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MASS MOVEMENT PATTERNS OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION: STABILITY AND PHASIC RELATIONSHIPS IN THE DEVELOPMENTAL SEQUENCE OF THE FORECEFUL OVERARM THROW IN CHILDREN

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ABSTRACT

MASS MOVEMENT PATTERNS OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION: STABILITY AND PHASIC RELATIONSHIPS IN THE DEVELOPMENTAL SEQUENCE OF THE FORECEFUL OVERARM THROW IN CHILDREN

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The purpose of this study was to determine the stability and phasic relationships established by the mass movement patterns of proprioceptive neuromuscular facilitation throughout the developmental sequence of the forceful overarm throw in children. The data consisted of simultaneous, two-view, 16 mm films of each subject performing one trial of a forceful overarm throw. A group of 91 boys and girls between 2 and 16 years of age were the subjects in the study. The subjects were mainly middle class, white, and threw with their right hands. Each subject was filmed individually while throwing a tennis ball as hard as possible against a brick wall.

The data reduction consisted of two procedures, each of which required a group of raters or judges. One procedure required that the 91 trials be classifed into the developmental stages of throwing. The other procedure required that the data be assessed for the presence of the MMP of PNF by a panel of judges. Rater objectivity and reliability were determined for both groups of

raters, based on the assessment and reassessment of 30 randomly selected subjects.

The interrater gamma coefficients for the stage recategorizations ranged from .87 to .99. The intrarater consistency ranged from gammas of .96 to 1.00 for the raters of the developmental stages. The interrater percentages of agreement, based on the modal MMP of each major body part during the preparatory phase, ranged from 46 percent to 93 percent. The intrarater consistency of the MMP raters ranged from 67 percent to 97 percent.

An acceptable objectivity criterion was set at a gamma of .85 or above for the stage categorizations and at a percentage of agreement of 67 percent for the MMP categorizations. Based on these criteria the stage raters' objectivity and reliability met the criterion. The MMP raters' reliability met the criterion, but their objectivity met the criterion for only four of the five major body parts.

The major question of this study was whether the MMP of PNF were consistent across the five developmental stages of throwing. It was hypothesized that this would occur. It was also hypothesized that the MMP would demonstrate stability within the developmental stages and that the modal MMP would display stability across and within the developmental stages. The criterion set for support of these hypotheses was 50 percent or more of occurrence. All four hypotheses were partially supported. The data indicated that the MMP and the modal MMP were consistent across the developmental stages in four of five major body parts. The data also indicated that the

MMP and the modal MMP were consistent within the developmental stages of four of five and three of five major body parts, respectively.

Another question of this study was to identify the modal MMP which emerged during each phase of the throwing performance. The following modal MMP emerged during the preparatory phase: flexion/rotation left for the head and neck; extension/rotation right for the upper trunk; D1 extension for the left arm, D2 flexion for the right arm; and extension/rotation right for the lower trunk. During the propulsive phase the following model MMP emerged: extension/rotation right for the head and neck; flexion/rotation left for the upper trunk; D1 flexion for the left arm; D2 extension for the right arm; and flexion/rotation left for the lower trunk. Finally, during the follow-through phase the following modal MMP emerged: extension/rotation right for the head and neck; flexion/rotation left for the upper trunk; D1 extension for the left arm; D2 extension for the right arm; and flexion/rotation left for the lower trunk. The modal MMP which emerged were consistenly similar for all four raters. Based on the apparent stability and inherent consistency displayed by the MMP of PNF in this study, the MMP of PNF or a modification of this system of movement classification may be a viable method for assessing the developmental sequence or stages of motor behavior.

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TABLE OF CONTENTS

Chapter		Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Research in motor development has dealt with motor behavior throughout the lifetime of an individual. One of the primary concerns of specialists in motor development has been the description of motor behavior. The description of movement has included the identification of the substrates of movement, referred to generally as basic or fundamental motor patterns.

The study of human movement should begin with an accurate description of the movement. Cooper and Glassow (1972) stated that since man has inherited his structure, function and nervous patterns, the study of human movement logically begins with an attempt to identify his basic patterns. Attempts to identify the basic motor patterns have been undertaken by researchers and practitioners in the areas of physical education, neurology and physical therapy. Some attempts at providing new information about man's movement include the identification of the developmental stages of motor skills, the role of movement in the integration of the central nervous system, and the use of reflexes and movement patterns to rehabilitate voluntary movement, respectively.

An accepted theory in motor development research is that human movement develops in stages. Thus far, the theory of stages in motor development research has been applied to "intra-skill" stages (Seefeldt, Reuschlein and Vogel, 1972) or "intra-task" stages (Halverson, Roberton and Harper, 1973). Future research is needed in the application of stage theory to the commonalities of movement patterns across motor skills (Seefeldt, 1972) or to "general motor stages" (Roberton, 1975). General motor stages refer to the consistency of movement characteristics across various motor skills. In general, the primary criterion used for the determination of motor skill stages has been the commonality of overt movement characteristics for selected body segments between performers.

There is a need for a more comprehensive and detailed approach to the study of the developmental stages of motor skills. Although past studies have made outstanding contributions to the understanding of the developmental sequences of many motor skills, these studies have limited their focus by describing the movement characteristics of selected body segments during selected portions of the performance cycle. Several investigators have suggested that there is a need to investigate, in detail, the progressive changes of the major body parts throughout the entire performance cycle (Fitts, 1964; Wellford, 1968; Kay, 1969, 1971; Higgins, 1977).

Interest in the organization of the nervous system has resulted in the study of the role that movement patterns play in the integration of the functional connections within the nervous system. By combining knowledge of neural function with the sequence of movement patterns, we may learn more about "motor control" programs. The use of reflexes, namely the tonic neck reflex, to pattern or sequence movement has been shown to be fundamental to the reestablishment of movement organization (Waterland and Hellebrandt, 1964; Magdol, 1969). Since the orderly emergence and progression of motor activities indicates a genetic control, perhaps a description of the relationships of movement patterns within the developmental sequences could provide clues to movement organization.

The role that reflexes play in the acquisition of movement has provided a source of interest in the identification of movement patterns. Bruner (1971) referred to the important role that reflexes may play in the early development of movement patterns. Numerous other reports have emphasized the importance of reflexes in the development of voluntary movement (Fukuda, 1961; Milani-Comparetti and Gidoni, 1967; Twitchell, 1965, 1971; Easton, 1977). Thus, it appears that the role of reflexes in the development of voluntary movement is an important aspect in understanding the continuum of motor development.

Reflexes have been used in the rehabilitation of patients, especially in the area of physical therapy, and therefore, have a prominent role in the history of therapeutic exercise. Reflexes were popular in the rehabilitation of movement because they are a form of patterned behavior and thus, a natural product of the orderly developmental process (Gesell and Amatruda, 1974). Since reflexes are engrained in the central nervous system, they should be used as the foundations of patterns for future movements (Fay, 1955).

The identification of movement patterns has theoretical as well as methodological implications for research in motor development.

Further insight into movement patterns may provide a technique for comparing activities which are predominantly phylogenetic or ontogentic. Movement pattern research may provide a better understanding of the underlying processes for movement regulation through observation of the movement itself (Higgins, 1977). It may support or refute the notion of a fundamental motor pattern of movement which implies that there is uniformity of movement organization which permeates a broad spectrum of performance situations (Higgins, 1977). This notion is similar to the question of general motor stages across motor tasks, raised by Seefeldt (1972) and Roberton (1977). The observation and measurement of movement patterns provides the means by which we can determine the nature of the spatial and temporal components of a skill and the effect of practice on the alteration of movement patterns over time (Spaeth, 1972; Higgins, 1977). From the instructional point of view, understanding what movement patterns are contributing to the total performance may provide further insight to the teaching of movement.

