approximately at the age of three months, do the various segments of the upper and lower extremities move as distinctly separate units. A baby lying motionless or only moving his legs and arms feebly presents definitely an abnormal motor behavior and should be brought to medical attention.

However, these early kicking movements must not be mistaken for voluntary purposeful movements; they are uncoordinated random and often only reflex movements.
CHAPTER II

REFLEX MOVEMENTS

Reflex movements take place in response to manipulations, to stretching of muscles, to changes in position, to application of different tactile stimuli such as heat, cold or pressure, to light and sound and to restrictions of normal body motions. A number of investigators have studied the reactions of infants to these stimuli. Their findings have been reported in the medical and psychological literature.

In 1918 Moro described a reflex reaction (which has since become known under his name) which he found almost uniformly present during the first few days of life and frequently up to the age of three months. The infant is laid on his back on a springy surface; when this surface is struck on either side of the infant, he spreads his arms apart and then brings them together to form a bow; the legs engage in a similar movement. The reflex has also been observed in the form of a rapid rhythmic shaking or extension of arms and legs which will last for a fleeting moment, after which the infant relaxes spontaneously. Tapping the child on the abdomen, blowing on his face and extending both legs suddenly and simultaneously brought about similar reactions.

One will have to be very careful when using and evaluating such reflex activities for diagnostic and prognostic purposes. There seems to be little doubt that cerebral illness defers the disappearance of
this reaction. If it persists after the age of six months, it is regarded as a symptom of cerebral or pyramidal injury.

There is, however, some disagreement in regard to the absence of the Moro reflex. Gordon states that absence of the response in an extremity indicates either motor paralysis or injury on that side. Sanford disagrees with Gordon; he tested 465 infants, a few hours to ten or fourteen days of age, and came to the conclusion that the response was often absent for several days at a time. However, he never found an assymetrical response except in cases of fractures of the clavicle; in that case there was no reaction on the injured side.

Although interpretation of these phenomena may still offer many difficulties, the application of such reflex type of stimuli offer, nevertheless ample opportunity to observe and record motions of all extremities and to obtain an estimate of strength and working condition of the muscles normally engaged in the execution of such motions.

The Tonic Neck Reflex (TNR) has a more practical application in regard to diagnosis. Originally observed by Magnus as a body-righting reflex of decerebrate animals, it was later adapted for study on infants. The tonic neck reflex consists of the tendency to bring the body into a position corresponding to the position of the head. It has been described in a more detailed way as follows:


"The head is turned to the right side, the trunk slightly flexed to right, the left arm is flexed at the elbow, fully abducted and externally rotated. The other arm, toward which the face is turned, rests in an extended position at the side of the body or somewhat abducted. If the legs participate, the leg on the side toward which the face is turned, is more flexed and externally rotated than the face leg. When the child falls asleep, the arms are usually shifted from the asymmetrical to the symmetrical overhead position...This disappearance of the asymmetrical position is presumably due to relaxation of the neck muscles in which the reflex originates..."

In this connection it may be of interest to say that Gesell's clinical studies lend support to the belief that there is a relationship between TNR and subsequent handedness; an infant who shows a predominantly left TNR during the first 12 weeks of life is almost always by nature left-handed.

The TNR is almost uniformly present during the first four weeks of life, then gradually disappears; it is almost never found after the age of six months. In older children it was observed by several investigators; they always found some pathologic conditions such as hydrocephalus and idiocy to be present. It is now generally agreed that a tonic neck reflex after the age of six months is indicative of a lesion in the central nervous system, particularly in the extrapyramidal tracts.

\[1/\text{White House Conference on Child Health and Protection, "Growth and Development of the Child," The Century Company, 1933.}\]
When at rest, the newborn baby usually lies with the head turned to one side; this position is due to the previously described tonic neck reflex. However, from his first day the infant is able to turn his head from side to side while lying on his back; he will do so freely and with no preference for one side or the other. Therefore, persistent rotation of the head to one side only should receive early attention, particularly if this rotation to one side is accompanied by lateral flexion of the head to the opposite side; it is the position characteristic for Torticollis (wry neck). Certainly, passive range in lateral flexion and rotation of the head should be compared on both sides; tightness or contracture of the sternocleidomastoid muscles on one side are always signs of some abnormality.

Remembering the fact that development occurs in a cephalo-caudal direction, it is very important to observe how the infant gains control of head motions; any irregularity in this region may well be the forerunner and indicative of other lesions.

Generally, the very young infant lifts his head first from the prone position. This movement cannot be considered a voluntary one at this age; it is purely a reflex motion, most likely due to the instinctive urge to free the nose for breathing when lying on the stomach. The fact, however, that the infant is able to lift his head at all in the prone
position, shows that there is in early infancy a definite predominance of the posterior neck muscles as compared to the anterior neck muscles.  

1/\ A.A. Aldrich attributes this fact to an evolutionary theory that "bodies were originally built for a walking position on all fours and the muscles at the back of the neck, since they bore the weight of the head, were necessarily much stronger than those in front...."  

A number of authors have recorded the age levels at which they have observed children performing motor activities, such as lifting the head, rolling over, sitting, creeping, and so on. Following is a table pertaining to lifting the head from the prone position; other similar tables will be presented later in the course of this study.

These data from various sources have been collected to show: (1) the average age at which the respective investigators found normal infants engaging in these activities; (2) to call attention to the wide differences in age found when comparing the data; (3) to show different ways in which these activities were performed:

Obviously, the differences in age levels at which these authors observed children lifting their head can be attributed to a difference in the execution of this movement. Lifting the head for a fleeting moment (possibly reflexly) must be differentiated from the effort of lifting it intentionally to look around. There were also differences in degrees to which the head was lifted. Gesell classifies performances according to range of motion ("Zones").

For testing posterior neck muscles, the following procedure is suggested: While lying on his stomach, the infant is lifted from the table. It will be found that a normal baby lifts his head slightly above the horizontal level; when lowered to the surface, he lifts his head momentarily, turning his face to one side before resting it on the


2/A. Gesell and C. Armatruda, op. cit.


surface. This demonstrates normal posterior neck muscles. An infant older than two or three months who makes no attempt at lifting his head, or who attempts to lift it unsuccessfully and drops it, most likely has weak neck muscles.

A similar position can be used to test posterior neck and back muscles simultaneously. Landau has described a reflex movement in infants which is obtained by placing a hand under the infant’s abdomen and then lifting him into the air. He found that there occurred a tonic extension of neck and back, and frequently of the legs, too. The infant assumes a lordotic position which lasts from half a minute to two minutes. If during this movement pressure is applied to the back of the head, the extension tonus disappears immediately and the infant flexes the trunk in a jackknife manner, completely relaxing the posterior neck and back muscles. This reflex behavior is found in infants from the age of 6 to 18 months and sometimes up to two years. It is considered to be a response to labyrinthic stimulation, an effort made by the child to regain the balance of the body which is only supported on a small base (the hand). Although it must not be forgotten that this reflex activity is of a subcortical nature, it can help to evaluate the strength and functions of the posterior neck and back muscles.

The next stage in the development of neck muscles is reached when the infants can hold their heads in a plane with the body while held in a sitting position. The average age at which investigators report this achievement follows:

1/ A Landau, op. cit.
Janes — for 2 seconds or longer by the 19th day (50%)  
Linfert and Hierholder — 4 weeks....30%  
9 weeks....34%  
13 weeks....46%  
Buehler — 9 weeks  
Hazlitt — 17 weeks  
Gesell — 17 weeks  

Observations have shown uniformly that lifting of the head from the supine position occurs later than all other head movements. The first attempt is frequently made at about three months of age. At this early stage an attempt usually results in a disturbance of equilibrium; the head wobbles and bobs to the side. At the age of four to six months a baby can be expected not only to lift the head freely and voluntarily against gravity when lying on his back, but also to hold it steady and to rotate it freely to all sides while sitting.

Lifting of the head in the supine position is a preliminary postural adjustment to sitting up. The infant's desire to sit up can be observed by his facial expressions; his chin pulling forward, his mouth open, an anxious expression in his eyes, the baby pulls himself up as soon as any help is offered. However, if his anterior neck muscles

oscope Seminary, Volume 33, 1926.


3/ C. Buehler, op. cit.


5/ A. Gesell and C. Amatruda, op. cit.
(sternocleidomastoids) are not sufficiently strong, his head wobbles, falls and stays backward while his trunk is pulled up to sitting position. Although it is possible that normally the head may sag backward during the first phase of sitting up (about 30 to 40 degrees trunk flexion), it was found that when the head was supported passively in line with the body the healthy baby was always able to maintain the position by himself and to come up without further support of the head. The most advanced stage has been reached when the infant lifts the head of the surface first, followed by lifting the shoulders, retraction of the abdominal wall and thus pulling himself up to the sitting position.

The following investigations did not differentiate between the above described phases in this activity; according to their research, these are the median ages at which infants lifted the head from the supine position:

<table>
<thead>
<tr>
<th>Author</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shirley</td>
<td>20</td>
</tr>
<tr>
<td>Beuhler</td>
<td>22</td>
</tr>
<tr>
<td>Gesell</td>
<td>28</td>
</tr>
</tbody>
</table>

Lifting the head against gravity and maintaining this position requires not only muscle strength but also muscle coordination and skill; it is one of the early manifestations in infancy of any interest to explore the outside world. This is the reason why this stage in the

1/M. Shirley, op. cit.
2/C. Buehler, op. cit.
3/A. Gesell and C. Amatruda, op. cit.
development of an infant is of great significance; frequently, it has even diagnostic implications. Inability to lift the head up (while obviously wanting to do so) in an infant older than six months points to faulty muscular or neural development. Absence of the desire to do so, inspite of apparently good musculature of the neck, frequently represents an early symptom of retardation of normal development; it may well be associated with other motor disturbances less easily discernible at this early age.

