CINEMATOGRAPHICAL ANALYSIS OF THE EFFECT OF THE POSITIVE SUPPORTING REFLEX ON STOMPING ACTIONS IN NORMAL, CEREBRAL PALSIED AND CLUMSY CHILDREN

by

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ABSTRACT

Motor performance such as running, hopping and jumping becomes less efficient when reflexive delays occur. To determine whether a child's poor motor performance results from delayed reflex development, a reflex test was given. Most contemporary reflexive tests require co-action and/or passive manipulation of the limbs by the evaluator; thus, ability to assess reflex development was limited by size and weight of the child. A technique was needed to assess reflex development on older, heavier children.

In this descriptive cinematographical study, four subjects--one cerebral palsied child, two motorically delayed children, and one motorically normal child--performed a single leg stomp action in three directions and then three consecutive stomps in a closed foot position. The purpose was to determine the amount of positive support reflex reaction by analyzing the duration of foot contact time after strike and angular joint measurements of the body parts prior to, during, and after foot strike.

Results indicated that foot strike in a forward and backward direction elicited exaggerated positive supporting reflexes by the demonstration of total leg extension after foot strike with the ankle exhibiting plantar flexion prior to and after foot strike. However, the foot stomp to the side decreased the base of support.

Therefore, the reflexive reaction was not as easily elicited as in the forward and backward foot placement. The single leg stomp in three directions and the three consecutive stomps indicated a substantial delay in reaction time by the motorically delayed subjects compared to the normal subject.

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THE PROBLEM

Introduction

Primitive reflexes are among an infant's first movement patterns and are responsible for the child's ability to lift the head, roll from side to side, sit, and eventually stand. (22, 26, 52) As important as these automatic reactions are, should they persist beyond the first year of life they become detrimental to a child's ability to develop efficient voluntary movement patterns. (15)

Twitchell (53, 54) reported when reflex delays occur, motor performance such as running, hopping and jumping becomes less efficient. Werbel (56) and Rider (45) established a relationship between reflex dysfunction and subsequent perceptual motor functions. Individuals who demonstrate a significant number of reflex development delays have depressed perceptual motor scores in balance, posture and body image. (27) Illingworth (27) and Arnheim (3) stated that when balance and posture are delayed, "clumsy movement" behaviors result. However, not all clumsy children have delayed reflex development. (42)

To determine whether a child's poor motor performance results from delayed reflex development, a reflex test must be given. (15, 26, 47, 48, 42, 20) Most contemporary reflexive tests require co-active and/or passive movement of the limbs by the evaluator (15, 20, 21, 20); thus, ability to assess reflex development is limited by size and weight of the child. What is needed by the practitioner who is attempting to assess reflex development of older, heavier children is a technique that elicits persisting primitive reflexes without having to physically manipulate the child's entire body.

Purpose of Study

In this descriptive cinematographical study one normal, one cerebral palsied and two motorically delayed students performed a single leg foot stomp in three directions and then three consecutive stomps in a closed foot position. The purpose was to determine the amount of positive supporting reflex reaction by analyzing the duration of foot contact time after strike and angular joint measurement of the lower body prior, during and after foot strike.

Scope of Study

The scope of this study was to analyze lower body movement during foot stomping motion of four subjects. Using the graduation evaluation scale described by Compute et al. (15) in the Primitive Reflex Profile, the scoring of zero to four respectively determined the absence or presence of positive supporting reflex in the subjects. One subject elicited no reflex response and three subjects were identified as demonstrating positive supporting reflex.

Using the cinematographical technique to film and record movement patterns, each subject's foot stomping action was demonstrated in a forward, lateral and backward direction. The following mechanical components were analyzed and described:

(1) Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

(2) Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.

(3) Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact.

(4) Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike.

(5) Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off.

(6) Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off.

(7) Reaction time recorded in 0.01 of a second performing the above six mechanical components.

For the purpose of analyzing the stretch response a variance score was computed using the above mechanical components three through six. The larger degree angles were subtracted from the smaller angles to determine the variance score for the hip, knee, ankle and supporting limb. Degree angle variance scores determined similarities and differences of the four subjects.

The same mechanical components were also used to describe and analyze the three consecutive foot strikes. Ten phases were selected to compare hip, knee and ankle angular measurement, uplift, first contact, after strike, lift off, uplift, second contact, after strike, lift off, uplift and third contact.

The duration of reaction time was recorded and compared for the single leg foot strikes in three directions and for three consecutive foot strikes.

Assumptions

The following assumptions were declared before the study was conducted:

(1) Each child stood the same way with similar body positions and all were encouraged to stomp equally hard.

(2) The camera plane variability of movement activity was normal.

(3) The subjects were representative of having a positive reflexive response, a mild reflexive response and without (inhibited) reflexive responses.

Limitations

The following limitations were determined after the study was conducted:

(1) The researcher did not instruct the subjects to fixate at eye level on a projected object during filming.

(2) The severity of mental retardation of the cerebral palsied subject interfered with comprehension of task and task completion.

(3) The camera and equipment was a distracting element for the subjects.

Significance of the Study

Often "clumsy" children are awkward in their movements and lack coordination skills; therefore, they shy away from physical interaction with their peer group. Arnheim (3) suggested that a nervous system dysfunction may be a characteristic of the "clumsy" child and implies an absence of complete or normal functioning. Crow et al. (18) stated that minimal motor deficits are often a result of persisting primitive reflexes that cause a child to move in a clumsy, awkward manner.

As a child increases in size it becomes more and more difficult to lift the child to test reflexes. A technique to test reflexes that eliminates the need to physically manipulate the child needs to be developed. This study will help determine whether a stomping action can be used to elicit a primitive reflex, specifically the positive supporting reaction.

Definitions

The investigator referred to the following definitions in reference to given terms throughout the study:

(1) Clumsy--Individuals who have motor learning difficulties and display asynchronous and inefficient motor behavior when attempting to carry out movement tasks that they would commonly be expected to accomplish under reasonable circumstances. (3)

(2) Cerebral Palsy--comprises a group of conditions resulting from injury or mal-development of the brain occurring in earliest childhood. (10)

(3) Crossed Extension Reflex--An extension of all joints of a limb which accompanies the flexion reflex in the opposite limb and which under prolonged or severe stimulation may become alternating so that it resembles stepping movements. (40)

(4) Positive Supporting Reflex Reaction--Increase of extensor tone of legs. Plantar flexion of feet, genu recurvatum (hyperextension at the knee joint) may occur. (22)

(5) Proprioceptor--A receptor that responds to stimuli originating within the body itself, especially those responding to pressure, position, or stretch. Example: muscle spindles. (49)

(6) Dorsiflexion of Ankle--Raising the foot toward the anterior surface of the leg. (24) See Appendix K.

(7) Plantarflexion of Ankle--Lowering the foot as when pointing the toes. (24) See Appendix K.

(8) Pes Equinus or Equinovarus--Bent inward, walking without touching the heels to the ground and with the sole turned inward. (49) See Appendix K.

(9) Stomp--A movement which projects a flexed knee upward (off the ground) and downward to contact ground surface with entire sole of foot.

(10) Normal--A motor skill acquisition performed within an appropriate age developmental range.

Abbreviations

C.N.S. - Central Nervous System

P.S.R. - Positive Supporting Reflex

P.R.P. - Primitive Reflex Profile

C.P. - Cerebral Palsy

Cl+1 - Clumsy (A Primitive Reflex Profile grade)

Cl+2 - Clumsy (A Primitive Reflex Profile grade)

Nor. - Normal

Chapter 2

REVIEW OF LITERATURE

Introduction

The purpose of this study was to compare the amount of leg reaction between subjects during a stomping motion. The four subjects compared included: one cerebral palsied child, two motorically delayed children and one motorically normal child. The stomping reactions were then related to the degree of primitive and postural reflexes remaining in each child.

The review of literature and research has been divided into seven sections. First is a brief review of neurological development related to primitive and postural reflexes. The second summarizes reflex contributions and development. The third reports relationships of postural reflexes to voluntary movement. The fourth reviews gait patterns. The fifth includes descriptive characteristics of the "clumsy" child. The sixth covers reflex evaluation. The seventh and final discusses the methodology of cinematographic analysis.

Neuromotor Development Relating to Primitive Reflexes

Reflexes probably underlie all or most volitional movements in man and lower animals, and their involvement justifies the hypothesis that the muscles engaged in associated movements are functionally connected by reflexes. (20) Banus (5) stated that two reflex maturation patterns occur in man. The first is phylogenetic progression, which refers to the repeating of primitive patterns derived from the evolutionary development of man as a vertebrate. The second is ontogenetic progression, which refers to more recently evolved traits (5, 20, 3, 53), such as the ability to stand erect, in the biological development of the individual. (5)

The central nervous system, including the brain, spinal cord, and cervical and spinal nerves, is not fully developed at birth. (4, 5, 20, 45) Because of this developmental lack, voluntary motor performance is not possible. As the nervous system matures, so do motor skills. (53) Basic neuromotor development is nearly complete by the age of two years, but continues in refinement throughout life. (5) Easton (20) and Banus (5) stated the structures of the brain mature in the order that they were formed phylogenetically and ontogenetically. The lower, older portions of the brain which are concerned with regulation of vital functions mature first. As a result, early motor behavior regulated by the lower nervous centers is stereotyped and automatic. (14, 20) As the higher nervous centers mature, some of the early primitive reflexes, referred to as "transient" reflexes, are assimilated and gradually inhibited. (5, 20)

Capute et al. (15) reported primitive and postural reflexes comprised a substrate for development of voluntary motor control and are eventually integrated into the C.N.S. Both primitive and postural reflexes can be described as "primitive," meaning disappearing after infancy. (15)

Neuromotor development is continuous (5, 20, 28, 53); however, all areas of neuromotor maturation do not develop simultaneously or at the same rate. Each area has spurts and dormant periods; therefore, each child establishes an individual rate and pattern of development. (5)

The C.N.S. is designed to respond automatically to certain stimuli. (4, 5, 6, 16) Easton (20) explained that the term "coordinative structures" involves one or more muscles working together. A coordinative structure or reflex is stereotyped, whereas volitional movements are activated by a single command of either peripheral or central origin. (13, 20) Peripheral input may regulate motor acts. However, the essential design of an act is set, or programmed within the C.N.S., and would not be economical if prearranged responses were ignored when volitional movements had to be composed. (20)

The lowest level of organization for control of motor movement is the gray matter of the spinal cord. (45) Sage (45) stated that two types of spinal motorneurons are found in the anterior horn of the spinal cord. The first is called the alpha motorneuron. Its cell body is located in the spinal cord and its axons and collaterals pass through spinal nerves to terminate on extrafusal muscle fibers, which are the main skeletal muscles. It is through these neurons that impulses must pass on their way to skeletal muscles. The gamma motor neuron is the second type and functions in the same manner, but terminates on the specialized muscle fibers of the muscle spindle, the intrafusal muscle fiber. (45) The stretch receptor is located in the muscle spindle. (45) The essential feature of the muscle spindle is that it contains sensory receptors and muscle fibers. Therefore, it has both sensory and motor functions. (45) The spindles are arranged parallel with extrafusal muscles, and when stretched, such as when an external force is applied, the intrafusal fibers displace the spindle receptor, causing an impulse to be fired. When the spindle's afferents fire, their impulses are transmitted over gamma fibers to the spinal cord where they synapse with alpha motorneurons that activate skeletal muscle. (45) Banus (5) and Sage (45) report that when the alpha motorneurons fire, contractions of the stretched muscle group results.

A reflex is a relatively constant pattern of response behavior that is similar for a given stimulus. (5, 20, 45) The word "reflex" is from the Latin meaning "bending back." To bring about a reflex, nerve impulses travel from a sensory receptor along a sensory axon to the central nervous system. (45) There the impulse "bends back" and moves away from the C.N.S. along a motor neuron axon, to activate a muscle. Sage (45) listed four basic nervous units necessary for reflexes:

(1) A receptor--All of the sensory receptors in the body are potential receptor organs for reflexes.

(2) An afferent neuron--A sensory neuron projecting to the central nervous system.

(3) An efferent neuron--A motor neuron projecting to the central nervous system.

(4) An effector--All of the muscles and glands are effector organs.

Banus (5) used systems of classification based on the source of the stimulus and location of the receptor--i.e., interoceptors, teleceptors, exeroceptors and proprioceptors. According to Banus (5) proprioceptors keep the brain appraised of the physical state of the body at all times. The proprioceptor mechanism found in skeletal muscle is the muscle spindle, which consists of a fluid-filled capsule tapering at both ends and containing both sensory receptors and specialized muscle fibers. The stimulus that excites the muscle's spindle receptors is the stretching of this specialized sensory region. (45) Muscle spindles are interspersed in all the skeletal muscles and found in both flexors and extensors of every joint. (45) The density of spindles tends to be particularly high in small muscles, producing fine movement. (45)

The Golgi organ is located in the tendon. (12) Basically, the Golgi organ inhibits the agonist and facilitates the antagonist, whereas spindle organ does the opposite. (12)

One of the critically important mechanisms for the control of reflex movements and coordination of motor activity is the reticular formation. (53) Ayres (53) reported the reticular formation exerts subtle influences of control over basic patterns of reflex connections to conform to postural needs. The reticular formation consists of a netlike mass of interwoven neurons that extend from the brainstem to the thalamus. The axons of the neurons project into the lower brainstem and spinal motorneurons. (53)

Holle (25) reported a strong connection between myelination and development of physiological activities including the child's movements. Myelination enables impulses from a nerve center to pass along the nerve fibers into the nervous system. In the newborn infant, the cerebral cortex has no influence on the lower regions of the brain because the myelin sheaths are not yet formed. However, the spinal cord is myelinated at birth, making possible all the newborn's movements. (25) As the cortex and the myelin sheaths develop, connections with the spinal cord are established, reflexive mass movements lessen and the voluntary directed movements become more and more accurate. Holle (25) listed four stages of neuromotor development:

(1) Reflex movement (uncontrolled by the brain).

(2) Symmetrical movements (brain control just beginning).

(3) Voluntary, motivation-differentiated movements.

(4) Automatic movements, habitual movements such as walking, eventually become automatic.

According to Sage (45), reflex activity plays an essential role in motor integration and control. The strength of a reflex response increases as the intensity of the stimulation increases. Sage (45) reported three factors that determine the latency period between stimulus and response: (1) speed of transmission over nerve fiber, (2) time required to cross the synapses, including the neuromuscular junction synapse, and (3) the time required for the muscle to contract. A reflex after-effect occurs when a sensory receptor is stimulated and the muscle reflexively contracts. When the stimulus is withdrawn, the muscle continues to contract for a brief period, normally less than a second. (45)

Contributions of Reflexes to Posture

Sherrington, during his classic research transecting the brain stem of the cat by passing through the pons and cutting off the cerebral hemispheres and midbrain, found certain muscles responded by increasing tone (hypertonus). The tone of the decerebrate animal was confined to those muscles which maintain the animal in its natural standing posture. Sherrington's observation reported by Walshe in 1923 lay in the discovery that muscle tone is a true reflex, dependent upon the integrity of the afferent nerve supply of the tonic muscle. Therefore, a muscle deprived of its afferent nerve supply immediately loses its tone. (55) The reflex is a deep or proprioceptive reaction arising in the muscle itself, whereas "tone" is simply a state of active tension. (45, 55) Sherrington, Magnus and deKleijin's studies caused Walshe (55) to conclude that "muscle tone is nothing else than the basis of posture, and decerebrate rigidity, as the phenomenon is called, is reflex standing."

Walshe (55) observed that tone was influenced, or modified, by impulses arising in deep structures, muscles, tendons and joints. In 1969 Bobath (9) reported tonic activity influenced and produced predictable tonus changes which facilitated extensor and flexor activity of the limbs according to position of the head in relation to trunk. Banus (5) believed that principle groups of attitudinal reflexes are proprioceptive and arise from the stimulation of receptors of position and movement located in the muscles, tendons and inner ear.

The work of Magnus (28) coincides with Sherrington's and supports the position that posture is an active process and is the result of the cooperation of a great number of reflexes. Magnus (28) and Banus (5) placed postural activities under the following categories: local static, segmental static and general static reaction. They then differentiated the following information:

(1) Local static reflexes affect single extremities and are exemplified by the positive and negative supporting reaction.

(2) Segmental static reflexes are those in which a stimulus in one extremity affect the homologous opposite extremity.

(3) General static reflexes originate in one segment and affect motor responses in other segment. (5, 28)

Two different stimuli cooperate in evoking static reflex (28): proprioceptive stimuli, evoked by the dorsiflexion of the distal parts of the limb, and exteroceptive stimuli, which are evoked by the contact of the pads of the feet of animals with the ground. A very light touch to the pads of the foot is sufficient to evoke a strong tonic extension of the whole limb even if dorsiflexion of the foot is carefully avoided. (11, 15, 22, 54)

Magnus (28), in reporting the condition of segmental static reaction in which stimulus and effect are not confined to the same limb but to the same segments, shows the interconnection of separate parts of the body in static functions. One such reaction, known as the "cross extension reflex," causes increased tone in the extensor muscles of the opposite limb. A similar reflex is present if the body is moved forward or backward, and is used for the maintenance of equilibrium and for the purpose of walking. (28) The third reaction, "general static," requires involvement of more than one segment of the body. A spinal severation in the thoracic region will evoke ipsi-lateral flexion, extension reflexes, a cross extension reflex, and rhythmic movements resembling walking and running.

The whole process of the supporting reaction, the passing from flexive condition to the stiffness needed for support, results from the feet's touching the supporting surfaces. At that point there is a stretch on the intrinsic muscles of the feet, resulting in synergistic reinforcement of all extensors. Hence, simultaneous contraction of both flexors and extensors results. (20, 28, 45, 54, 55)

According to Sage (28), the primary purpose of the stretch reflex is to oppose change in muscle length, especially sudden change. Even though it is not clearly understood, this reflex functions to prevent jerkiness and overshooting (hypermetria) during movement.

The findings of Orlovskii and Shik (37) in 1965 as reported by Easton (20) assumed that a flexion command overrides an extension command, that extensor inhibition maintains flexion, and that if an extended leg is not ordered to flex, it remains extended.

Relationship of Postural Reflexes to Voluntary Movement

Easton (20) reported that in normal human infants the simplest purposeful motor movements and postural changes depend upon the appearance and subsequent integration of primitive reflexes.

Fiorentino (22) stated that primitive reflexes are essential in normal development. Response to these reflexes prepares the child for progressive development. In normal development, these primitive spinal and brain stem reflexes gradually diminish in order that higher patterns of righting and equilibrium reaction may become manifested. (3, 20, 22, 54)

The following description given by Banus (5) supports the position that motor developmental tasks emerge from a postural framework:

> The labyrinthine righting reflex as it acts on the head, leads the body to the erect posture. Early in the baby's development, the positive supporting reaction, acting through the feet, enables his legs to support his body. The evolvement of the landau reflex provides extensor tone to the back and legs and augments standing. When the infant is standing, the righting reflexes act to maintain the normal alignment of the head and body. The development of equilibrium reaction allows automatic responses to postural shifts. The protective extension of the arms acts to protect the body during falls.

Twitchell (52) reported that upon modification of the positive supporting reaction and development of the hopping reaction, contact placing, and the instinctive grasp response of the feet, the ability to stand and walk evolves.

According to Barnes (6), there are two types of positive reaction: the neonatal positive, a privimitive reflex; and the more mature form of reflex, the weight-bearing positive supporting reaction or definite standing.

In cases of cerebral palsy, signs of retarded motor behavior appear and interfere with the primitive patterns. (8, 9, 10) The pathology common to all cases of cerebral palsy is abnormal muscle tone and spasticity, called hypertonus. (8, 9, 10) Children with hypertonic muscles elicit typical postures and movement, and the lesion causing cerebral palsy releases abnormal postural reflex mechanism. (10)

Barnes (6) explains that the lower extremities in the infant with an exaggerated positive supporting reaction are internally rotated and adducted. The knee extends and the feet plantar flex and invert. Thus, the infant is dominated by a total extensory pattern. Barnes (6) also stated that in walking, these infants touch the ball of the foot to the ground first. This provides stretch (proprioception) and tactile input (contact); the result is an abnormal extension. This increased extensor posture prevents separation of the legs so that transfer of weight from one leg to another is impossible. The individual can neither place his heel on the floor nor dorsiflex his foot. Barnes (6) further stated that the infant can carry the weight of the body but is not mobile for balance. The increased extensor posture can lead to structural deformities such as hip dislocation and deformities in other parts. (6)

Bobath (11), in describing the cerebral palsy patient, explained that exerting pressure on the reflexogenic area of the positive supporting reaction when the patient was attempting to stand prevented him from putting his heel to the ground. An upsurge of extensor spacticity produces extension, inward rotation and adduction of the whole leg, with plantar flexion of the foot. This force throws the patient backward and off balance, making weight transfer over the standing leg difficult. By raising one leg, extensor spasticity in the standing leg is increased; and after placing the raised leg down to take body weight, the extensor spasticity in the standing leg will diminish, and it will flex. Both results are due to the added effect of the crossed extension reflex on the positive supporting reaction. Bobath (11) further reported that by bending forward, the position of the head will weaken the exaggerated extensor activity produced by the positive supporting reaction; extension of the head backward will have the opposite effect. Twitchell (52) reported the part of the sole of the foot stimulated can, to a marked degree, determine the kind of response elicited. Stimulation of the lateral border of the foot is more likely to elicit dorsiflexion, and stimulation of the medial side will likely elicit plantar flexion response.

The characteristic posture of a child who toe-walks is very similar to the posture obtained when testing for a positive supporting response in normal children. (34) One of the explanations for toe-walking is that such children are hypotonic and have inadequate integration of vestibular input. The increasing tactile and proprioceptive input from toe-walking facilitates support tone in the lower extremities. (34)

Twitchell (52) indicated that evolving voluntary movement in the human infant has a reflex substrate, and reflexes have their origin in fetal life. The reaction can be elicited in the living human fetus by stimulating various body parts with a fine hair. At ten and one-half to eleven weeks, when the soles of the feet are stimulated, the reflex occurs. (52)

Capute et al. (15) agreed with other studies when concluding that reflexes comprise a substrate for the development of voluntary motor control with which reflexes are eventually integrated. He made the following statement:

> Normal infants are born with numerous primitive reflexes because of the unrestrained influence of the "old brain" (deep gray matter), which contains the centers for such reflexes. These centers include the brain stem, cerebellum, midbrain and basal ganglia. The "new brain" (cerebral cortical mantle) can be viewed as an inhibitory organ. During development, primitive reflexes are inhibited and integrated into more functional postural and voluntary motor responses. With cerebral insults, this cortical suppression integration is released and various deep gray matter responses (primitive reflexes) reappear. These can be considered neurodevelopment markers for brain dysfunction and motor impairment. The Cerebral Palsied is at one end of the spectrum of braim damage syndrome: the child with minimal cerebral dysfunction may well represent the opposite end of this same spectrum. (15)

The distinction between reflexes of posture and reflexes of movement is not clear cut. Similarly, it is difficult to clearly delineate normal and abnormal motor development. (9, 53) Patients with cerebral palsy demonstrate that there are quantitative variations from most severely involved to those minimally involved. Those with minimal degrees represent the link between normal and abnormal motor functioning. (15) Thus, the physiological basis for mild motor defect in the clumsy child is identical to that found in cerebral palsy, although to a lesser degree. (9) Bobath (9) and Twitchell (54) reported the complex interweaving with voluntary neuromotor function is most clearly visible in the reappearance of these infantile reflexes in older children and adults who have suffered brain damage.

Twitchell (53) was of the opinion that defects in voluntary movement and defects in reflex mechanisms have a common basis. The common ingredient is a defect in sensory-motor integration with conflict between hypertrophied infantile reflexes. Defects of voluntary movement of any kind result not from exaggeration of one reaction of the motor mechanism, but rather from exaggeration of several that are in mutual conflict.

Easton (20) summarized the results of his findings by stating stereotyped phases of movements do not necessarily reflect identification with reflexes even though reflexes may have much in common with them. Proof depends on electrophysiological demonstration that the same cells fire in the same way to activate the muscles during reflex activation as during volitional activation.

The final review of studies indicated that any voluntary activity requires subcortically controlled postural activity to prepare for the movement and to support it throughout its duration. (30) The division between automatic and voluntary activity per se is impossible to make. Some activities will be more voluntary and less automatic--e.g., tennis--while others, such as regaining one's balance when in danger of losing it, will be most automatic. (30, 14)

Coordination of movements occurs on the basis of known patterns--i.e., using the experience and memory of what we have done before. (30) Patients with abnormal coordination will, therefore, initiate a movement on the basis of sensori-motor patterns which are in themselves abnormal, and volition will reinforce those patterns. (30)

Gait Patterns

Traditionally the gait cycle is divided into two phases according to percentage of time the limb is in weight-bearing and non-weight-bearing. The two phases are termed "stance" and "swing." The stance phase is divided into heel strike or weight acceptance. (31)

Marley (31) reported that in infancy during early supporting walking, stance and swing phases can be identified, although striking differences persist when compared to the adult. Marley (31) further reported that gait studies of children usually modify the phases accepted for adults because children's developing gait patterns differ from those of adults. However, over a period of 6-13 months, after the initiation of independent gait, all the parameters of adult gait are demonstrated by non-handicapped children.

Marley (31) explained that the first phase of heel strike or weight acceptance reaction of adult gait pattern at initial floor contact exhibits knee extension but quickly flexes with onset of weight. The ankle extends or plantar flexes as the entire foot is lowered to contact floor. The children's gait pattern between 9 and 20 months on initial floor contact exhibits knee extension and ankle flexion, but dorsiflexion following onset of weight-bearing.

Children with chronic neuromuscular disorder such as cerebral palsy frequently exhibit excessive ankle plantar-flexion during gait. Predominant features of spastic cerebral palsy are exaggerated stretch reflexes, accompanied by clonus, exaggerated deep tendons reflexes and persistance of primitive reflexes. (31) When muscle action is attempted, it is thwarted by reflex activation of the antagonistic musculature via the stretch reflex. Two specific patterns exist in these children: (1) equinus pattern of the feet and ankle (position of plantar flexion) and (2) adduction and internal rotation pattern of the hip. The gastrocnemius muscle, a three-joint muscle (ankle, knee and subtalar joint), has been observed to be the primary offender or responsible muscle for the equinus patterns. The gastrosoleus has a lever arm of almost twice that of the tibialis anterior muscle (its principal antagonist) with a muscle mass advantage of almost four to one.

"Scissoring" is the common term used to describe the adduction and internal rotation of the hip and ankle. Adduction, internal rotation of the hips and the equinus pattern of the ankle make lateral balance very insecure and narrow the base of support. When balance is compromised by lack of ground contact, the cerebral palsied child flexes the hips and knees to lower the center of gravity to increase balance. Pressure on the balls of the feet triggers a stretch stimulus and elicits an exaggerated positive supporting reaction. This lack of inhibition of stretch reflex, causing some muscles to fire at inappropriate times, results in impairment of free forward and backward swing of the leg. (31, 5, 20, 45)

Inhibition of the strong ankle plantar flexors, primarily the gastrocnemius muscles, facilitates the contraction of the ankle dorsiflexors (tibialis anterior and entensor digitorum longus muscles). The sensory receptor area located on the plantar surface of the heel reflexively facilitates contraction of the foot dorsiflexor, primarily the tibialis anterior. With more weight over the heel at initial floor contact, the dorsiflexors are given more opportunity to contract. (31, 52, 7, 8)

Characteristics of the Clumsy Child

According to Arnheim (3), the term "clumsy" is used both as a colloquial pejorative and as a specific diagnostic entity. Colloquial implications may not accurately represent the children who are causing concern. The American Heritage Dictionary's (35) meaning for clumsy is "lacking in coordination, skill, grace, awkward, gauche and inelegant." There is a different between inelegant performance and inability to perform a task.

According to Illingworth (27), "clumsy" is a generic term used to describe the older child who is awkward in his movement, much like the young child. Observation of these children indicate that they are always falling, walking into objects, misjudging the width of the doorway, knocking objects over, having unwanted movements in the opposite hand, have difficulty in climbing, throwing and jumping, are unaware of their feet, can't keep up with the other children, and are impulsive and poor at concentrating. (1, 3, 27, 50) Touwen and Prechtl (51) reported that a major complaint accompanying cases of mild disabilities of motor coordination is clumsiness and awkwardness.

According to McKinlay (32), "clumsy" may be used to describe motor coordination that is two years or more behind chronological age level. Thus, McKinlay (32) stated, there is a full range from clumsy gifted children to mentally handicapped children. Illingworth (27) reported that there is a definite correlation between a low I.Q. score and poor motor dexterity, though many clumsy children have a high I.Q.

Arnheim (3) stated that clumsiness may result from cerebral dysfunction. The nervous system controls and coordinates all bodily functions and provides a means by which alternation in the body's internal and external environment can be accomplished. These changes are the result of stimuli that cause impulses to occur in specific receptor organs, such as skin, joints and muscles. Although not commonly associated with clumsiness, dysfunctions within the spinal cord or nerves, or both, can produce varying problems of proprioception and problems of tendon reflexes; dysfunction within the brain stem can create problems along sendory or motor pathways. Muscle spasticity, hypertonicity or lack of tone, poor tactile discrimination and postural problems can be associated with problems in the brain stem. (3)

Touwen and Prechtl (51) reported that associated movement, often more marked on one side of the body than on the other, was probably related to cerebral dominance, which permits movements to spread to one side of the body more easily than to the other. (51) Associated movement is not easy to predict, but in older children whose cerebral dominance is definitely established, spreading is generally believed to occur from the nondominant toward the dominant side. Towen and Prechtl further reported the persistence of associated movements may be one indicator of slow neurological development. There may or may not be developmental retardation, which means that only a maturational lag such as in walking, hopping and standing on one leg, or the persistence of infantile reflexes (diadocholinesia), will be observed. Signs of neurological dysfunction and high amount of associated movement may often be observed at the same time. Clumsy children may show a low amount of spontaneous movement, and often their speed of movement is slow. (51)

Molnar (33) studied the relationship among motor milestones, primitive reflexes and postural reactions in 53 mentally retarded children. He found that primitive reflexes disappeared at the normal age, but postural reflexes were delayed.