The literature in the area of physical therapy has identified a group of movement patterns described as the common denominators of many motor skills. These motor patterns have been referred to by various names, but are most commonly called spiral, diagonal patterns or the mass movement patterns (MMP) of proprioceptive neuromuscular facilitation (PNF). In several experiential reports, the MMP have been referred to as the common substrates of many motor skills, whether developmental, sport or activities of everyday living (Kabat, 1958; Knott and Voss, 1968; Voss, 1967; Schambes and Campbell, 1973).

The MMP have also been used to pattern or sequence motor behavior for athletic performance (Kabat, 1958). Based upon this experiential evidence, this study was initiated to determine the stability and to identify the phasic relationships of the MMP of PNF in the developmental sequence of the overarm throw in children.

In brief, the motor development specialist has little information of a comprehensive and detailed nature concerning the description of movement patterns (for all contributing, major body parts) during the entire performance cycle of motor skills. Such information could assist in understanding the contributions of the major body parts to the movement patterns necessary for the acquisition of motor skills, provide more appropriate teaching cues and suggest a more detailed classification system for the sequential progression of motor behavior which may, in turn, improve the diagnostic ability of the teachers of movement. This study of movement pattern stability in the overarm throw was an attempt to advance theory and improve methodology in the field of movement analysis.

1.1 Terminology

The study of human movement has divided movement into two categories; namely, movement product and movement process. The difference between movement product and movement process has been cited in the literature a number of times (Hartson, 1939; Bowne, 1956; Glassow, Halverson and Rarick, 1965; Atwater, 1970; Halverson, 1971; Roberton, 1972, 1975). Movement product refers to an achieved outcome of a movement such as a score or time or distance. Movement process refers to the description of an overt movement (joint actions) to generate a movement product.

With a more detailed approach to movement analysis, the meaning of the term movement pattern has become less clear. Movement pattern has been used in this study to refer to those joint actions or combinations of joint actions associated with a major body part which appear during the performance of a motor skill in a specified direction. The movement patterns referred to in this study include those associated with the techniques known as "proprioceptive neuromuscular facilitation" which refer to "methods of promoting or hastening the response of the neuromuscular mechanism through stimulation of the proprioceptors" (Knott and Voss, 1968, p. 4). The movement patterns associated with proprioceptive neuromuscular facilitation (PNF) have been referred to as "mass movement patterns of proprioceptive neuromuscular facilitation," "facilitation patterns," "mass movement patterns of facilitation," "spiral and diagonal patterns," and "irradiation patterns." The description of the movement patterns or body configurations associated with a specific level of development will be referred to as the stage of development for a particular motor skill.

1.2 Statement of the Problem

The purpose of this study was to describe the stability and phasic relationships of the mass movement patterns of proprioceptive neuromuscular facilitation of children 2 to 16 years of age as they performed a forceful overarm throw. The "Developmental Sequence of

Throwing" used in the study were those identified by Seefeldt, after Wild (1937, 1938). See Appendix A.

The major question of the study was whether the mass movement patterns of proprioceptive neuromuscular facilitation occurred during the performance of the overarm throw. If so, did they show stability within or across the developmental stages of throwing? If not, did other movement patterns emerge and show stability within or across the developmental stages of throwing?

A secondary purpose of the study was to identify the phasic relationships of the mass movement patterns (MMP) of proprioceptive neuromuscular facilitation (PNF) across the developmental stages of throwing.

1.3 Hypotheses

Hypothesis 1: The MMP of PNF will show stability across the five developmental stages of throwing.[1]

Hypothesis 2: The modal MMP of PNF will show stability across the five developmental stages of throwing.[2]

Hypothesis 3: The MMP of PNF for a major body part will show stability within the five developmental stages of throwing.[3]

Hypothesis 4: The modal MMP of PNF for a major body part will show stability within the five developmental stages of throwing.[4]

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[1]Support for Hypotheses 1 and 3 will be claimed if 50% or more of each rater's observed patterns are MMP of PNF.

[2]Support for Hypotheses 2 and 4 will be claimed if 50% or more of each rater's observed patterns fall within the modal MMP.

[3]See Footnote 1.

[4]See Footnote 2.

CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of this study was to describe the stability and phasic relationships established by the MMP of PNF for children 2 to 16 years of age as they performed a forceful overarm throw. The purpose of this chapter is to synthesize the background information and research literature pertaining to the development of movement patterns associated with the overarm throw.

2.1 Views of Movement Patterns Within Motor Development

Motor development has dealt with the study of motor behavior throughout the lifetime of an individual. The study of sequential motor development became popular during the 1920's and 1930's (Gesell, 1929; Shirley, 1931; Halverson, 1933; Bayley, 1935). These studies produced a number of developmental scales based upon the observation of movement. In time, these observations of movement were extended to include performance measures and the analysis of fundamental motor skills. Correlational studies identified the relationships between physical growth measures and motor performance measures across age and sex variables. Subsequently, interest in the movement of children with learning problems emerged and movement became associated with the cognitive learning process.

The orderly and sequential development of motor behavior has been well documented. Observation of movement provided the basis for the developmental milestones and indicated developmental progress in early childhood (Shirley, 1933; Bayley, 1935, 1969; Gesell and Amatruda, 1947; Sloan, 1955; Frankenburg and Dodds, 1967). Reports of systematic observations of motor behavior resulted in the developmental sequences of locomotion (Halverson, 1933), throwing (Wild, 1937, 1938), prone behavior (Gesell, 1939), swimming (McGraw, 1939), jumping (Zimmerman, 1956; Waterland, 1967), various motor skills (Wickstrom, 1970) and catching (Seefeldt, et al., 1972). Although significant contributions to the field of motor development have resulted from all of the earlier studies, there still was not enough detail and precision in the observation of movement for a thorough understanding of the participating movement patterns throughout the entire performance cycle.

The concept that basic movement patterns are inherited and therefore, engrained in the central nervous system, has been suggested in the literature. Weiss (1941) stated that the basic patterns of coordination are inherently conceived within the central nervous system. The evolution of movement led Hines (1942) to identify motor synergies inherent in the developing organism and in lower primates which exquisitely coordinated the head, limbs and trunk to produce total movement patterns. Eckert (1973), in reference to the phylogenetic nature of various locomotor skills, stated that certain motor patterns are engrained in the central nervous system.

There appears to be ample evidence which suggests that reflexes are highly integrated with voluntary movement (Twitchell, 1965; Fiorentino, 1972). Paillard (1960) suggested that learning skilled movement comes from selecting and assembling motor combinations from pre-existing functional units (instinctive reactions embedded within the CNS). Ayres (1968) stated that the poor performance of preschool and primary grade children was in part due to the inadequate inhibition or integration of reflexive movements. Easton (1972, 1977) suggested that reflexes provide the raw material in the form of pre-organized acts which may represent all or part of voluntary movement.

The presence and contributions of specific reflexes to voluntary movement has been demonstrated by several investigators. In a study using animals, Magnus (1924) described various postural reflexes and stated that some, namely the tonic neck reflex (NTR) and the labyrinthine reflex, show definite participation in the formation of normal animal postures. Studies on human beings demonstrated the presence of the TNR and labyrinthine reflexes in the posture of newborn babies and the latent presence of those reflexes in adults (Luhan, 1932; Pacella and Barella, 1940; and Gesell and Amatruda, 1945). Other studies on the TNR have suggested that it may link movements of the arms and the shoulder girdle (Hellebrandt and Waterland, 1962). Hellebrandt and Waterland also concluded that various reflexes can be deliberately activated to reinforce commands to a muscle and thus combat fatigue.