Rolling of the head, jerky head motions, banging of the head against a surface or wall, and other such incoordinated movements, are usually due to emotional factors and should be called to medical attention as soon as they are observed.
CHAPTER IV

ARMS AND HANDS

No other aspect of motor development has aroused as much interest in literature and has been investigated as intensively as the one dealing with the upper extremities. Almost all tests that are used for evaluating early behavior of a child are based on activities which involve the use of the hands. Obviously, the outcome of such tests cannot be interpreted exclusively in terms of strength of muscles and motor development of the upper extremities. These tests are complex, involving factors such as intelligence, emotion, and so on; they are also very closely linked with the development of faculties which are generally grouped under the term of "learning". For the purpose of this study, activities will be considered primarily from the point of view of motor development. It was previously pointed out in this paper that the evaluation of motor development per se has to be considered as but one of the many components to be investigated, for the complete diagnosis.

One of the most difficult, if not the most difficult, task is to determine whether a baby's hand is normal or not. While the movements of the arms, legs and feet of an infant can be compared -- to a certain extent at least -- with those of an adult, it is impossible to evaluate the hand of an infant by the methods used for older children or adults. For example, an infant three months old cannot be expected to reach out intentionally for objects. When testing motor functions of the upper
extremities, one will, therefore, have to keep in mind at what age level any such activities can reasonably be expected; one will also have to be aware of the wide differences existing in the form of execution of such activities at various stages of development.

One of the earliest responses of the infant -- grasping an object -- is frequently misinterpreted. Many authors have investigated the grasp of infants and have come to the conclusion that a "grasp reflex" is present from the moment of birth. If an object is placed in the hand of a newborn baby, he grasps it in a paw-like fashion; this is entirely different from the mechanism of the voluntary grasp which develops only later.

The early grasp reflex is of a subcortical nature and is so strong that the entire weight of the infant can be supported when he grasps a rod or the examiner's finger. The same mechanism, observed in many primates, is attributed to a survival and defense reaction, by which the young attempt to hold on to their mother and can be carried safely.

Most authors agree that this reflex prevails in healthy children until the age of about three months and that it becomes less pronounced during the second quarter of the first year; it disappears toward the end of the first year.

McGraw, using a bar for her experiments, describes the progression of the grasp mechanism in infancy as follows:

1. There is a strong grasp of the fingers, with the thumb flexed below the bar.

2. After the second month, the intensity of the grasp decreases and the thumb inactively surrounds the bar.

3. There is a period of rejection, when the hand will refuse to grasp or will even push the bar away.

4. The true grasp follows. In this, the thumb is actively wrapped around the bar which is held firmly in the palm. In the second year, when this is accomplished, the reflex nature of the grasp has largely disappeared and the activity is entirely under voluntary control.

During the first few weeks, the outside fingers of a baby's hand are stronger than the index and middle finger; he grasps with the whole palm and often includes motion of the wrist which is apt to deviate to the ulnar side. Later, the index and the middle finger become stronger, the grasp shifts to the radial side, the fingers grasp more actively. This radial palmar grasp usually can be observed shortly before thumb opposition occurs.

Thus it is evident that early grasp reflex activities should not be evaluated in terms of normal or abnormal muscle strength of the hand. Although the normal newborn and very young infant habitually lies with his fingers bent into a fist and although he may exhibit the grasp reflex when properly stimulated, his fingers can always be straightened out passively through the full range into complete extension. In contrast, excessive strength of the finger flexors is demonstrated by an overactive grasp; if accompanied by a limited range of passive finger extension, it is most likely due to a lesion in the central nervous system, such as cerebral paralysis.

Absence of a fairly strong grip is frequently indicative of
impeiment of muscle power, possibly due to obstetrical paralysis, poliomyelitis and other diseases of the neuro-motor system.

The thumb is the last finger to develop independent motion. At four weeks it is still of no practical use; even at the age of three to six months its only motion is that of flexion and extension. However, the child will grasp and hold objects in his hand by using the flexors and adductors of the thumb. The opponens pollicis itself, taking the thumb through a semi-circular movement into opposition, functions rarely before the age of nine months.

Halverson describes the difference between earlier and later grasp mechanism as follows: "Early grasping is immediate, unadjustable, forceful and tenacious. At one year grasping is deliberate, adaptable with respect to size, form of weight of the object and only as strong and tenacious as the occasion requires."

Many types of activities have been used to test and evaluate prehension at various age levels. Reaching for cubes, resistance to withdrawal of objects placed in the infant's hand, picking up objects which were placed in various positions before the baby, and releasing of the objects, are only a few of the test items used by Gesell,

Linfert and Hierholzer, Bayley, and others.


2/A. Gesell and C. Armatruda, op. cit.


These tests are not only too well known but also too complex in its nature to be described here in detail. A short summary of findings may serve as a guide for comparing normal prehension with motor behavior that seems to be retarded or abnormal:

1/ Buehler -- 4 months: hands move toward object within reach
   5 months: objects are gripped in both hands
   6 months: reach toward objects out of reach
   6 months: grasp all objects they see

2/ Shirley -- 3 months: waving or reaching in the direction of an object
   4 months: reaching, touching and momentarily grasping objects
   5 months: retention of stationary objects
   6 months: grasping
   6 months: transferring object from hand to hand

3/ Gesell -- 4 months: resistance to withdrawal of a rod placed in hand (75%)
   6 months: pick up cube (75%)
   6 months: retains cube placed in hand (57%)
   9 months: retains cube placed in hand (100%)

4/ Bailey -- 5 months: reaching for cube
   6 months: picking up cube
   7 months: picking up cube deftly and directly.

Muscle strength and coordination can be evaluated by carefully observing the infant when he engages in these activities. An analysis of the muscles involved in the act of, e.g. picking up a cube and retaining it in the hand would thus serve to evaluate the following

1/C. Buehler, op. cit.
2/M. Shirley, op. cit.
3/A. Gesell and C. Amatruda, op. cit.
4/N. Bayley, op. cit.
muscle groups: Flex. dig. profundis
Flex. dig. sublimis
Lumbricales
Interossei
Flex. polli. longus and brevis
Opponens

The flexors and extensors of the wrist interact by stabilizing the wrist. Deviation of the wrist to the ulnar side demonstrates that the extensors or flexors (carpi ulnaris or both) are stronger than the radial group; as discussed previously, it is important to consider at which age level this deviation occurs. While at the age of two or three months this form of grasp may still be normal, at the age of five to six months the infant should have shifted to a more radial type of grasp with the wrist steadied in a neutral position and all the fingers participating in the act. The infant who consistently picks up objects with his fingers curled, the wrist flexed and deviated to the ulnar side is likely to suffer from some neuro-muscular disorder.

Releasing an object voluntarily (not just dropping it) constitutes a further step in the progression of hand activities, leading to throwing of objects. This desire to throw things, primarily caused by the infant's wish to hear them fall, frequently appears between the age of six to nine months; at the age of 12 months most children throw quite well. Good control and coordination, not only between finger flexors and extensors but also of the musculature of arm and shoulder, are pre-requisites for such a complex activity.

From the above example it can be seen how important it is to understand the developmental stages through which every infant has to go. Ignorance of what constitutes "normal" development may lead to a
misinterpretation of observed motor patterns. Up to the age at which a certain motion can be expected of a baby, such as reaching, grasping, and so on, the examiner will have to rely on observations of random movements, consistency of such patterns, their character, rhythm and coordination. To a greater extent still, he will have to use passive motions and manipulations in order to determine muscle tone, muscle strength and range of joint motion.

Restricting the infant's motions by holding his arms in unusual positions is a technique often proved useful. A healthy, normal baby will meet any such attempt with strong resistance; there will be no doubt as to the efficiency and strength of the child's muscles which participate in such resistive movements. Many of these defensive reactions are, however, not voluntary movements, but primitive reflex motions on a subcortical level.

\(^{1/}\) Watson, \(^{2/}\) Shirley, and \(^{3/}\) Pratt reported the reactions of infants when their noses were pinched. Although these investigations do not always agree as to the characteristics of the responses, they all report several non-specific reactions, such as kicking with one or both legs, extending the head or back, waving or kicking of the arms, and general restlessness. Around the fourth month these reactions generally become


\(^{2/}\) H. Shirley, *op. cit.*

more specific defense movements, such as real pushing away movements, turning the head away and pulling away from the stimulus disturbing.

Certainly, a normal baby should react in some form or other to any such restriction of his freedom; a child who lies passively and does not protest when parts of his body are pinched, tickled or stroked, who does not try to free himself when his arms are held down at his sides, or who does not protest vigorously when his arms are held crossed over his chest or extended over his head, such a child certainly represents some deviation from normal behavior. Obviously, it is possible that the absence of such reactions is due to mental retardation, but it may also be due to sensory disturbances or to the inability of the motor apparatus to engage in muscular activity.

From the first moment of his life a baby kicks about vigorously with his arms and legs and he practically never -- except in his sleep -- keeps his extremities motionless. However, as was mentioned before, these movements are, at first, purposeless and stereotyped; shoulder, elbow, wrist and fingers participate simultaneously; single or isolated movements of one of these parts are rarely seen at an early age.