A study by Rider (43) reported that learning-disabled children had significantly more abnormal reflex responses than do normal children. The purpose of Rider's study was to determine whether a relationship existed between postural reflex level and academic performances. The children who had no abnormal reflex responses scored higher on achievement tests than did the children who had abnormal responses. All the neurologically impaired children displayed abnormal responses in greater number than the normal children. Rider found that eight of the 19 normal children displayed primitive reflex patterns. Developmentally, reflex levels corresponded to levels of the central nervous system, and it is assumed that maturation of each level presumes maturation of all preceding levels. Nevertheless, Rider's study evidenced a much higher percentage of abnormal responses at the midbrain level than the higher cortical level. Apparently, through learning and experience these children were able to develop equilibrium responses despite deficiencies at a lower central nervous system level.

Illingworth (27) studied 150 cerebral palsy cases and diagnosed development on the history, the examination and interpretation during the first year of life. The most common complaint of a mother of an affected child was backwardness in development. It was emphasized that clumsiness, or some disorder of coordination, was the most common reason for referral of the 117 cases reported in a study by Abbie, Douglas and Ross. They agreed that clumsiness alone is sufficient reason for treatment, because abnormal reflex development often appears in normal children.

Pyfer (41) administered Fiorentino's Reflex Testing Methods and Perceptual Motor tests to 262 subjects and reported that almost half of the subjects demonstrated seven or more abnormal reflex patterns. In her opinion, reflex abnormalities are known to interfere with movement stability and may have an adverse effect on perceptual development. Another study by Werbal (56) indicated children who demonstrate more than three abnormal reflexes experience reading difficulty behavior problems in the classroom.

In a presentation titled "Growth and Development, the Preschooler," Pyfer (42) explained that at least 36 reflexes are crucial to normal motor development. Fourteen of these appear during the first year of life and eventually enable a child to assume an upright posture and to move. After a child becomes mobile, these "primitive" reactions are inhibited and do not reappear unless the individual is traumatized in some way. Should these reflexes persist past the time a child begins to walk, a clumsy, jerky movement pattern may result. Pyfer also gave a description of the child with prevailing postural reflexes. "Children with severely delayed reflex and vestibular development move in an awkward, clumsy manner, fall easily, have trouble learning to ride a bike, and are slow in developing fine motor skills." She reported that facilitating reflex and vestibular development has a direct positive effect on static and dynamic balance.

In connection with a study of the evolution of postural reflexes in neurologically abnormal infants (38), it becomes apparent that existing information about the ages at which various changes take place in these reflexes in normal children needs to be amplified. It is essential to know the outer limits of normal in order to interpret apparent abnormalities. (38) The evolution of neurological signs with special attention to the postural reflexes was studied serially during the first year of life with 66 normal infants examined at four- to six-week intervals. Some of the major conclusions made by Paine (38) were as follows:

> The positive supporting reaction in newborn includes partial flexion of the hip and knee and differs from the response of the older infant in which the knee is locked in full extension. In 76% of the babies, the neonatal supporting reaction was diminished and replaced by the more mature form, but the transition may be unbroken. Support of weight in the equinus position was seen in 24 of the 66 infants in one or another occasion. Scissoring was rare and inconsistent.
>
> In vertical suspension in space, flexor posture of the limbs was lost by four to five months. Consistent adduction in extension or scissoring of the lower extremities was not seen in normal infants.
>
> Tactile impulses play a role in initiating the placing reaction, but traction on the ankle joint and lower extremity may be important. It is usually considered to be a cortical reflex but is demonstrable with almost all normal newborns. The placing reaction does not have a clearcut disappearance at any specific age but is gradually suppressed or covered up by voluntary activity toward the end of the first year.
>
> The stepping reaction when supported in the standing position and inclined forward was lost or declined in parallel with the supporting reaction which was more consistently obtainable or absent.
>
> The supporting reaction (positive Stutzreakton of Rademaker) was elicited by supporting the infant vertically and allowing its feet to make firm contact with a flat surface.

The positive supporting reaction facilitates simultaneous contraction of opposing muscles so as to fix the joints of the lower extremities. Paine (38) believes the origin is partly tactile but probably based on proprioceptive impulses. Paine also reported the reaction was not intended for prolonged maintenance but more as a posture preparatory for motion followed by automatic stepping. (38)

According to Abbie (1), children who are described as suffering agnosia, sensory integrative dysfunction, agnosic ataxia, minimal cerebral palsy, perceptual-motor difficulties and/or dysynchronous, usually have clumsiness as one of their problems. Terms commonly used to label such children are "minimal cerebral dysfunction" or "minimal brain dysfunction" (MCK or MBD). (3) Because of the attention which has been focused on these children in recent years, one tends to think MCD and clumsiness are synonymous. (1, 3) Although they do frequently occur together, children can be clumsy for other causes such as normal variation, delayed maturation of the motor system, familial factors, mental subnormality, or mirror movements.

The previous range of variation of postural reflexes of normal infants furnished a background for Paine's (38) serial study of 200 abnormal infants over a three-year period. Of the 129 infants who completed serial examinations, the majority proved to have motor disabilities associated with nonprogressive chronic brain syndromes and classifiable cerebral palsies. Several showed general and comparable retardation of mental and motor development and specific abnormalities of muscle tone, reflexes, or involuntary movement.

Touwen and Prechtl (51) have identified several primary factors associated with minor nervous dysfunction: (1) hemisyndrone, a form of specific unilateral pattern that could be quite inconspicuous, (2) associated movements, known as synkinetic movements, co-movements, and mirror movements, which often accompany voluntary or involuntary movements in young children, generally in contralateral and symmetrical parts of the body, and (3) development retardation, meaning a maturational lag in neurological functions such as walking, hopping, and standing on one leg.

Banus (5) stated neuromuscular dysfunction pertains to impaired functioning of the nerves and muscles, which includes dysfunction of the nervous system. Motor dysfunction may result from involvement of the nervous system, the peripheral nerves relaying impulses from the brain stem or spinal cord to the muscles, the nerve and muscle junction, called the myoneural junction, or the muscles. According to Banus (5) and Taylor (50), motor development is delayed or retarded in some children without a pathologic cause. The quality of motor tasks is within limits, but the timing is delayed. Possible causes of delayed or retarded motor development are: (1) delayed maturation of the central nervous system, (2) prolonged illness resulting in debilitation, (3) marked obesity, (4) lack of opportunities to practice motor skills, (5) illness or physical deprivation, (6) a familial characteristic, and/or (7) an individual developmental response.

Reflex Evaluation

Since primitive and postural reflexes follow an orderly sequence of appearance and disappearance, Capute (15) reported that it is generally accepted that a neurodevelopmental evaluation provides an accurate means of distinguishing the degree of prematurity. Developmental evaluation is based on the developmental scales of Gesell. Although Gesell's norms for her development scales are standardized, the majority of tests derived from them for evaluation of the child with neurological deficit are not standardized. Missing in the type of developmental test based on the achievement of milestones is information about the developmental neurophysiological processes themselves.

Semans (48) believes that, when possible, a distinction should be made between frankly pathological posture and movement responses and movement responses and those of a normal but immature nervous system.

Fiorentino (22) developed the "Reflex Testing Methods for Evaluating Central Nervous System Development." The purpose of this instrument was to determine neurophysiological reflex maturation of the central nervous system at the spinal, brain stem, midbrain and cortical levels for use in evaluation and treatment of the cerebral palsied child.

The testing technique for the Positive supporting reaction requires the evaluator to hold the subject upright by wrapping the evaluator's arms around the subject's trunk below the axillae, keeping the head in a neutral or midline flexed position. While maintaining this position, the subject is bounced several times so that the soles of the feet hit the floor. (22)

Extension of the lower limbs is normal from three to eight months of age; however, a positive reaction after eight months may be one indication of delayed reflexive maturation. That is, after eight months of age one would expect to get a negative reaction which would be no increase of extensor tone--legs volitionally flex, after age eight months would be no increase of extensor tone in legs.

Plantar flexion of feet and genu recurvatum (hyperextension at the knee joint) may also occur during an abnormal response. The reflex testing score is assessed entirely on a presence/absence basis. (22)

Capute (15) included the positive supporting reflex among seven reflexes in his "Primitive Reflex Profile." The profile was scored on a graduated scale from 0-4 respectively to reflect whether the reflex was absent or present. For a reflex to be scored at a given stage on any of the following scales, that level of performance must be observed on at least three out of five trials. Voluntary actions do not enter into the actual graduation because the scales are meant to be applied uniformly to both very young infants as well as older retarded patients unable to cooperate in the performance of such movements.

The technique used by Capute (15) to test the positive supporting reflex was to suspend the child around the trunk below the axillae with the head in a neutral or midline flexed position and to bounce him five times on the balls of the feet. The balls of the feet are then brought in contact with the floor and the child is held in a vertical position to assess the degree of supporting response. The gradation of grading includes:

0 Absent: child goes into flexion and does not support his weight.

1+ The child maintains his weight momentarily (between 1 and 30 secs.).

2+ The child is able to maintain his weight for longer than 30 secs. with a quick (less than 5 secs.) movement from plantar flexion to dorsiflexion (i.e., the heel makes contact with the examining surface).

3+ There is delayed movement from plantar flexion to dorsiflexion: the child remains in the equinus position longer than 5 secs. but less than 30 secs.

4+ The child remains (longer than 30 secs.) in an equinus position. (The child is unable to move out of this position without circumducting his legs.)

Test Batteries

(1) The items of the "Cerebral Palsy Assessment Chart for Basic Motor Control" were selected and adapted from the Assessment Chart development by Karl and Berta Bobath. (47) The rationale Seman (47) offered for her test protocol was that by selecting characteristic postural patterns simple enough for accurate observation, an assessment can be reasonably objective. The progress sequence from horizontal to upright postures indicated how far the child has come in his development of postural control. The test includes 20 items, three of them relating to positive supporting reaction.

Number 18 is a test to assess the ability to shift weight forward onto stance leg with rear leg extended ready for push-off. Specifically, the testing procedure involves placing an individual in a forward step position, then having him shift his weight over the forward leg with trunk, pelvis, thigh and leg correctly aligned over foot; the rear leg should be extended, outwardly rotated at hip, and resting on the normal roll-off points; arms should be relaxed. For children in grades two to five, the therapist may steady the child by holding one hand.

Number 19 is a test to assess the ability to support the body over one leg. From a symmetrical standing position the child is required to shift the weight laterally over one leg and lift the other free of the floor, as for the swing phase of walking. The trunk should remain erect. For grades two to five, the therapist may steady the child by holding one hand.

Number 20 is a heel strike test. One foot is advanced in dorsiflexion with the heel placed on the floor. Weight is supported mainly on rear leg, hip extended, both knees straight. Ankles at approximately 90 degrees. Arms should be relaxed. For grades two to five, therapist may steady child by holding one hand.

A grading system with values from 0 to 5 is used as follows:

0 Cannot be placed in test posture.

1 Can be placed in test posture, but the position cannot be held.

2 Can hold test posture momentarily after being placed.

3 Can assume an approximate test posture unaided, in any manner.

4 Can assume and sustain test posture in a near-normal manner (note any abnormal detail).

5 Normal.

Grades 0 to 2 indicate the severity of the handicap as tested by resistance to passive motion, by limitation of joint range, or by ability to maintain posture. Grades 3 to 5 indicate the quality of movement when performed actively by the patient.

(2) The "Test for Gross Motor and Reflex Development" was designed by Hoskins and Squires (26) because of the inconsistencies among motor development tests and to avoid the usual practice of testing reflex and voluntary motor development as two separate

entities. (26) According to the authors, a revised form of being used in a clinic setting, and its ultimate value as an assessment and treatment planning tool for gross motor development in cerebral palsy is being determined. The authors stated that gross motor development may be operationally defined as "the sequential integration of automatic, stereotyped reflex phenomena leading to the emergence of voluntary, discrete, nonobligating motor behaviors concerned with posture and locomotion."

The test battery included 19 reflex items and 60 voluntary activities. Two of importance to testing of the positive supporting reaction are numbers 11 and 29. Number 11 states that the positive supporting reaction is elicited in the upright position. The child is suspended, bounced on his feet to elicit extension of both lower limbs, including plantar flexion of the feet. This reflex should be inhibited by the age of seven months. Item number 29 involves the child's standing at the rail and lifting first one foot, placing it back down, then lifting the other foot. The following grading symbols were suggested so that a more definitive differentiation of motor deficit can be made:

P = present and normal

P = present, abnormal in time--i.e., should have disappeared

Px = present, abnormal in tone.

A = absent, but abnormal--i.e., should have appeared

A = absent, but normally so

This Gross Motor and Reflex Test was evaluated for reliability and validity on a sample of seventy-two normal children.

Overall interrater was (.96). The single items with low reliability (.78) were revised. Hoskins and Squires (26) stated:

> Two of the items which showed a significant trend to exceed the norm also had relatively low reliability. The positive supporting reaction was recorded as present in eight children in whom it persisted beyond the age of normal disappearance. This reflex should become integrated before voluntary weight bearing can be achieved. The difficulty in evaluation arises in differentiating between a reflex supporting reaction and voluntary supporting stance. The authors now recognize that the positive supporting reaction stereotypically demands plantar flexion, whereas, in weight bearing, dorsiflexion occurs with hips and knees extension. Examples such as this suggest that the significant difference between the observed and expected frequencies may be related to the lower interrater reliability.

(3) In The Neurological Examination of the Child with Minor Nervous Dysfunction, Touwen and Prechtl (51) state that minimal cerebral dysfunction is a vague and global concept that covers a wide range of signs and symptoms. The syndrome of cerebral dysfunction manifests itself both in neurological and behavioral dimensions. Touwen and Prechtl point out that no valid correlations have been established between the neurological syndromes described in their examination and any specific types of behavioral problems.

Their examination was concerned with the conclusions that may be drawn from neurological signs. Included were associated movements, known as synkinetic movements, co-movements, and mirror movements, which often accompany voluntary or involuntary movements in young children, generally in contralateral and symmetrical parts of the body. Touwen and Prechtl (51) further said that associated movements decrease with age, and their disappearance was reckoned to be a sign of the functional maturation of the nervous system. They tested the associated movements through walking on tiptoes, and walking on heels. According to the authors, many factors may influence the amount of associated movements shown, including the complexity of the movement involved, the intensity with which the "trigger" movement is carried out, the order in which the tasks are presented, and the familiarity with the requested movement. The grading scale for associated movements are gradations from 0 to 3.

Cinematography Methodology

Cinematography provides a means of detecting movement that is not possible under ordinary circumstances (17), for human motion is a transient phenomenon which exceeds the capacity of human optics. (36)

The majority of the literature agreed that the main asset of cinematography was that it provided a means by which precise observation of human movement could be made both anatomically and mechanically. (36)

The term "developmental kinesiology" refers to the application of kinesiological techniques to motor development. (44) By using the cinematographic kinesiological approach to chart movement within skills and across skills, within individuals and across individuals, motor development research comes closer to understanding what development is and the course it takes. (48) Clarke and Clarke (17) reported that comparative data are lacking on the differences between skilled and unskilled performers because the descriptions of movements are empirical, fragmentary, and devoid of theoretical insight.

Clarke and Clarke (17) reported that the investigator must balance such factors as time and cost with sample reliability. Given that the analysis of data may be quite time-consuming and the production costs of film rather expensive, there is a tendency to select very few subjects.

Using cinematography, Semans (48) reported studies of the effect on the equilibrium reactions of lesions on different parts of the central nervous system. Anderson (2) filmed a mentally retarded population and a normal population and found the differences in mechanical components of the vertical jump were in vertical displacement of center of gravity. In another study, Marley (31) analyzed the effects of platform shoes on initial floor contact during gait in children with cerebral palsy and found platform shoes do decrease ankle plantar flexion. Forney (23) photographed the effects of torsion cables, a brace used to correct for abnormal internal and external rotation of the lower extremity. She used cinematographical gait analysis to compare handicapped subjects to nonhandicapped subjects.

Plagenhoef (40) reported that critical analysis of motion is concerned largely with measurement of body angles. Logan and McKenney (29), Cureton (19), and Clarke and Clarke (17) agree that motion pictures are the only method available which allows a total body force and joint analysis of all types of motion.

Camera, Film and Apparatus

Two types of camera are appropriate for use in cinematographical analysis: the spring-driven camera with variable speeds up to 64 frames per second and the electronically driven camera capable of moving film at a rate of thousands of frames per second. (17, 29) As opposed to spring-driven cameras, motor-driven cameras have a relatively more constant timing factor.

Basic cinematographic analysis can be done effectively by using 32-64 frames per second. Less than 32 frames per second will blur during maximum velocity performances of the limbs. (17, 29) The camera should have a variable shutter setting to reduce the time exposure of each frame. (29)

It has been recommended that the 16mm camera be used rather than the 8mm equipment because the 16mm camera provides both a larger image and greater detail. (17, 29, 19)

A camera with interchangeable lens system with "zoom" capabilities reduces the amount of parallax, which involves perspective errors when the camera is relatively close to the subject. This telephoto lens reduces such errors, enabling the photographer to be further away from the subject. (17, 29) Perspective errors are recorded by the camera lens because the lens cannot make size adjustments as the human eye does. An ideal camera should have the following f stops: (1) The standard lens should have f stop settings from 1.9 to 22; (2) The wide-angle lens should have f stop settings from 1.8 to 16; and (3) The telephoto lens should have an f stop setting from 2.5 to 32. (17, 29)

The film selected is based on the camera used, film speed and lighting conditions. For analytical purposes, black and white film is preferable to color film because it provides better contrast. (17, 29)

Filming Procedures

Prior to filming, several factors must be considered before the subject is to be analyzed: (1) the position of the camera in relation to the performer, (2) the height of the camera in relation to the center of mass of the individual to be filmed, (3) the actual distance of the camera from the performer, (4) the size of the performer in relation to the viewfinder, and (5) the time taken to perform the skill. (40)

Human motion occurs in a predominant plane to which the optical axis of the camera must be set at a right angle. Also, the camera should be placed at a 90-degree angle to the most important plane of motion. (19, 36) The variation in the lens-to-subject distance and the resultant effect on the size of the image can be established by an object of known dimensions or a portable grid screen in the background. (36)

Literature reviewed stated that the camera should be placed perpendicular to the plane of motion. (17) When more than one plane is desired, two or three cameras facing front and to the side of the subjects are used for dimensional analysis. (17) When a more complete analysis of skill is desired, two cameras are used, each of which must be calibrated so that its precise speed is known. (36)

Photographing two views of the same subject on one frame can be accomplished by using a dichroic mirror and photographing the individual from above, the side, or in front. (29) Using a third camera permits description of rotary movement. (36)

Controlling the distance of the camera from the performing subject is often difficult. Therefore, at least one known distance must be included in the film for future reference to determine the velocity of linear motion as well as the actual size of the object in various positions and the range of motion of the joints involved. (29) An actual measurement of some part of the body can be taken for future reference.

Plagenhoef (40) suggested a meter yardstick and a hanging plum bob be used in the plane of motion to obtain the scale and to provide a vertical reference when the film is projected.

Measurement of body angles has been recognized as a problem. (40) Angular measurement may be the single most important variable in analysis of human motion. (17) Angular measurements require no multiplier or correction factor to obtain true size dimension except for aspects of perspective due to lens used or photographic errors. To maintain a constant level as well as stability for the camera, a tripod has been recognized as an essential piece of equipment. (17)

Distortion in body angles were said to be produced when "angle of incidence" was varied, and may be seen to vary from 0 to 180 degrees. Noss (40) suggested the method of triaxial photography to correct the distortion for the analysis by yielding three sets of data whose mean value equals the true value of the subject angle.

When calibrating a camera, a time device can be included in the film. A one-second sweep hand, divided into 0.01-second intervals, provides a check on the accuracy of the frames-per-second of the camera. The number of frames elapsing between seconds can then be counted. (40, 29) When placed within camera range, the image of the subject and the clock can be transferred from film to graph paper by use of a film analyzer. (17) Film readers are designed primarily for cameras capable of operating at 64 to 128 frames per second, and the time per frame is of the order of .0156 seconds, which is usually sufficient to detect the significant aspects of movement. (40) Photographing an object falling from a known height is one method of calibrating a spring-driven camera. ( )

Analysis of Data

Once the film is developed, film analysis begins by viewing the frames to be selected for measurement through a Lafayette stop-action projector. After the frames are selected, the analysis of filming entails tracing the projected image off the Recordak film reader onto graph paper, which included two reference points so that subsequent frames could be viewed in perspective. (17) To make film identification more accurate, the joints of the body are selected as anatomical landmarks. These anatomical landmarks include (a) acromion process of the shoulder, (b) head of the ulna, (c) head of the trochanter, (d) lateral condyle of the femur, (e) lateral malleolus,

(f) the tip of the toe. (29) It was suggested that the subjects be prepared by placing markings such as black tape or marking the skin directly on the selected bony prominences. (29) The subject should wear a minimal amount of clothing so that limbs are visible. (17) Contour body outlines of point and line stick figures of the subject were noted as being the common means of obtaining data from film. (17) Questions of velocities, acceleration, and angular changes will be answered from each body part selected provided that the factors of time and distance are known. (40)

Summary

Sherrington's "reflex standing" description and Magnus and de Kleijin's observation revealed that standing posture was not dependent upon higher brain level functioning, but by pressure on the foot pad. In cases of decerebrate animals, severing the brain from the brain stem and spinal cord will cause the foot to extend against the pressure that is applied to it. Walshe (55) reported that if the animal is placed on its feet, the foot pad will reflexively stiffen and the limbs will support the weight of the body. Magnus (28) defined this reflex as positive supporting and reported that it produced an antigravity contraction of the extensor muscles resulting in an erect posture.

Neurological reflexes, the raw material from which the central nervous system builds voluntary movements, were described by Fiorentino (22), Bobath (8), Banus (5), Sage (45), Twitchell (53), and Arnheim (3), and their descriptions are filled with irreconcilable differences. These theorists disagreed in definition rather than observation. Capute (15) stated that neurological reflexes are involuntary motor responses elicited by appropriate peripheral stimuli, but Easton (20) stated that reflexes lend a facilitory influence to volitional effort, and reflexes may be activated by higher levels of central nervous system as well as by peripheral stimulation.

Easton (20) reported that it is easy to find stereotyped aspects or phases of movement, but such invariances do not necessarily reflect an identification with reflexes, even though they may have much in common with them. In his opinion, coincidence of volitional movement invariances with reflex patterns may be attractive, but only through the use of electrophysiological demonstration will reflex activation and volitional activation be differentiated.

Illingworth (27) defines "clumsy" as a generic term to describe the older child who is awkward in his movement like a much younger child. These children often lag two years or more behind their chronological age level. Taylor (50) reported the routes to clumsiness may be through lack of integrity of the central nervous system, slow maturation, inappropriate state of arousal or poor rehearsal.

Observations made of clumsy children by Arnheim (3) indicate that they are always falling, having difficulty in climbing, throwing and jumping, are unaware of their feet, are impulsive, and are poor at concentrating. Touwen and Prechtl (51) reported that a major complaint accompanying cases of mild disabilities of motor coordination is clumsiness and awkwardness. Arnheim (3) stated that clumsiness related to cerebral dysfunction with neurological implication may occur within the central nervous system.

Marley (31) reported in her study on gait in children with cerebral palsy that traditionally the gait cycle is divided into two phases according to percentage of time the limb is in weight bearing and non-weight bearing. The first phase of heel strike or weight acceptance reaction of adult gait pattern at initial floor contact exhibits knee extension but quickly flexes with onset of weight. The ankle extends or plantar flexes as the entire foot is lowered to contact floor. The children's gait pattern between 9 and 20 months on initial floor contact exhibits knee extension and ankle flexion, but dorsiflexion following onset of weight bearing. Children with chronic neuromuscular disorder such as cerebral palsy frequently exhibit excessive ankle plantar-flexion during gait. When muscle action is attempted, it is thwarted by reflex activation of the antagonistic musculature via the stretch reflex. Two specific patterns exist in these children: (1) equinus pattern of the feet and ankle (position of plantar flexion), and (2) adduction and internal rotation pattern of the hip. These patterns make lateral balance very insecure and narrow the base of support.

Cinematography provides a means of detecting movement that is not possible under ordinary circumstances. (17) The term "developmental kinesiology" refers to the application of kinesiological techniques to motor development. (44)

Logan and McKenny (29) stressed these factors which must be considered prior to filming: (1) the position of the camera in relation to the performer, (2) the height of the camera in relation to the center of mass of the individual to be filmed, (3) the actual distance of the camera from the performer, (4) the size of the performer in relation to the view finder, and (5) the time taken to perform the skill.

Angular measurement may be the single most important variable in analysis of human motion. (40) Angular measurements require no multiplier or correction factor to obtain true size dimensions except for aspects of perspective due to lens used or photographic errors.

Film analysis begins by viewing, through a projector, the frames to be selected for measurement. The projected image is traced off the Recordak film reader onto graph paper, which includes two reference points. To make film identification more accurate, the joints of the body are selected as anatomical landmarks. It was suggested that the subject be prepared by placing marking such as black tape directly on the selected bony prominences. (40)

Clarke and Clarke (17) reported that the investigator must balance such factors as time and cost with sample reliability. Given that the analysis of data may be quite time-consuming and that production costs of film are rather expensive, there is a tendency to select very few subjects. (17)

Chapter 3

PROCEDURE

Research Design

The purpose of this study was to determine the amount of positive supporting reflex reaction in children by analyzing selected filmed frames of angular joint measurements prior to, during, and after foot strike, and the duration of foot contact time after strike.

The following mechanical components were examined and described:

(1) Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

(2) Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.

(3) Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact.

(4) Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike.

(5) Maximum ankle extension including flexion/extension of hip, knee and supporting limb prior to lift off.

(6) Maximum extension of ankle including flexion/extension of hip, knee and supporting limb at lift off.

The reaction time was recorded in 0.01 of a second for six mechanical components. The duration of foot contact time was analyzed and described in selected comparison time periods. The reaction time periods were (1) "up lift" through "lift off," (2) "up lift" through "foot strike," and (3) "foot strike" through "lift off."

The period of time for reflexive reactions to occur are described in angular measurements taken from mechanical components 3 through 6. For purpose of descriptive interpretation these measurements are computed into variance scores. The Foot Placement Variance Chart for three directions are found in Appendices E, F, and G.

For quantitative analysis three consecutive foot strikes were described, including the six mechanical components. A combination of those components was selected and used to compare the four subjects by hip, knee and ankle angular measurements. The duration of reaction time for three consecutive foot strikes was recorded in (1) "up lift" through "lift off," (2) first "contact" through "lift off," and (3) second "contact" through "lift off."

Selection of Subjects

The subjects selected for this study were previously reflex tested by measurements included in the "Primitive Reflex Profile." Each subject was selected because he/she represented a distinct example of motor development and ability ranging from no evidence of positive support reaction to marked evidence of the reflex.

One of the subjects selected for the study was a cerebral palsied student enrolled in a practicum class for handicapped children at Cordley Elementary School in Lawrence, Kansas. Two other subjects were referred to the investigator from the University of Kansas Perceptual-Motor Clinic. Each of these subjects had completed his/her evaluation and was to receive therapy. One of the assessments used by the clinic was "Reflex Testing Methods for Evaluating Central Nervous System Development," and each subject was diagnosed as eliciting the positive supporting reflex reaction. The subject chosen as normal was randomly selected from a group of children playing on the Cordley Elementary School grounds.

The parents of the subjects were contacted by letter for permission to include their children in the cinematographical research study. Written permission was granted by the parents of all four subjects with the agreement to withdraw at any time (see parent's approval letter in Appendix A).

Data Collection Before Filming

Prior to filming, demographical information was given to the investigator by the parents (see Table 1).

Reflex Evaluation Procedures

Each subject was tested individually, and the demographical information was gathered on the day of filming. With only the investigator present, the following technique was used to elicit the positive supporting reflex.

Table 1

Demographic Information on Four Subjects Who Demonstrated Varying Degrees of the Positive Supporting Reflex

Subjects	Age Yr.-Mnth.	Sex	Height	Weight	Diagnosis	Primitive Reflex Profile
1	7-4	M	4'-0"	50 lb.	Normal	0
2	10-8	M	4'-4"	58 lb.	Cerebral Palsy	4+
3	6-9	M	3'-11"	55 lb.	Clumsy	1+
4	5-5	F	3'-10"	51 lb.	Clumsy	2+

The subject was suspended around the trunk below the axillae and bounced five times on the balls of his/her feet. The balls of the feet were then brought in contact with the floor and held in a vertical position to assess the degree of supporting response.

All subjects were measured by grading scales included in the Primitive Reflex Profile:

0 Absent: child goes into flexion and does not support his weight.

1+ The child maintains his weight momentarily (between 1 and 30 secs.).

2+ The child is able to maintain his weight for longer than 30 secs., with a quick (less than 5 secs.) movement from plantar flexion to dorsiflexion (i.e., the heel makes contact with the examining surface).

3+ There is delayed movement from plantar flexion to dorsiflexion: the child remains in the equinus position longer than 5 secs. but less than 30 secs.

4+ The child remains (longer than 30 secs.) in an equinus position. (The child is unable to move out of this position without circumducting his legs.)

Cinematographical Procedures

Prior to filming of action, equipment selection was made and experimental protocol such as camera and film was chosen. Frame rate, f-stop, shutter speed, and lighting were determined for data analysis.

Equipment Used

The following equipment was used in the filming of the single leg stomp movement:

(1) 16mm Bell and Howell high-speed camera

(2) Film ESO Super Speed--Index 400 ASA black and white

(3) Tripod

(4) Reference yardstick

(5) One-revolution-per-second clock

(6) Weston light meter

(7) Numbers to record subject and trial number

(8) Magic Marker for marking joints

(9) Portable ballet barre

(10) Two pair and four single vinyl child-size footprints

Location and Time

The filming was conducted at Robinson Gymnasium, University of Kansas, Lawrence, Kansas, in the Perceptual Motor Clinic. The filming session was arranged and filming was completed after two one-hour sessions on July 22, 1980, and July 24, 1980. A ten-minute rest period was allowed per subject.

The background was white to provide the greatest amount of light. The portable ballet barre was black. It measured six and one-half feet long and thirty-eight inches high, and was constructed of iron with a wooden base.

The bright red footprints measured seven and one-half inches in length and were placed two inches apart in a vertical and/or horizontal direction.

Location of the Equipment and Photographic Data

The Bell and Howell camera was placed perpendicular to the predominant place of action of the skill. The camera was located 30 feet from the subjects and the camera lens was three feet six inches from the ground. The one-revolution-per-second clock was placed to the right of the ballet barre and the two sets of numbers were placed to the left of the ballet barre. The set of numbers indicated the subject and the trial of the subject performing the foot placement movement.

The camera was loaded with black and white film and set on a tripod at 64 frames per second. No lighting other than the tungsten lighting was used for the filming. The shutter factor of the camera was set on 1.20 and the f-stop was set at 1.9-2.0. Diagram of equipment seen in Figure 1.