Postural or attitudinal reflexes also display strong relationships to voluntary movement. Fududa (1961) stated that postural reflexes are the basic reflexes ruling the daily movements of normal human adults. He concluded that postural reflexes underlie, as reflex patterns, the various postures and quick movements in sports such as Judo, especially in cases where the maximal exertion of force is required.

Attitudinal or postural reflexes provide for the maintenance of upright posture in relation to the environment (Twitchell, 1965). In reference to upright posture, Zelazo (1972) demonstrated that stimulation of the walking reflex in the newborn leads to coordinated walking movements similar to adults. The postural reflexes can be observed in voluntary movement and, therefore, appear to be an integral part of it.

The patterning of motor behavior has been used in the field of motor development as a facilitator of cognitive development. Patterning, the assisted manual guidance of movement patterns, is based upon a hierarchical order of theoretically sequential movement patterns. According to a theory of patterning, the omission of specific skills will restrict proficiency in subsequent skills (Shirley, 1931; Delacato, 1959).

Programs based on the patterning of movement experiences have been developed which were intended to enhance cognitive development. These program originators have incorporated movement experiences of a general and specific nature in their programs. Examples of these programs include: the establishment of motor generalizations and movement perceptions (Dunsing and Kephart, 1965), perceptual-motor development based upon the integrity of the visual system (Getman and Kane, 1964), "Movigenics" (Barsch, 1967), and the establishment of hemispheric dominance based upon neurological organization (Delacato, 1963).

2.2 Views of Movement Patterns Associated with Therapeutic Exercise

Patterning with various movement combinations and reflexes has been used in the field of exercise therapy to restore function in patients with movement restrictions resulting from injury or various disabilities. The use of patterning in exercise therapy was influenced by the early studies of Gellhorn (1947), on movement patterns and their regulation. Also, it has been found that various reflexes can be deliberately activated to reinforce commands to another series of movement patterns (Hellebrandt and Waterland, 1962).

Studies on pattern analysis have found that progressively increasing stress can facilitate motor patterns. Waterland and Hellebrandt (1964) facilitated motor patterns derived from basic reflexes in this way. Waterland and Munson (1964) induced pattern expansion, the overshoot to related facilitating muscles, by exercise stress.

Pattern analysis has become a useful tool in human movement facilitation. Denny-Brown (1962) stated that pattern analysis of posture has been adopted as a procedure in the rehabilitation of patients. Pattern analysis has also been suggested as a useful tool in the analysis of athletic performance. Kabat (1958) and Knott and

Voss (1968) have identified an efficient natural movement pattern which can be used to pattern athletic performance. Kabat, Knott and Voss have referred to it as the "facilitating groove." Keogh (1970) suggested that various medical and educational approaches to movement or pattern analysis be studied carefully since they reflect some notion of normal motor development as the underlying basis for their diagnostic and treatment procedures.

Pattern analysis of motor development and its disorders has been the basis of rehabilitation efforts in therapeutic exercise. Early recognition of patterned motor behavior emanated from the field of developmental neurology (Schaltenbrand, 1925). Efforts to determine the atypical patterned response associated with various disorders influenced the development of motor behavior screening instruments for normal infants (Gesell and Amatruda, 1954; Koupernick, 1954; Andre-Thomas, Chesni, Saint-Anne Dargassies, 1960; Illingworth, 1960; Paine, 1960; Bobath, 1962; Ballea, 1963; Prechtl and Beintema, 1964; Milani-Comparetti and Gidoni, 1965). The use of patterning for specific disorders such as cerebral palsey has been well documented (Fay, 1948; Bobath, 1959, 1964, 1965; Milani-Comparetii, 1964; Paine, 1960, 1964; Twitchell, 1961, 1962, 1963).

Several neurophysiological methods have been introduced to influence the CNS in the facilitation of normal movement. In the area of reflex exercise therapy, it was pointed out by Licht (1958) that Kabat introduced the techniques of Proprioceptive Neuromuscular Facilitation (PNF) based on the works of Sherrington, von Bechterew, Pavlov, Magnus and others. Other physicians developed reflex techniques in exercise therapy. Fay used the amphibian reflex to reduce spasticity in cerebral palsied children and Hellebrandt used the crossed extension reflex to exercise one muscle and strengthen its contralateral mate (Licht, 1958). Thus, the breakdown of movement into its constituent patterns has received major emphasis in the field of exercise therapy.

The method of PNF was developed at the Kabat-Kaiser Institute over the years 1946 to 1951 (Knott and Voss, 1968). Kabat based his techniques upon the body of knowledge of neurophysiology and motor development. Many combinations of motions which were related to primitive patterns and the employment of the postural and righting reflexes formed the basis of the motor repertoire. Body part positioning was considered valuable since it helped to obtain a stronger contraction in the desired muscle groups. In early 1951, the most effective combinations of motion were identified as those which permitted maximum elongation of related muscle groups to allow the stretch reflex to be elicited throughout a pattern. The patterns were spiral and diagonal in character and very similar to normal functional patterns of motion and closely resembled movements used in sports and work activities. The patterns became basic in all the techniques of PNF and were called mass movement patterns (MMP) of PNF. According to Voss (1967), various other designations have been reported in the physical therapy literature describing these basic substrates as "facilitation patterns," "MMP of facilitation," "spiral and diagonal patterns," and "irradiation patterns." The spiral and diagonal character of the MMP was consistent with the spiral and rotary characteristics of the skeletal system.

According to the tenets of PNF, movements are specific and directed toward a goal (Knott and Voss, 1968). There are two diagonals of motion for each of the major body parts; the head and neck, upper trunk, lower trunk and the four extremities. Each diagonal has two patterns which are antagonistic to each other. Each pattern has a major component combined with two other components for each major body part. Therefore, each MMP is a 3 component motion. The three components include either flexion or extension, with adduction or abduction, and rotation right or left.

The PNF patterns of the upper and lower extremities are named for the three components of motion occurring at the proximal joints--the shoulder and hip. The intermediate joints in the extremities may either remain straight or they may flex or extend, and they remain consistent with the rotation and adduction or abduction occuring at the shoulder or hip. The distal components of motion also remain consistent with the proximal components. Each pattern has a "groove" or optimal diagonal line of movement during maximal contraction, determined by the structural locations and relationships of major muscle components.

The MMP have universal application in the techniques of PNF. MMP are used in exercise therapy as passive motion to determine the limitation in the range of motion, as free active motion, as guided active motion or as resisted motion. The goal of treatment in PNF is the coordinated performance of the patterns of facilitation through

a full range of motion and with a balance of power between antagonistic patterns of both diagonals of motion.

The techniques of PNF developed by Kabat grew in popularity in the field of exercise therapy. Kabat (1958) discussed the ways in which PNF techniques could be used to facilitate voluntary movements. The use of PNF patterns and associated techniques for patients with functional deficits of the central nervous system (CNS) promoted increased coordination and strengthened the range of motion in the disabled body parts (Knott, 1966; Knott and Voss, 1968). Shambes and Campbell (1973) stated that the cross-diagonal movement patterns of Kabat, Knott and Voss seemed to form the basis of man's motor inheritance since they are so universally observed in reflex, developmental, sport and motor activities of everyday living. They also suggested that practitioners and researchers in the areas of physical therapy, occupational therapy and rehabilitation medicine have found that patients with neuromuscular disorders can be successfully rehabilitated by teaching "diagonal" patterns such as those of PNF.

The techniques and patterns of PNF have been praised for their contribution to the area of movement rehabilitation. PNF has been considered valuable for its techniques and coverage of normal movement (Hollis, 1976).