Coordinated movements of both arms, such as reaching out for an object dangling in front of the infant, cannot be expected before the age of four to six months. At first, these efforts seem to lack direction and intention. Usually both arms act simultaneously, reaching out for the object at once. Often the attempt fails because the flexor muscles of the arm still predominate at this stage; the infant pulls his arm back, the hands jerking toward his mouth. The extensor muscles of the
arm gain only later — approximately between the sixth and seventh month — sufficient strength and motor control to allow for complete voluntary reach for an object.

With increasing age the child's activities become more complex; it will be more difficult for the examiner to differentiate between involuntary manipulations and voluntary, learned behavior. However, it has to be stressed again that we are concerned in this study with the isolated aspect of motor behavior and that the interpretation of the findings is beyond our discussion. The following test items established by several investigators may guide the examiner in the selection of activities which, in turn, he can analyze as to muscles involved in their execution:

1/
Shirley -- 5 months: putting object into mouth
7 months: put cup to mouth as if to drink
8 months: pat an object
10 months: points with index finger, uses it to touch objects and pry into holes

from 6 to 12 months: objects are often held in one hand and banged with the other
12 months: throwing a ball with aim (50%)
18 months: throwing a ball with aim (85%)

2/
Buehler -- before
4 months: touching, holding, knocking and rubbing an object
4 months: object is simply lifted and lowered with arm
6 months: object is permitted to fall
7 months: begins to play with two objects, moves them separately, rubbing and knocking them together
11 months: begins pressing, stretching and tearing object

Gesell -- 4 months: playing with hands, brings hand to mouth
4 months: plays with objects (50%)
6 months: splashes with hands in bath
6 months: pats the table (50%)
9 months: pats the table (100%)
9 months: imitates ringing of bell (50%)
12 months: imitates ringing of bell (75%)
12 months: scribbles on paper with large crayon when shown the movement (75%)
12 months: piles one block on top of another (75%)
12 months: piles three blocks on top of another (60%)
12 months: piles four blocks on top of another (40%)
18 months: piles three blocks on top of another (100%)
18 months: piles four blocks on top of another (40%)
18 months: scribbles spontaneously (75%).

Other test situations which arouse or hold the infant's interest are listed here as suggestions for activities appropriate at certain age levels:

1. Nesting boxes with large differences in their sizes (1½ to 2 years)
2. Piling blocks
3. Open cover of a box
4. Crumpling piece of paper (6 to 9 months)
5. Unwrapping an object after seeing it wrapped (1½ to 18 months)
6. Try to put on shoes (12 months)
7. Take off shoes (12 months)
8. Use of fork and spoon beginning at 1½ months (accomplished at 24 months).

Studies have borne out that in the first half year of life most infants are ambidexterous and show no preference for either right or

1/ A. Gesell and C. Armstruda, op. cit.
left hand. According to Lederer 1/ "there were about equal numbers of cases showing right and left handed status during the second half of the first year of life, with a sudden increase to a predominance of right-handed cases in the second year". Lippman 2/ reports an increasing tendency to use the right hand at the age of four and a half months. Shirley 3/ comes to less definite conclusions in regard to handedness; in the lying posture both hands were used for touching, grasping and retaining; both hands were also used in sitting; when one hand was used only, there seemed to be a slight preference for the right hand. Shirley makes the observation that when an infant engages first in the performance of some activity, he uses both hands interchangeably and that only after some degree of skill is achieved, he will begin to prefer the use of one hand. She concludes that, generally, the position of the object determines which hand is used and that the infant reaches with the hand nearest the object.

It is interesting to note how many different opinions have been put forth in regard to the cause of left-handedness. Experts differ according to their concept whether handedness is a biological, social or physical phenomenon. They all seem to agree that environmental conditions and social demands influence at least some degree preference


2/H. S. Lippman, "Certain Behavior Responses in Early Infancy," Pedagogical Seminary, 1927, Volume 34.

for one hand. Whether we believe that dominance of one hemisphere of
the brain is an explanation for the existence of handedness, or that
inheritance according to the Mendelian law is the most important factor,
or -- as has been suggested by sociologists -- that handedness stems
from the remote beginning of the race, there can exist no doubt that we
live in a right-handed world and that there is a strong influence -- if
not pressure -- to conform to this standard.

Gesell's studies show that handedness is not a simple trait but
rather a product of growth which is closely related to other developments
of laterality, such as the tonic neck reflex, eyedness and footedness.
Gesell's cinematographic records taken at the Yale Clinic of Child
Development furnish data relating to hand preference at various age
levels which are summarized as follows:

Schematic Sequence of Major Forms of Handedness

16-20 weeks: contact unilateral and, in general, tends to be with
left hand
24 weeks: a definite shift to bilaterality
32 weeks: shift again to bilateral
36 weeks: bilaterality dropping out and unilateralty coming in;
behavior usually characterized "right" or "left";
left predominates in the majority
40-44 weeks: same type of behavior, unilateral, "right" or "left",
but now right predominates in the majority
48 weeks: in some a temporary, and in many a first shift, to
use left hand -- as well as use of right hand --
either used unilaterally
52-56 weeks: shift to clear unilateral dominance of right hand.

From this table it can be seen that there occur frequent changes

1/A. Gesell and L. B. Ames, "The Development of Handedness," Journal of
General Psychology, 70, 1947.
in the ways that infants manipulate objects and that these shifts are closely related to the total action system of the child. Gesell explains this interaction in the genesis of laterality in his study "Ontogenesis of Laterality" in these words:

"... Men, inspite of his bilateral construction, does not face the world on a frontal plane of symmetry.... He develops monolateral aptitudes and preferences in handedness, eyedness, footedness and other forms of unidexterity. Perfect ambidexterity, if it exists, would seem almost an abnormality, because effective attentional adjustment require an assymetric focalization of motor set. The behavior center of gravity always tends to shift to an eccentric position. Unidexterity of hand, foot or eye does not so much represent an absolute difference in skill as a predilection for stabilized psycho-motor orientation."

The interweaving maturation of symmetric and assymmetric behavior forms which was demonstrated in Gesell's Sequence of Handedness is thus attributed in this study also to changing patterns in the genesis of laterality.

From the above discussion it can be seen that comparison of the movements of both extremities is just as important as the observation of the functions of an arm or a hand itself; any discrepancy between functions on either side generally indicates a disturbance in motor development. If one arm or hand is preferred consistently to the other, and particularly if one extremity does not participate at all in activities, a central or peripheral injury of the nervous system is very likely to be the cause.

CHAPTER V
LEGS AND FEET

At birth and during the very first few weeks of life, the infant moves his lower extremities more actively than the arms and hands. This may seem to be contradictory to the quoted law of cephalo-caudal development which indicates that at birth development is most advanced in the cortical region which controls the cervical spine and the upper extremities. However, this rather confusing motor pattern may be explained on the basis that at this early age there may possibly be sufficient development of cortical regions controlling the upper part of the body to allow for some degree of inhibition of motion in the shoulder and arm region, while the cortical regions controlling the pelvic girdle and the lower extremities are not sufficiently developed yet to prevent more active random motions of the legs.

At birth the most advanced cortical development has occurred in regions which control the flexion mechanism; it is, therefore, not surprising to find that -- also due to the previous intra-uterine position -- the very young infant retains for some time this characteristic preference for patterns of flexion of the trunk and the extremities.

Acute flexion of the hips and knees is the habitual position which the infant assumes when lying on his back until he is about four months old. The legs are outwardly rotated to such a degree that the lateral
aspect of the thigh frequently rest on the bed. However, a healthy baby shows a normal passive range of motion of his lower extremities; his hips and knees cannot only be passively flexed until the knees touch the chest, but they can be passively extended through the full range of motion so that the entire posterior aspect of thighs and legs touches the bed.

There should be complete range of motion in adduction and abduction and inward and outward rotation. The following table lists the average range of passive motion of infants to be expected at various age levels:

| Hip flexion with knees bent | knees can be brought to chest at any age. |
| Hip flexion with knees straight (straight leg raising) | |
| to 6 months: 50° to 60° | |
| 6 to 9 months: 60° to 80° | |
| 9 to 24 months: 80° to 110° | |
| Hip extension: | |
| to 3 months: to neutral or possibly minus 10° | |
| 3 to 9 months: neutral to 10° hyperextension | |
| 9 to 24 months: 10° to 20° hyperextension | |
| Hip abduction: | |
| to 6 months: 40° to 50° | |
| 6 to 24 months: 50° to 80° | |
| Hip external rotation: | |
| to 3 months: 60° to 90° | |
| 3 to 9 months: 50° to 70° | |
| 9 to 24 months: 40° to 60° | |
| Hip internal rotation: | |
| to 3 months: 10° to 20° | |
| 3 to 9 months: 10° to 30° | |
| 9 to 24 months: 10° to 45° | |

It is, therefore, of the greatest importance to test the passive range of motion and not to confuse habitual resting positions with abnormal motor patterns and restriction of joint motion due to spasticity, contractures, and so on. Any gross restriction in passive range of motion should be investigated.
It is considerably more difficult to evaluate active movements of the lower extremities. Certainly, a healthy baby kicks vigorously with his legs; he rarely, except in his sleep, keeps his lower extremities motionless for any length of time. During the first few weeks, these movements are primarily hip and knee flexion -- with the hips held outwardly rotated -- and to a lesser degree hip and knee extension. Characteristically, there will occur a rather jerky motion of bending the knees to the chest (frequently touching the chest) followed by a jerky extension of hips and knees through a range of about 45 degrees. The extension phase of this movement ordinarily is considerably briefer than the flexion phase, the baby holding the knees close to or toward the chest for quite awhile before relaxing the flexors sufficiently to allow for a brief extension motion. Generally, both legs participate simultaneously in this activity. Occasionally, one leg may lead the movement, but the infant usually begins only at the age of six to eight weeks to engage in alternate flexion and extension movements. Frequently the trunk participates in the movement, bending laterally; the upper extremities often take part, too, in this general activity, expressing the need of the infant to move freely.