Preparation of the Subject

The subjects were relaxed and every effort was made for the activity to be enjoyable. The subjects wore dark-colored bathing

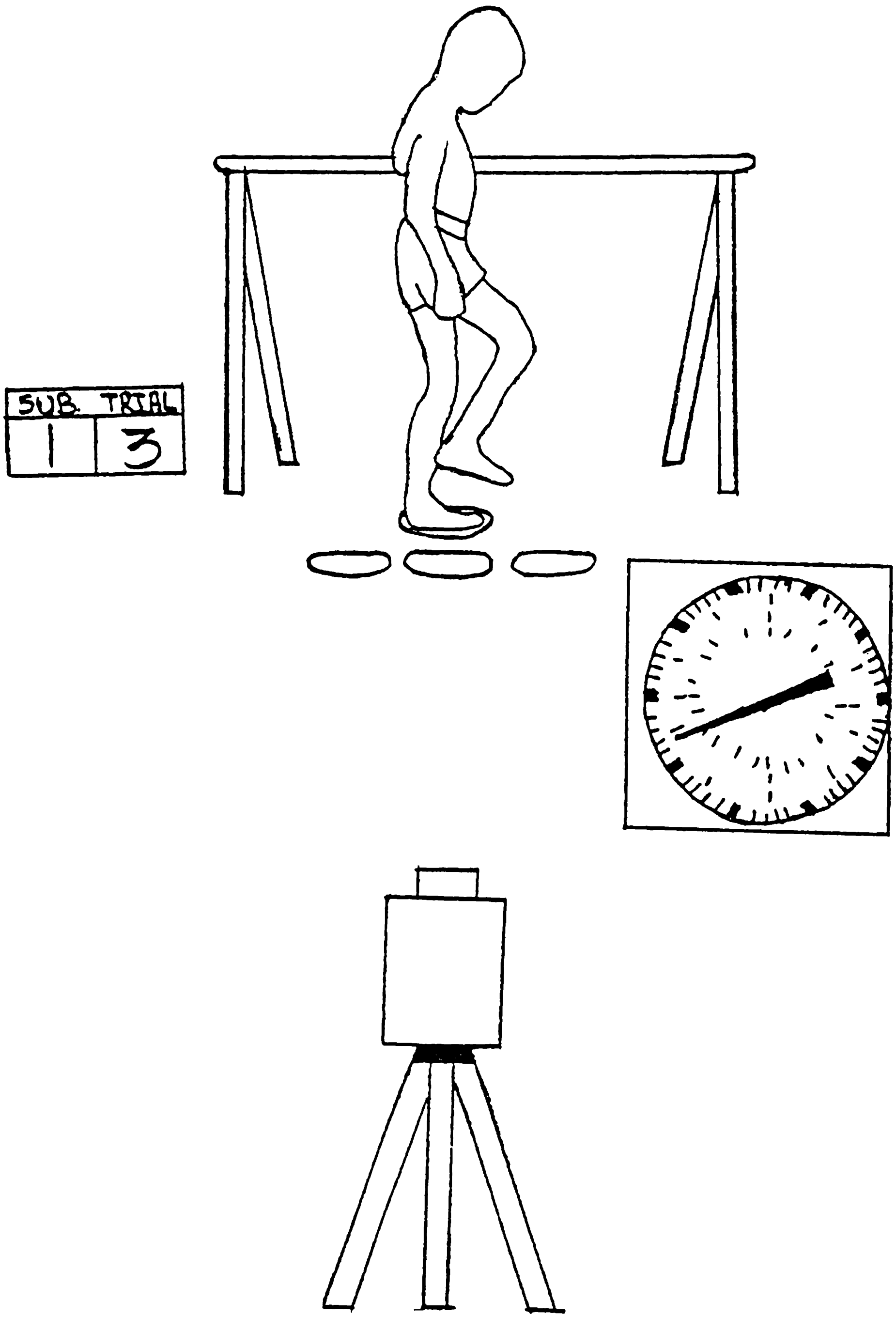


Figure 1. Diagram of Equipment and Subject's Foot Placement

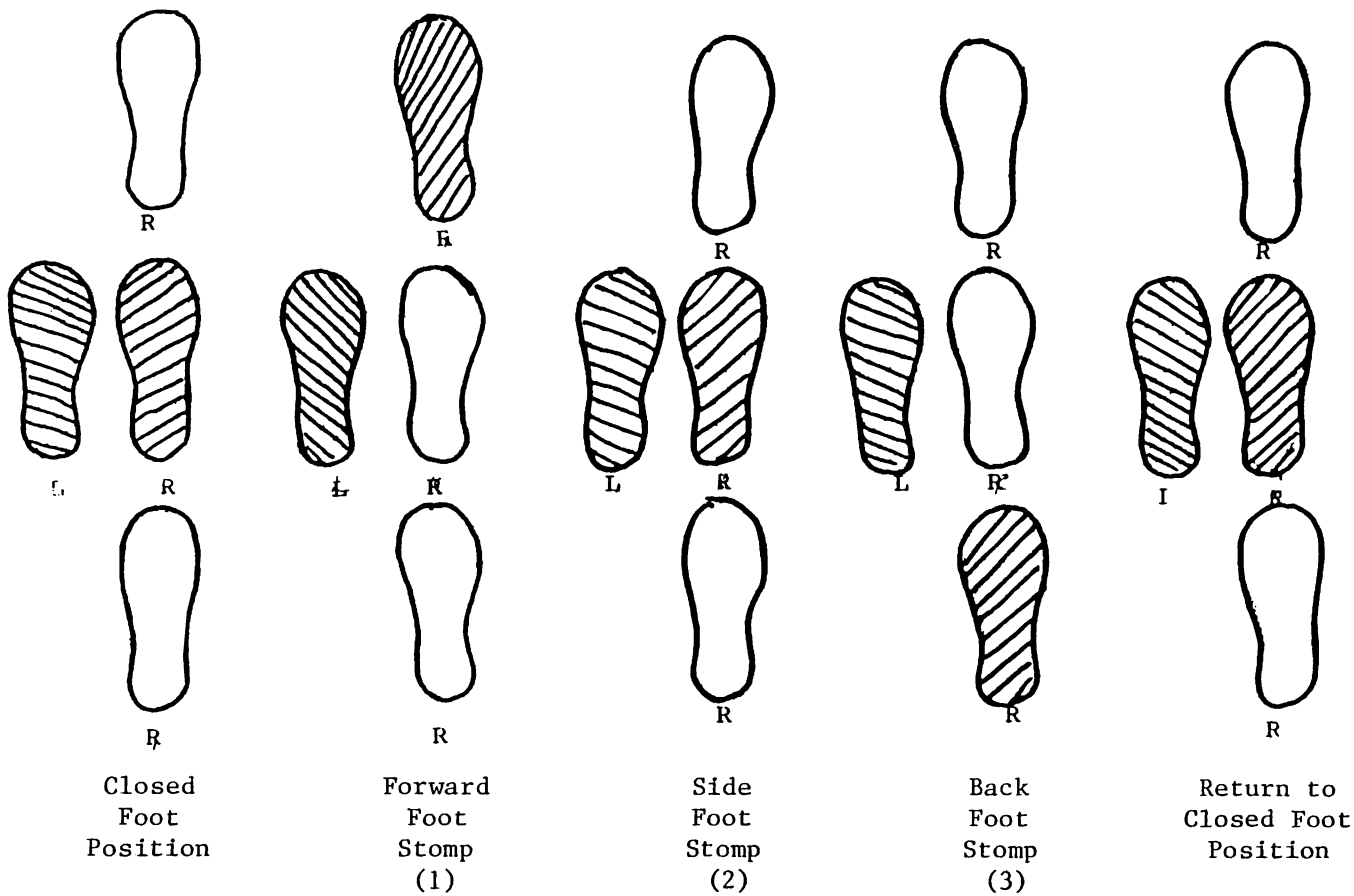
suits and performed barefoot. Each subject had markings applied with magic marker on the right and left acromion process of the shoulder, right and left head of the ulna, right and left condyle of the femur, and right and left lateral malleolus. Tape was applied to the swim shorts at the location of the trochanter. Distracting elements were avoided by using magic marker instead of tape.

Filming of the Foot Placement

After instructions concerning foot placement, a short rehearsal familiarized the subjects on direction of foot placement. Then each subject was filmed performing the foot placement on the right and left foot. Each performed the action on the right foot, then turned and faced the opposite direction for action on the left.

Only the investigator and the photographer were present in the room while the filming took place. The subjects were motivated to perform by the sight of the colored vinyl footprints placed on the floor. The subjects were instructed to take a closed standing position with their feet placed on two of the designated footprints, while holding onto the portable ballet barre. Additional footprints were placed on the floor to the front and to the back of the subjects. The subjects were instructed to stomp one time on each of the footprints, totaling three stomps (Figure 2), then return to the closed position and stomp three consecutive times in the closed standing position.

Figure 2. Footprint Placement Pattern



Right foot placement. Left foot held in a stationary position.

Procedures for Tracing
the Selected Frames

The film was previewed through a Lafayette stop-action projector to determine the essential frames for tracing. The film was placed on a Recordak Film Reader magnified 40 times. Tracings were done on a piece of eight and one-half inch by eleven-inch graph paper (Appendix L). For each tracing, the first step was to locate two reference points: the right and left corner of the ballet barre. The two reference points were selected to ensure that, for each frame, each stationary point of the image was in the same relative position. The anatomical landmarks were located and measured with a protractor for joint angle degrees of the hip, knee, ankle and supporting limb. The angle degrees were recorded on charts for comparison of the four subjects.

Validity and Reliability

The determination of validity using four subjects is subjective. Cinematography is accepted as an accurate analysis of performance; therefore, face validity is claimed. The "Primitive Reflex Profile" was used as a testing measure and is currently being evaluated in a large-scale quantitative study.

The reliability of this analysis centered around the researcher's ability to accurately plot joint centers. To determine the intraexaminer reliability of the plotting technique, the first frame of the (uplift knee angle) of subject number one Nor. was traced ten times. The knee angle was plotted, then recorded, and the first trial was compared to the date recorded on the other ten trials. The percentage of error in plotting joint centers was within .05 degree.

Chapter 4

RESULTS, DISCUSSION AND SUMMARY

Results

The purpose of this study was to examine and analyze cinematographically a single leg stomp movement in three directions, front, lateral, and back of the body, and then three consecutive stomps. The study compared the differences and similarities of purposeful foot pattern placement of four subjects demonstrating (1) a simple foot strike in three directions, and (2) three consecutive foot strikes. The motion analysis determined (1) angular measurements of body parts prior to, during, and after foot strike, and (2) duration of foot contact time after strike, which provided a qualitative and quantitative method of reflexive evaluation.

The following mechanical components of each foot strike were examined and described:

(1) Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

(2) Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.

(3) Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact.

(4) Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike.

(5) Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off.

(6) Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off.

The reaction time was recorded in 0.01 of a second found in Comparison Time Table 2 (forward foot strike), Table 3 (lateral foot strike), and Table 4 (backward foot strike). Reaction time was recorded during (1) "uplift" through "lift off," (2) "uplift" through "foot strike," and (3) "foot strike" through "lift off."

The four subjects selected were previously reflex tested by the measurement criteria included in the "Primitive Reflex Profile." Each subject was selected because he/she represented a distinct example of motor development and ability. The description of the subjects was as follows: Subject 1 was classified as having "normal" (Nor.) motor ability with no evidence of reflex abnormality and a graded score of "0" on the PRP scale. Subject 2 was diagnosed as having "cerebral palsy" (C.P.) and elicited an exaggerated positive supporting reflex reaction and was given a grade of 4+ on the PRP scale. Subject 3 was classified as "clumsy" (Cl.) with a grade of 1+ on the PRP scale. Subject 4 classified as "clumsy" (Cl.) received a grade of 2+ on the PRP scale.

Intraexaminer reliability was determined by selecting one forward foot strike frame of Subject 1. Nor., 0, and measuring procedure of one body part was repeated ten times. The data from the angle of the knee on the first trial was compared to the data from the same point on the ten trials to obtain percentate of error in plotting joint centers. The plotted point was within .05 degree accurate.

Selected Drawings

For the readers's convenience, drawings of six selected movements are presented in Appendixes M, N, O, and P. The drawings are from selected frames and tracings of the six mechanical components referred to as uplift, prior to strike, contact, after strike, prior to lift, and lift off. The six drawings of each subject illustrate the similarities and differences found in the four subjects.

Subject 2 (C.P.) was unable to complete the required series of movements on the right leg; therefore, the left leg was used for illustration purposes. The subject could not lift the right leg after foot strike because of intervening reflexive behavior.

When reviewing these drawings, the following inconsistencies were noticed: (1) weak posture, forward and backward trunk inclination, (2) downward head projection, (3) plantarflexion prior to foot contact, on contact, and after contact, (4) overflow of movement in the arms and hand (associated reactions), (5) homolateral body involvement, and (6) exaggeration of leg in uplift.

Appropriate body alignment, posture control, weight transfer to supporting leg, and no noticeable excessive body limb or trunk movements hindered skill acquisition was demonstrated in Appendix M.

An inconsistency of the above items was demonstrated in Appendices N, O, and P.

Forward Foot Placement

A descriptive interpretation describing similarities and differences of six mechanical components is found in Figures 3 through 8, including angular measurements of the hip, knee, ankle, and supporting limb. Each angle was measured with a protractor by tracing the frame at maximum degree of flexion and/or extension. Raw scores are found in Appendix B. Data information includes the right foot as the performing leg and the supporting limb as the opposite leg. Subject 2 C.P. could not complete "lift off"; therefore, no score will be recorded.

Mechanical Component One. Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle, and supporting limb, as seen in Figure 3.

Hip: Subjects 1 Nor. and 3 Cl+1 demonstrated 134-degree and 135-degree extension, respectively. Subject 2 C.P. and 4 Cl+2 demonstrated 89-degree and 91-degree flexion, respectively, indicating approximate 44 degrees more hip flexion than Subjects 1 Nor. and 3 Cl+1.

Knee: Subject 4 Cl+2 demonstrated excessive 65-degree knee flexion, while the other three subjects ranged from 85-degree flexion to 118-degree extension. Subject 2 C.P. elicited 19 degrees more flexion than Subject 1 Nor.

Joint Measurements for Forward Foot Strike

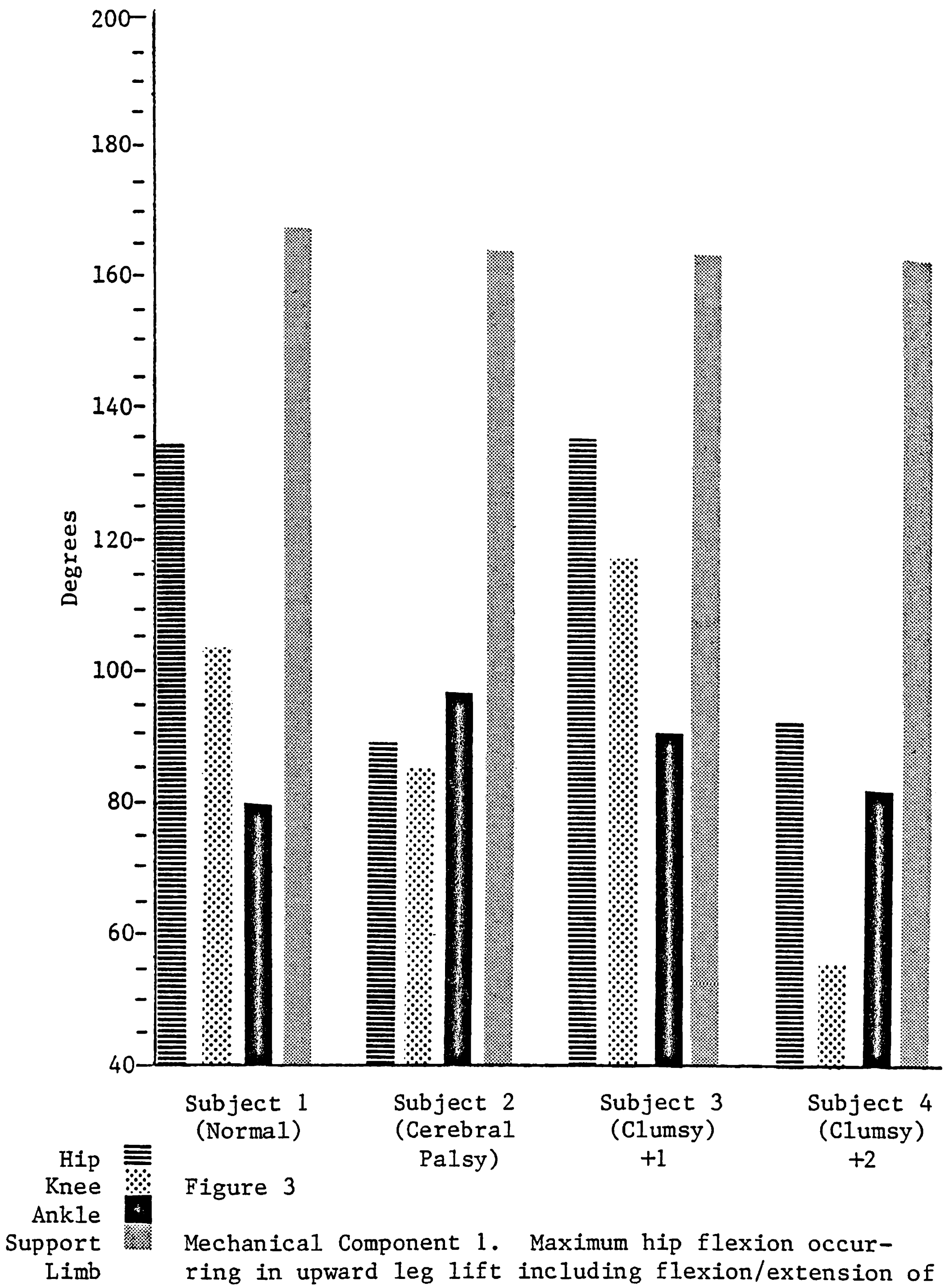


Figure 3

Mechanical Component 1. Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

Ankle: Subject 1 Nor. and Subject Cl+2 elicited 80-degree and 82-degree, respectively, slight dorsiflexion. Subject 3 Cl+1 demonstrated a neutral 90-degree angle, but 2 C.P. demonstrated a 97-degree plantarflexion.

Supporting Limb: All subjects demonstrated approximately the same angle range of 162 to 168 degrees.

Subject 1 Nor. demonstrated neutral hip extension, knee in moderate flexion with slight ankle dorsiflexion and supporting limb in extension, indicating proper body alignment and trunk control. Subject 2 C.P. demonstrated excessive hip and knee flexion, causing trunk instability with slight ankle plantarflexion. Subject 3 Cl+1 demonstrated appropriate trunk control with neutral hip and ankle positioning. Subject 3 Cl+1 demonstrated slight knee extension. Subject 4 Cl+2 elicited excessive hip and knee flexion, causing an exaggerated leg lift with slight ankle dorsiflexion.

Mechanical Component Two. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike, as seen in Figure 4.

Hip: Subjects 1 Nor. and 3 Cl+1 demonstrated 142-degree and 155-degree extension, respectively. Subject 2 C.P. demonstrated a 102-degree angle, measuring 40 to 52 degrees more flexion than Subject 1 Nor. and 3 Cl+1. Subject 4 Cl+2 elicited 116-degree flexion, also eliciting more hip flexion than Subject 1 Nor. and 3 Cl+1.

Knee: Subject 4 Cl+2 elicited 105-degree angle, the greater knee flexion. Subject 2 C.P. measured 129 degrees, Subject 1 Nor.

Joint Measurements for Forward Foot Strike

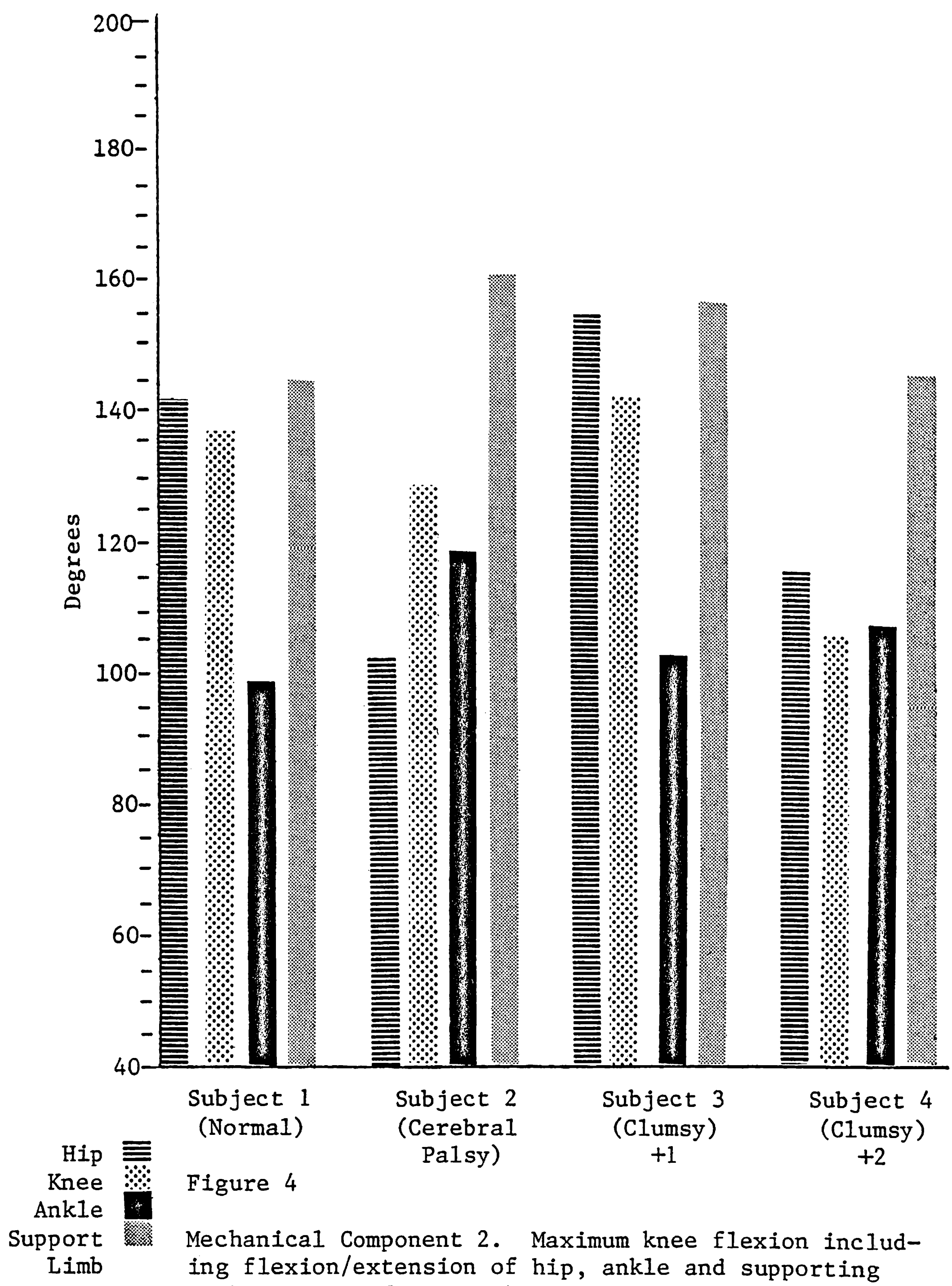


Figure 4

Mechanical Component 2. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.

measured 136 degrees, and Subject 3 Cl+1 measured the greater knee extension, 142 degrees. Comparing mechanical component one and two indicated greater knee angle inconsistency was performed by Subjects 2 C.P. and 4 Cl+2.

Ankle: Plantarflexion was demonstrated by all subjects. Subject 2 C.P. demonstrated the greater 118 degrees and Subject 1 Nor. demonstrated the least 99 degree plantarflexion.

Supporting Limb: The angular measurements varied from 161 to 144 degrees extension, indicating no significant difference in relationship of supporting limb action between subjects.

Subjects 1 Nor. and 3 Cl+1 demonstrated comparable hip, knee and supporting limb angle measurements, indicating a consistency of trunk inclination and leg motion prior to foot strike. Plantar-flexion was elicited by Subjects 1 Nor. and 3 Cl+1. Subject 2 C.P. and Subject 4 Cl+2 demonstrated similar angle measurements with an inconsistency of forward trunk inclination, indicating unstable trunk control due to hip and knee flexion. Subject 2 C.P. elicited the greatest ankle plantarflexion of the four subjects.

Mechanical Component Three. Maximum knee extension including flexion/extension of hip, ankle, and supporting limb at contact, as seen in Figure 5.

Hips: Subjects 1 Nor. and 3 Cl+1 demonstrated approximately the same degree of angle extension measurements, 155 and 157 degrees, respectively. Subject 4 Cl+2 demonstrated 130-degree

Joint Measurements for Forward Foot Strike

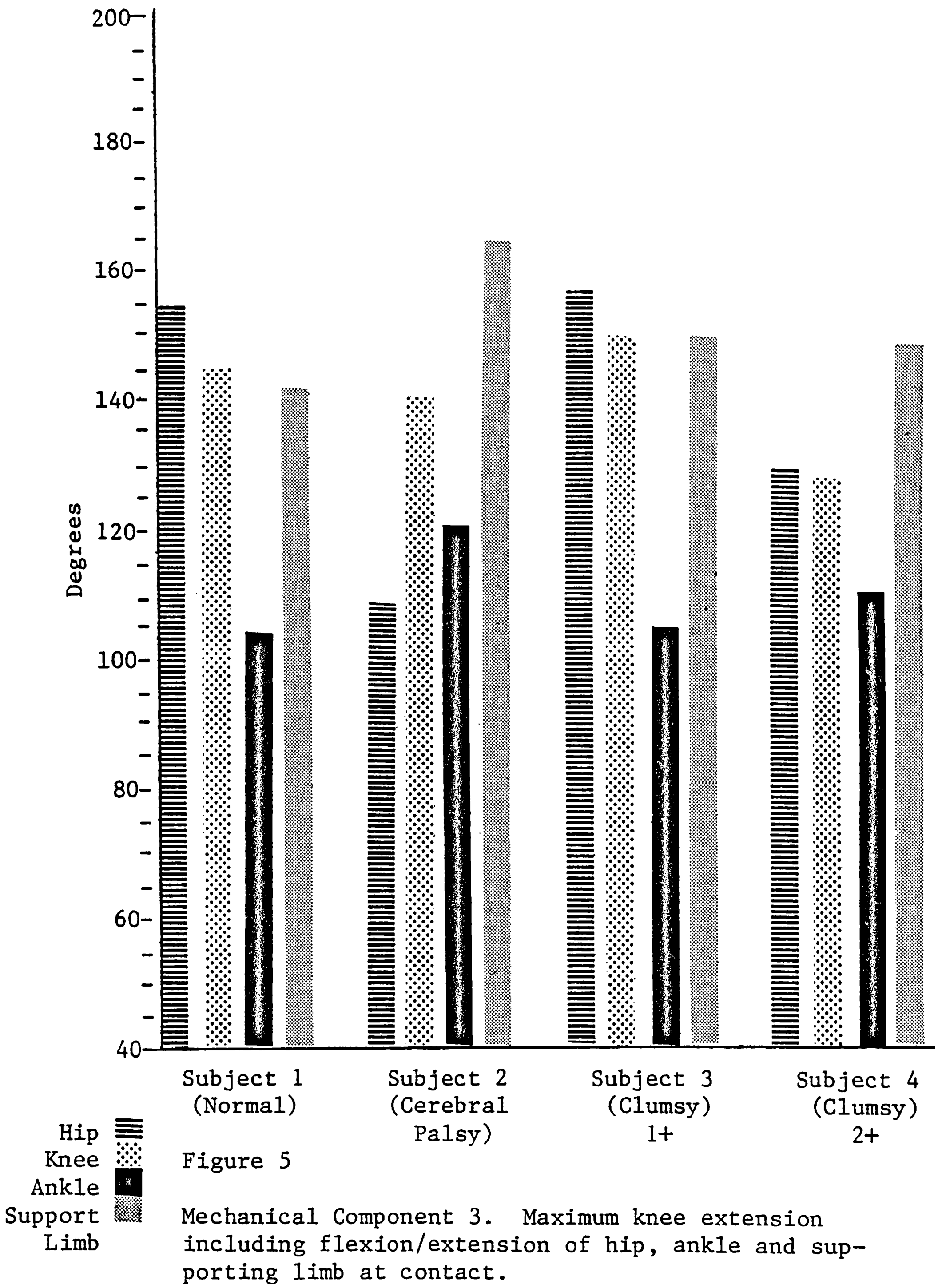


Figure 5

Mechanical Component 3. Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact.

measurement and Subject 2 C.P. demonstrated the greater hip flexion, that of 109 degrees.

Knee: Subjects 1 Nor., 2 C.P. and 3 Cl+1 demonstrated knee angle measurements of 145, 140 and 150 degrees extension, respectively. Subject 4 Cl+2 received a 128-degree measurement. Subjects 2 C.P. and 4 Cl+2 elicited 11 and 23 degrees more extension, respectively, after mechanical component two and during mechanical component three.

Ankle: Plantarflexion was demonstrated by all subjects varying in measurements of 103 to 121 degrees. Subjects 2 C.P. and 4 Cl+2 touched the floor with the ball of the foot, thereby eliciting the strongest degree of plantarflexion.

Supporting Limb: Subjects 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated similar angles of measurement, while Subject 2 C.P. demonstrated a maximum 164-degree extension.

Subject 2 C.P. demonstrated excessive hip flexion and knee extension with ankle plantarflexion (heel off surface) at contact. Reflexive behavior was detected by excessive supporting limb extension and contrasting knee flexion and ankle plantarflexion. Subject 4 Cl+2 demonstrated similar body angles to that of subject 2 C.P. with excessive hip flexion, demonstrating poor trunk control and ankle plantarflexion (heel off surface). Body angles differed by greater knee flexion and less supporting limb extension by Subject 4 Cl+2, while both subjects elicited knee extension.

Subject 1 Nor. and 3 Cl+1 demonstrated comparable angle measurements of the hip, knee and ankle plantarflexion. The supporting limb of Subject 3 Cl+1 extended by 9 degrees more than Subject 1 Nor.

The elicitation of a positive supporting reflex is demonstrated after the foot makes contact with a surface. The pressure on the sensory receptor (reflexogenic area) located on the ball of the foot commonly excites the stretch reflex, which releases a reflexive reaction. Beginning with mechanical component four and continuing through five, the discussion will include number of frames taken to elicit the reflexive reaction.