Based upon Kabat's empirical evidence, PNF techniques were refined and became more effective in the rehabilitation of patients with various disorders. In two of his own studies, Kabat (1952a, 1952b) found that his PNF techniques enhanced and accelerated recovery of neuromuscular function in patients with paralysis, including

paraplegics. Magnus (1953) implied that PNF patterns constituted a positive therapy for the rehabilitation of hemiplegics. In the same year, Kabat and Knott (1953) suggested that the PNF patterns were a more effective treatment for paralysis than an isolated muscle therapy. Several studies found that the use of the PNF patterns in treatment enhanced the recovery and restored the normal movement functions in patients with rheumatoid arthritis (Ionta, 1960; Ault, 1960; Knott, 1964) and with amputated lower extremities (Knott and Mead, 1960).

The facilitation of movement patterns has been the focus of several studies on movement. In a study of sprint running, Carr (1971) concluded that the effects of the PNF technique to reverse the antagonistic muscle groups resulted in an increase in horizontal velocity but then had no effect in the angular velocity of the lower extremity. When studying the reaction times of the upper extremity, Nakamura, Saito and Viel (1973) found an increase in reaction time when the upper extremity was placed in a facilitating position compared to when it was placed in the anatomical position. PNF patterning was found, within limitations, to improve related movement and response times in an underarm throwing task (Surburg, 1977).

Specific techniques in the area of human movement are not without criticism. Kabat was criticized for implying that PNF was a magical force in the treatment of neuromuscular disorders (Bennett, 1961). More generally, Taft (1962) criticized all therapeutic approaches for patients with CNS disfunctions as being too costly, in time, effort and required training and for their inconsistent and limited effectiveness. The effectiveness of current neurophysiological

procedures and techniques were also criticized for the lack of systematic, rigorous and appropriately designed investigations (Gonnella, 1973).

Movement patterns described by numerous investigators show similarities to those described as PNF patterns. Early studies described movement patterns which has apparent similarities to those later identified by Kabat as the MMP of PNF (Riddoch and Buzzard, 1921; Walshe, 1923; Schaltenbrand, 1928; Weisz, 1938; Gesell, 1939). After Kabat identified and published reports on the MMP of PNF, other investigators identified movement patterns in their reports which had close similarities (Twitchell, 1951; Magnus, 1953; Simons, 1953). Further empirical evidence suggested that MMP of PNF were present in activities of everyday living and various sport activities (Kabat, 1950; Voss, 1967; Knott and Voss, 1968; Schambes and Campbell, 1973).

2.3 Movement Patterns in the Performance of the Overarm Throw

The movement patterns associated with the forceful overarm throw were chosen for this study since several cross-sectional studies using stages of development have been reported (Roberton, 1975) and since, according to Bunn (1955), throwing is second only to running as a common element in the various sport skills. Contributions to the body of knowledge on throwing have been completed on the age differences of certain movement characteristics, the effects of instruction on throwing performance, the comparative kinematic descriptions of performers and the formulation of developmental stages and their validation. In spite of the important contributions of the earlier and more current studies on throwing, a detailed description of the movement patterns involving all the major body parts during each phase and across the suggested stages of throwing is lacking. Therefore, the forceful overarm throw was chosen for this study.

Several investigators have attempted to identify the age differences in the throwing performance of children. In her classic study, Wild (1937, 1938) identified 6 types, later condensed to 4 stages, of throwing and associated them with children of a particular age group. Guttridge (1939) subjectively catagorized young children in throwing and found that greater proficiency was displayed by the older children. Eighty-four percent of the 6 year old children threw well. Jones' (1951) kinematic study on the throwing characteristics of children classified the throwing types by age and deduced that trunk rotation contributed the most to the production of force in the underarm throws. A comparison of "good" versus "poor" female performers 8-11 years of age described differences in greater range of motion (Singer, 1961).

The throwing patterns of normal and atypical children have been investigated and the age differences described in several studies. An analysis of the throwing patterns of elementary school children concluded that males had a greater range of motion because of greater reversed spinal rotation. Ekern (1969) implied that teaching techniques should emphasize coordinating pelvic and spinal rotation during the preparatory and propulsive phases. In a study of the throwing patterns of 110 mentally retarded children 7-12 years of age, Auxter (1973) used the participation of the number of body parts and the integration of the elements of the throw to determine the maturity of the patterns. Lerner (1975) classified the age differences of preschool children across several motor skills, including throwing, and classified them into developmental stages of throwing suggested by Seefeldt (see Appendix A) after Wild (1937, 1938). Although the developmental levels of throwing performance have been identified by age groups in several studies, sufficient detail in describing the associated movement patterns in the contributing body parts has been limited.

The effect of instruction on the learning of motor skills has been a controversial topic. Brophy (1948), who studied the throwing patterns of 9 college females, found that instruction improved performance as measured by the distance the ball was thrown and that the range of motion increased. In a study of kindergarten boys and girls, Hanson (1961) concluded that the children had learned to modify, with instruction, their patterns of the overarm throw. The correct pattern seems to develop in young children through practice and with instruction as they begin to throw for greater distance (Wickstrom, 1970; Glassow and Cooper, 1972). If motor skills are not taught, many children will not develop mature patterns of movement in many locomotive and manipulative activities (McClenaghan and Gallahue, 1978).

In a study to determine the most effective learning environment for teaching motor skills, Miller (1978) found that preschool boys and girls progressed more rapidly with instruction from a trained teacher of movement or the trained parent than in a free play situation. The measured their improvement based on their progress to a more mature stage of the particular motor skill.

Several investigators have stated that instruction is not a requisite to learning motor skills. Ames (1966) reported that behavior is highly patterned and structured and that much of a person's motor development unfolds from within, rather than being taught or imposed from the outside. Pikler (1968) and Flinchum (1971, 1975) stated that children will achieve motor skills naturally and therefore, progress in the stages of motor skill ability without instruction. However, Flinchum did suggest that teachers of movement should be able to recognize correctly executed motor patterns and be aware of reflex movements in order to understand the continuum of motor development.

Reference has been made to movement patterns in several kinematic studies on throwing. In studies dealing with the development and maturation or age differences in the throwing performance, the majority of movement patterns identified were associated only with selected body parts that occurred primarily during the propulsive phase (Wild, 1937, 1938; Jones, 1951; Singer, 1961; Glassow, Halverson & Rarick, 1965; Humphries, 1968; Ekern, 1969). In several studies dealing with a comparative kinematic description of performers at different skill levels, the results again dealt primarily with the movement patterns involved during the propulsive phase (Bowne, 1956, 1960; Collins, 1960; Lyon, 1961; Deutsch, 1969; Atwater, 1970; Toyoshima, Hoshikawa, Miyashita and Oguri, 1974). The findings for these studies indicated that the overarm throwing motion is generally comprised of pelvic rotation, spinal rotation, shoulder medial rotation, elbow extension and wrist flexion during the propulsive phase.

Movement patterns are a natural part of studies dealing with a description of the stages of a motor skill. Several attempts to identify the stages of throwing development have been undertaken (Wild, 1937, 1938; Deach, 1951; Hanson, 1961; Halverson and Roberton, 1966; Wickstron, 1970; Seefeldt, Reuschlein and Vogel, 1972; Leme, 1973; Cratty, 1975; Roberton, 1975; McClenahan and Gallahue, 1978). In general, the results from these studies have contributed valuable information about the performance of throwing. However, in the majorith of these studies and their descriptions, it is difficult to follow the major body part joint action sequences throughout all the phases of the performance cycle. One reason for this is that standard kinesiological nomenclature, as recommended by Rasch and Burke (1974), has not been used in the majority of these studies. Occasional movement patterns are cited, but the reader was left to interpret during which phase it occurred, in what direction it occurred and if it was the only contributing joint action for the particular body part. The sequence or flow of movement patterns was not followed throughout the full performance, since emphasis has clearly been on the propulsive phase. Emphasis has also been placed on selected body parts such as the trunk and throwing arm movements in the majority of studies.