But while it must be stressed that the pattern of holding the hips and knees flexed most of the time during the first few months is a normal one, it must be emphasized equally strongly, that the normal infant resists, too, any attempt at holding his hips passively flexed for any length of time. As a matter of fact, it has frequently been observed during the course of this study that from the moment the examiner bends his knee forcibly to his chest, the infant shows much stronger movements
of hip and knee extension while offering resistance then he would demonstrate on a voluntary motion. Certainly, this early defense mechanism (whether based on subcortical reflex or on voluntary motion) can be used to advantage to elicit a pattern of hip and knee extension. Absence of an attempt to push the legs down after they have been held in extreme flexion for a period of time is a rather definite symptom that motor development is disturbed. Tickling of the feet will cause any normal baby to pull his feet up toward his chest; absence of this reflex act is also a very helpful diagnostic aid.

A more difficult task is the testing of the strength of the hip abductor muscles. An infant engages very rarely in the motion of abducting his legs. While it may sometimes be possible to palpate the abductors (gluteus medius, tensor fasciae latae) when the baby flexes and outward rotates his legs, this activity usually does not afford enough opportunity for a thorough evaluation of this muscle group, which is one of the most important one for diagnosis of certain diseases and disabilities (dislocated hips, and so on).

However, again we can make use of the infant’s desire to free himself from hindering external restrictions. If the legs are adducted to the fullest passive range by crossing them over each other as far as possible, the infant will react by vigorously trying to pull them apart in order to resume his habitual resting position. Frequently it is possible to observe and palpate abductor activity in this way.

Another test which has sometimes been successful was to lift the baby while he is lying on his side. He is supported at the trunk and
hips with the legs hanging downward. The child is then lowered rather fast and suddenly through the air (still in side lying position). In his attempt to regain balance ("righting reflex") he frequently lifts his top leg, abducting it at the hips. However, only about 50 per cent of the infants tested in this way reacted in this fashion; furthermore, the reaction disappeared after the first or second attempt. Normally, infants lose this response to a change in equilibrium when they are about three to six months old.

Another position which was found useful for testing hip abductors was to hold the infant sitting on one knee. Rather suddenly, the infant is tilted over to one side, almost as if letting him fall sideways off the knee. In the attempt to regain his balance and sitting position, the infants abducts the top leg (the one away from the side to which he is being lowered).

Although it is probably more difficult to evaluate hip abductor musculature than any other muscle group, it should be possible to obtain at least an estimate of their functions. Absence of reactions to all above described techniques is likely due to some irregularity in the neuro-muscular mechanism. However, it is rather rare to find inactive hip abductors without other symptoms of abnormal motor behavior. Tight hip adductors are probably the most frequently found adjuncts to a faulty hip abductor mechanism. Deformities such as hip adduction contractures, in or outward rotation contractures, elevated pelvis on one side, piston mobility in the hip joint, pain or grating noise when the leg is moved, are only a few of the many symptoms which help in the
diagnosis of disorders of the hip.

An evaluation of the strength of the hip adductors can usually be obtained fairly easily by abducting the infant's legs bilaterally through their fullest passive range (about 120 to 150 degrees). A vigorous attempt to bring the legs back to the habitual resting position will enable the testing of this muscle group.

Fortunately, it is not very often necessary to test too accurately the muscle strength of hip inward and outward rotators; these muscles are very difficult to rate in infancy. The amount of passive range of motion is generally accepted as an indication of their functional level. Obviously, there should be no limitation to full passive motion in either direction (see table on range of passive hip motion, page 55).

Even when lying on his stomach, the very young infant maintains this position of hip flexion and outward rotation; sometimes the knees are drawn completely under his stomach. The arms are bent at the elbows, adducted close to the body, the fists clenched, the head resting frequently on the hands. Again, it must be emphasized that, whatever the preferred resting position of an infant may be, it will be possible at all times to extend his hips and knees passively through complete normal range of motion without any difficulty. Gradually, the extreme flexion position of the hips disappears; but the infant still likes to lay with his knees bent. At the age of three to four months, however, most infants assume the position of leg extension or semi-extension for longer periods of time; the pattern of marked hip and knee flexion is rarely seen after the age of five months.
At about the same time the infant starts to lift the chest of the supporting surface and attempts to extend the cervical and thoracic spine. The three to four months old normal infant cannot only lift head and chest temporarily off the bed from a prone position but he can thus explore the world around him at considerable length. He may even attempt to support himself on his forearms and palms. At this point the trunk is lifted so that the iliac crest may be the upmost point of support on the bed.

Obviously, in this position it will be easy to evaluate posterior neck and back muscles. While the baby is exploring his surroundings, his head may be pushed down gently until the nose touches the surface; any normal infant will resist this attempt at restricting his freedom by pressing back against the examiner's hand. The back muscles can be evaluated by the same technique, although the young infant is apt to resist less vigorously to his being pushed down into the prone position.

In trying to test back musculature, it was found helpful to lift the baby from a prone position, with only the legs and hips well supported. The upper part of the trunk is allowed to drop beyond the horizontal. Any child with normal back musculature struggles to regain his lost equilibrium; he makes vigorous efforts to come up to the horizontal and by doing so uses his back extensors. An infant who extends the neck strongly, but fails to extend his back, is likely to have weak trunk musculature. If the head as well as the trunk remain flexed when put in this rather uncomfortable position, it may safely be assumed that his passive behavior is either due to weakness of neck and/or trunk muscles.
Holding the infant supported in midair can also be effectively used for testing the hip extensors (glutei maximus). If a child is lowered fast and suddenly, he will respond to such a change in balance by extending his legs at the hips and knees and by holding them extended until the downward movement comes to a stop. Then, the hips will flex, the legs dropping down to a right angle. This reflex reaction is lost after a few repetitions.

Another method of hip extension can also frequently be obtained by having the infant lay in the prone position with the legs hanging over the edge of the supporting surface. Tickling the buttocks or stroking along the spine (from the buttock upward) often results in varying degrees of hip extension; if all these stimulations fail, there is good reason to suspect that there actually exists weakness of the hip extensors.

Differences in the appearance of the buttocks, inequality of size, poor muscle tone or decreased muscle mass, are definite symptoms of some existing abnormality. The gluteal folds should be observed carefully for irregularities, such as decreased number of folds and reduced depth of the folds and difference of the direction in which the folds are running. Frequently, apparent abnormality of the gluteal fold is an early diagnostic aid in the spotting of muscular weakness.

A baby's feet are well formed; they are well developed and more flexible and mobile than they are at a later age. The muscles and ligaments are still soft and relaxed and allow a wider range of movement than in later childhood. There is a fat pad on the baby's foot which
gives the arch a flat appearance. The toes are held in flexion, and active extension is usually not observed in the first few weeks of life. However, if the toes are stimulated by a pin prick, or if the sole of the foot is tickled, it will be observed that the great toe will extend while the other toes stay flexed. This phenomenon, called the "Babinsky reflex", is a normal reflex in infants up to the age where they start to walk. It disappears later with maturity of the spinal cord; if it persists after the age of about two years, it is considered an abnormal reflex, indicating a lesion in the central nervous system.

A baby tends to assume various positions of the feet which still fall within the variations of normal motor behavior; he may turn his feet strongly outward, thus giving the impression of pronated feet; he may dorsiflex his feet to such an angle that one could suspect that the plantarflexors of the foot are weak (as found in talipes calcaneus); and he may also turn his feet in and supinate them.

In spite of these variations in normal mobility, a study undertaken at the Thomson Clinic, Lincoln, Nebraska, indicates that about 15 percent of all newborn babies show a true calcaneo-valgus deformity. It is pointed out that these children tend to sleep on their stomach, their legs and their feet turned outwardly, a position which contributes to further foot deformity. Therefore, one has to distinguish between the natural and normal flexibility of a baby's foot and an abnormally increased range of motion. The author of the study points out that in a

well developed baby's foot,

"...the dorsum of the foot could often be approximated to the antero-lateral aspect of the leg with some pressure but it came down to at least 135 to 145 degrees with the pressure of one finger. Conversely, when the foot was brought into equinus, 15-30 degrees of varus was present."

In contrast to these characteristics of normal feet are those classified as definitely being of the calcaneus-valgus type:

"The dorsum of the foot tended to lie against the antero-lateral aspect of the leg with little or no resistance and a typical finding was that extension was markedly restricted. Marked resistance was often found just beyond the right angle and a definite tendency was noted toward external rotation of the whole leg so that the toes tended to be everted. Examination showed that the heel-cords were relaxed and the anterior joint and tendinous structures were shortened."