Mechanical Component Four. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike as seen in Figure 6.

Hip: Subjects 2 C.P., 1 Nor., and 4 Cl+2 demonstrated 122-, 139-, and 153-degree hip extension, respectively. Subject 3 Cl+1 elicited 173-degree hip extension with a backward thrust of the trunk.

Knee: Subject 1 Nor. demonstrated 135-degree flexion with no apparent increase after contact. Subject 2 C.P. demonstrated excessive extension of 174 degrees. Subjects 3 Cl+1 and 4 Cl+2 demonstrated 170 and 168 degrees, respectively, after contact. The above subjects elicited 33 to 39 degrees greater extension than subject 1 Nor.

Ankle: Subjects 4 Cl+2, 3 Cl+1 and 2 C.P. demonstrated similar plantarflexion of 115, 112, and 114 degrees, respectively. Subject 1 Nor. demonstrated 100-degree ankle plantarflexion.

Joint Measurements for Forward Foot Strike

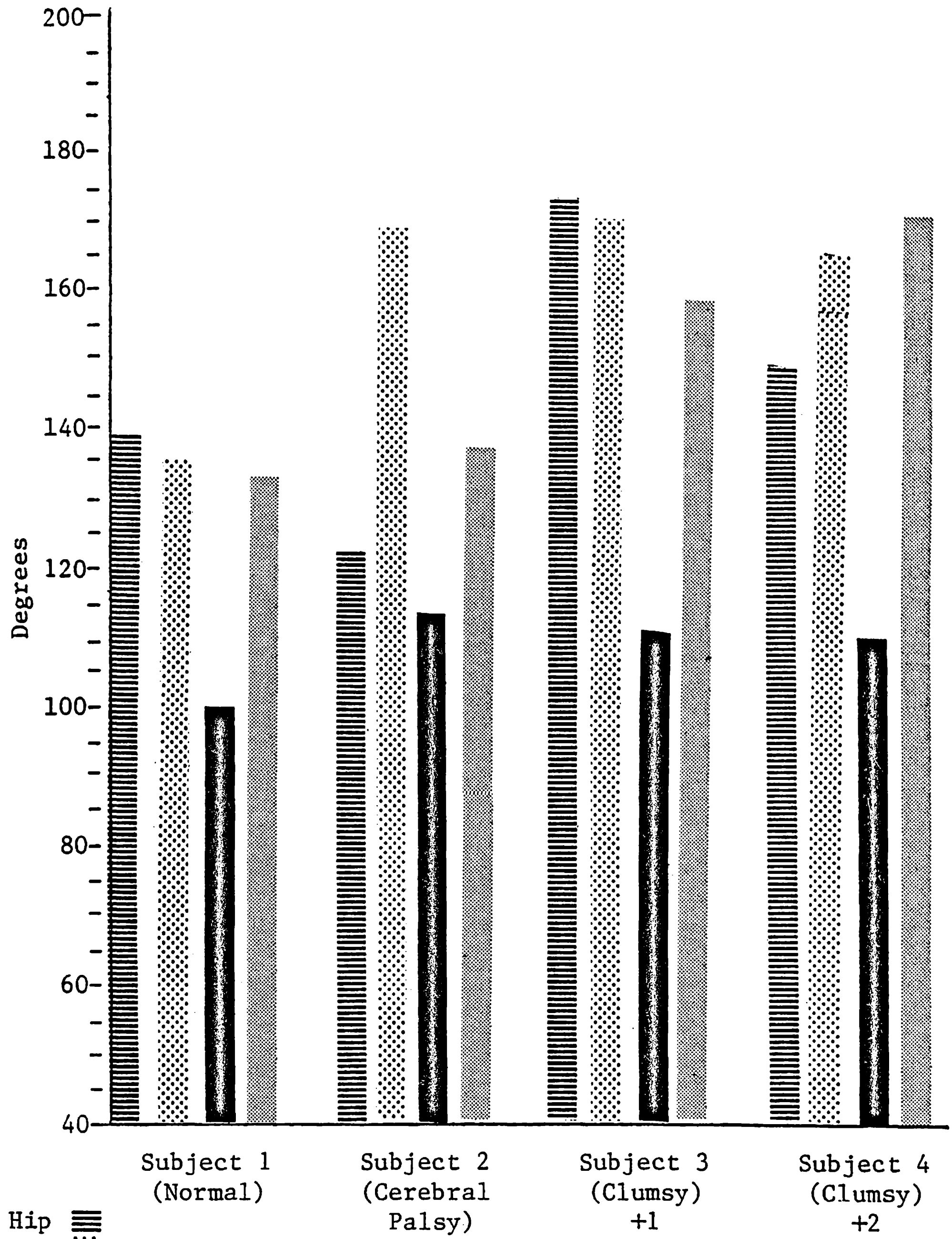


Figure 6

Mechanical Component 4. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike.

Supporting Limb: Subjects 1 Nor. and 2 C.P. demonstrated similar angular measurements, but due to different responses. Subject 2 C.P. decreased supporting limb extension and increased knee flexion simultaneously. Subject 1 Nor. decreased extension by 8 degrees after "contact" phase. Subject 3 C1+1 and C1+2 demonstrated 158- and 165-degree extension, respectively.

Subject 1 Nor. maintained similar knee, ankle, and supporting limb angular measurements with more hip flexion after "contact" phase. Equal knee and supporting limb measurements produced good bilateral integration of both sides of the body. Maximum 135-degree knee flexion occurred in the second frame after contact.

Subject 2 C.P. demonstrated 165-degree knee extension in the fifth frame with both feet making complete floor contact. After foot strike the supporting limb exhibited slight flexion, suggesting the appearance of a crossed extensor reaction. As greater knee extension continued on the performing limb, P.S.R. appeared in approximately the eleventh frame. The knee then elicited 169-degree extension, and two primitive reflexes occurred simultaneously, with the supporting limb eliciting 48 degrees greater flexion than in previous frames. The heel lifted off the floor while the ball of the foot remained in a stationary position. The knee elicited maximum 174-degree extension as the total foot remained on the floor in the 20th frame. Excessive hip flexion was seen as trunk assumed a forward thrust position. Hip flexion, internal hip rotation, and knee adduction prevent a clearly visible anatomical mark on the knee. The reflex reaction continued to occur until approximately the 25th frame. At that time the ball and heel of both feet again made floor contact. The hip demonstrated slight flexion and reverse circumduction, causing the anatomical mark to reappear.

Subject 3 Cl+1 demonstrated maximum hip extension (backward trunk thrust) and maximum knee extension in the fourteenth frame. Internal hip rotation was assumed because the anatomical mark on the knee was not plainly visible. The supporting limb angle remained the same and the performing ankle elicited plantarflexion, indicating a possible positive supporting reaction.

Subject 4 Cl+2 demonstrated knee flexion in the first frame after "contact" with maximum flexion of both knees in the third frame (heels on surface). In the sixth frame the performing knee and supporting limb demonstrated extension and ankle plantarflexion. Slowly greater knee extension occurred from the 13th to the 33rd frame when maximum 167-degree extension elicited a possible P.S.R. reaction.

<u>Mechanical Component Five</u>. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off, as seen in Figure 7.

Hip: Subject 1 Nor. elicited 152-degree extension, a 13-degree increase from previous component measurement. Subject 2 C.P. demonstrated a 47-degree increase with apparent trunk rotation because of reflexive involvement. Subject 4 Cl+2 also demonstrated 20-degree increase extension, while Subject 3 Cl+1 decreased hip angle by 11 degrees from previous measurement.

Joint Measurements for Forward Strike

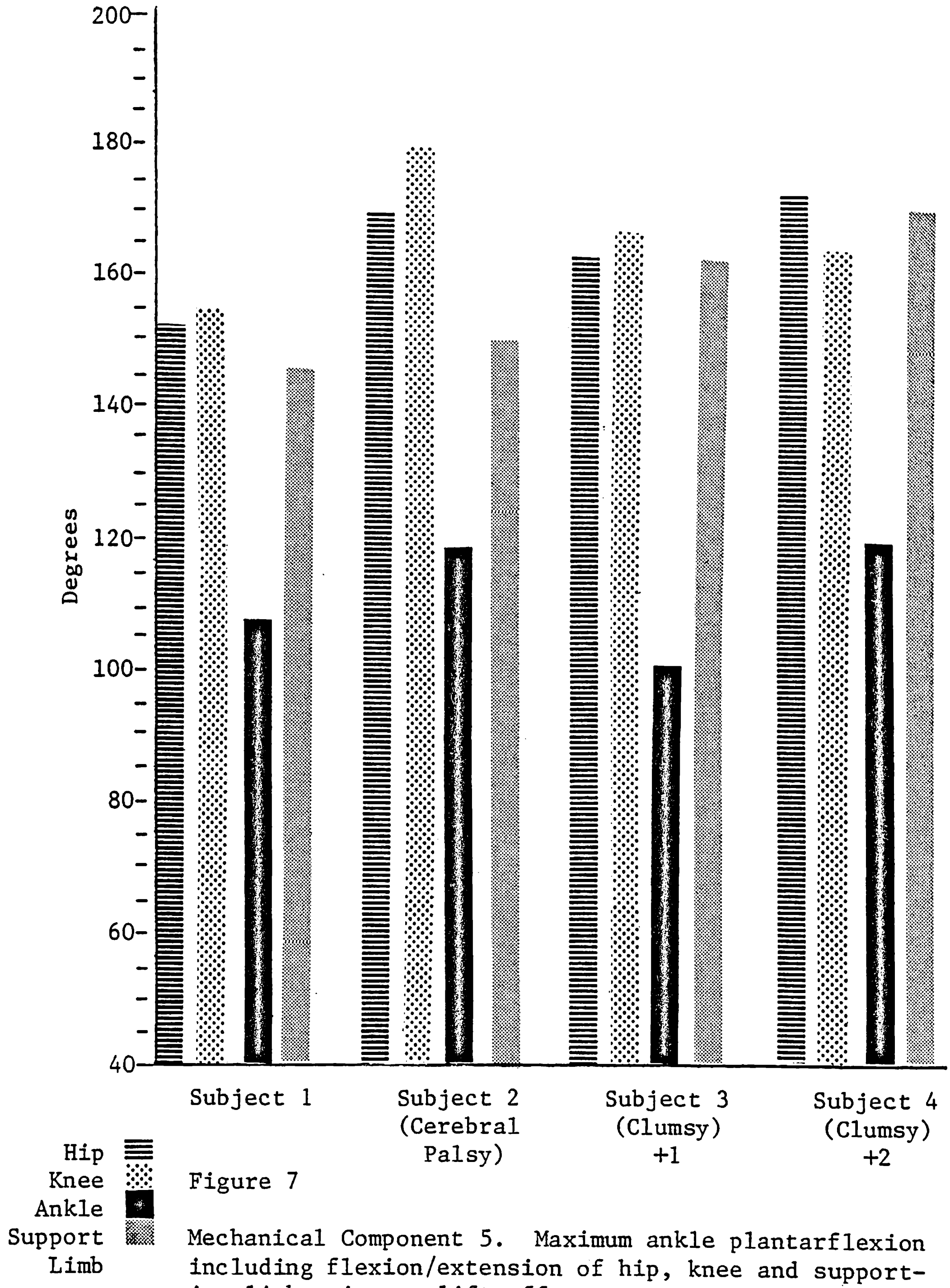


Figure 7

Mechanical Component 5. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off.

Knee: Subject 1 Nor. elicited 20 degrees more extension than in the previous component measurement. Subject 2 C.P. extended the knee 11 degrees more after completing leg circumduction. Subjects 3 Cl+1 and 4 Cl+2 elicited 166- and 163-degree extension, respectively, reducing knee angle by several degrees from previous component measurement.

Ankle: Subjects 2 C.P. and 4 Cl+2 demonstrated a 119-degree angle measurement, increasing plantarflexion by 4 degrees. Subject 1 Nor. also increased plantarflexion by 8 degrees, while Subject 3 Cl+1 decreased plantarflexion by 11 degrees from previous component measurements.

Supporting Limb: All subjects demonstrated a slightly greater supporting limb extension, but no significant difference in relationship to other subjects.

In the seventh frame after foot contact, Subject 1 Nor. maintained approximately the same angle measurements and body alignment. The hip, knee and supporting limb measured 10 to 20 degrees more extension than in the previous component. The ankle range was 8 degrees more plantarflexion. In the 70th frame after foot contact, Subject 2 C.P. demonstrated excessive hip extension, increased knee extension, ankle plantarflexion and leg circumduction. The elicitation of P.S.R. and Crossed Extensor Reflex contributed to poor trunk control and loss of balance. In the 21st frame after foot contact, Subject 3 Cl+1 demonstrated a slight hip and knee flexion with ankle in dorsiflexion position (toes lifted) and slight supporting limb extension. If a P.S.R. response occurred, the release appeared with ankle dorsiflexion. Subject 3 Cl+1 over-projected foot placement target on footprint, which could have contributed to excessive hip and knee extension. In the 55th frame, Subject 4 Cl+2 demonstrated continued hip extension assuming erect posture. The knee further extended and the ankle elicited dorsiflexion, indicating a possible reflex release. Subjects 4 Cl+2 and 3 Cl+1 demonstrated similar reflexive response by stretch reflex release and plantarflexion, changing to dorsiflexion prior to lift off.

Mechanical Component Six. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off, as seen in Figure 8.

Hip: Subject 1 Nor. elicited approximately 4 degrees more flexion than in the previous mechanical component. Subject 3 Cl+1 elicited 9 degrees more extension, and Subject 4 Cl+2 demonstrated the same hip degree angle as in the previous component. Subject 2 C.P. was unable to complete "lift off."

Knee: Subject 1 Nor. demonstrated slight flexion, but no significant change of angular measurement. Subject 3 Cl+1 demonstrated 15 degrees more flexion than in the previous mechanical component. Subject 4 Cl+2 demonstrated 8 degrees more flexion than in previous mechanical component.

Ankle: Subject 1 Nor. demonstrated 101-degree plantarflexion. Subject 3 Cl+1 demonstrated a neutral 92 degrees, and Subject 4 Cl+2 demonstrated a 112-degree plantarflexion.

Joint Measurements for Forward Strike

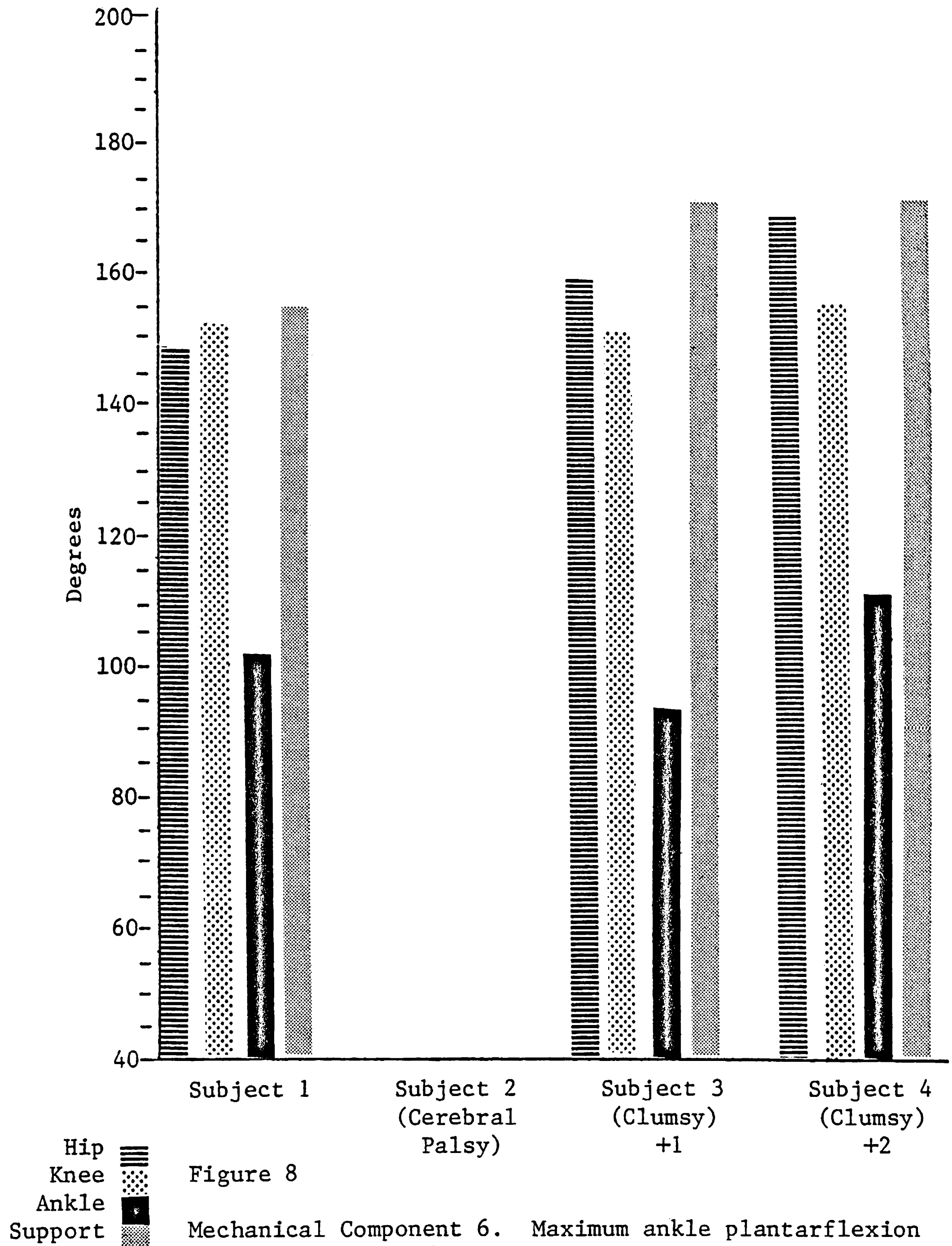


Figure 8

Mechanical Component 6. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off.
* No Lift Off.

Supporting Limb: Subject 1 Nor. demonstrated increased extension of 9 degrees more than previous component. Subject 3 Cl+1 demonstrated increased extension of 9 degrees. Subject 4 Cl+2 remained the same 170 degrees extension.

At lift off, Subject 1 Nor. maintained approximately the same hip, knee and supporting limb angular measurement as in the previous components, with ankle positioned in less plantarflexion. Subject 2 C.P. was unable to complete the lift off component. Subject 3 Cl+1 demonstrated increased knee flexion and supporting limb extension with ankle in 92-degree neutral position. Subject 4 Cl+2 demonstrated increased knee flexion, but supporting limb angle remained the same as in the previous component with ankle eliciting a 112-degree plantarflexion.

Reaction Time

The reaction time for the forward foot strike is another method of determining reflexive involvement. The actual reflex response occurs during mechanical components three through six ("foot strike" to "lift off"). The comparison time chart is found in Table 2.

Subject 1 Nor. performed the forward foot strike in .23 seconds in the least amount of time of the four subjects. No apparent reflex response occurred. Subject 2 C.P. demonstrated a 1.30-second reaction time, 1.07 seconds longer than Subject 1 Nor., indicating a Positive Supporting Reflex reaction. Subject 3 Cl+1 performed the foot strike in .40 seconds, .17 seconds longer than Subject 1 Nor., indicating a possible Positive Supporting Reflex reaction. Subject 4 Cl+2 demonstrated a reaction time of .87 seconds, .64 seconds longer than Subject 1 Nor., indicating a possible Positive Supporting Reflex reaction.

Table 2

Comparison Time Table (Forward Foot Strike)

Subject	Primitive Reflex Profile Score	Up Lift - Lift Off	Up Lift - Foot Strike	Foot Strike Lift Off
1. Normal	0	.36	.13	.23
2. Cerebral Palsy	+4	1.45*	.15	1.30
3. Clumsy	+1	.51	.11	.40
4. Clumsy	+2	1.04	.17	.87
		seconds	seconds	seconds

*Subject 2 C.P. could not complete lift off with the right foot. The recorded time was accomplished on the left foot.

Discussion

Angular measurements taken from mechanical components three through six and computed into variance scores are included in this discussion. The Foot Placement Variance Chart in the forward direction is found in Appendix E. Variance scores and range of variance angles are included to describe reflexive involvement.

Subject 1 Nor. recorded the lowest variance scores for all body parts included in mechanical components three through six. The maximum ankle plantarflexion degree indicated no equinovarus patterning. The angle ranges were significantly lower than the other subjects. Motion efficiency was demonstrated and determined by the following characteristics: (1) symmetrical body motion, (2) trunk control, (3) neutral trunk inclination, (4) no exaggerated hip, ankle, knee or supporting limb angles, (5) equal weight distribution and weight transfer (observation only), (6) no noticeable associated body part movement, and (7) no delayed reaction time.

Subject 2 C.P. demonstrated an exaggerated stretch reflex response with excessive knee flexion causing an asymmetrical body formation. Excessive hip angles fluctuated the trunk forward and then in a backward inclination. The greatest maximum knee extension angular measurement was recorded by Subject C.P. Ankle variance score was small because plantarflexion occurred prior to mechanical component number three, and leg lift was not completed. The reaction time was considerably more than the other subjects, indicating a delayed reaction. A P.S.R. reaction and a Crossed Extensor Reflex reaction occurred during the 5th and 30th frame. Characteristics describing performance are as follows: (1) uneven weight distribution and transfer, (2) poor balance, (3) limb misalignment, (4) adduction of hip and knee, (5) plantarflexion with slight equinus positioning, and (6) associated movements of the upper extremities with overflow motion into the hands.

Subject 3 Cl+l demonstrated similar hip, knee and supporting limb variance scores to Subject 1 Nor., but outer limits of degree ranges were numerically higher, therefore eliciting greater extension. The ankle variance score was dissimilar due to plantarflexion and dorsiflexion positioning. Subject 3 Cl+l demonstrated a weak exaggerated stretch and an internal hip rotation in the 14th frame after "contact." Reaction time was slower than Subject 1 Nor. and faster than Subject 4 C1+2. More efficient movement was demonstrated by Subject 3 C1+1 than Subject 2 C.P. or Subject 4 C1+2. The following characteristics contributed to a possible P.S.R. reaction: (1) slight trunk inclination, (2) similar range of variance scores to Subject 1 Nor., but different numerical limits, (3) ankle plantarflexion, (4) slightly exaggerated knee extension, and (5) minimal associated reaction with homolateral involvement of upper extremities and overflow into hands.

Subject 4 C1+2 demonstrated an excessive range of hip angle measurements, which exhibited poor trunk control and posture fluctuation. An excessive knee variance score described a full range of knee movement. Ankle plantarflexion variance score was similar to Subject 1 Nor., but the outer limits of range were numerically higher, therefore eliciting greater plantarflexion than Subjects 1 Nor. and 3 C1+1. The supporting limb variance score was slightly less than the knee variance score, indicating a possible Crossed Extensor Reflex reaction and P.S.R. reaction. Reaction time was considerably slower than Subject 1 Nor. Less than efficient movement was demonstrated by the following characteristics: (1) excessive hip flexion, contributing to poor trunk control and forward trunk inclination, (2) excessive knee flexion and extension, producing an exaggerated stretch reflex, (3) overprojection of knee during uplift and strike, (4) continual elicitation of plantarflexion, and

(5) associated reactions and homolateral movement involving upper extremities.

Lateral Foot Placement

A description interpretation describing similarities and differences of the six mechanical components is found in Figures 9 through 14, including angular measurements of the hip, knee, ankle and supporting limb. The raw scores can be found in Appendix C. Data information includes the right foot as the performing leg and the supporting limb as the opposite.

Mechanical Component One. Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb, as seen in Figure 9.

Hip: Subjects 1 Nor. and 3 Cl+1 demonstrated 126- and 133-degree flexion, respectively, while Subjects 2 C.P. and 4 Cl+2 demonstrated 14 to 24 degrees greater flexion.

Ankle: Subjects 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated ankle dorsiflexion ranging from 78 degrees to 82 degrees. Subject 2 C.P. demonstrated 99-degree plantarflexion.

Knee: Subject 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated more knee flexion than Subject 1 Nor., with Subject 4 Cl+2 demonstrating the greater knee flexion, that of 60 degrees.

Supporting Limb: Subjects 1 Nor. and 2 C.P. demonstrated comparable 165- and 162-degree extension, respectively. Subjects 3 Cl+1 and 4 Cl+2 demonstrated comparable 178- and 174-degree limb angles, respectively.

Joint Measurements for Lateral Foot Strike

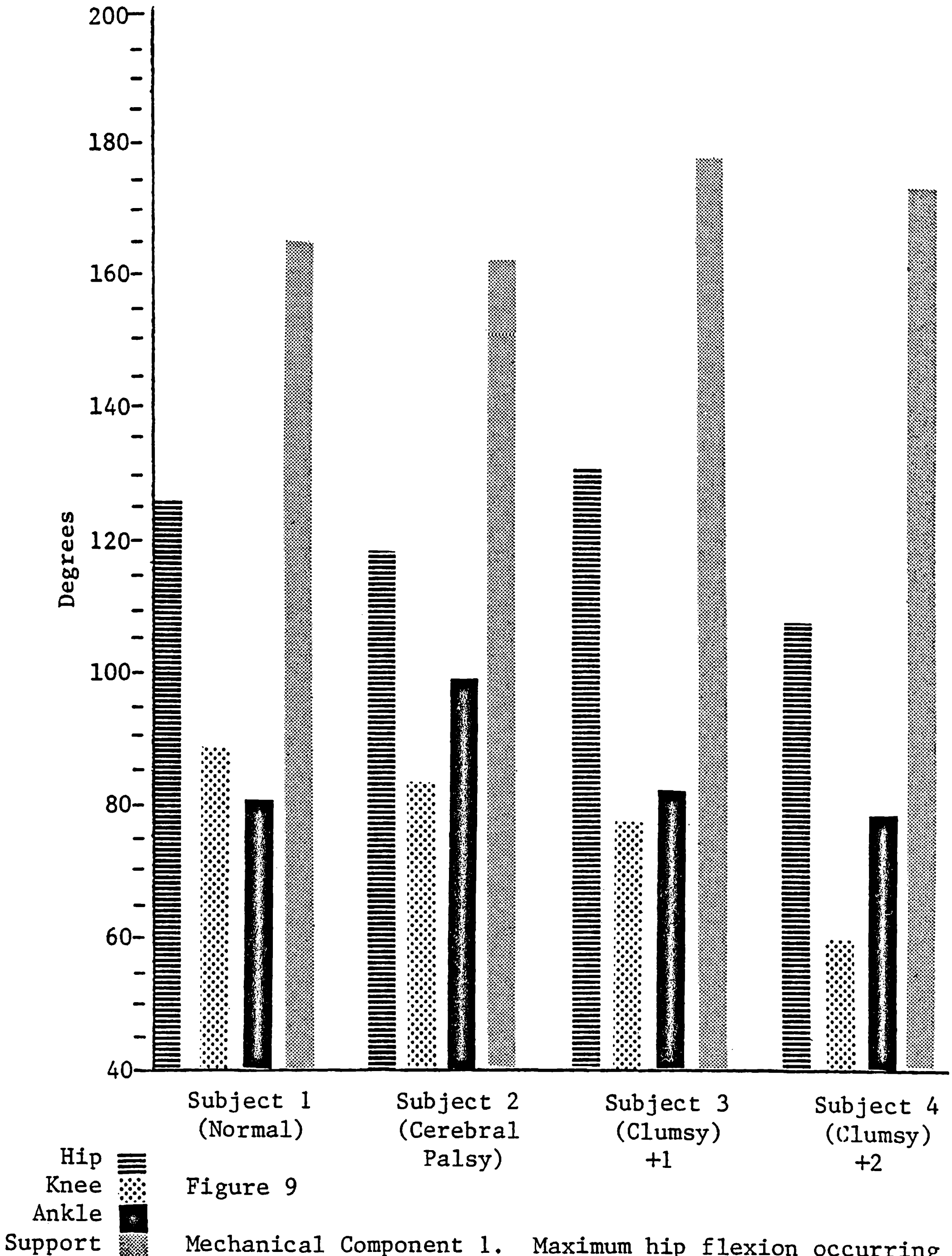


Figure 9

Mechanical Component 1. Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

Subject 1 Nor. demonstrated neutral hip extension, ankle dorsiflexion, supporting limb extension and the least knee flexion of all the subjects. Subject 2 C.P. demonstrated slight hip and knee flexion and supporting limb extension with neutral ankle plantarflexion. Subject 3 Cl+1 demonstrated similar angle formations as Subject 1 Nor. with the exception of slightly greater knee flexion. Subject 4 Cl+2 demonstrated ankle dorsiflexion, supporting limb extension and the greatest hip flexion of all the subjects.

Mechanical Component Two. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike, as seen in Figure 10.

Hip: Subjects 1 Nor. and 3 Cl+1 demonstrated similar angle extension of 140 and 145 degrees, respectively. Subject 2 C.P. demonstrated 10 degrees greater flexion than Subject 1 Nor.

Knee: Subjects 1 Nor. and 3 Cl+1 demonstrated similar angles of flexion, 128 and 123 degrees, respectively. Subject 2 C.P. demonstrated 16 degrees greater flexion than Subject 1 Nor.

Ankle: Subject 1 Nor. demonstrated dorsiflexion while Subject 2 C.P. elicited plantarflexion and Subject 3 Cl+1 demonstrated neutral ankle positioning.

Supporting Limb: Subjects 1 Nor. and 2 C.P. demonstrated similar extension patterns and Subject 3 Cl+1 elicited 18 degrees greater extension than Subject 2 C.P.