The human body in motion is represented by a complex, interrelated series of movement patterns all working together to achieve a specific performance objective. A given purpose is not always accomplished with one and only one movement pattern (Cooper and Glassow, 1968). The entire body, including all of its parts, is contributing or influencing the performance in some way. Therefore, it is necessary to determine the movement patterns of all contributing major body parts throughout all phases of the performance of a motor skill if a thorough understanding of the movement contributions of the entire body is desired. In order to achieve a better understanding of the development of motor skills, it is essential to obtain a more detailed analysis of the movement process. This statement reinforces the findings of Hanson (1961), Roberton (1972) and Halverson, Roberton and Harper (1973); namely, that movement product scores may mask development at certain times in the life-span, and therefore, would not be an accurate indicator of young children's progress through the throwing stages.

There has been evidence for the need for greater detail in the analysis of the movement process as it relates to the performance of the motor skills. A stricter measure of the time sequence of the constituent parts is necessary to evaluate their contribution to the total skill (Fitts, 1964; Welford, 1968; Kay, 1969, 1971). According to Higgins (1977), much of the research in skill has failed to analyze carefully and meaningfully the very movements and skills we are attempting to teach. Higgins suggested that the similarities and consistencies of the movement elements at the macro and micro levels should be identified for an understanding of human movement. This requires that we place the parts of movement into a meaningful, integrated and useful form. If we are to follow these suggestions. the total body, including all the major body parts, needs to be analyzed and described in terms of joint actions and their direction. The analysis should also be conducted across all the phases of the

performance in order to understand the integration between the body parts throughout the entire performance cycle.

Too often, analyses of movement have focused on the highly skilled performer (Higgins, 1977). It is obvious that such an approach has limited application. According to stage theory, as applied to the development of motor skills, the pattern of movement differentiates as skill improves (Wild, 1937, 1938; Hanson, 1961; Halverson and Robertson, 1966; Seefeldt et al., 1972; Leme, 1973; Roberton, 1975). Insight can be gained by a more detailed task analysis of the components of the skills such as the joint action patterns of the major body parts involved (Ridenour, 1978). A system of classifying and identifying the actions of the performing body parts, as motor behavior matures, would be useful information for the teacher and researcher of human movement. In light of the literature associated with the role of movement patterns in the performance of a motor skill, the present study was undertaken.

CHAPTER III

METHODOLOGY

The purpose of this study was to describe the stability and phasic relationships established by the MMP of PNF for children 2 to 16 years of age as they performed a forceful overarm throw. The purpose of this chapter is to describe the procedures that were followed in obtaining the data and reducing them for a meaningful analysis.

3.1 Subjects

The subjects in this study were from the Early Childhood Program and the Motor Performance Study at Michigan State University. These two programs are part of a longitudinal study initiated in 1967 to provide a setting for research on the physical growth and motor performance of children. The primary criteria for the selection of subjects were that they be children of preschool to school age and that they perform the overarm throw in a right-handed fashion. The requirement of righthandedness alleviated the need to rearrange the filming situation for left-handed individuals. Records from the first data collection were analyzed for 110 subjects (56 males and 54 females). Their ages at the time of filming ranged from 2 to 16 years.

3.2 Filming the Subjects

3.2.1 Nature of the Data

Cinematography was chosen as the data collection tool because it permits one to qualitatively describe what has been captured on film. The data consisted of simultaneous, two-view, 16 mm films of each subject performing one trial of a forceful overarm throw. The filmed trial for each subject was analyzed according to the stage of development as determined by the "Developmental Sequence of Throwing" described by Seefeldt, after Wild (1937, 1938). (See Appendix A.) The trials were then analyzed for the presence of MMP identified by Kabat (Knott and Voss, 1968).

3.2.2 Filming Procedures

The location of the filming equipment used during all filming sessions is illustrated in Figures 3.1, 3.2 and 3.3. Two Locam, Model 51 cameras (25 mm lens; ASA 160 exposure time of 1/192 sec.; shutter angle of 120°; 64 frames/sec.) were operated from the front and side views. The two cameras were 25 feet from the performing area of the subjects and were placed at 90 degree angles to each other. Standardized filming procedures were followed. Additionally, an L-W Photo-Optical Data Analyzer was in operation during the filming sessions to muffle the sound of the cameras (Roberton, 1975). The cameras were switched on and off simultaneously by the camera operators on command. The timing device used was a series of lights desgined by R. Wells, Michigan State University, housed in separate frames for the two views, but synchronized with each other (Walton, 1970).

Key:

1. Performance area
2. Cameras (front & side)
3. Timing device
4. Film identification number board
5. Spatial reference markers
6. Filming backdrop
7. Projector
8. Backstop for the throws

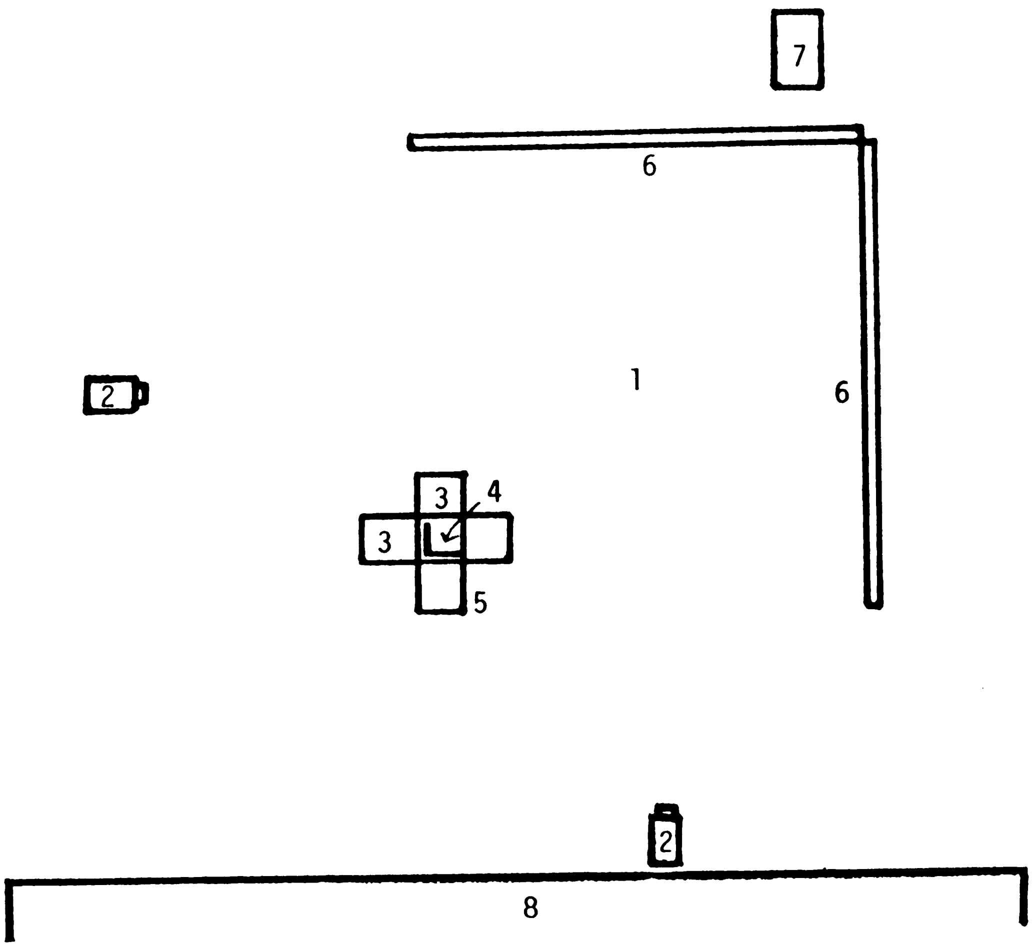

Figure 3.1.--Floor plan of filming equipment as seen from overhead view.