In early infancy bowing of the legs may be present, which some authors ascribe to the position of the child in the uterus. This bowing usually disappears before the child starts to walk. However, some bowing of the legs or a slight knock-knee deformity may persist even during the first few years of childhood without necessarily being alarming. Bow-legged walking with accompanying shifting of the body from side to side indicates a more severe type of deformity. Such swaying of the body may also be caused by knock-knee deformity; in this way the child tries to prevent his knees striking each other in walking.

The causes of all the conditions mentioned above should be investigated before they become too severe, and particularly if they are associated with deformities of the foot such as unduly flattened arches, pronated feet, and so on. A careful muscle examination should be made to determine any imbalance in muscle power which might contribute to later deformities of the feet.
Most babies toe out to some degree when they first start to stand and to walk. A child who holds his feet parallel at this early stage will most likely be "pigeon-toed" later. The fat pad on the soles of a baby's foot, giving the impression of a flat foot, disappears later gradually. If it persists after the time when the child has started walking, it should be considered abnormal. The diagnosis of true pronation, however, is not primarily based on the presence of a flat arch but on the existence of a downward displacement of the inner malleolus. Normally, the height of the arch increases as muscles and bones develop by continued walking practice; only at this stage will the foot of an infant start to resemble the foot of an adult.
CHAPTER VI
ROLLING OVER, CRAWLING AND CREEPING

The abdominal, the back and practically all muscles of the extremities participate as the infant attempts to roll over from the prone to the supine position or vice versa. A newborn baby cannot perform this act voluntarily yet. However, when he finds himself in a position which allows the use of gravity, he may roll from a back-lying to a side-lying position; sometimes he may even roll around completely. McGraw points out that "this is a total body response rather than a segmental response. Such diffuse movements diminish during the first few weeks of life. Subsequently, the infant tends to lie in the supine position and makes no observable effort to rotate the body".

Rolling over -- like any other phase of motor development -- does not occur spontaneously; again it is only one step further forward in the achievement of a complex motor behavior which started as the newborn baby wriggled and kicked his extremities.

According to the literature as well as to the observations made for this study, attempts at rolling over from the supine to the prone position takes place at approximately the same age as does rolling over

from prone to supine. Some babies may engage in one or the other form of turning over first, but -- generally -- the two activities emerge about simultaneously. For the sake of analysis the two phases are discussed separately here, although it must be understood that they are closely interrelated.

Rolling from supine to prone position. -- Apart from the above described mechanism of rolling with the aid of outside forces, e.g. gravity, the baby's first voluntary attempt may be expected at the age of three to four months. At first, he turns his face to the side and pushes the head back against the bed. This movement helps to lift one shoulder off the surface. Gradually, extension progresses caudally, until the whole back is arched. One foot frequently participates by pushing against the surface in an attempt at lifting the pelvis off. Frequently, this is too difficult a task and results in a rather vigorous bouncing of the hips. If the infant is successful, he lifts his shoulders and hips almost simultaneously and turns over on his side. The complete movement is generally not mastered before the age of four to five months. Unless the infant flexes the head forward at the moment he rolls into the side lying position, he will fall backward again into the supine position. A little later -- at the age of about six months -- he has realized that by crossing or throwing one leg over the other, he can work up enough momentum to turn himself over without much pushing of the legs and without the marked back extension. When this stage of motor behavior has been reached, it can be said that the child rolls over completely from the supine to the prone position; all the previous motions were only preparatory phases.
Obviously, in such a complex activity, any kind of disturbance of the neuro-muscular apparatus must inevitably influence its performance. Not only the back extensor and abdominal muscles, but also the anterior and posterior neck muscles, the muscles of the shoulder girdle and the muscles of the legs (participating in the push-off phase) are needed; absence or weakness of only one of these muscle groups greatly hampers the execution of this complex act.

**Rolling from prone to supine position.**-- This activity is one of the most important ones in motor development; it is very closely influenced by the preceding stages of development; it also relates to future phases, such as crawling and creeping. A description of the infant's first attempts at lifting the head from the prone position and an analysis of the participating muscles has been presented in an earlier chapter.

Gesell describes further progress as follows:

The infant rests on knees, abdomen, chest, head (1 month)
The infant rests on knees, abdomen, chest, forearms (2 to 3 months)
The infant rests on thighs, abdomen, chest, forearms (4 to 5 months)
The infant rests only momentarily on abdomen and chest (5 months)
The infant rests only on thighs, lower abdomen, hands (6 months).

Only when the last phase in the preparatory stages of rolling over has been mastered, can it be claimed that the infant turns over completely on a voluntary basis; previous movements may have by chance resulted in occasional turns.

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Posterior neck and back muscles are involved in the extension movements of the spine; the muscles of the forearm, particularly the triceps, participate in the push-off phase. Unless there is stabilization of the shoulder girdle by the scapular muscles and unless the latissimus dorsi and the serratus anterior muscles are working, the infant will not be able to lift his weight off the surface. Abdominal muscles are needed to clear the abdomen and hip off the bed; knee flexors come into play as the infant pulls his legs under his abdomen when shifting his weight onto his knees. Hip and knee extensors finally engage in the final pushing off phase which results in a complete turn.

Again, all the muscles involved in this complex pattern must participate fully; inability to use some muscle may handicap the infant greatly; unless there is sufficient motivation to attempt substitution patterns (which sometimes prove to be successful), the child may postpone altogether an attempt at turning over. Additional motivation and encouragement to find substitution patterns are frequently needed to develop latent motor capacities. Development of motor behavior and acquisition of skills due to learning may take place — though possibly in somewhat modified patterns — in spite of apparent physical limitations.

Crawling and creeping. — Once the infant has learned to roll over, he usually advances fairly rapidly to the stage of motor development where he becomes dissatisfied with his stationary position; he wants to move around in order to explore his surroundings more thoroughly.

The development of crawling and creeping proceeds again in an
orderly and well defined way, although -- as has been pointed out previously -- the speed and rate of progress may vary with each individual.

The terms "crawling" and "creeping" have often been used interchangeably, but actually they are well defined separate stages of motor development. Certainly, from the point of view of muscular analysis, they are completely different activities. Diagnostically, it is frequently very important to observe in which type of propulsion the infant engages and why he prefers one type of locomotion to the other.

McGrew has given the following excellent description of the very first stages of crawling:

"In most infants this first manifestation of a progressive urge is expressed in the region of the shoulder girdle and upper extremities. Usually the baby releases his support on the arms, drops the head and chest, extends an arm forward, and strains with the shoulder muscles. Sometimes the hands pull a little on the surface of the floor or bed on which the baby is lying. He is still unable to make progress, but the impulse to do so is indicated by the action of muscles in the upper part of the body. Usually the pelvis and lower extremities rest heavily on the surface. Sometimes the advanced development in the upper part of the body is expressed by the swaying of the infant's shoulder from side to side, while he supports himself on the palms with the upper extremities extended. Often the impulse to move the body becomes so exaggerated and the imbalance between development in shoulder and pelvic girdles is such that the infant actually moves backward as he pushes with the hands against the floor until he turns completely around."

Generally, it may be said that crawling is the stage of development preceding creeping when the infant's abdomen stays in

1/ M. B. McGrew, op. cit.
contact with the underlying surface, while the body is pulled along mostly by the arms, with the legs still dragging. At the age of nine months an infant usually masters this activity.

From the detailed description quoted above, it can be seen easily that a great number of muscles participate in the mechanism of crawling. Posterior neck muscles must enable the baby to lift his head off the surface; if these muscles are impaired, there will be no incentive and certainly very little possibility to see what is before him and to explore the world from the prone position. Next in importance are the muscles of the arm and shoulder girdle which enable the infant to reach up and over his head; trapezi, serratus, anterior and posterior deltoid and triceps are the most important ones in this phase of crawling. Biceps, bicepsradialis, wrist flexors and extensors as well as all the muscles of the hand come into play as the infant grabs the sheet or any other object he can reach in an attempt to pull himself forward. Even at the stage where the neuromuscular mechanism has not yet matured sufficiently to allow for participation of the lower extremities, it can be observed that the infant engages in diffuse, squirming motions of hips, legs and feet which are an indication that the whole body participates -- often without much success -- in this attempt at locomotion.

Although there are wide variation in the ways a baby crawls (some propelling themselves forward, some crawling backward at first, some pivoting around themselves), there are certain abnormalities that can be spotted early.
The baby who wants to crawl, but is unable to do so, shows his desire in facial expressions and squirming movements. He lifts his head from the prone position, his shoulders and chest are raised, too; he attempts to lift his arm over the head, but may not succeed. Obviously, there is something wrong with the muscles of the shoulder girdle or the arms (see previous analysis). The baby who reaches up with one or both arms, but cannot pull himself forward, either lacks sufficient strength of the elbow flexors or of the muscles of the hand. If the lower extremities do not participate in the motion, they probably are too weak to propel the body forward. Marked weakness of the abdominal and trunk musculature prevents the wiggling and squirming movements which normally help in shifting at least part of the weight from one side of the body to the other.

If an infant shows no desire or does not attempt to crawl at the age of about eight to nine months, it can be suspected that this passive behavior may be caused by mental retardation, lack of stimulation or some pathologic condition.