Prior to foot strike, Subject 1 Nor. demonstrated near symmetrical angle body formation. Subject 2 C.P. demonstrated forward

Joint Measurements for Lateral Foot Strike

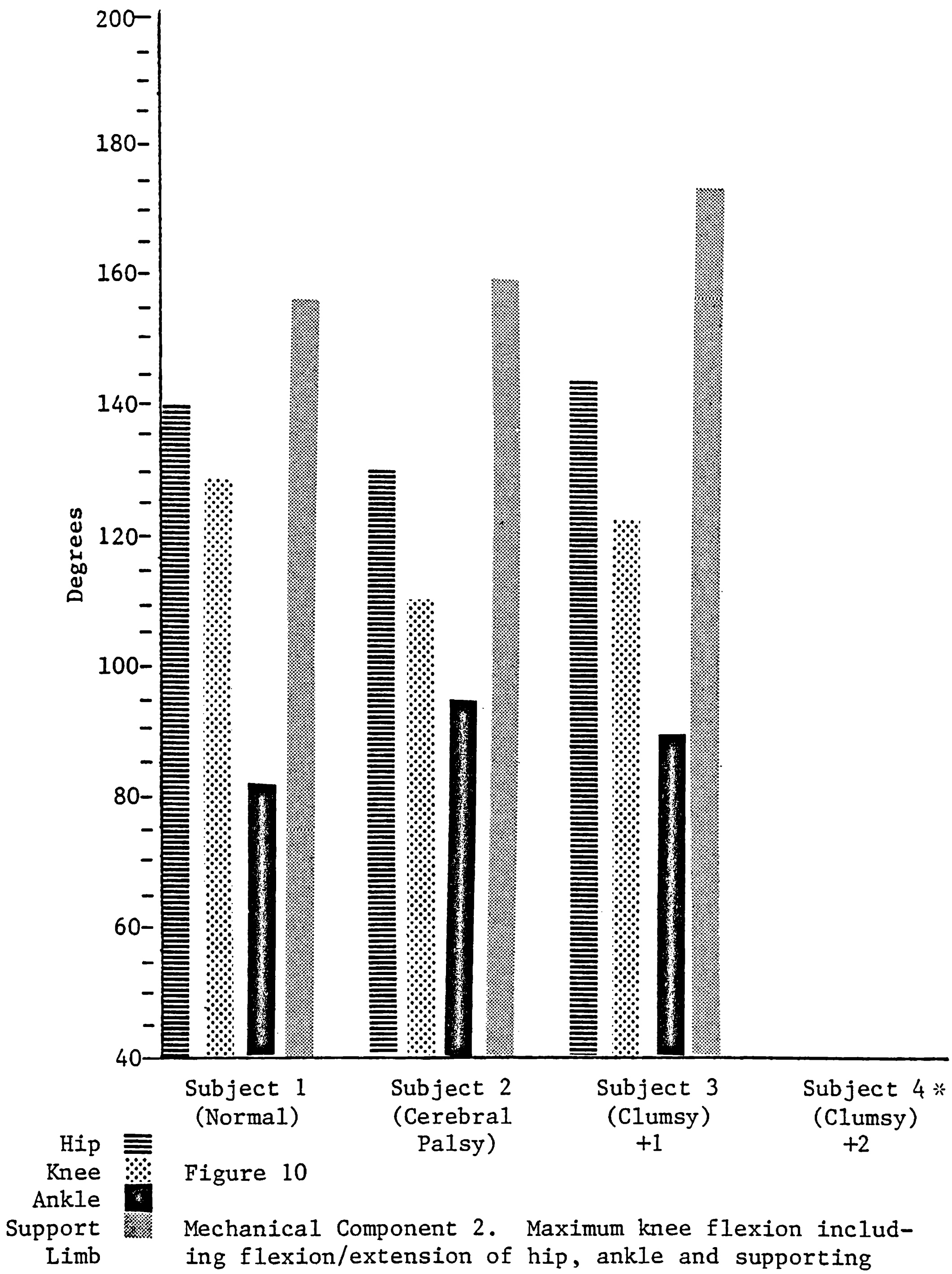


Figure 10

Mechanical Component 2. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.
* No data.

trunk inclination, knee flexion and ankle plantarflexion. Subject 3 Cl+1 demonstrated similar hip angle measurements to Subject 1 Nor. but elicited slightly less knee extension and greater supporting limb extension, exhibiting asymmetrical form with ankle in neutral position. No data was recorded for subject 4 Cl+2 because of a blurred image on the appropriate frame.

Mechanical Component Three. Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact, as seen in Figure 11.

Hip: Subjects 1 Nor. and 3 Cl+1 demonstrated similar angles of measurement, 150 and 153 degrees extension, respectively. Subject 2 C.P. demonstrated 136-degree angle extension, while Subject 4 Cl+2 elicited a 127-degree hip angle.

Knee: Subjects 1 Nor. and 3 Cl+1 demonstrated maximum knee extension of 147 and 150 degrees extension. Subjects 2 C.P. and 3 Cl+1 demonstrated similar knee measurements of 130 and 128 degrees, respectively, approximately 20 degrees less extension at contact.

Ankle: Subject 1 Nor. demonstrated 91 degrees neutral positioning and Subject 2 C.P. elicited plantarflexion. Subjects 3 Cl+1 and 4 Cl+2 demonstrated dorsiflexion.

Supporting Limb: Subjects 1 Nor., 2 C.P. and 3 Cl+1 demonstrated angle measurements ranging from 160 to 163 degrees extension, respectively. Subject 4 Cl+2 demonstrated the least degree of extension, 128 degrees.

Joint Measurements for Lateral Foot Strike

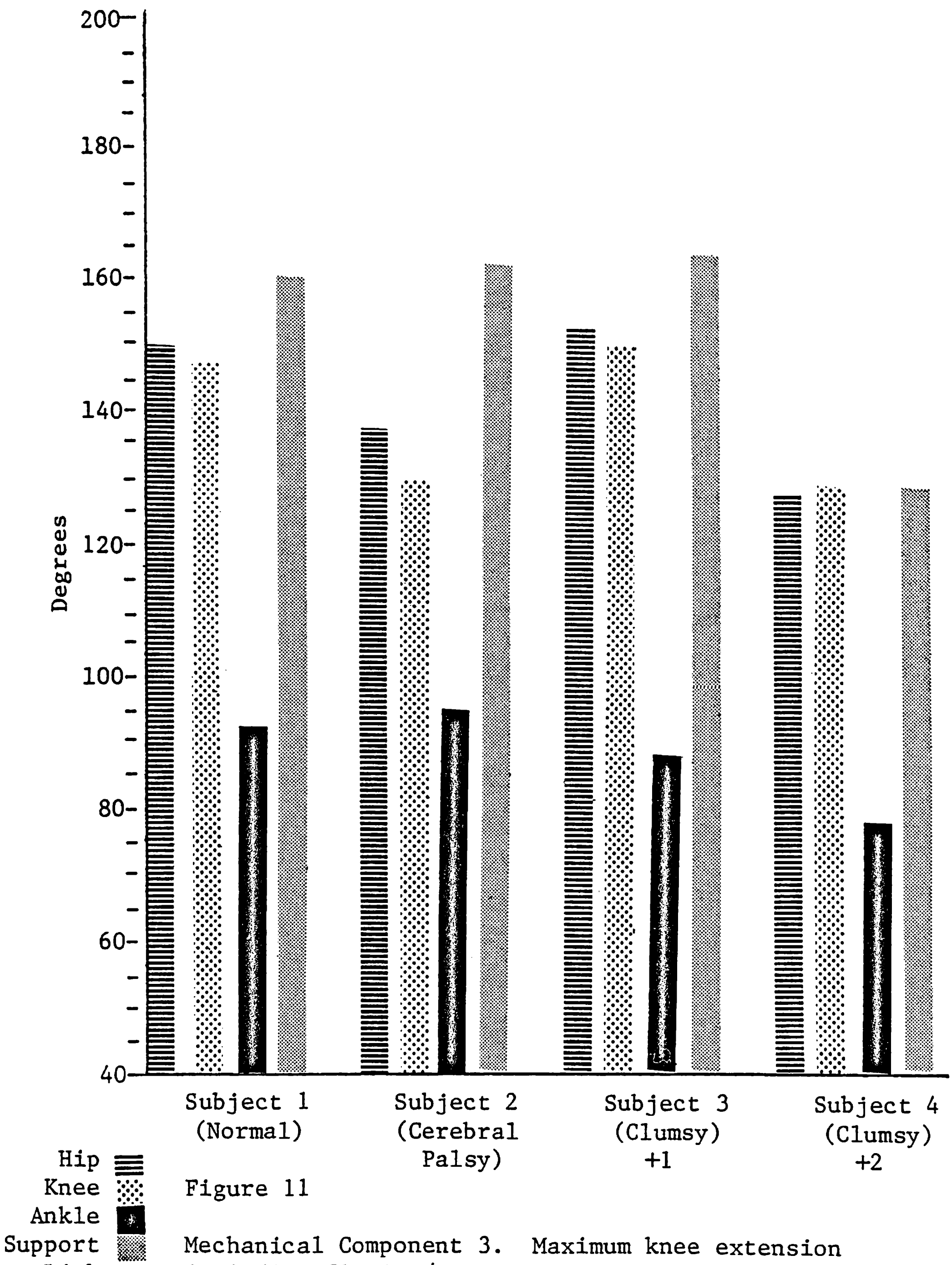


Figure 11

Mechanical Component 3. Maximum knee extension including flexion/extension of hip, ankle and supporting limb at contact.

Subjects 1 Nor. and 3 Cl+1 demonstrated consistent hip, knee and supporting limb angle measurements and elicited neutral to dorsiflexion ankle positioning. Subject 2 C.P. demonstrated excessive hip flexion, causing forward trunk inclination and ankle plantarflexion at foot contact with the knee positioned in less extension than the above subjects. Subject 4 Cl+2 performed similar to Subject 2 C.P. with excessive hip flexion and excessive ankle dorsiflexion. The performing leg and supporting limb demonstrated identical degree angle measurements, causing the knees to bend simultaneously.

Mechanical Component Four. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike, as seen in Figure 12.

Hip: Subjects 1 Nor., 2 C.P. and 3 Cl+1 demonstrated 150 degrees, 145 degrees and 157 degrees extension, respectively. Subject 4 Cl+2 demonstrated 116-degree hip angle with trunk in a forward position.

Knee: Subject 1 Nor. demonstrated the same degree of extension as in the previous component. Subject 2 C.P. increased knee extension by 20 degrees and Subject 3 Cl+1 increased knee extension by 8 degrees. Subject 4 Cl+2 decreased extension by 10 degrees more than in the previous component.

Ankle: Subject 1 Nor. decreased neutral ankle position to a slight dorsiflexion. Subject 2 C.P. increased plantarflexion by 11 degrees and Subject 3 Cl+1 demonstrated a 4-degree angle increase

Joint Measurements for Lateral Foot Strike

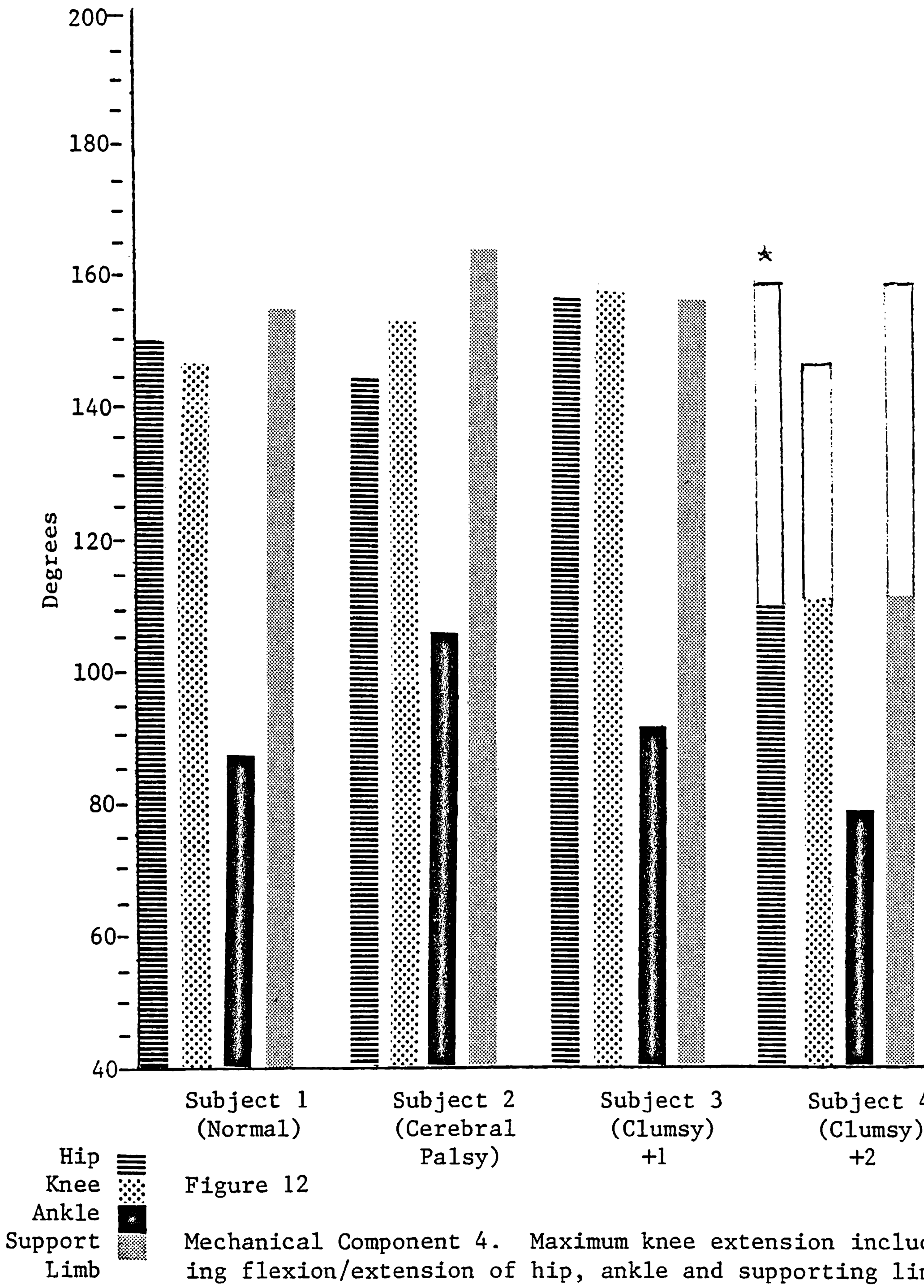


Figure 12

Mechanical Component 4. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike. +4A Maximum extension following maximum flexion.

after foot contact. Subject 4 Cl+2 maintained the same 78-degree angle as in the previous component.

Supporting Limb: Subjects 1 Nor. and 3 Cl+1 demonstrated similar angle measurements with a slight decrease in extension from measurement in previous component. Subject 2 C.P. increased extension slightly and Subject 3 Cl+2 demonstrated a 10-degree decrease in measurement.

Subject 1 Nor. maintained comparable hip and knee measurements to those demonstrated at initial foot contact. Slight flexion of the supporting limb occurred, causing the legs to bend together. The ankle was placed in dorsiflexion. Maximum knee extension was seen in the second frame after foot strike. Subject 2 C.P. demonstrated hip flexion, knee and supporting limb extension, slight ankle plantarflexion with a slight forward trunk inclination. The heel contacted the surface approximately seven frames after initial foot strike. A minimal P.S.R. reaction occurred, but the total body involvement was not as severe as in the forward foot strike. Subject 3 Cl+1 demonstrated similar body measurement angles to those of Subject 1 Nor. with the exception of 5 to 7 degrees more extension elicited in the hip, knee and supporting limb after initial foot strike. Neutral positioning was seen in ankle measurement. No obvious reflexive responses occurred, but associated movements appeared prior to foot strike. Subject 4 Cl+2 demonstrated maximum hip, knee and supporting limb flexion in the third frame after foot strike. During the next 20 frames maximum hip, knee and supporting limb extension occurred with head projected downward and trunk in a forward inclination. Associated reactions occurred during both body positions. Slow, immature motion caused the total body to react with the performing leg. No apparent P.S.R. reaction occurred during the very delayed reaction time.

Mechanical Component Five. Maximum ankle extension including flexion/extension of hip, knee and supporting limb prior to lift off, as seen in Figure 13.

Hip: Subject 1 Nor. demonstrated no significant change from previous component. Subjects 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated increased extension by 10 degrees, 11 degrees and 5 degrees, respectively, from previous component.

Knee: Subject 1 Nor. demonstrated no significant change of angle measurement. Subject 2 C.P. increased extension by 17 degrees and continued the internal rotation as reflexive response occurred. Subject 3 Cl+1 demonstrated a slight decrease in extension, and Subject 4 Cl+2 demonstrated an 18-degree decreased extension from previous component.

Ankle: Subjects 1 Nor. and 3 Cl+1 demonstrated no significant change of angular measurement, while Subject 4 Cl+2 elicited neutral ankle positioning. Subject 2 C.P. elicited 6 degrees more plantarflexion than in the previous component.

Supporting Limb: Subjects 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated increased limb extension ranging from 9 to 15 degrees more

Joint Measurements for Lateral Foot Strike

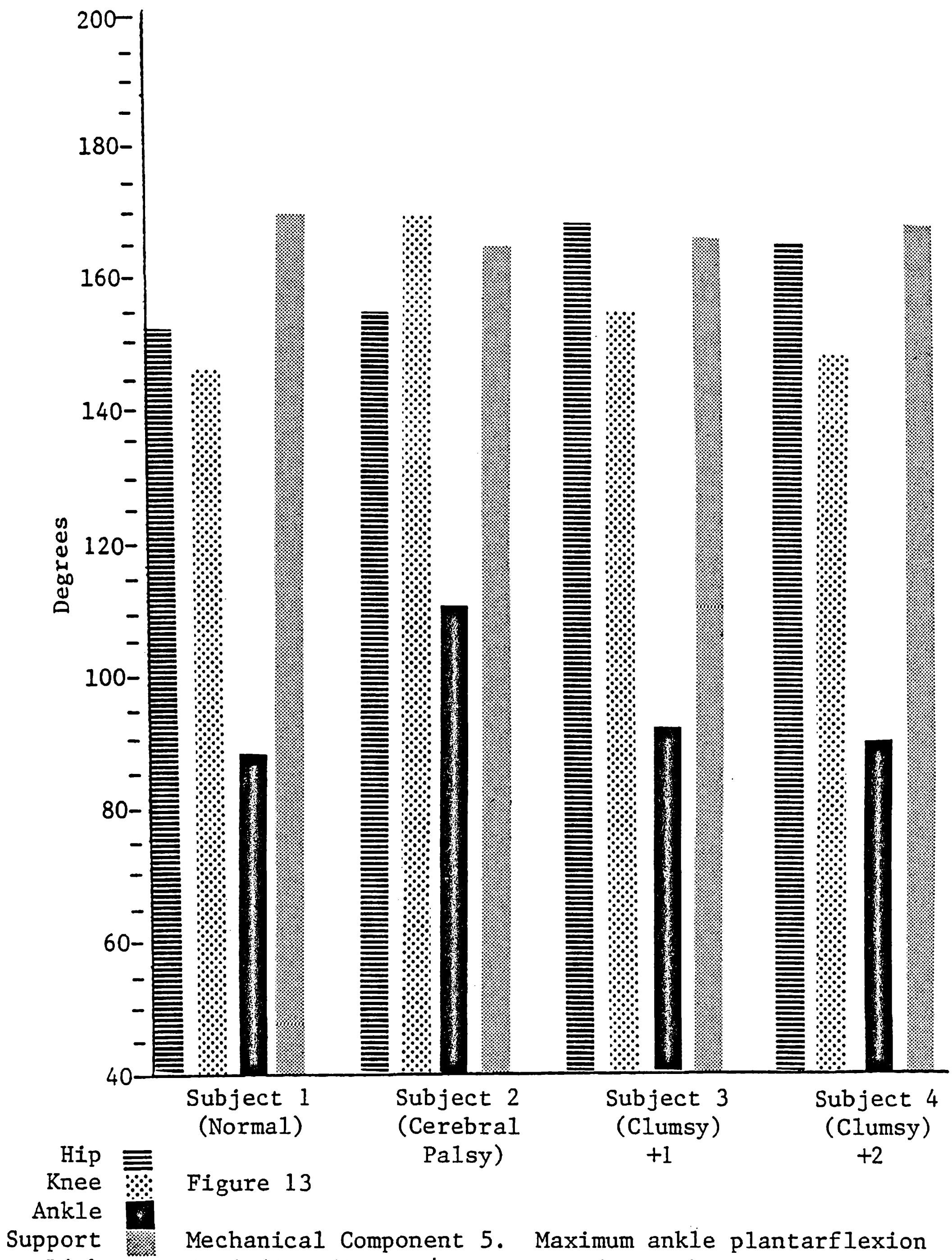


Figure 13

Mechanical Component 5. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off.

than previously recorded. Subject 2 C.P. maintained the same angle.

Subject 1 Nor. demonstrated similar angular measurements to those in previous component, with the exception of increased supporting limb extension. Subject 2 C.P. improved trunk control by elicited minimal hip extension. Increased knee extension and ankle plantarflexion indicated the minimal P.S.R. response. Subject 3 Cl+1 demonstrated greater knee and hip extension than Subject 1 Nor. with ankle in neutral position. Subject 4 Cl+2 demonstrated hip, ankle and supporting limb measurements comparable to Subject 3 Cl+1 and supporting limb measurements comparable to Subject 3 Cl+1, with the exception of less knee extension prior to lift off.

Mechanical Component Six. Maximum extension of ankle including flexion/extension of hip, knee and supporting limb at lift off (as seen in Figure 14).

Hip: Subjects 1 Nor. and 3 C.P. demonstrated 144 degrees and 141 degrees extension, respectively. Subjects 3 Cl+1 and 4 Cl+2 demonstrated similar measurements, but greater than the above subjects. All subjects elicited less hip extension than the previous components.

Knee: Subjects 1 Nor., 2 C.P., 3 Cl+1 and 4 Cl+2 decreased knee extension by 5 degrees, 37 degrees, 15 degrees and 16 degrees, respectively, from the previous component.

Ankle: Subject 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated dorsiflexion ranging from 83 degrees to 85 degrees, while Subject 2 C.P. demonstrated 100-degree plantarflexion.

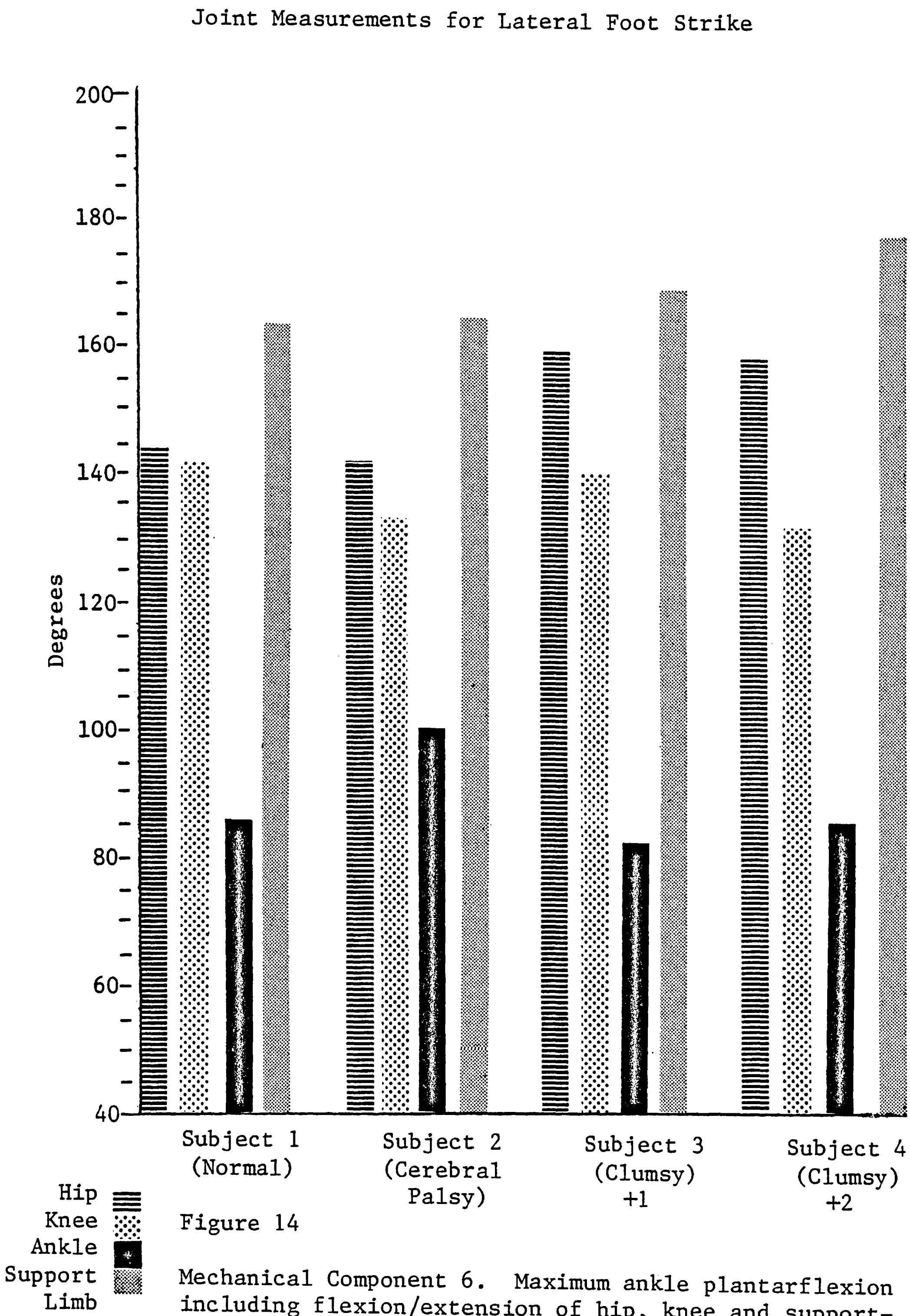


Figure 14

Mechanical Component 6. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off.

Supporting Limb: Subjects 1 Nor., 2 C.P. and 3 Cl+1 maintained approximately the same degree of extension as in the previous component. Subject 4 Cl+2 increased extension by 10 degrees.

Subjects 1 Nor. elicited hip and knee flexion with ankle in dorsiflexion and supporting limb held in extension. The measurements described a forward trunk inclination and neutral knee bend at lift off. Subject 2 C.P. demonstrated slightly more knee flexion than Subject 1 Nor., but hip and supporting limb angles were similar. Ankle was positioned in plantarflexion. Subjects 3 Cl+1 and 4 Cl+2 demonstrated comparable hip measurements and ankle dorsiflexion. Subject 4 Cl+2 elicited slightly more knee flexion and slightly more supporting limb extension than Subject 3 Cl+1.

Reaction Time

The reaction time for the lateral foot strike is another indicator for determining reflexive behavior. The comparison of reaction time can be found in Table 3. The actual reflexive response occurs during mechanical components three through six (foot strike to lift off).

Subject 1 Nor. demonstrated a .23-second reaction time, the least number of seconds to complete the foot pattern, indicating no reflexive response. Subject 2 C.P. demonstrated a reaction time of .73 seconds, .50 seconds longer than Subject 1 Nor. The delayed movement pattern indicates a Positive Supporting Reflex. Subject 3 Cl+1 demonstrated a .40-second reaction time, .17 seconds longer than Subject 1 Nor., indicating a possible reflexive response.

Table 3

Comparison Time Table (Lateral Foot Strike)

Subject	Primitive Reflex Profile Score	Uplift Lift Off	Uplift Foot Strike	Foot Strike
1. Normal	0	.36	.13	.23
2. Cerebral Palsy	+4	.86	.13	.73
3. Clumsy	+1	.56	.16	.40
4. Clumsy	+2	.96	.22	.74

Subject 4 Cl+2 demonstrated a reaction time of .74 seconds. .51 seconds longer than Subject 1 Nor., indicating a possible reflexive response.

Discussion

Angular measurements taken from mechanical components three through six and computed into variance scores are included in this discussion. The Foot Placement Variance Chart in the lateral direction is found in Appendix F. Variance scores and range of variance angles are included to describe reflexive involvement.

Subject 1 Nor. recorded the lowest variance scores for all body parts in mechanical components three through six. A limited hip variance muscle stretch provided knee flexion and ankle dorsiflexion from foot strike to lift off. The lateral foot strike was performed in the same amount of time as the forward foot strike.

Subject 2 C.P. demonstrated inconsistent angular variance scores, but lower variance scores were recorded in the lateral direction than in the forward or backward directions. The knee variance range described a slightly exaggerated stretch reflex with knee extension. The most inconsistency was noticed during the stretch reflex when the plantarflexion was released to dorsiflexion positioning on "lift off." A slight internal hip rotation occurred with homolateral involvement of the upper extremities as stretch reaction intensified, but subsided with onset of release. Reaction time was considerably shorter for the lateral foot strike than the forward foot strike, indicating less reflexive involvement because of the reduced base of support, causing less pressure on the reflexogenic area. Subject 2 C.P. demonstrated improved skill acquisition by the following conditions: (1) base of support was decreased (lateral foot strike), making foot strike closer to supporting limb, and (2) the more trunk control provided better balance and weight transfer, and therefore no apparent Crossed Extensor Reflex response.

Subject 3 Cl+1 demonstrated a wide range of variance scores for the hip and knee. The neutral ankle positioning was comparable to Subject 1. The over-projection of the knee at "lift off" and the readjusting of the heel and toe at "contact" made the foot placement and strike awkward. Knee extension and supporting limb extension gave the appearance of an exaggerated stretch, but actually the reduction in base of support inhibited the stretch reaction. Ankle plantarflexion was not elicited: therefore, the slow reaction time may be due to immature motor coordination and over-projection of limb. Associated movements occurred throughout foot placement procedure, but no internal rotation was noticed. The reaction time was slower than Subject 1 Nor. by .17 seconds, indicating a possible reflexive reaction.

Subject 4 Cl+2 recorded the largest variance scores of all the subjects because of the wide numerical range limits. The extreme trunk fluctuations and deep knee bends exhibited exaggerated motion. The subject was unable to perform the bilateral motor task in the lateral direction. The supporting limb reacted to the performance of the foot strike. The reaction time was .51 seconds slower than Subject 1 Nor., indicating a possible reflexive behavior.

Backward Foot Placement

A descriptive interpretation describing similarities and differences of six mechanical components are found in Figures 15 through 20, including angular measurements of the hip, knee, ankle and supporting limb. The raw data can be found in Appendix D. Information was recorded using the right foot for Subjects 1 Nor., 3 Cl+1, and 4 Cl+2, but the left foot was used for data analysis for Subject 2 C.P. The Subject was unable to complete the task on the right foot.

Mechanical Component One. Maximum hip flexion occurring in upward leg lift, including flexion, extension of knee, ankle and supporting limb, as shown in Figure 15.