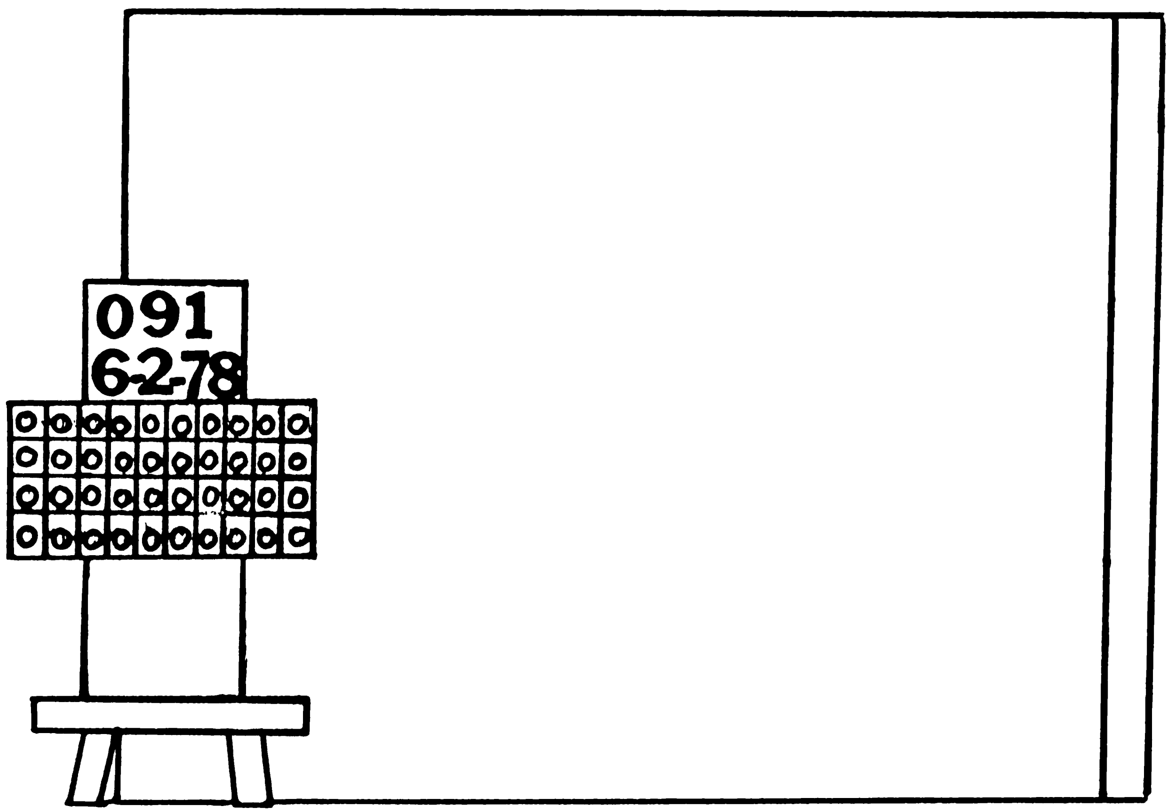

Figure 3.2.--Equipment included in front camera field of view.

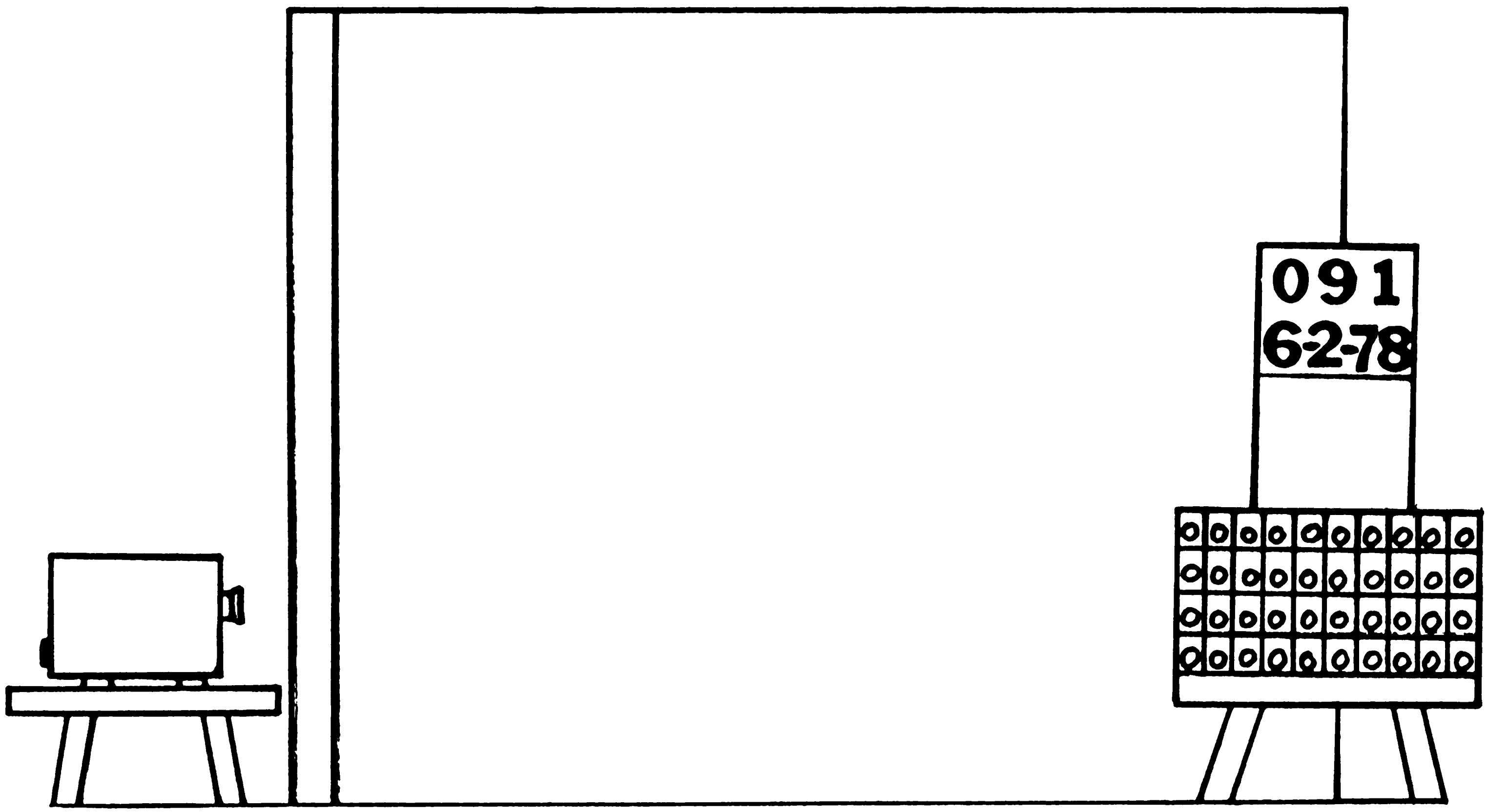

Figure 3.3.--Equipment included in side camera field of view.

The performance area was approximately a four feet by six feet section of concrete sidewalk. The subjects were free to move as they wished in the performance area, the only stipulation was that they throw as hard as they could toward a brick wall about 30 feet in front of them. The focal point for the cameras was located in the center of the performance area. Since the filming was done outdoors, natural light provided the illumination.