The term "creeping" is used to designate any type of locomotion in which the body is raised from the floor on hands and knees or on hands and feet. It is generally assumed that the trunk remains parallel to the floor, thus eliminating the form of walking where the hips are raised very high, another form of locomotion in which infants often engage. Creeping considerably helps in the development of shoulder girdle, trunk, arms and legs; most babies creep spontaneously without prompting.
The outstanding characteristic of creeping as compared to crawling is that in creeping the infant flexes his hips under his abdomen, thus lifting the buttocks and approximating or pushing his hips toward his shoulders. Many babies rise on their toes and hold their weight on feet and hands for a moment before settling back on their knees and then propelling themselves forward. Other infants rock back and forward on hands and knees for a considerable time before they attempt to creep. Generally, it has been observed that most infants do not get up on hands and knees and start creeping, but that they maintain a stationary creeping position for a varying amount of time, before they actually progress to locomotion in this position.

There are wide variations in the early stages of creeping. The beginner may either move one arm forward, then the other one and then flex both hips simultaneously, or he may reach out with one arm, then move the leg on the same side or the opposite side. He may raise his buttocks and hips up in between these phases of motion or he may relax them and fall back on his stomach or on his side. Again, as in crawling, he may move forward, backward and sideward. Whatever type of creeping the normal infant prefers, there can be no doubt that he wants to move on and that his urge for propulsion has become manifest.

At the age of nine to ten months, most children creep well. At this stage of motor development maturation of cortical centers has progressed sufficiently to allow organization into a definite creeping pattern. The infant uses upper and lower extremities simultaneously, although the movement itself may still be arrhythmic and somewhat jerky.
Most frequently opposite arm and leg move forward at the same time, the arm reaching forward while the opposite hip is being flexed; this is followed by hip extension and pulling of the arm while the collateral extremities start to engage in the first phase of the motion. As the infant perfects the activity, his motions become smoother and all extremities work in greater harmony; he now can cover greater distances without toppling over and without having to rest on his buttocks or on his abdomen.

Creeping was reported at the following age levels:

**Gesell**
- 6 months: 20%
- 9 months: 75%
- 13 months: 100%

**Linfert and Hierholzer**
- 6 months: 10%
- 9 months: 97%
- 12 months: 100%

Inability to creep may be due to weakness in the shoulder girdle or in the arms; if the arms are used normally, but the knees are not drawn up under the abdomen, there is probably weakness of the abdominal musculature or the hip flexors (psoas and sartorius). Weakness of the knee flexors prevents the baby from bending the knees, although this particular muscle group participates not as actively in creeping as the knee extensors (quadriceps) and hip extensors (glutei); they are most important in the phase when the body is propelled forward. Even normally functioning hip and knee musculature may not suffice to enable

1/ A. Gesell and C. Armbrud, op. cit.
the infant to creep; the muscles of the foot which stabilize it first against the underlying surface and then participate strongly in the push-off phase of the movement are needed. At first, the dorsiflexors of the foot (anterior tibial, toe extensors) come into play; next, the plantarflexors (gastrocnemius, soleus and toe flexors) finish off the movement by pushing against the surface and thus propelling the body forward.

It can readily be seen that lack of participation of any of these muscle groups may prevent the infant from creeping. Weakness of any or possibly all muscles of the lower extremities frequently results in the infant's attempt to pull himself forward by means of his arms only. He succeeds only rarely and, therefore, very likely postpones attempt. If the arms are weak, the infant may be able to propel himself forward by pushing with his legs only, unless the arms are so weak that they are caught under the abdomen in the process of propulsion and are too much of an obstacle to overcome. Certainly, weakness of the abdominal and back musculature prevents the baby from assuming or staying in a position where his trunk is lifted off the surface; he will fall back on his stomach and move forward crawling, although -- according to his maturational level -- he may be ready for the next stage of locomotion.

Following is a description of various faulty patterns of creeping which were observed during the course of this study and of the factors which caused such abnormal motor behavior:

1. Does not attempt to move legs (complete paralysis, lack of incentive, mental retardation, and so on)
2. Flexes hips and knees toward chest but cannot complete motion (weakness of hip or knee flexors)

3. Flexes hip and knee but cannot draw it under abdomen as abdomen rests too heavily on surface (abdominal or back weakness)

4. Draws knee under abdomen, but cannot propel himself forward (weakness of hip or knee extensors)

5. Draws knee under abdomen, keeps foot plantarflexed on surface without attempt of putting toes in position where they help in propulsion (weakness of dorsiflexors)

6. Draws knee under chest, dorsiflexes foot, does not succeed in push-off phase (weakness of plantarflexors)

7. Engages in all above described motions, head remains on surface (weakness of posterior neck or upper back musculature)

8. Abducts arms in attempt to reach up and forward but does not reach high enough (weakness of serratus, anterior or posterior deltoid)

9. Brings arm overhead, cannot take hold of surface or object (weakness of wrist or hand musculature)

10. Lifts arms over head, takes hold of object or pushes against surface -- cannot pull himself up (weakness of elbow flexors)

11. Engages in all of above described activities in a normal pattern, but does not creep (insufficient maturation of the neuromuscular mechanism to allow for coordinated action -- possibly overstimulation or advanced mentally beyond level
of physical maturation -- possibly interference with centers regulating coordination).

In summarizing, it can be said that the majority of children go through certain progressive stages in crawling and creeping, which are assumed to be preparatory for sitting and standing. Only few infants sit and stand without ever having crawled or creep. If, therefore, a baby does neither crawl nor creep, there certainly is some reason to suspect that motor development is retarded and medical advice and help should be sought.
CHAPTER VII
SITTING

Most infants first attempt to sit up at about the time they engage in other forms of locomotion, such as rolling over, crawling and creeping. However, the term "sitting" needs some clarification; if a baby, after having been pulled up to a sitting position, falls back when the support is taken away, or can only balance his body for a fleeting moment, it should not be claimed that "he is sitting up".

Being pulled up to a sitting position is, however, a definite step toward independent sitting and, therefore, deserves some analysis.

During the first four to six weeks of life, an infant’s head drops backward when he is being pulled up from the supine position. Frequently, the weight of his head causes his back to arch backward, too. Once he has been pulled up completely, his head drops forward so that his chin rests on his chest. A few weeks later -- at the age of two to three months -- the infant is no longer as passive; he holds his head in line with the body when he is pulled up; there is definite evidence that some degree of independence from the influence of gravitational forces has been reached. At the age of about four to five months the child not only keeps his head in line with the axis of the body, but he flexes it further forward; he also assists by flexing his trunk and by drawing his legs up to his stomach. At this stage he may or he may not pull hard with his arms when support is given.
If he wants to sit up, his desire to do so shows by various facial expressions and by craning his neck and shoulders forward. Now when he sits he holds his head steady.

Child psychologists have frequently observed that in any phase of development when the child attempts to gain a certain amount of independence, he refuses to continue the pattern he had previously followed. During this period a casual observer may think that the child is not making any progress; occasionally it may seem that he is regressing. Actually, a re-arranging of behavior pattern on a higher maturational level takes place during this transitory phase and this may lead to some confusion in the child's neuro-muscular system.

The infant frequently goes through such a period at a time when he refuses to be pulled up to sitting. He pulls his hands away when help is offered; he drops his head backward; he arches his back or extends his hips; sometimes he just remains passive and completely relaxed.

Most infants start to sit up by rolling from the supine to the prone position. They put their weight on their palms and knees and lift the trunk. At first their abdomen may still touch the bed; soon they eliminate all unnecessary movements and lift themselves up by making a half turn and by pushing up on one or both arms. It takes the average infant six to eight months to attain this goal. At this age most children have eliminated the prone position and are able to come up directly from the back lying position to sitting by simply turning onto the side and by pushing up with one arm.
At the age of about six to seven months the infant usually sits up; he supports his weight on his hands, or he may sit unsupported for a brief moment; he cannot maintain his balance for a longer period. His legs may be outwardly rotated, the soles of the feet almost touching each other; one leg may be flexed and the other extended, thus widening the base of support as he relies less and less on steadying himself with his arms. Any slight disturbance of his equilibrium will cause him to topple forward or sideward. Only rarely do infants fall backward from the sitting position; usually they fall sideward or forward rather than backward; this indicates that the trunk musculature has become stronger. If a baby consistently falls backward from the sitting position, there is reason to suspect some abnormal development.

The stage of independent sitting has been reached then, according to McGraw,

"The infant can maintain an erect sitting position on a flat surface, usually with one of the lower extremities flexed and abducted, while the other is fully extended in front of the body. The arms are free to engage in other movements. The position of the lower extremities provides a wider base and aids in the maintenance of equilibrium. Ordinarily an infant can maintain an erect sitting position when his legs are stretched out upon a flat surface before he can sit with his knees flexed over the edge of the seat, his feet being at a lower level. The baby does not suddenly achieve the ability to sit erect. There will be periods when he rests his weight on his arms most of the time, lifting them from the supporting surface only occasionally. There will also be occasions when he sits with his hands resting on the underlying surface, or more frequently on his thighs, though he is not actually depending upon his arms for support."

Age levels for sitting were quoted as follows:

1/M. B. McGraw, op. cit.
Shirley 1/ -- tensing neck muscles when being lifted: 15 weeks
complete head control in sitting: 18-19 weeks
sits alone for one minute: 31 weeks

Gesell 2/ -- sitting with slight support of
pillow: 20% at 4 months
over 50% at 6 months
sitting alone: 20% at 6 months
100% at 9 months

Buehler 3/ -- sits with assistance: 6 months
sits alone: 8 months
can get into and out of
sitting position with
help: 8 months
alone: 9 months

In order to be able to come up to a sitting position and to
maintain equilibrium in a free sitting position, abdominal and back
muscles have to function; any abnormality in their function will be
evidenced by a variety of symptoms.