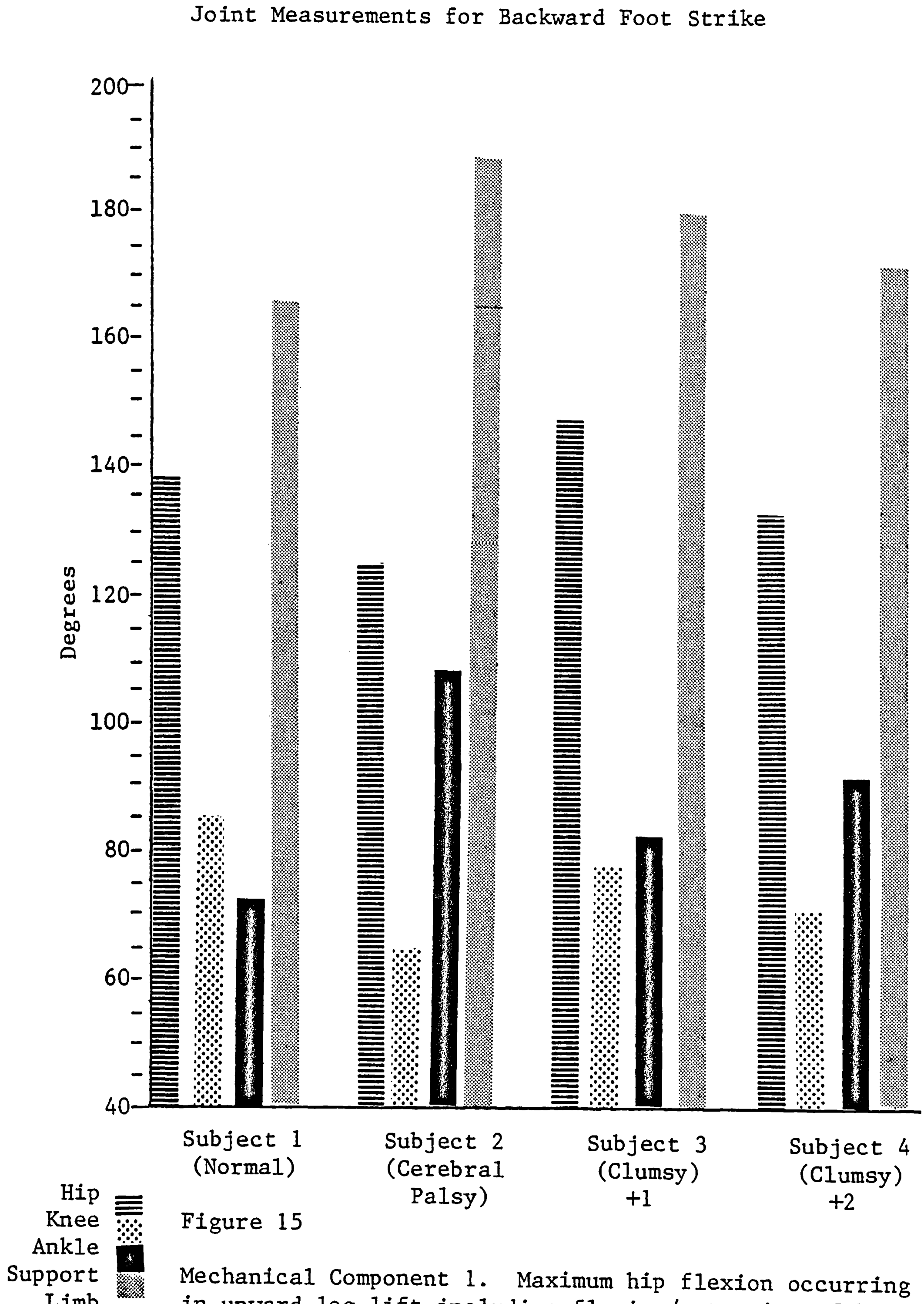


Figure 15

Mechanical Component 1. Maximum hip flexion occurring in upward leg lift including flexion/extension of knee, ankle and supporting limb.

Hip: Subject 2 C.P. demonstrated 123-degree hip extension, and subject 3 Cl+l demonstrated 147 degrees. The other Subjects ranged in between the two degrees.

Knee: Subject 1 Nor. demonstrated 85-degree extension, and Subject 2 C.P. demonstrated 65-degree flexion. The other Subjects ranged in between the two degrees.

Ankle: Subject 1 Nor. and Subject 3 Cl+l demonstrated dorsiflexion. Subject 4 Cl+2 demonstrated neutral positioning, and Subject 2 C.P. demonstrated plantarflexion.

Supporting Limb: Subject 1 Nor. demonstrated 166-degree extension. Subject 3 Cl+l and Subject 4 Cl+2 demonstrated 180 degrees and 171 degrees. Subject 2 C.P. demonstrated hyperextension.

In the upward leg lift, Subject 2 C.P. demonstrated a forward trunk inclination, the greatest knee flexion, ankle plantarflexion, and hyperextension of the supporting limb. Subject 1 Nor. demonstrated neutral hip position, the least knee flexion, ankle dorsiflexion, and the least supporting limb extension. Subject 3 Cl+l demonstrated the greatest hip and supporting limb extension. The ankle was placed in dorsiflexion and the knee was positioned similar to Subject 1 Nor. Subject 4 Cl+2 demonstrated similar angle measurements to Subject 2 C.P., with the exception of ankle plantarflexion and supporting limb extension.

Mechanical Component Two. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike, as seen in Figure 16.

Joint Measurement for Backward Foot Strike

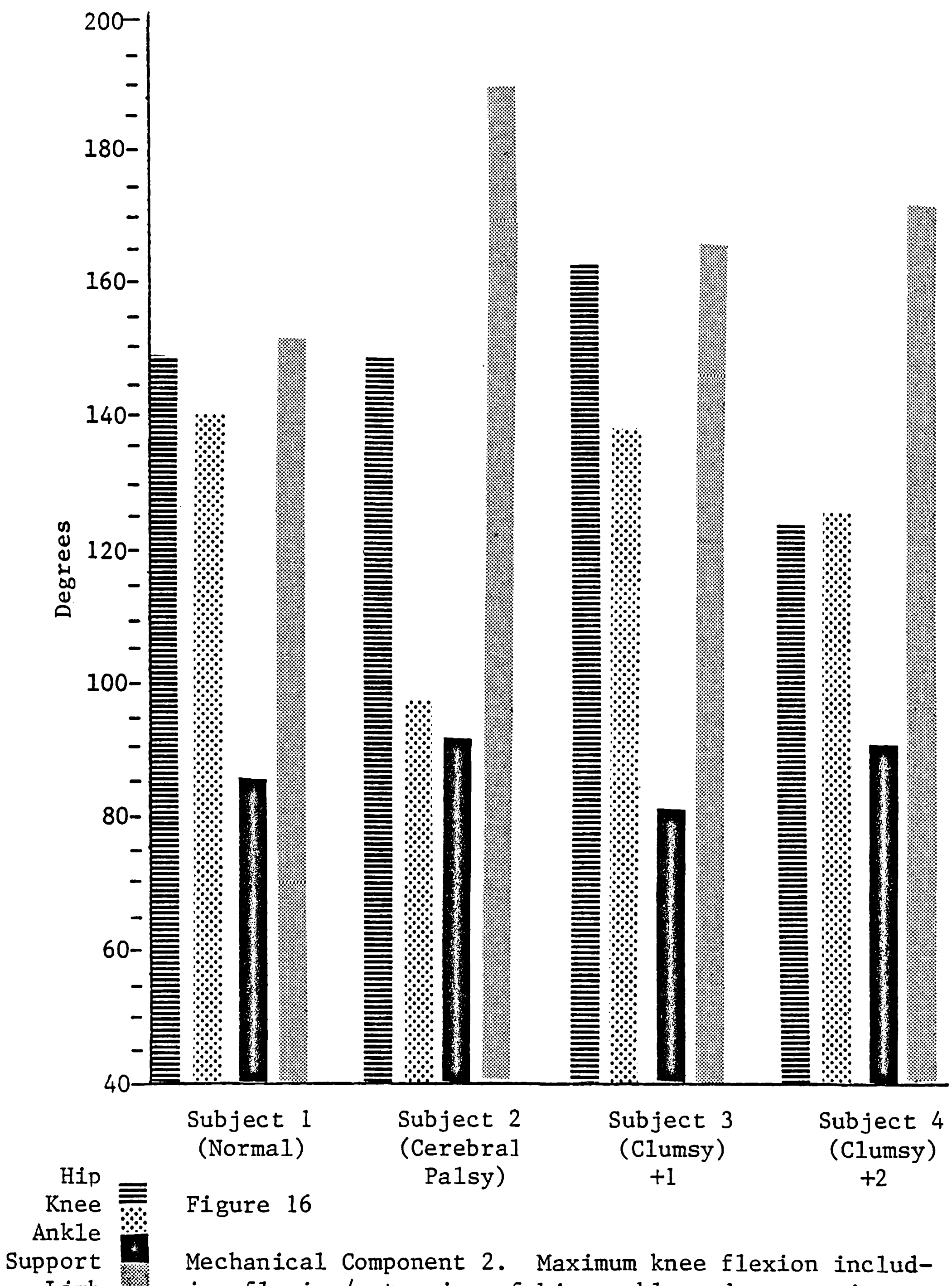


Figure 16

Mechanical Component 2. Maximum knee flexion including flexion/extension of hip, ankle and supporting limb prior to foot strike.

Hip: Subject 3 Cl+1 demonstrated the greatest hip extension, 162 degrees, and Subject 4 Cl+2 demonstrated the least extension, 124 degrees. The other Subjects ranged between the two degree limits.

Knee: Subjects 1 Nor., 3 Cl+1, and 4 Cl+2 demonstrated extension of 140 degrees, 138 degrees and 126 degrees. Subject 2 C.P. elicited extreme flexion of 96 degrees.

Ankle: Subject 1 Nor. and Subject 3 Cl+1 positioned the ankle in dorsiflexion, and Subjects 2 C.P. and 4 Cl+2 placed the ankle in neutral position.

Supporting Limb: Subject 1 Nor. demonstrated the least degree of extension, 151 degrees. Subject 4 Cl+2 demonstrated the greatest extension, 175 degrees. Subject 3 Cl+1 followed with 9 degrees less than Subject 4 Cl+2. Subject 2 C.P. elicited 190 degrees hyperextension.

Subjects 1 Nor. and 3 Cl+1 performed similar symmetrical body form with the exception of greater extension of the hip and supporting limb. Subject 2 C.P. demonstrated hyperextension of the supporting limb, excessive knee flexion, ankle in neutral position and poor trunk control. Subject 4 Cl+2 demonstrated a variety of body postures during uplift component. Maximum angle measurements determined excess trunk inclination, knee flexion, neutral ankle position with toe projected downward and supporting limb in excess extension.

Mechanical Component Three. Maximum knee extension including flexion/extension of hip, ankle and supporting limb at foot contact, as seen in Figure 17.

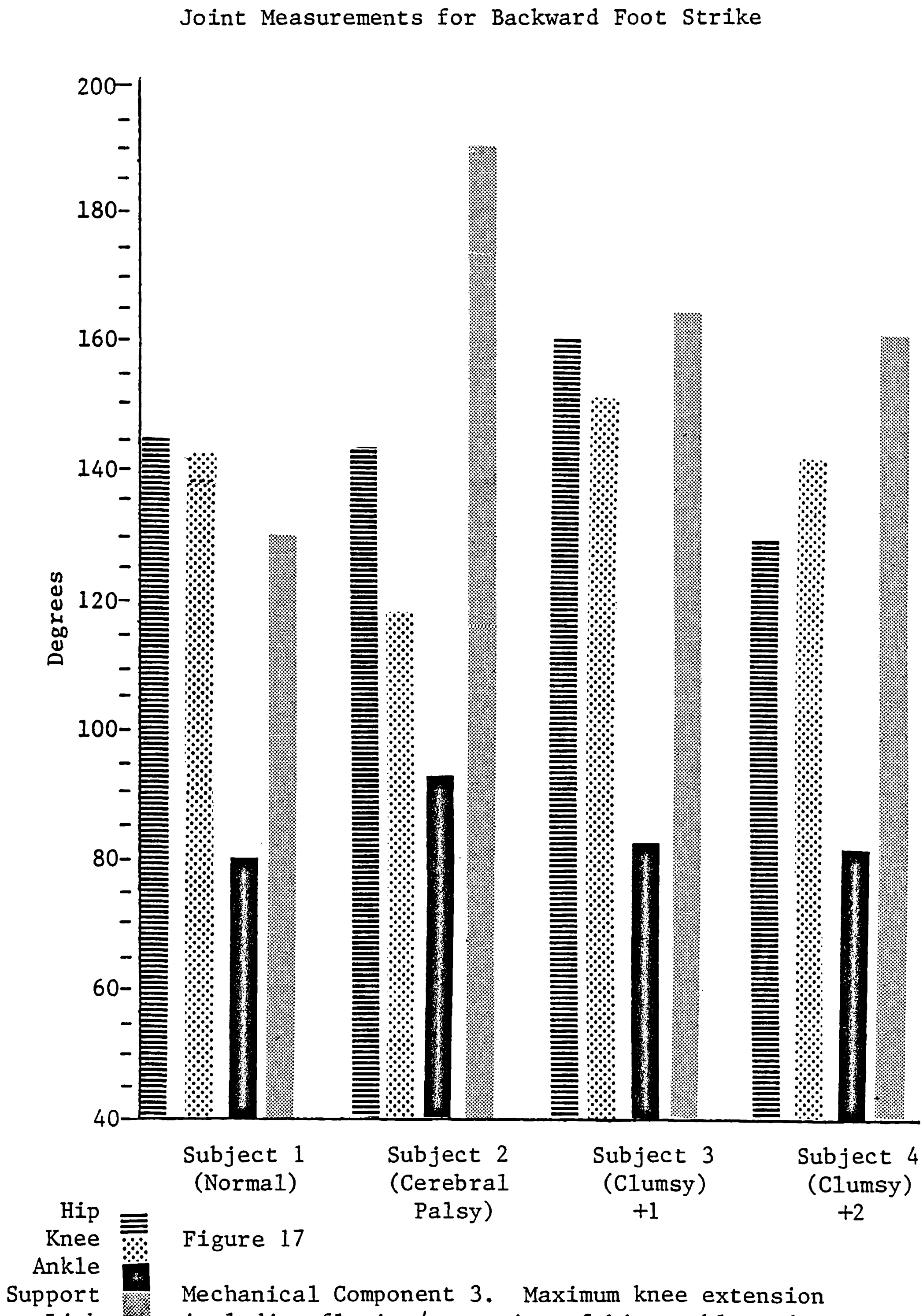


Figure 17

Mechanical Component 3. Maximum knee extension including flexion/extension of hip, ankle and supporting limb at foot contact.

Hip: Hip angle measurements ranged from 130-degree flexion to 160 degrees extension. Subject 4 Cl+2 exhibited the most hip fluctuation at contact.

Knee: Subjects 1 Nor. and 2 Cl+1 demonstrated similar knee angle extension, 141 degrees and 142 degrees, respectively. Subject 3 Cl+1 demonstrated the greatest extension, 152 degrees. Subject 2 C.P. continued to position the knee in flexion, 117 degrees.

Ankle: Subjects 1 Nor., 3 Cl+1, and 4 Cl+2 elicited ankle dorsiflexion, and Subject 2 C.P. positioned the ankle in neutral plantarflexion.

Supporting Limb: Subject 3 Cl+1 and 4 Cl+2 demonstrated similar degree angles. Subject 2 C.P. elicited hyperextension and Subject 1 Nor. demonstrated the most flexion, 131 degrees.

Each Subject exhibited a different pattern of angular movement. Subject 1 maintained erect posture with stable hip positioning, simultaneous flexion of both knees, ankle dorsiflexion with the total foot contacting the floor, and no noticeable upper extremity-associated movement. Subject 2 C.P. demonstrated a forward trunk inclination, a downward toe projection with the toe making contact with the floor, and hyperextension of supporting limb. Subject 3 Cl+1 demonstrated knee and ankle positioning similar to Subject 1 Nor., but hip and supporting limb elicited 20 to 30 degrees more extension than Subject 1 Nor. Subject 4 Cl+2 elicited immature posturing during the first three mechanical components with also a downward toe projection as toe contacted the floor. The knee and supporting limb were placed in flexion, and the general movement pattern was similar to subject 2 C.P.

Mechanical Component Four. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike, as seen in Figure 18.

Hip: Subjects 3 Cl+1 and 4 Cl+2 demonstrated 169 degrees and 170 degrees extension, respectively. Subject 3 Cl+2 elicited 40 degrees increased extension from previous component. Subjects 1 Nor. and 2 C.P. maintained approximately the same body angles as in the previous component.

Knee: Subjects 3 Cl+1 and 4 Cl+2 elicited 10 to 23 degrees more extension than in the previous component. Subject 2 C.P. elicited 17 degrees more extension than in the previous component. Subject 1 Nor. demonstrated a similar knee angle.

Ankle: Subject 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated dorsiflexion ranging from 75 degrees to 85 degrees. Subject 2 C.P. demonstrated plantarflexion. Subject 3 Cl+1 exhibited a total foot placement pattern while Subject 3 Cl+2 exhibited a toe to heel foot placement pattern.

Supporting Limb: Subjects 3 Cl+1 and 4 Cl+2 increased limb extension by 4 degrees from previous component. Subject 1 Nor. increased extension by 26 degrees from the previous component, and Subject 2 C.P. elicited hyperextension.

The description of the trunk, knee, ankle and supporting limb of Subjects 3 Cl+1 and 4 Cl+2 are angularly similar, with both

Joint Measurements for Backward Foot Strike

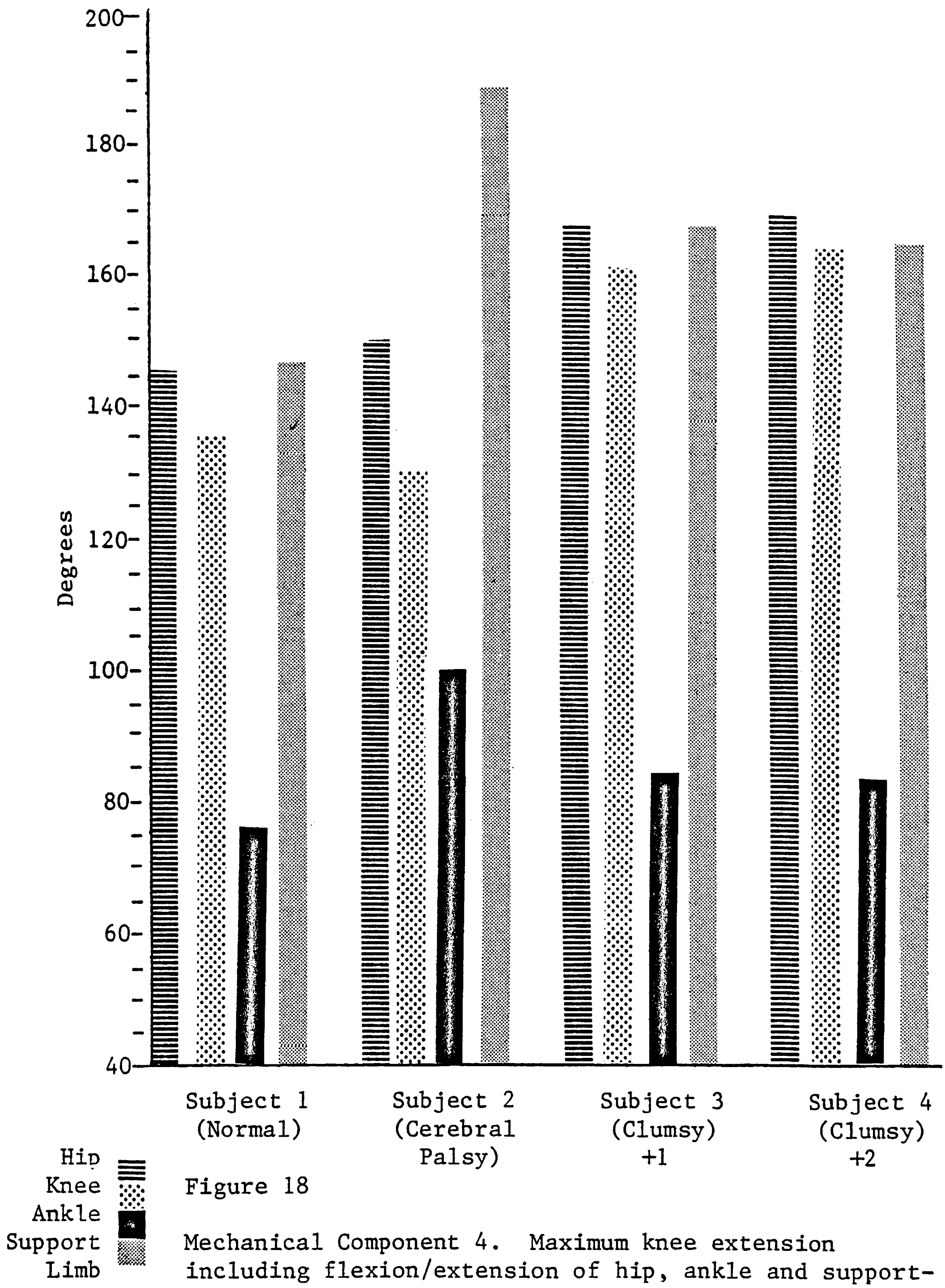


Figure 18

Mechanical Component 4. Maximum knee extension including flexion/extension of hip, ankle and supporting limb after foot strike.

subjects increasing knee extension from previous component. Subject 4 Cl+2 elicited the greatest knee extension. Subject 2 C.P. demonstrated slightly less hip and knee extension than in the previous component. Hyperextension of the supporting limb has continued to occur in all the components. Subject 1 Nor. demonstrated a symmetrical body pattern, with only 6 degrees decrease in knee flexion and slight flexion of the supporting limb from the previous component.

Mechanical Component Five. Maximum ankle extension including flexion/extension of hip, knee and supporting limb prior to lift off, as seen in Figure 19.

Hips: Subject 1 Nor., 3 Cl+1, 4 Cl+2 demonstrated similar angles of extension, 167 degrees, 168 degrees, and 167 degrees, respectively. Subject 2 C.P. demonstrated 127-degree flexion.

Knee: Subject 1 Nor. demonstrated the greatest knee angle extension, an increase of 17 degrees from previous component. Subject 2 C.P. demonstrated the most flexion. Subjects 3 Cl+1 and 4 Cl+2 elicited similar knee flexion angles and a decrease of 15 and 24 degrees, respectively, in knee angle from previous component.

Ankle: Subject 1 Nor. demonstrated 66 degrees dorsiflexion, a decrease of 9 degrees from previous component. Subjects 2 C.P. and 3 Cl+1 demonstrated 97- and 95-degree plantarflexion. Subject 4 Cl+2 positioned the ankle in 89-degree neutral flexion. Subjects 3 Cl+1 and 4 Cl+2 increased ankle plantarflexion positioning by 5 degrees to 10 degrees from previous component.

Joint Measurements for the Backward Foot Strike

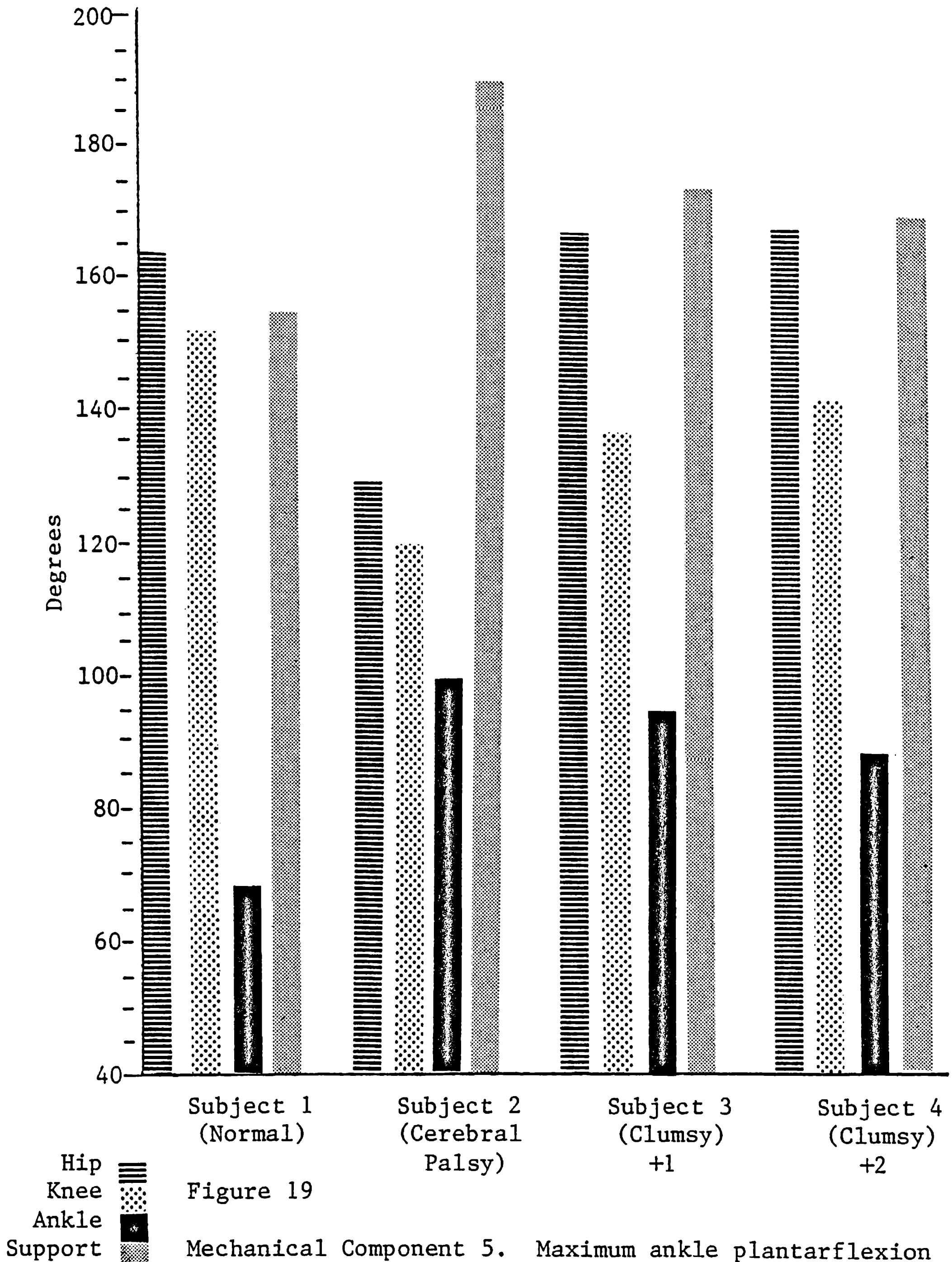


Figure 19

Mechanical Component 5. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb prior to lift off.

Supporting Limb: Subject 1 Nor. demonstrated the least degree of extension prior to lift off. Subject 2 C.P. elicited hyperextension, and Subjects 3 Cl+1 and 4 Cl+2 demonstrated 174 degrees and 169 degrees extension. All subjects increased extension from the previous component.

Subject 1 Nor. demonstrated symmetrical body formation with the performing knee and supporting limb in similar degrees of angles of extension prior to lift off. The ankle elicited dorsiflexion, and the total foot contacted the floor. The knee increase of 17 degrees from previous component indicated the difficulty of the backward foot strike. Subject 2 C.P. demonstrated a forward trunk inclination and plantarflexion, with only the toe contacting the floor surface for the backward foot strike. The supporting limb demonstrated hyperextension, and the performing knee elicited flexion, causing an asymmetrical formation. Subject 3 Cl+1 maintained erect posture, but demonstrated greater knee flexion and ankle plantarflexion. Only the toe contacted the floor surface. The supporting limb elicited extension. Subject 4 Cl+2 demonstrated similar joint angle measurements to Subject 3 Cl+1 with the exception of slightly increased knee extension and decreased supporting limb extension. The ankle elicited neutral positioning, and the toe contacted the floor surface.

<u>Mechanical Component Six</u>. Maximum extension of ankle including flexion/extension of hip, knee and supporting limb at lift off, as seen in Figure 20.

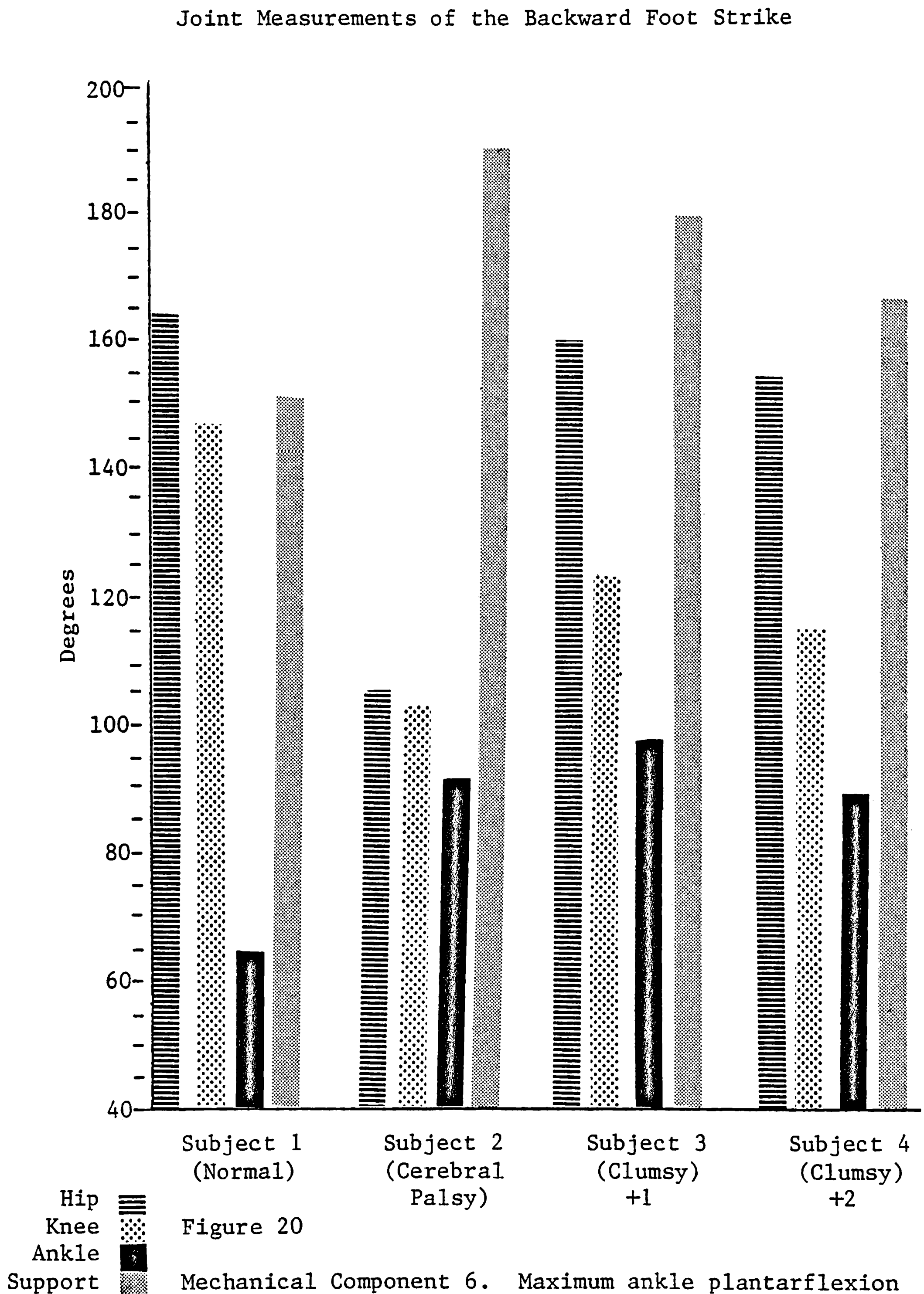


Figure 20

Mechanical Component 6. Maximum ankle plantarflexion including flexion/extension of hip, knee and supporting limb at lift off.