Each subject was filmed individually while performing a forceful overarm throw with a tennis ball against a brick wall until one trial was successfully recorded. To facilitate observation of the mass movement patterns of the major body parts, a body marking plan (see Figure 3.4) consisted of marking key bony projections with strips of adhesive tape and fastening marked elastic bands around the trunk at the upper chest, just below the level of the umbilicus and around the head at the forehead. The medial and lateral condyles of both upper extremities were marked by two one-half inch dots. An elastic band was fastened via shoulder support straps around the upper trunk just below the axilla regions. A similar elastic band was worn at the waist of each subject and around the forehead. The elastic bands gave an indication of trunk rotation characteristics during the performance.

After body markings were in place the subject was oriented to the filming set-up and procedures. The subject was directed not to begin a throw until a signal was given by the investigator. The signal to throw was given after the two cameras were in operation and functioning properly. After three practice throws, one complete trial

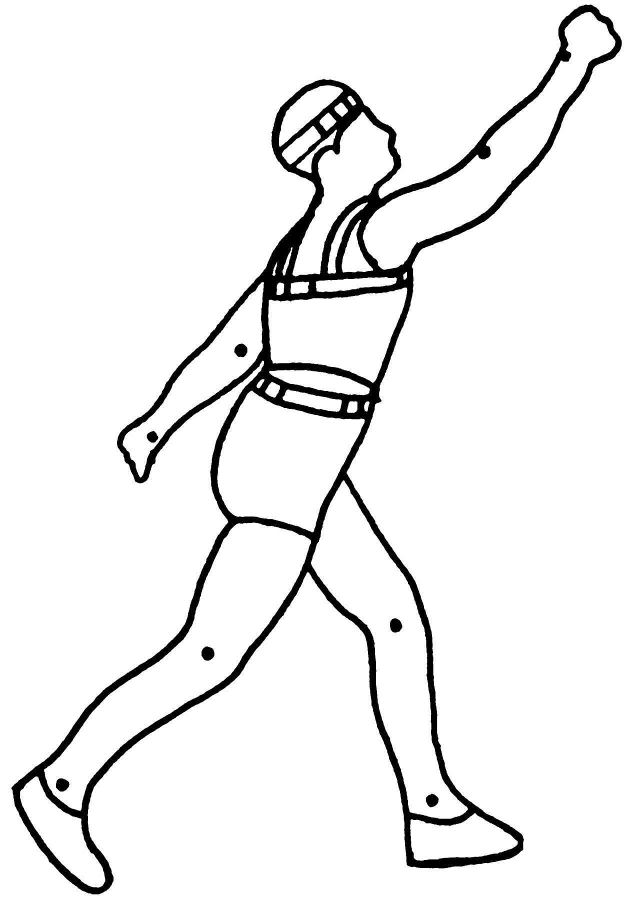

Figure 3.4.--Body marking plan showing eight different joint markings and three marked elastic bands for the head, upper trunk, and lower trunk.

was recorded on film. If a subject substituted another style of throw, he was asked to execute the overarm task and that trial was refilmed. The subject retrieved a ball from an area adjacent to the performance area for each trial. This was done to eliminate any stance which may have been imposed upon the performer by virtue of the ball placement within the throwing area. The subjects were repeatedly urged to throw the ball as hard as possible. No cues other than random praise were given.

3.3 Film Reduction

The available data consisted of 110 trials, 1 trial for each of the 110 subjects. The 110 trials were then classified into developmental stages by a panel of movement experts. The criteria for assignment to a stage of development based upon the "Developmental Sequence of Throwing" described by Seefeldt. (See Appendix A.) General guidelines for determining the stages were followed by the panel of movement experts to promote objectivity. The guidelines were similar to those identified by Roberton (1975).

3.3.1 General Guidelines for Determining Stages

1. The two views were projected for analysis alternately by two motion analyzer projectors.

2. The throw was considered to have begun two frames before any observable body movement. The moment was determined by the use of an electronic timing light device (Walton, 1970) in each field of view which displayed the elapsed time.

3. In order for a movement pattern within a phase to be considered present, it had to occur in at least two consecutive frames.

4. Movements that occurred but were not accounted for in the description of that stage were recorded by the panel member.

5. All subjects whose throw could not be classified by the criteria for determining stages were included in the study and designated as unclassified subjects.

3.3.2 Determination of the Stages

To distinguish between stages, several key questions were asked of each trial: (See Appendix A).

1. Was the throwing motion essentially in the sagittal plane with the feet stationary and very little trunk rotation occurring? If it was, the throw was categorized as Stage 1. If a step was taken with the ipsilateral foot coincident with the preparatory arm action, it was categorized as Stage 3. If a step was taken with the contralateral foot, it was categorized as Stage 4.

2. Was the throwing motion essentially in the transverse plane with the arm extended and the trunk rotated as one unit about an imaginary vertical axis? If so, the throw was categorized as Stage 2.

3. Was the throwing motion essentially one of an ipsilateral arm-leg action with little preparatory rotation of the spine and hips? If so, it was categorized as Stage 3.

4. Was the motion essentially one of a contralateral arm-leg action with little preparatory rotation of the spine and hips? Did the throwing arm move back and up, advancing over the shoulder in high wind-up during the preparatory phase? If the answer to both questions was 'yes', it was categorized as Stage 4.

5. Was the motion essentially similar to Stage 4 except for a downward and backward arc replacing the upward and backward arc of the throwing arm during the preparatory phase? Was there much more rotation/derotation of the shoulders, spine and hips throughout the motion. If the answer to both questions was yes, it was categorized as Stage 5.

3.3.3 Determination of the Mass Movement Patterns

After the determination of the stage of development, the data were independently assessed for the presence of mass movement patterns by a panel of three Registered Physical Therapists (RPT) and the investigator. Each RPT was an expert in the assessment of the mass movement patterns associated with the techniques of Proprioceptive Neuromuscular Facilitation (PNF) identified by Kabat, Knott and Voss (1968). A checklist (See Appendix B) was utilized by the RPT panel to identify the mass movement patterns appearing in each of the three phases of the overarm throw.

3.3.4 General Guidelines for the Identification of the Mass Movement Patterns

To promote objectivity, the guidelines for determining stages were also followed by the panel of RPT and the investigator. In addition, several other guidelines were followed.

1. All combinations of mass movement patterns occurring within one trial were considered as individual patterns and considered present.

2. All patterns that occurred, but were not considered mass movement patterns were recorded by the panel member.

3.4 Reliability

3.4.1 Stage Classifications-Observer Objectivity

In order to prevent potential investigator bias (Rosenthal, 1966; Rosenthal and Jacobson, 1968; Thorndike, 1968), a panel of experts in movement analysis assessed the developmental stage of the overarm throw for each subject. The investigator and the panel arrived jointly at the procedures listed on pages 28-30. To assess objectivity, agreement between judges was set at .85 or above as an acceptable objectivity criterion. Within-raters' reliability was determined by having each rater recategorize 30 of the same subjects two weeks after the data had been categorized by the panel.

3.4.2 Mass Movement Pattern Classifications-Observer Objectivity

A panel of RPT, experts in the mass movement patterns associated with the techniques of PNF and the investigator, assessed the mass movement patterns associated with the three phases, namely the preparatory, propulsive and follow-thru, of the overarm throw for each subject's major body parts. The RPT and the investigator arrived jointly at the procedures listed on page 31. In addition, a checklist to facilitate identification of the mass movement patterns by the RPT was designed jointly by the RPT and the investigator. (See Appendix B.) The determination of objectivity and within-raters' reliability for the RPT was similar to that obtained for the panel of movement experts classifying the stages of the overarm throw.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to determine the stability and phasic relationships of the MMP of PNF in the development sequence of the overarm throw in children. The results and discussion of the results of this study will be presented in this chapter. First, the subjects will be classified by age, sex and stage to identify the number of subjects per category. Next, the reliability and observer objectivity for the stage categorizations and the pattern classifications will be reported. Next, the results of the test of Hypotheses 1-4 concerning the stability of the MMP of PNF will be reported. Finally, the phasic relationships of the MMP will be identified.