Arching the back and inability to flex the trunk forward, with
accompanying bulging of the abdomen, is most likely caused by weakness
of the abdominal musculature. It may also be due to stiffness of the
back. Pulling over more to one side than to the other and shifting of
the umbilicus to one side demonstrates unilateral weakness of lateral
abdominals; possibly there may be a lateral curvature of the spine.

If the infant consistently supports his weight on his hands at an
age where he is supposed to sit freely (after seven to eight months),
there may be either weakness of the abdominals or back muscles or some
interference with the centers regulating coordination and balance.

1/M. Shirley, op. cit.
2/A. Gesell and C. Armatruza, op. cit.
3/C. Buehler, op. cit.
Frequently, this is indicative of mental retardation. A tendency to sit with a marked rounded back (after the age of eight months) also points toward weakness of the back extensors. If the infant falls backward consistently from the sitting position (see previous discussion) the cause may be found in spasticity of the extensor muscles of the back or in weakness of the abdominals. Sitting with the weight shifted to one buttock, or with the trunk leaning to one side, always represents an abnormal pattern; it is most likely due to unilateral weakness of the trunk musculature, spinal curvature or weakness of one leg.

Whenever there is any reason to doubt that the trunk musculature is normal, one should determine which muscles are the affected ones in order to prevent later deformities. Weak abdominal muscles may be evaluated by watching the respiratory expansion and retraction of chest and abdomen and by observing and palpating the abdomen while the child is either pulled up or pulls himself up to the sitting position.

Proper development of the musculature of the trunk is even more important in early infancy than in later childhood. Uneven pull of opposing muscle groups, and particularly imbalance of the muscles on either side of the trunk, may be the cause of later deformities of the spine. Early recognition and correction of faulty alignment of the trunk is likely to prevent more extensive damage.
CHAPTER VIII
STANDING AND WALKING

It has been shown previously that most infants go through a well-defined, almost orderly sequence of motor development, starting with rolling from supine to prone position, from prone lying to sitting, and from crawling to creeping.

Next, they progress to standing up and walking. Although most children can take at least a few steps unsupported before they are ready to get up independently from the lying position; this phase of "getting up" is discussed first in this study.

Even a very young baby can be pulled up to a standing position. First he is pulled up to a sitting position; by pushing down on his feet and by extending his hips, he usually succeeds in raising his buttocks off the ground. His back remains arched and he cannot lift himself up. This first effort, therefore, should not be called standing or getting up; it is simply a passively exerted pull accompanied by a reflex-like push-off movement of the hip. In the next phase of development the child starts out in the same manner, but after having pushed with his feet against the surface, he thrusts his shoulders forward, then -- with a smooth and coordinated movement -- pushes himself upward, thus assuming the erect position. At this point, usually at the age of nine to twelve months, there is no need to offer any help; the infant now uses any object within his reach to
pull himself up.

At the age of about one year the infant starts to engage in a still more advanced form of rising from the recumbent to the standing position; he rolls from supine to prone; he then pushes up on his hands and arms, the chest and stomach are lifted off the surface. He flexes his hips and knees, pushes first with his feet against the surface (sometimes one knee remains bent while the other is extended); then the trunk is raised, either independently without holding on to an object or using the arms to pull himself up.

Still a little later the child omits the prone lying position altogether. After having assumed the sitting position, he carries his weight forward to assume the quadrupedal position from which he gets up in the previously described manner.

Frequently, a baby who can get up alone will not be able to lower himself back to sitting. He has not yet learned to master the anti-gravity muscles; he may either fall or he may start to flex his hips and knees, lose his control over this movement and collapse into sitting; only after he has gained better control of hip and knee extensors will he lower himself slowly from standing into the squatting or sitting position.

A child stands unsupported at the average age of seven to nine months; but there are wide variations which still fall within the normal range.

At first, the baby places his feet wide apart; this gives him a broader basis and helps him to maintain his equilibrium. His hips and
knees are usually slightly flexed and often outwardly rotated. His feet are pronated; he may stand on his toes. The use of the toes in gripping the surface affords the much needed balance.

Again, as has been mentioned previously, the infant may pass through a transitory phase of development before proceeding to the next, more advanced stage; during this period it may be difficult to induce him to stand on his feet. McGraw states that at this period

"...it may often be difficult to induce the child to stand on his feet. He will do so when he pulls himself up by the crib, but when an upright position is imposed upon him, he may deliberately flex the lower extremities against the abdomen so that he is suspended by his hands, or he may try to lower himself to a sitting position. Such behavior, however, presages increasing advancement of voluntary control over his neuro-muscular activities. It denotes the onset of cortical participation, although not complete control over progressive movements of the legs."

It seems important to call attention to the possibility of such behavior at this age level (nine to twelve months); resistance of a child to assume or maintain the standing position may thus be attributed to such causes and not to faulty motor development.

Needless to say, there also must be sufficient motivation for the infant to want to stand up.

Following are the age levels for standing up by:

1/ M. B. McGraw, op. cit.

2/ A. Gesell and C. Armstrude, op. cit.
The rather awkward posture described above is normal for a child who has just started to stand and has not yet acquired good balance and technique; there are, however, motions and patterns which can be considered definitely abnormal.

Standing with the legs adducted or pressed close together always presents an abnormal stance; the child may assume this position because of tight or spastic hip adductor muscles; there may be deformity in the hip joint, such as coxa vara or dislocated hips. A very wide base in standing may also be due to malformation or instability of the hips or impairment of sense of balance. Other symptoms of some abnormality are: (1) difference in the length of the legs; (2) difference in size or muscle tone of buttocks; (3) difference in shape and size of hips; and (4) increased lumbar lordosis.

Although the normal young infant frequently stands on his toes (because he can grip the ground better with his toes and because he can explore the world around him better), he assumes this position only very temporarily; generally, he rests his weight on his whole

1/ H. E. Linfert and H. M. Hierholzer, op. cit.
2/ M. Shirley, op. cit.
foot. An infant who stands on his toes most of the time presents an abnormal motor pattern which should be investigated. The plantar flexors of the foot may be spastic or there may be secondary contractures of the heel cords due to weakness of the dorsiflexors of the foot.

Some infants skip the preparatory phase of standing; others go through a relatively long period of standing before they take their first step. Thus there are wide differences in the pattern of progression in locomotion.

First of all, it is necessary to determine what is understood by the term "walking". It is well known that even a newborn infant may engage in some motions which are similar to walking; when he is supported in the upright position with his feet touching the surface, the very young infant engages in rhythmic alternate flexion and extension movements of the legs. Some infants who are somewhat hypertonic may even put some weight on their legs and thus take several steps in succession. This kind of activity has led many parents to believe that their baby "walks" when only a few days or weeks old; publicity has been given to children who have shown this "strange" motor behavior.

Obviously, these are only reflex and random movements, similar to the Moro and the suspension grasp reflex; they are involuntary reflex movements of the legs; there is no coordination between the lower extremities, upper extremities, trunk and head. Gradually, the child's postural adjustment becomes more deliberate and cortical
inhibitory influences are reflected by fewer reflex activities.

Langworthy discusses the relationship between myelinization of the pathways in the brainstem and improved organization of subcortical functions during the first two months of life; he concludes that the above described transitory phase of locomotion cannot be considered a true preparatory stage of walking.

A child does not need to be taught how to walk. When he is ready, the normal child makes the transition from standing to taking a few steps without any prompting. Walking, however, requires the ability to combine functions and skills which the infant had gained previously. McGraw points out,

"...that in order to walk independently, it is necessary to maintain balance in an erect position and to propel the body forward by alternate movements of the lower extremities. However, by the time these two features become sufficiently coordinated so that an independent step is possible, considerable development in both the equilibratory and propulsive mechanism has occurred."

As contrasted to the previously described phase of reflex "walking" (when the child had to be supported under his arms), he now shows postural control and coordinated motions of the extremities and the trunk; he takes steps deliberately and uses only his hands for support. He may not yet have acquired sufficient control over the cortical centers which regulate balance and coordination; his


movements may still be jerky or propulsive.

At the age of about one year the baby still holds on to the sides of the crib or some other object; he cruises around sideways, pushing one leg out to the side and then pulling the other close to it; this helps to maintain a wide base and to assure better equilibrium. The upper extremities are used to gain and maintain balance; the arms are extended and held in abduction; the fingers may be spread apart. When the infant starts stepping forward he keeps his feet wide apart, the hips and knees are flexed. He may either plant one foot firmly ahead of the other and pause before lifting the other forward, or he may do better by taking small, quick, almost running steps and then stop suddenly or fall. His whole body participates in this early phase of walking, his trunk swinging forward with the leg. There is very little ankle motion at first; the hip is flexed and the knee lifted high as the first steps are taken but the foot does not participate actively in the motion.

Again, as has been observed with other structures (hands, thumbs, and so on), the more complex forms of motor development in an organ result only from longer series of stages in the phylogenetic and ontogenetic development of this organ. Davenport says of the genetics of walking:

"The mutations that have led to the human foot are the end of a series of mutations that have been going on for a long time in the primate series and which have been found

advantageous for survival. The human foot has permitted the upright position and that has freed the hand from locomotion and permitted its higher uses; this has favored the evolution of a brain adapted to meet the needs of the hands.

When better coordination has been achieved (usually at the age of from 12 to 15 months), the child begins to walk in heel-toe progression. The swinging leg strikes the surface with the heel first, while the foot of the supporting leg is plantarflexed in order to push off with it. The ankle and the foot participates now in the stepping movement; there is less need to flex the hips and knees highly.