Hip: Subjects 1 Nor., 3 Cl+1 and 4 Cl+2 demonstrated similar angles of 165 degrees, 160 degrees and 155 degrees extension, respectively. Subject 2 C.P. demonstrated 105 degrees flexion with excessive forward trunk inclination.

Knee: Subject 1 Nor. demonstrated no change of knee positioning. All other subjects decreased knee angle from 14 degrees to 24 degrees from previous component.

Ankle: Subject 1 Nor. positioned ankle in dorsiflexion, and subjects 2 C.P. and 4 Cl+2 positioned ankle in neutral plantarflexion. Subject 3 Cl+1 positioned ankle in plantarflexion.

Supporting Limb: Subject 1 Nor. demonstrated 150 degrees limb extension. Subject 2 C.P. demonstrated hyperextension, and Subjects 3 Cl+1 and 4 Cl+2 demonstrated 178 degrees and 168 degrees greater extension, respectively.

Subject 1 Nor. demonstrated trunk control, greater knee extension than the other subjects, dorsiflexion with the total foot lifting and no apparent associated reactions. Subject 2 C.P. demonstrated excessive forward trunk inclination, knee flexion, ankle positioned in neutral plantarflexion with the toe projected downward toward floor surface. The supporting limb elicited hyperextension. Subject 3 Cl+1 demonstrated trunk control, knee flexion, ankle plantarflexion with toe projected downward toward floor surface and exhibited upper extremity-associated movement. Subject 4 Cl+2 demonstrated slight forward trunk inclination, knee flexion, ankle positioned in neutral plantarflexion with toe projected downward toward the floor surface.

Reaction Time

The reaction time for the backward foot strike is another method of determining reflexive involvement. The comparison time table is found in Table 4. The actual reflex response occurs during mechanical components three through six ("foot strike" to "lift off").

Table 4

Comparison Time Table (Backward Foot Strike)

Mechanical Components Subject	Primitive Reflex Profile Score	Uplift Lift Off	Uplift Foot Strike	Foot Strike Lift Off
1. Normal	0	.36	.12	.24
2. Cerebral Palsy	+4	.43*	.17	.26*
3. Clumsy	+1	.53	.16	.37
4. Clumsy	+2	1.56	.78	.78

*Subject 2 C.P. performed the foot strike on the left foot.

Subject 1 Nor. performed the backward foot strike in .24 seconds, less time than the other three subjects. No reflexive response occurred. Subject 2 C.P. performed the task in .26 seconds, .02 seconds longer than Subject 1 Nor. Subject 2 C.P. demonstrated a dropped toe touch rather than a foot stomp, and the body fell backwards and off balance. Subject 3 Cl+1 performed a reaction time of .39 seconds, .11 seconds longer than Subject 1 Nor., indicating a possible Positive Supporting Reflex response. Subject 4 C1+2 performed a reaction time of .78 seconds, .52 seconds longer than Subject 1 Nor., indicating a possible Positive Supporting Reflex response.

Discussion

Angular measurements taken from mechanical components three through six and computed into variance scores are included in this discussion. The Foot Placement Variance Chart in the backward direction is found in Appendix G. Variance scores and range of variance angles are included to describe reflexive involvement.

Subject 1 Nor. recorded consistently lower variance scores for all body parts. Hip variance scores indicated a slightly greater hip fluctuation to perform the backward strike than in the other directions. The knee variance scores indicated no excessive exaggerated angles. Greater knee extension was elicited prior to lift off, possibly due to full foot placement on floor or the difficulty of task. The ankle elicited dorsiflexion and the total foot made contact. The variance scores for the knee and supporting limb recorded near equal angles, indicating symmetrical body motion. No associated reaction occurred with upper extremities. The motion analysis reaction time describe the backward direction to be comparable in time to the forward direction and lateral direction.

Subject 2 C.P. demonstrated inconsistent angular variance scores. The excessive range of hip fluctuation caused a backward and forward trunk inclination. Excessive knee flexion and hyperextension of the supporting limb suggested the appearance of a Crossed Extensor Reflex response in the fifth mechanical component. The narrow range of ankle variance scores indicated a lack of flexibility due to plantarflexion. The subject executed a toe touch rather than a foot stomp with a backward thrust, causing improper balance. The improper execution of the task discredits the reaction time.

Subject 3 C1+1 demonstrated a possible reflexive reaction by description of variance scores and reaction time. The hip variance score described proper trunk control and erect posture. The variance scores for knee angular measurement were inconsistent, indicating an exaggerated stretch response. Plantarflexion was elicited in the fifth and sixth components, and the toe projected toward the floor on contact and lift off. The total foot never made full contact. The supporting limb received a low variance score, and the knee received a higher score, indicating asymmetrical body formation. Associated reaction occurred during knee extension and stretch response. A slightly delayed reaction time was recorded.

Subject 4 C1+2 demonstrated a possible reflexive reaction by variance scores and reaction time description. Inconsistent hip and knee variance scores described forward and backward trunk inclination and excessive knee extension. Neutral plantarflexion occurred with toe projected downward. Total foot placement occurred in the fifth component, but a toe lift was demonstrated by three of the subjects. Reaction time indicated delayed response and immature gross motor functioning because of unrefined skill development.

Three Consecutive Foot Strikes

The four subjects assumed a closed foot position and stood on one pair of footprints holding the ballet barre. See Figure 2 for Footprint Placement Pattern. Figures 21, 22 and 23 describe the similarities and differences of the hip, knee and ankle measurements while performing the three consecutive foot strikes. The following ten phases were selected and used as a guide for comparison of angular measurements and reaction time. The ten phases included six mechanical components used for motor analysis of the single foot strike in three directions. The raw scores are found in Appendices H, I and J.

(1) Uplift

(2) Contact (1)

(3) After Strike

(4) Lift Off

(5) Uplift

(6) Contact (2)

(7) After Strike

(8) Lift Off

(9) Uplift

(10) Contact (3)

The Positive Supporting Reflex response is demonstrated after the "contact" phase and continues through the "after strike" phase. The hip angular measurements are described in Figure 21. Subject 1 Nor., 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated a 30-degree, 61-degree, 44-degree and 69-degree hip angle variance, respectively. Subject 4 Cl+2 consistently elicited the greatest hip fluctuation during the "uplift" and "contact" phases. Subjects 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated 15 to 20 degrees more hip extension on the first "after strike" phase and 20 to 25 degrees more extension on the second "after strike" phase than Subject 1 Nor.

Subject 1 Nor. demonstrated efficient motor movement with consistent hip stability for the ten phases. Subject 2 C.P. demonstrated the greatest hip extension throughout the three consecutive foot strikes, including the "after strike" phase. Subject 3 Cl+1 demonstrated the second greatest hip angle extension and elicited equal extension for the second "after strike" phase with Subject 2 C.P. Subject 4 Cl+2 demonstrated the greatest hip flexion during "uplift" and "contact" phases while eliciting hip extension for "after strike" phases.

The knee angular measurements are described in Figure 22. Subjects 1 Nor., 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated a 66-degree, 77-degree, 91-degree and 122-degree knee angle variance, respectively. Subject 4 Cl+2 consistently demonstrated greater knee flexion than the other subjects on the "uplift" phase. Subjects 2 C.P. and 4 Cl+2 demonstrated greater knee flexion at the "contact"

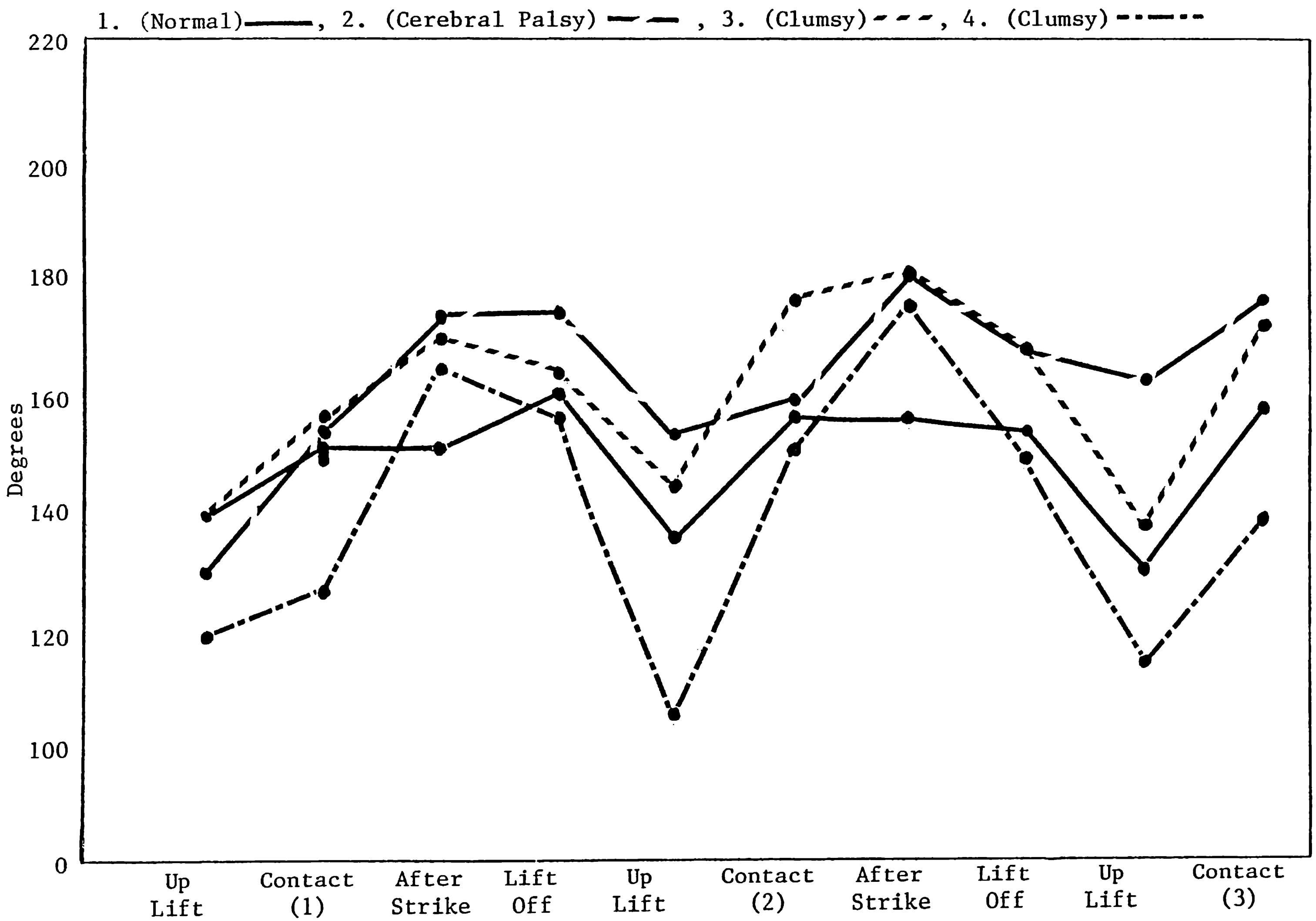


Figure 21. Hip Measurements for Three Consecutive Foot Strikes

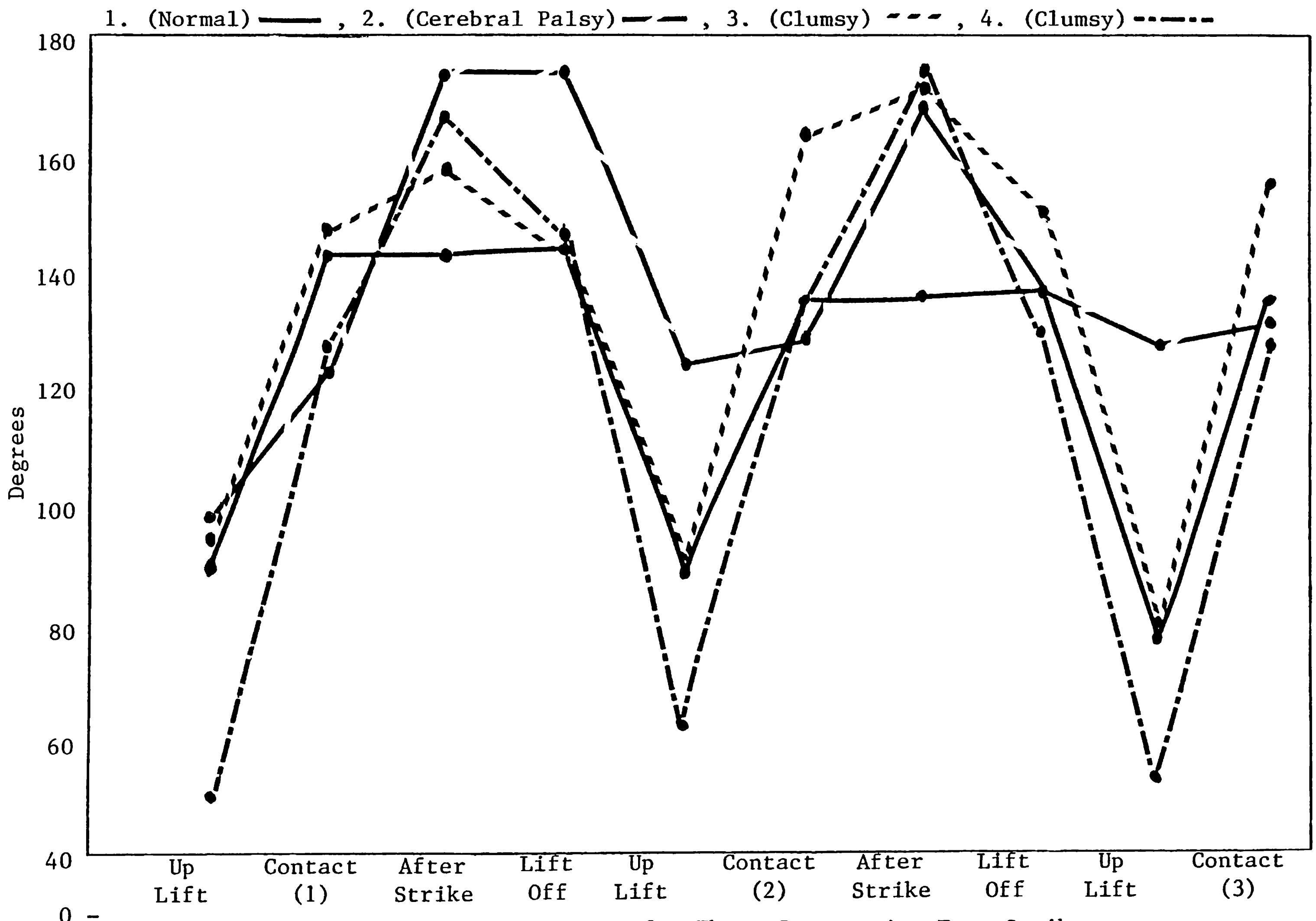


Figure 22. Knee Measurements for Three Consecutive Foot Strikes

phase than Subject 1 Nor. Subject 3 Cl+1 demonstrated greater extension at the "contact" phase than Subject 1 Nor. Subjects 2 C.P., 3 Cl+1 and 4 Cl+2 demonstrated 10 to 30 degrees more knee extension on the first "after strike" and 30 to 35 degrees more extension on the second "after strike" phase than Subject 1 Nor.

Subject 1 Nor. demonstrated efficient motor functioning with consistent knee angle measurements from "contact" to "lift off." Subject 2 C.P. was unable to perform the three strikes: therefore, the last two attempts at uplift and foot strike were foot taps. The knee maintained extension for the remaining phases. Subject 3 Cl+1 demonstrated knee angle measurements much like Subject 1 Nor., with the exception of "after strike" phases, when the knee exhibited extension. Subject 4 Cl+2 demonstrated the greatest knee flexion, but elicited knee extension during the "after strike" phases.

The ankle angular measurements are described in Figure 23. Subject 1 Nor. demonstrated neutral plantarflexion to dorsiflexion. Dorsiflexion was elicited after each "contact" phase. Subject 2 C.P. demonstrated greater plantarflexion in the first and second "contact" phase than Subjects 1 Nor., 3 Cl+1 and 4 Cl+2. After phase number six, the foot remained on the floor performing small taps (Clonus Response) in a plantarflexion ankle position. Subject 3 Cl+1 demonstrated dorsiflexion, neutral and plantarflexion. A slight increase in plantarflexion was demonstrated after the first "contact" phase and a slight plantarflexion release after the second "contact" phase.

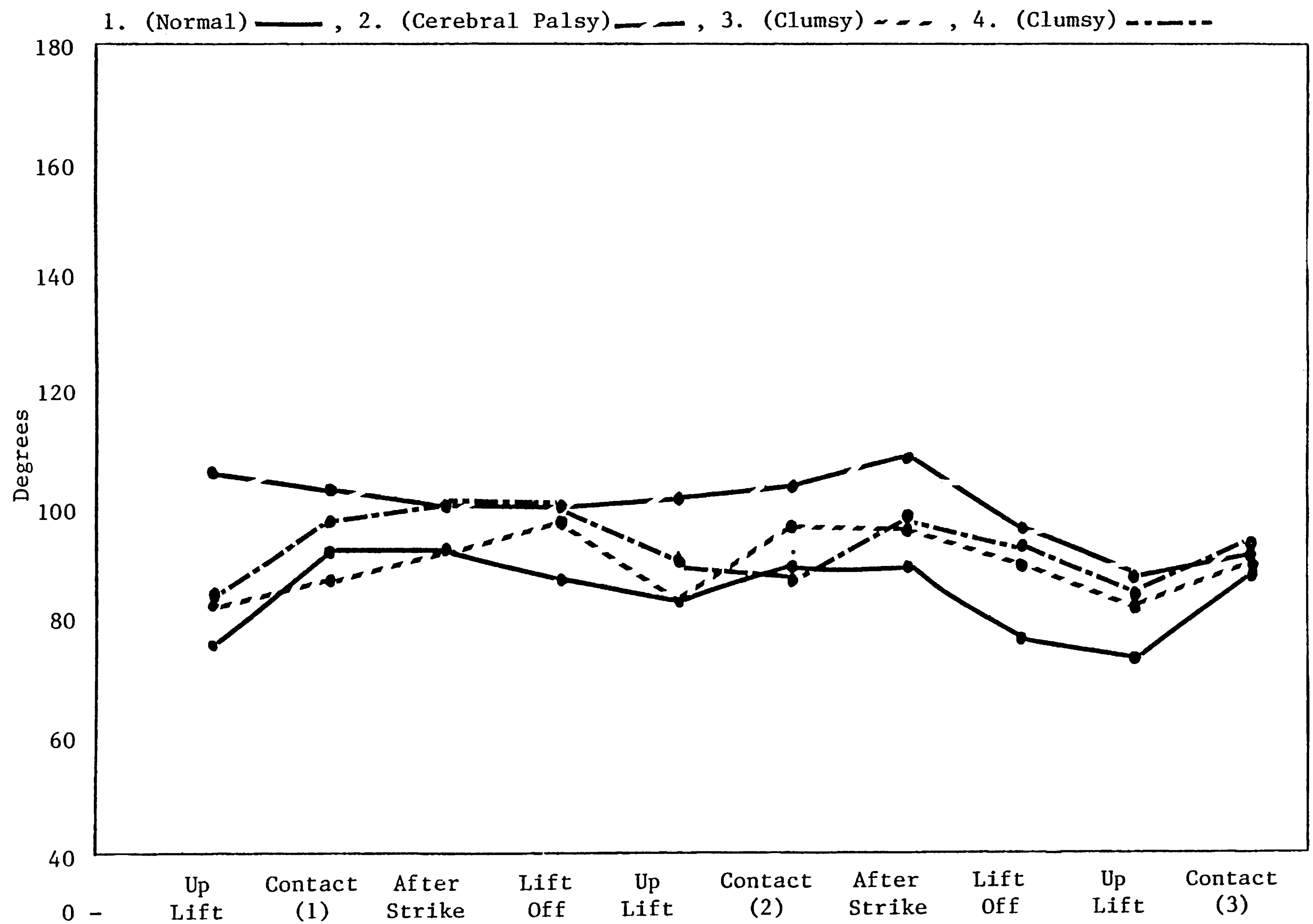


Figure 23. Ankle Measurements for Three Consecutive Foot Strikes

Reaction Time

Table 5 lists the reaction time for each subject to complete the three consecutive foot strikes. Reaction time indicates more time was taken by Subjects 2 C.P., 3 Cl+1 and 4 Cl+2 than Subject 1 Nor. to complete the "uplift" through "lift off" phase, including first and second "contact" phases. Subject 2 C.P. could not perform the task on the right foot; therefore, the reaction time was recorded on the left foot. Subject 1 Nor. recorded 1.12 seconds from "uplift" to "lift off" to perform the three foot strikes. Subjects 3 Cl+1 and Cl+2 took .33 seconds and .66 seconds longer than subjects 1 Nor., respectively. Subject 2 C.P. was unable to execute the last foot strike, and the recorded reaction time represents minimal foot movement.

TABLE 5

Comparison Time Table (Three Consecutive Foot Strikes)

	Primitive Reflex Profile	Uplift through Lift Off	First Contact	Second Contact
1. Normal	0	1.12	.19	.16
2. Cerebral Palsy	4	*1.32	.37	.49
3. Clumsy	+1	1.45	.31	.29
4. Clumsy	+2	1.78	.62	.45
		Seconds	Seconds	Seconds

*The recorded time was accomplished on the left foot, representing minimal movement.

Summary

Motion analysis measurements of the single leg foot strike compared the subtle reflexive responses performed by one normal child, two "clumsy" children and one cerebral palsied child. The volitional movement patterns of the "clumsy" characterize the movements of the cerebral palsy. Although the movements are not identical, the responses are similar.

Range of variance degree angles described and determined reflexive involvement. Six mechanical components, including maximum angular joint measurements, were computed for variance scores.

Reaction time was another method of determining reflexive involvement, and the results compared delayed motion to efficient movement performed in three directions.

The normal subject demonstrated the most efficient movement in the least amount of time and recorded the lowest variance scores. No exaggerated knee extension, ankle plantarflexion, excess hip flexion or supporting limb extension occurred after foot placement pattern.

The cerebral palsied subject demonstrated an exaggerated stretch reflex with excessive knee extension, supporting limb flexion and ankle plantarflexion. This Positive Supporting Reflex occurred in all three directions, and the appearance of the Crossed Extensor Reflex occurred in the forward and backward directions. The subject demonstrated asymmetrical body formation, trunk inclination, internal hip rotation, poor balance, difficulty in weight

transfer, and elicited associated movements of the upper extremities with overflow into the hands. The subject often did not complete the foot placement pattern.

Subject 3 Cl+1 demonstrated similar variance scores to subject 1 Nor., but recorded different numerical range limits, indicating some minimal differences. The hip, knee and supporting limb exhibited similar measurements with the exception of slight knee extension. The ankle position ranged from dorsiflexion to minimal plantarflexion. The knee exhibited a weak exaggerated stretch with some internal hip rotation in the forward foot placement. More efficient movement was demonstrated by subject 3 Cl+1 than by Subject 4 Cl+2. Reaction time was delayed in all directions.

Subject 4 Cl+2 demonstrated excessive hip and knee flexion prior to foot strike with an overprojection of the knee at uplift and foot strike in all directions. Subject 4 performed an immature movement pattern with the head projected downward as lower limbs exhibited deep knee bend to accommodate the performing strike leg. Greater plantarflexion was elicited than Subject 3. Reaction time was more delayed than Subject 3.

Angular measurements demonstrated during the three consecutive foot strikes indicated an appearance of the Positive Supporting Reflex for Subjects 3 and 4. Slight hip and knee extensions occurred after the first "after strike" phase, and greater extension occurred after the second "after strike" phase. Subject 3 elicited a slight plantarflexion position after the first "contact" phase, and

Subject 4 increased greater plantarflexion after both the first and second "contact" phases. Reaction times were consistently longer than the normal subject, but shorter than the cerebral palsied subject, who had difficulty completing the multiple foot placement pattern.

Subjects 3 and 4 demonstrated the following observable characteristics: (1) excessive trunk fluctuation, (2) minimal exaggerated stretch reflex prior to onset of P.S.R., (3) minimal ankle plantarflexion, (4) associated reactions, (5) weak proprioceptor system, and (6) unrefined motor acquisition.

Chapter 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

Summary

This study compared differences and similarities of a single leg stomp placement using one normal child, one cerebral palsied child and two motorically delayed children classified as "clumsy." The purpose was to determine a positive supporting reaction by using cinematographical analysis technique to record movement patterns of each subject.

A common P.S.R. reaction was observed after a stimulus was received from bouncing an infant several times on a surface. That movement provides pressure to a specific area on the sole of the foot. This induces a stretch response and the leg increases extensor tone, causing a plantarflexion pattern in the ankle and foot. Whether this response occurs by passive manipulation or of voluntary functioning, the response will occur to some degree and will occur automatically or stereotypically during or after the stimulus.

Twitchell (53) stated that defects in voluntary movement and defects in reflex mechanisms have a common basis; that ingredient is a defect in sensory motor integration. The defects of voluntary movement of any kind result from exaggeration of several reflexes that are in mutual conflict.

The possibility of conflicting reflexes may be present in postural reactions during and before a movement is performed, as reported by Buchwald (14). Postural reactions accompany voluntary movement and occur automatically before a movement is initiated, such as before a step is taken, weight is shifted toward the other leg.

Bobath (9) stated that mild motor defects in clumsy children are identical to those found in cerebral palsy, although to a lesser degree. Illingsworth (27) further stated that clumsiness itself, whatever the causes, includes minimal cerebral palsy. If defects are to a mild degree, the child may show a low amount of spontaneous movement. Often the speed of movement is slow and within the limits of the motor task, but the timing is delayed, according to McKinley, Touwen and Prechtl (32, 51).

A possible relationship of mild defects and delayed timing may be found in the reporting by Easton (20) through research of Orlovskii and Shek, which states that "flexion command overrides an extension command and that if an extended leg is not ordered to flex it remains extended." Using a specific motor skill such as gait pattern, the statement made can be applied to the explanation given by Marley (31), that adult gait pattern at initial floor contact exhibits knee extension but flexes with onset of weight, whereas children with chronic neuromuscular disorders such as cerebral palsy exhibit excessive ankle plantarflexion and exaggerated muscle stretch during a gait.

Methods of evaluating P.S.R. reaction include qualitative and quantitative aspects. A numerical grading scale providing qualitative measurements was suggested by Capute (15) in the "Primitive Reflex Profile" to determine the degree of positive supporting reflex. Hoskins and Squires (26) designed a test for evaluation of gross motor development which incorporates the interrelatedness of reflexes with motor milestones, but difficulty arose when differentiating between reflex supporting reaction and voluntary supporting stance. Eight normal children exceed the norm for positive supporting reaction because the reflex was observed to persist beyond the age of normal disappearance. Semon (47) designed the "Basic Motor Control Test" and used simple postural patterns for objective reporting and evaluation.

In this descriptive interpretation of evaluating the single leg stomp placement, the P.S.R. reaction was observed in two classified "clumsy" subjects as a mild and subtle response. Subject 1 Nor. demonstrated no apparent reflexive response and performed within a normal range of motor development. Subject 1 C.P. demonstrated a positive reflexive involvement, which has previously been diagnosed by the Capute scale. (15)

The angular joint motion analysis and reaction time of Subject 3 Cl+1 demonstrated a slight delay in motor development with possible reflexive involvement, and Subject 4 Cl+2 demonstrated moderately immature motor ability with positive reflexive involvement.

Quantitative measurements were demonstrated by three consecutive foot strikes. Those responses supported the qualitative aspects observed by the single leg foot placement in two out of three directions using angular variance scores and reaction time.

Conclusions

Within the assumptions and limitations of this study, the following conclusions are acceptable for determining the alternate method of evaluating Positive Supporting Reflex. The cerebral palsied subject and the two motorically delayed "clumsy" subjects demonstrated similar measurements and reaction time scores.

Foot Stomp Placement in Three Directions

(1) Excessive hip flexion was elicited in all three directions prior to "foot strike," then hip extension occurred after "foot strike," causing unstable trunk control and backward inclination at foot "lift off."

(2) A slight to moderate exaggerated stretch at maximum knee extension occurred after foot strike.

(3) A slight to moderate ankle plantarflexion was elicited in the forward and backward direction.

(4) The supporting limb angle measurements were often inconsistent with performing knee measurements, therefore demonstrating asymmetrical body alignment and a possible Crossed Extension Reflex.

(5) The duration of reaction time to complete the forward and backward movement directions consistently indicated difficulty in executing foot placement, immature motor functioning and the possibility of Positive Supporting Reflex.

(6) When comparing the reaction time from "uplift" to "foot strike" phase and "foot strike" to "lift off" phase, reflexive behavior occurred after foot strike.

(7) The exaggerated stretch response supports the research information stating that if an extended leg is not ordered to flex, it remains extended. The duration of reaction time to order flexion was an indication of reflexive involvement.

Three Consecutive Foot Placement Strikes

(1) Hip extension occurred after each "after strike" phase and hip extension increased on the second "after strike" phase.

(2) Knee extension occurred after each "after strike" phase and knee extension increased on the second "after strike" phase.

(3) Slight to moderate plantarflexion was demonstrated after each "contact" phase.

(4) The duration of reaction time to complete the three consecutive foot placements indicated difficulty in repetition of movement and/or reflexive involvement. Reaction time was improved slightly after the second "contact" phase, indicating repetition may inhibit the reflexive response.

Recommendations

(1) Further cinematographical studies could compare voluntary single leg foot stomp response and the acceptable involuntary response elicited by full physical prompting.

(2) Further studies to standardize and reference gross motor skills performed by the motor delayed "clumsy" individual.

(3) The use of a force plate to more accurately record reflex reaction time.

(4) The use of a platform shoe to measure and control ankle plantar flexion and weight transfer.

(5) The position of the head should be projected toward a stationary object at eye level to reduce the influence of tonic reflex activity.

Implications

This research implies the existence of the primitive reflex in ambulatory individuals. Therefore, knowledgeable differentiation is required when using a motor task to evaluate reflexive involvement. This simple testing method could be used by evaluators as a quick screening device if appropriate information regarding abnormal motor behaviors was available prior to testing.

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Appendix A

PARENTAL CONSENT FORM

Dear Parent,

The Department of Health, Physical Education and Recreation from Kansas University supports the practice of protection for human subjects participating in research. The following information is provided so that you can decide whether you wish to allow your child to participate in this study. You should be aware that even if you agree to participate, you are free to withdraw your child at any time from this study, and your child is free to withdraw at any time without penalty.

Your child will participate in a cinematographical analysis that will compare the positive supporting reflex elicited in the cerebral palsied child, the degree of reflex in the motorically delayed child and the motorically normal child.

With filming techniques, we can study the specific movements of the body more closely and determine the relationship of the joints for a more efficient method of reflex testing physically handicapped and the clumsy child.

Your child's participation is solicited, but strictly on a voluntary basis. Be assured that your name or your child's name will not be associated in any way with the project's results.

I appreciate your cooperation. If you have any questions please don't hesitate to call me at 843-0646 or 864-4076.

____

Signature of parent agreeing
to permit child to participate

Sincerely,

____

Signature of child consenting
to participation

Wanda Roach
Principal Investigator

Appendix B

RAW SCORES FOR JOINT ANGLE MEASUREMENT (FORWARD DIRECTION)

JOINT ANGLE MEASUREMENTS

(Forward Foot Strike)

Mechanical Component #1

Subject		Hip	Knee	Ankle	Supporting Limb
Nor	1	134°	104°	80°	168°
C.P.	2	89°	85°	97°	164°
Cl+1	3	135°	118°	90°	163°
Cl+2	4	91°	56°	82°	162°

Mechanical Component #2

Nor	1	142°	136°	99°	144°
C.P.	2	102°	129°	118°	161°
Cl+1	3	155°	142°	102°	157°
Cl+2	4	116°	105°	107°	146°

Mechanical Component #3

Nor	1	155°	145°	103°	141°
C.P.	2	109°	140°	121°	165°
Cl+1	3	157°	150°	106°	150°
Cl+2	4	130°	128°	111°	148°

Mechanical Component #4

Nor	1	139°	135°	100°	133°
C.P.	2	122°	174°	114°	136°
Cl+1	3	173°	170°	112°	158°
Cl+2	4	153°	167°	115°	165°

Mechanical Component #5

Nor	1	152°	155°	108°	146°
C.P.	2	169°	180°	119°	148°
Cl+1	3	162°	166°	101°	162°
Cl+2	4	173°	163°	119°	170°

Mechanical Component #6

Nor	1	148°	152°	101°	155°
C.P.	2*				
Cl+1	3	169°	151°	92°	171°
Cl+2	4	173°	155°	112°	170°

*No lift off

Appendix C

RAW SCORES FOR JOINT ANGLE MEASUREMENT
(LATERAL DIRECTION)

JOINT ANGLE MEASUREMENT

(Lateral Foot Strike)

Mechanical Component #1

Subject		Hip	Knee	Ankle	Supporting Limb
Nor	1	126°	87°	81°	165°
C.P.	2	118°	83°	99°	162°
Cl+1	3	132°	77°	82°	178°
Cl+2	4	108°	60°	78°	174°

Mechanical Component #2

Nor	1	140°	128°	82°	156°
C.P.	2	130°	116°	95°	159°
Cl+1	3	145°	123°	90°	178°
Cl+2	4				

Mechanical Component #3

Nor	1	150°	147°	91°	160°
C.P.	2	136°	130°	95°	162°
Cl+1	3	153°	150°	87°	163°
Cl+2	4	127°	128°	78°	128°

Mechanical Component #4

Nor	1	150°	147°	87°	155°
C.P.	2	145°	153°	106°	165°
Cl+1	3	157°	158°	91°	157°
Cl+2	4	116°	118°	78°	118°
	4A	159	166	95	159

Mechanical Component #5

Nor	1	152°	146°	87°	170°
C.P.	2	155°	170°	112°	164°
Cl+1	3	168°	155°	92°	167°
Cl+2	4	164°	148°	90°	168°

Mechanical Component #6

Nor	1	144°	141°	85°	163°
C.P.	2	141°	133°	100°	164°
Cl+1	3	159°	140°	83°	168°
Cl+2	4	158°	132°	85°	178°

Appendix D

RAW SCORES FOR JOINT ANGLE MEASUREMENT (BACKWARD DIRECTION)

JOINT ANGLE MEASUREMENTS

(Backward Foot Strike)

Mechanical Component #1

Subject		Hip	Knee	Ankle	Supporting Limb
Nor	1	138°	85°	74°	166°
C.P.	2	123°	65°	109°	188°
Cl+1	3	147°	78°	82°	180°
Cl+2	4	133°	71°	92°	171°

Mechanical Component #2

Nor	1	148°	180°	84°	151°
C.P.	2	135°	96°	92°	190°
Cl+1	3	162°	138°	82°	167°
Cl+2	4	124°	126°	91°	172°

Mechanical Component #3

Nor	1	144°	141°	80°	131°
C.P.	2	142°	117°	93°	189°
Cl+1	3	160°	152°	83°	165°
Cl+2	4	130°	142°	82°	161°

Mechanical Component #4

Nor	1	146°	135°	75°	147°
C.P.	2	150°	136°	100°	187°
Cl+1	3	169°	162°	85°	169°
Cl+2	4	170°	165°	84°	165°

Mechanical Component #5

Nor	1	163°	152°	66°	154°
C.P.	2	127°	119°	97°	188°
Cl+1	3	167°	137°	95°	174°
Cl+2	4	167°	141°	89°	169°

Mechanical Component #6

Nor	1	164°	152°	65°	150°
C.P.	2	105°	102°	91°	192°
Cl+1	3	160°	123°	98°	178°
Cl+2	4	155°	116°	90°	168°

Appendix E

VARIANCE CHART
(FORWARD DIRECTION)

Mechanical Components
3 through 6

Foot Placement Variance Chart

Forward Direction

	Subject 1 Normal Degree	Degree Range	Subject 2 C.P.	Degree Range	Subject 3 C1+1	Degree Range	Subject 4 C1+2	Degree Range
Hip	16	139-155	60	109-169	16	157-173	43	130-173
Knee	20	135-155	40	140-180	20	150-170	39	128-167
Ankle	8	100-108	7	114-121	20	92-112	8	111-119
Support. Limb	22	133-155	29	136-165	21	150-171	32	148-165

Appendix F

VARIANCE CHART
(LATERAL DIRECTION)

Mechanical Components
3 through 6

Foot Placement Variance Chart

Lateral Direction

	Subject 1 Normal Degree	Degree Range	Subject 2 C.P.	Degree Range	Subject 3 Cl+1	Degree Range	Subject 4 Cl+2	Degree Range
Hip	8	144-152	12	136-158	15	153-168	48	116-164
Knee	6	141-147	20	130-170	28	140-158	30	118-148
Ankle	6	91-85	27	85-112	9	83-92	2	78-90
Support. Limb	15	155-170	16	162-178	11	157-168	60	118-178

Appendix G

VARIANCE CHART
(BACKWARD DIRECTION)

Mechanical Components
3 through 6

Foot Placement Variance Chart

Backward Direction

	Subject 1 Normal Degree	Degree Range	Subject 2 C.P.	Degree Range	Subject 3 C1+1	Degree Range	Subject 4 C1+2	Degree Range
Hip	20	144-164	45	105-150	9	160-169	40	170-130
Knee	17	135-152	34	102-136	39	123-162	49	165-116
Ankle	15	80-65	9	91-100	15	98-83	8	82-90
Support. Limb	19	131-150	5	187-192	13	178-165	8	161-169

Appendix H

THREE CONSECUTIVE FOOT STRIKES
(HIP JOINT)

THREE CONSECUTIVE FOOT STRIKES

Hip Joint Angle Measurements

Subject	(Nor) (1)	(CP) (2)	(Cl+1) (3)	(Cl+2) (4)
1	139	129	139	119
2	150	152	155	126
3	150	173	170	164
4	160	173	163	157
5	134	153	144	106
6	155	150	175	151
7	155	180	180	175
8	153	168	168	150
9	130	162	136	113
10	158	176	172	138

Appendix I

THREE CONSECUTIVE FOOT STRIKES (KNEE JOINT)

THREE CONSECUTIVE FOOT STRIKES

Knee Joint Angle Measurements

Subject	(Nor) (1)	(CP) (2)	(C1+1) (3)	(C1+2) (4)
1	89	96	93	50
2	142	122	146	126
3	142	173	158	167
4	143	173	143	144
5	88	124	88	61
6	136	129	164	136
7	136	167	169	172
8	137	137	151	132
9	77	127	78	53
10	136	133	156	128

Appendix J

THREE CONSECUTIVE FOOT STRIKES
(ANKLE JOINT)

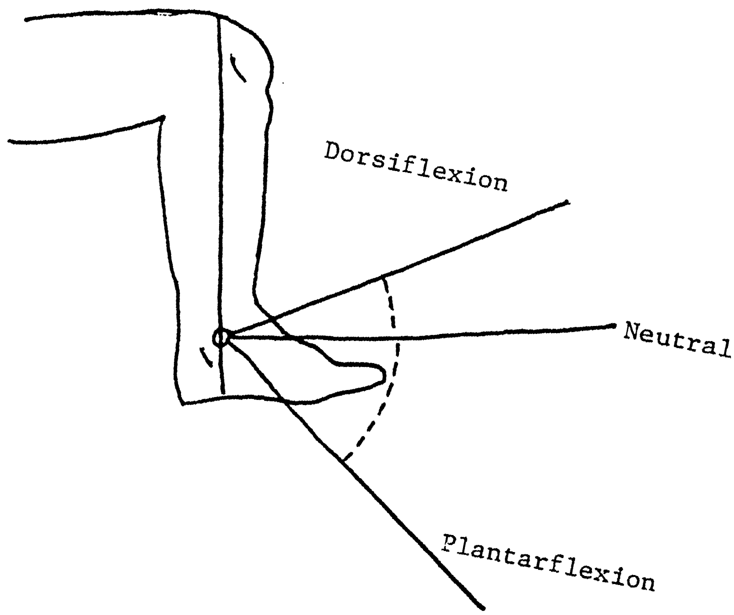
THREE CONSECUTIVE FOOT STRIKES

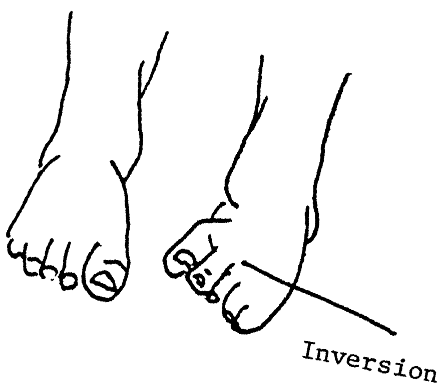
Ankle Joint Angle Measurements

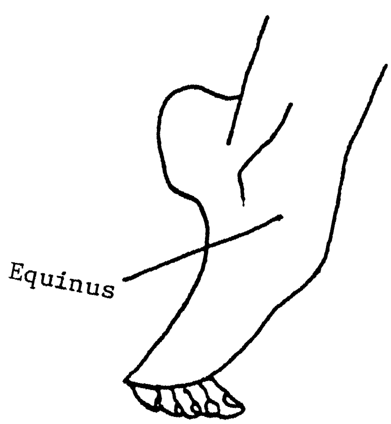
Subject	(Nor) (1)	(CP) (2)	(Cl+1) (3)	(Cl+2) (4)
1	76	107	83	84
2	92	103	87	96
3	92	100	92	100
4	88	100	98	100
5	84	101	84	87
6	89	105	97	87
7	89	109	95	99
8	77	96	92	94
9	74	88	83	84
10	87	91	90	92

Appendix K

ANKLE AND FOOT DIRECTIONAL CHART

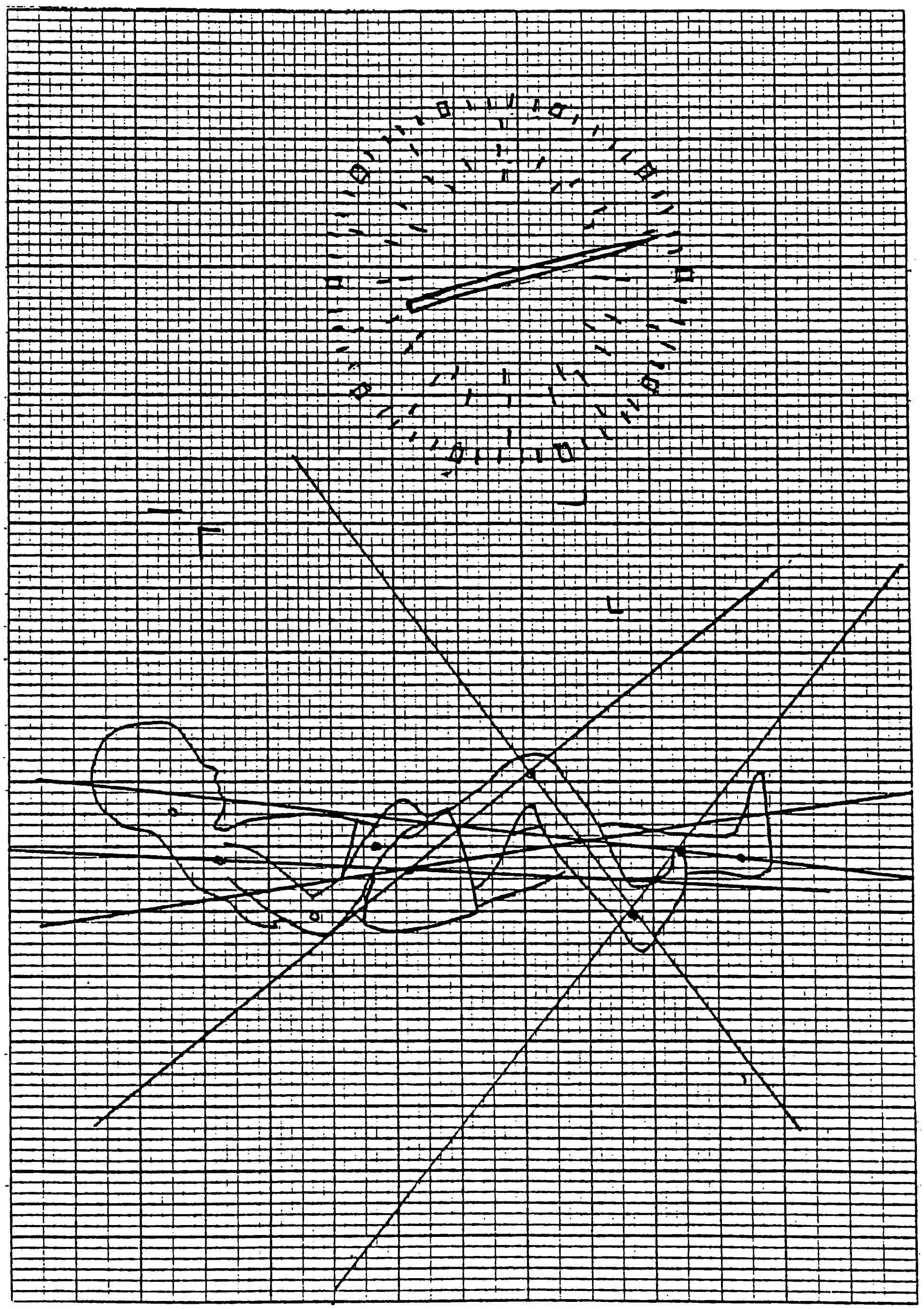

Dorsiflexion
Neutral
Plantarflexion


Inversion


Equinus

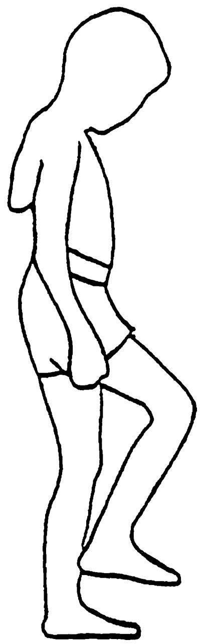
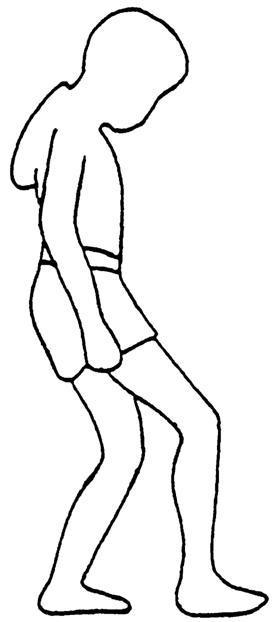
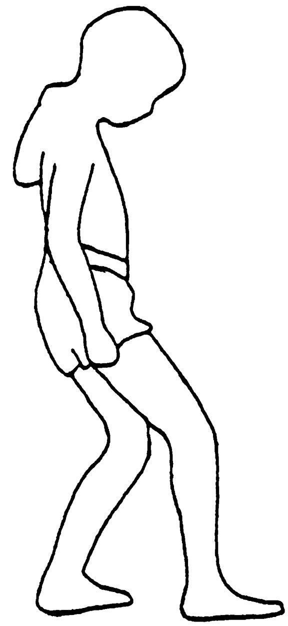
Appendix L

ONE SELECTED TRACING ON GRAPH PAPER

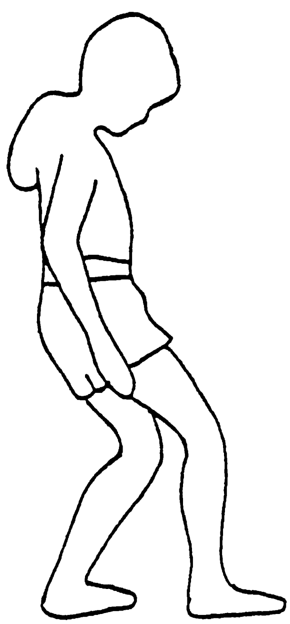
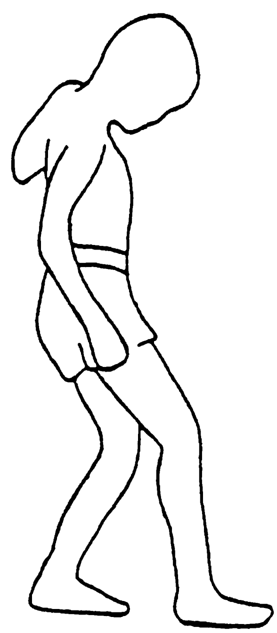
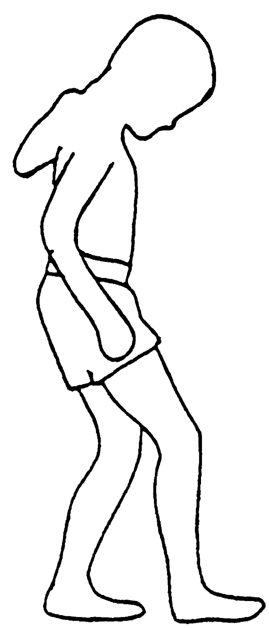


Appendix M

SELECTED DRAWINGS, SUBJECT ONE (NORMAL)
(FORWARD FOOT STRIKE)

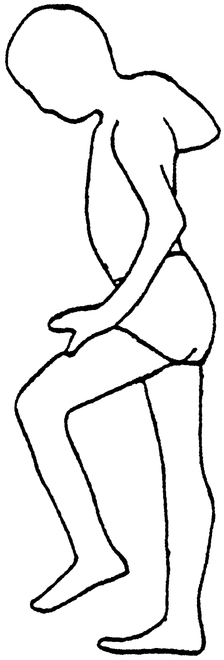
1. Uplift 2. Prior to Strike 3. Contact

4. After Strike 5. Prior to Lift Off 6. Lift Off

Appendix N

SELECTED DRAWINGS, SUBJECT TWO (CEREBRAL PALSY) (FORWARD FOOT STRIKE)



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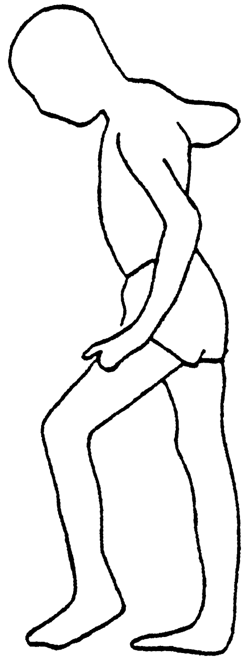
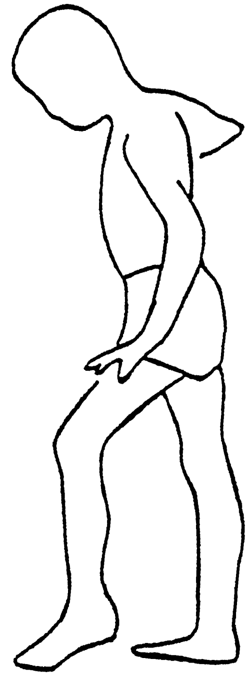
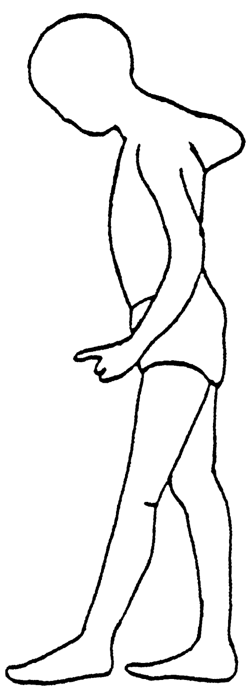


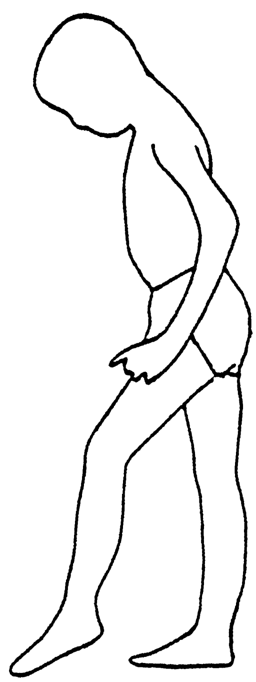
2. Prior to Strike



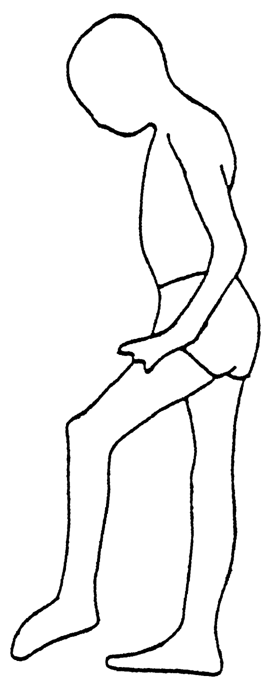
3. Contact



4. After Strike



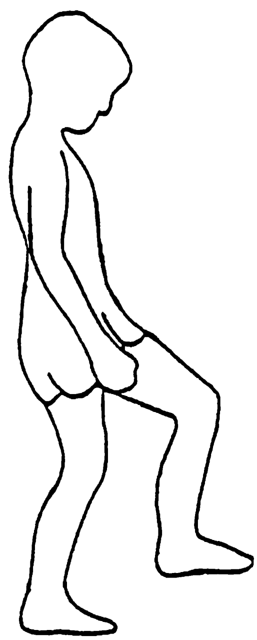
5. Prior to Lift Off



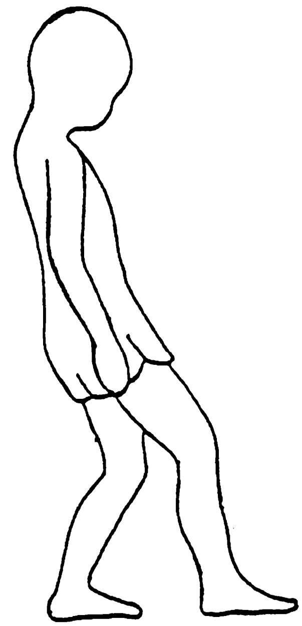
6. Lift Off

Appendix O

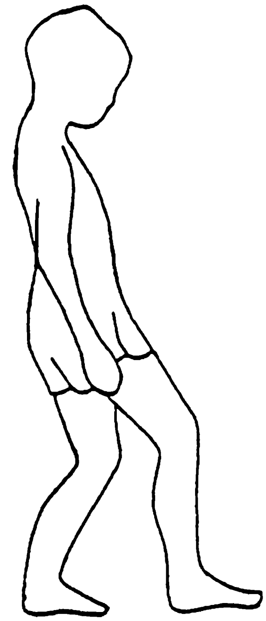
SELECTED DRAWINGS, SUBJECT THREE (CLUMSY +1)
(FORWARD FOOT STRIKE)



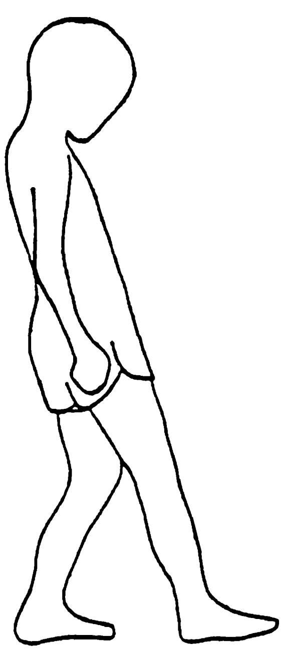
1. Uplift



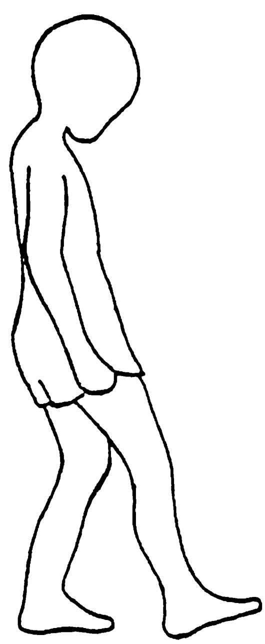
2. Prior to Strike



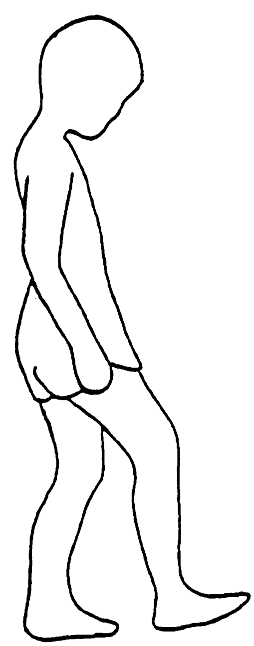
3. Contact



4. After Strike



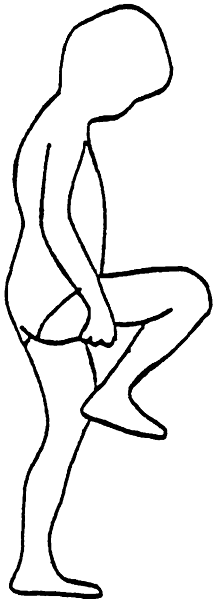
5. Prior to Lift Off



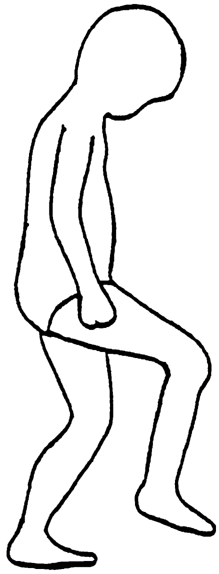
6. Lift Off

Appendix P

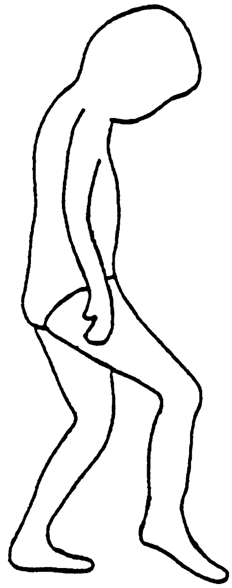
SELECTED DRAWINGS, SUBJECT FOUR (CLUMSY +2) (FORWARD FOOT STRIKE)



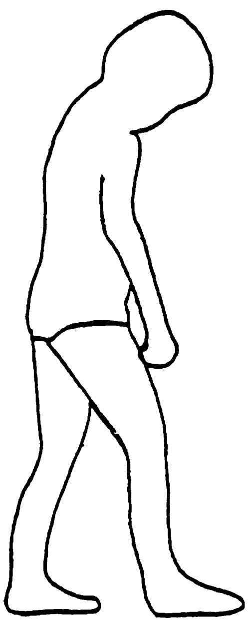
1. Uplift



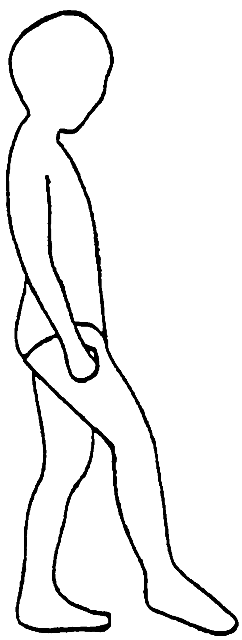
2. Prior to Strike



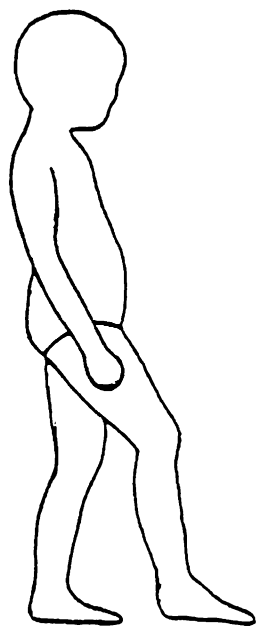
3. Contact



4. After Strike



5. Prior to Lift Off



6. Lift Off