The mature phase of walking is reached when the child has not only acquired good body balance and coordination in his lower extremities and trunk, but when he starts to use his arms in synchronous swinging movements along with his legs; the opposite arm swings forward as the leg is brought forward. However, most children do not reach this level of a rather advanced integration before the age of two years.

Average ages for various phases of walking were given as follows:

1/ Buehler —
   — many children walk with assistance: 9 months
   — most but not all: 1 year
   — with support: 14 months
   — without support: 15-17 months

2/ Gesell —
   — walk with help when supported: 9 months—less than 20%
   — walks along: 12 months—75%
   — 12 months—less than 50%
   — 18 months—practically all

1/ A. Gesell and C. Armatruda, op. cit.
2/ C. Buehler, op. cit.
Linfert and Hierholzer 1/ walking with help: 6 months - none 9 months - 37% 12 months - 94%
walking alone: 12 months - 30%

The above listed forms of locomotion are all characteristic of the successive phases of normal gait. As can be seen there exist wide variations in the execution of the first steps. It is, therefore, rather difficult, at this early stage, to distinguish between normal and abnormal patterns of locomotion; frequently, it will be necessary to observe the infant for a considerable time in his motor behavior and to watch his general reactions before one can make a developmental evaluation.

Rand points out that, "We are inclined to think of walking as a function established and complete in a fairly brief space of time at the close of the period of infancy; we fail to realize that as a skill it begins as training in early infancy with the stretching and wriggling which teach coordination and strength to all muscles of the body; nor do we as a rule understand that progress in perfection of the skill of walking extends throughout the entire period of childhood. Before the child walks, he must have experienced a long pre-requisite training in coordination and strengthening of the muscles which begins as early as the third or fourth month and continues well past the two-year level."

Failure to walk may, therefore, not necessarily be attributed to some deficiency existing at the time of the examination. It could be the result of a retardation at a former stage of motor development. The cause of such retardation may long have disappeared. In fact the

1/H. E. Linfert and H. M. Hierholzer, op. cit.
2/Sweeney and Vincent Rand, Growth and Development of the Young Child, W. B. Saunders Company, 1936.
presence of such a retardation may have been overlooked at the time.

The cause of such retarded motor development may be found in congenital or acquired diseases, such as cerebral paralysis, encephalitis, poliomyelitis, and so on. Rickets, undernourishment or overweight may also contribute to late development of the neuro-motor mechanism.

Feeblemindedness is a frequent cause of retarded or absent motor development. Studies have shown that the average child walks at the age of about 13 months, while the feebleminded child acquires this skill only at the average age of 25 months. It, therefore, can be said that most feebleminded children are retarded in their motor development; this does, of course, not mean that all children who are retarded in walking are feebleminded.

From experience it can be stated that there are many types of gait in early infancy which differ so much from the ones usually seen that some kind of abnormality is often suspected. However, frequently it will be found that -- as time goes on -- the infant "grows out of" or corrects these abnormal patterns and that his motor development continues normally. Sometimes it is difficult to establish whether there ever was any temporary deviation at all or whether the typical behavior was only the individual's own pattern. However, it is always better to be too careful rather than to neglect any irregularity in a baby's development. There are certain characteristics in gait which give rise to the suspicion that something is wrong in the motor development of the child. Parents should observe such a child carefully
in order to determine whether this behavior is only of temporary nature; they certainly should not wait very long before bringing it to a doctor's attention.

Limping is always a form of abnormal motor behavior. Normally, the weight of the body rests on one lower extremity (supporting leg) while the other executes the phase of locomotion (swinging by). In normal gait the "time element" in both phases is automatically measured; they should be equal in length and the steps should be even and rhythmical. If there is some abnormality, the child will either take a longer step with one leg than the other or it may remain on the weaker leg for a shorter time than on the stronger one, thus shortening the phase of support and protecting the weaker structure from bearing weight. Limping may be due to a number of abnormalities, such as weakness of the hips, weakness of the leg or foot, inequality of leg length, sensitivity or pain in any of the weight-bearing structures.

Dragging one leg behind the other is usually due to weakness of hip flexors, knee flexors or dorsiflexors of the foot or it may be caused by spasticity.

Inward rotation of the hips and legs generally indicate faulty motor development; tightly adducted or crossed legs are definitely abnormal at all age levels; these characteristics are usually due to spasticity. Exaggerated, jerky body movements often associated with tremor of the extremities and uncoordinated, purposeless movements of the arms, are found in children suffering from extrapyramidal tract
lesions. A reeling, staggering type of gait may be due to a lesion in the cerebellum, causing lack of coordination in the participating muscle groups.

Normally, in walking, the heel is first to touch the floor and the toes follow very shortly; in the push-off phase, the heel is raised first.

An infant does not always show such well integrated participation of dorsi and plantarflexors in his early gait mechanics; he may lack the plantarflexion associated with the take-off phase in walking; he may hardly move his ankle in the swinging phase of the step; or he may put his whole sole down as his foot strikes the floor. He may even supinate or pronate his foot considerably during the first few weeks of walking. It can be noted, however, that the normal youngster does not at all times use the same seemingly abnormal motor pattern; he may take several steps with his ankle held stiffly and his foot not participating noticeably in the motion; but then he may take several very well coordinated steps.

An infant who consistently engages in abnormal patterns should be observed carefully. Here are but a few illustrations: The child who obviously tries to lift the foot off the ground but whose foot still drags; the child who stands and walks on tip toes all the time and who tires easily because he cannot support the weight on his whole foot; the child who leans to one side in order to protect one leg or hip; and the child who throws his trunk sideways in walking; such a child shows unmistakably signs of pathologic motor development.
which should be investigated carefully.

We can, and should, therefore, be able to differentiate between
an infant who shows only individual variations from the average
pattern -- or possibly slight temporary retardation -- and the
abnormal infant who suffers from an organic defect or a progressive
ailment. While the latter requires immediate medical attention, the
former needs proper understanding and guidance. Such a child will in
due time catch up with other children of his age; he will -- without
any permanent defect -- leave behind the primitive crawling stage and
become a "homo sapiens erectus".
CHAPTER IX

SUMMARY

1. The standard procedures for manual tests which are widely used for evaluation of muscle strength in adults can rarely be employed when dealing with infants under two years of age. This study suggests certain adaptations, modifications and new techniques for testing muscle strength and motor performance in infancy.

2. Seventy-five infants were observed at the Children's Hospital; their muscle strength and motor functions were analyzed and compared with the standards of normal motor development established by experts in the field of child development.

3. When using the term "normal", it should be realized that it refers to the average rather than to a clearly defined "normal". Each individual child follows his own pattern of development; the trend and direction of development are more important than a comparison of achievement with the accomplishment of other children.

4. It has been claimed that deficiencies in motor performance generally become apparent only at the time when structures have matured sufficiently to function. This study maintains that it is frequently possible to determine the character and the location of motor loss before the age at which voluntary activities can be expected. In this paper methods and techniques are presented which have been used successfully in evaluating motor behavior at the age which is under
discussion here.

5. Maturation and learning are closely related phases of development. While it was formerly thought that function was directly dependent upon myelinization, more recent research has offered evidence that there exists an interaction between these processes and that myelinization actually occurs by usage. There are many still unexplored possibilities for the practical application of this theory in regard to training the handicapped child.

6. In the course of this investigation various types of stimulation were used to evoke reflex motions which, in turn, were evaluated as to muscle strength and motor behavior. This study presents and analyzes such reflex patterns and their diagnostic and prognostic value.

7. Lifting of the head is an important phase of motor development in early infancy. Normal motor control of the head and deviations which point to faulty development are discussed.

8. Differences between the early grasp reflex and prehension at a later developmental stage are described. This study presents the results of experimentation with several types of stimulation, passive motion and manipulations which were used to evoke motor responses in the upper and lower extremities when other methods of stimulation and motivation failed.

9. A discussion of how healthy infants roll over, crawl, creep and sit is presented; such normal behavior is contrasted with patterns which indicate motor deficiencies.

10. There are wide variations in the child's early stages of
standing and walking. An analysis and an interpretation of various characteristics are presented with the intention of facilitating diagnosis and prognosis of motor deficiencies.

It is hoped that further research will find additional ways and means for testing muscle strength and motor behavior in infancy.


20. Goldstein, K., "Uber die Plastizität des Organismus auf Grund von Erfahrungen am Nervenkranken Menschen."


32. Lippman, E. S. "Certain Behavior Responses in Early Infancy," Pedagogical Seminary, Volume 34, 1927.


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Deformities (Over)
Facial
Anterior Neck
Sternocleidomastoid
Posterior Neck
Upper Erect. Spinae
Lower Erect. Spinae
Quad. Lumborum
Ant. Abdom.
Lateral Abdom.
Oblique Abdom.
Gluteus Maximus
Hip Flexors
Sartorius
Inward Rotators
Outward Rotators
Tensor Fascia
Hip Abductors
Hip Adductors
Quadriceps
Semi-Tendinosus
Semi-Membranosus
Biceps Femoris
Gastroc. & Soleus

Tibial Ant.
Tibial Post.
Peronei

Ext. Hall. Long.
Flex. Digit. Long.
Flex. Digit. Met. - Phal.

Flex. Hall. Long.
Flex. Met. phal. Hall.

Length — Mall.
Length — Sole.
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