4.1 Subjects

4.1.1 The Number of Subjects by Age, Sex and Stage

Initially, twenty subjects per stage were sought across the five developmental stages of throwing. One half of the twenty subjects per stage were to be male and one half were to be female. The subjects were initially screened for the study by stage and sex to ensure an equal number of males and females within each stage. However, after the majority of subjects had been filmed there was a low number of subjects in stage 2. This was in part due to the variability of performance between the initial screening and the filmed trials. Also, since a shortage of subjects did not occur in any of the other stages between the initial screening of the subjects' stage of development and the data collection procedure, stage 2 may be a more transient stage of development.

The original available sample consisted of 110 boys and girls from 2 to 16 years of age. Due to incomplete film sequences, the number of subjects had to be reduced from the original 110 subjects to 91. The age, sex and stage of the subjects are shown in Tables 4.1 and 4.2. The stage categorizations used for the comparison of the stability of the patterns were determined by randomly selecting one of the three raters' stage categorizations. The ages of three subjects, two girls and one boy, were unknown and therefore classified as age unknown.

The subjects were classified into 6 age groups for the purpose of limiting the total number of tables for the SPSS cross tabulation data analysis. Of the 91 total subjects studied, 46 were females and 45 were males. Three of the 91 subjects' ages were not obtained and therefore were classified under the "age unknown" column. There were 26 subjects in the 1-3 age group--11 females and 15 males. There were 32 subjects in the 4-6 age group--13 females and 19 males. There were 19 subjects in the 7-9 age group--15 females and 4 males. There were 8 subjects in the 10-12 age group--4 females and 4 males. Finally, there were 3 subjects in the 13-16 age group--1 female and 2 males.

Table 4.1.--Number of female subjects by age group and stage.

Age Group	Stage 1	2	3	4	5	Total
Unknown	0	1	1	1	0	2
1- 3	6	4	1	0	0	11
5- 6	3	2	3	3	2	13
7- 9	1	0	4	8	2	15
10-12	0	0	1	0	3	4
13-16	0	0	0	0	1	1
Totals	10	7	10	11	8	46

Table 4.2.--Number of male subjects by age group and stage.

Age Group	Stage 1	2	3	4	5	Total
Unknown	1	0	0	0	0	1
1- 3	6	3	2	4	0	15
4- 6	6	0	3	7	3	19
7- 9	0	0	0	0	4	4
10-12	0	0	0	0	4	4
13-16	0	0	0	1	1	2
Totals	13	3	5	12	12	45

The number of male and female subjects per age group and per stage from Tables 4.1 and 4.2 is summarized below. There were 23 subjects in stage 1--10 females and 13 males. Six of these 10 females were in the age group 1-3, 3 were in the 4-6 age group, and 1 in the 7-9 age group. Of the 13 male subjects identified in stage 1, 6 were in the 1-3 age group, 6 were in the 4-6 age group and the age of one of these male subjects was unknown.

Stage 2 had the smallest representation, with only 10 subjects. Of these 10 subjects, 7 were females and 3 were males. Of the 7 female subjects, 4 were in the 1-3 age group, 2 were in the 4-6 age group, and the age of one of the female subjects was unknown. The 3 male subjects represented in stage 2 were all in the 1-3 age group. As mentioned earlier in this chapter, stage 2 subjects were more difficult to find and seemed to move out of stage 2 behavior more quickly.

Stage 3 subjects numbered 15 in total and were represented by 10 females and 5 males. Of the 10 female subjects, 1 was in the 1-3 age group, 3 were in the 4-6 age group, 4 were in the 7-9 age group, 1 was in the 10-12 age group and the age of one of these female subjects was unknown. Of the 5 male subjects, 2 were in the 1-3 age group and 3 were in the 4-6 age group.

Stage 4 was represented by 23 subjects--11 females and 12 males. Of the 11 female subjects, 3 were in the 4-6 age group and 8 were in the 7-9 age group. Of the 12 male subjects, 4 were in the 1-3 age group, 7 were in the 4-6 age group and 1 was in the 13-16 age group.

Stage 5 was represented by 20 subjects--8 females and 12 males. Two of the 8 female subjects were in the 4-6 age group, 2 in the 7-9 age group, 3 in the 10-12 age group and 1 in the 13-16 age group. Of the 12 male subjects, 3 were in the 4-6 age group, 4 were in the 7-9 age group, 4 were in the 10-12 age group and 1 was in the 13-16 age group. In general, the data indicated an age trend with respect to the stage of development which is common to motor development research, namely, that the stage of development increases with age.

4.2 Reliability-Observer Objectivity

4.2.1 Stage Classifications

The subjects were analyzed on film and classified into one of five stages of throwing based upon Seefeldt's Developmental Sequence of Throwing, after Wild (1937, 1938). (See Appendix A.) A panel, including the investigator and two other judges experienced in observing filmed movements, arrived jointly at the procedures listed on pages 28-30. The three judges independently categorized all 91 subjects and recategorized 30 trials randomly selected from the data.

Goodman and Kruskal's (1954) gamma coefficient was calculated since the data were hierarchically ordered categorical variables. Interjudge agreements on subjective decisions made from film have ranged from 71.79% (Wild, 1937) to .754 (Leme, 1973) to .89 (Harper, 1975) and to .95 (Roberton, 1975). It seemed justifiable, therefore, to expect gammas of .85 or above for the stage categorizations as an acceptable objectivity criterion.

The interrater objectivity and intrarater reliability are shown in Table 4.3. The intrajudge consistency based upon recategorization of 30 trials randomly selected from the data ranged from γ=.96 to γ=1.00 for assignment of subjects to overarm throw stages. The percentages of agreement ranged from 90% based on 27 of 30 stage classifications to 97% based on 29 of 30 stage classifications for the 3 judges. The interjudge gammas calculated ranged from γ=.87 to γ=.99 for the 3 judges. Thus, it was at least 87% probable that comparison of two rankings by any two judges would reveal concordant ordering.

The judge reliability and objectivity met the criterion set for the stage categorizations. Since all stage categorizations were the result of repeated, independent viewings, the results can be considered relatively free of judge variability and therefore relatively consistent and objective.

4.2.2 MMP Classification

The subjects were analyzed on film and five of the subjects' major body parts (head and neck, upper trunk, left arm, right arm, and lower trunk) were analyzed for the presence of 1 or more MMP exhibited during a phase of the throw. All three phases, namely the preparatory, propulsive and follow-through, of the throwing performance were analyzed for each subject. A panel, consisting of the investigator and three Registered Physical Therapists trained in PNF techniques, arrived jointly at the procedures listed on page 31. The panel also designed a checklist (See Appendix B) of all possible MMP

Table 4.3.--Rater objectivity and reliability for stage categorizations in percentage of agreement and their corresponding gamma (γ) coefficients.

	Rater 1^1	Rater 2^1	Rater 3^1
Rater 1^1	...	83% $\cong \gamma \cong$ .94	87% $\cong \gamma \cong$
Rater 2^1	...	...	83% $\cong \gamma \cong$ .94
Rater 3^1	...	...	...
	Rater 1^2	Rater 2^2	Rater 3^2
Rater 1^1	97% $\cong \gamma \cong$ 1.00	80% $\cong \gamma \cong$ .91	90% $\cong \gamma \cong$ .99
Rater 2^1	83% $\cong \gamma \cong$ .91	90% $\cong \gamma \cong$ .96	87% $\cong \gamma \cong$ .95
Rater 3^1	83% $\cong \gamma \cong$ .99	87% $\cong \gamma \cong$ .92	97% $\cong \gamma \cong$ 1.00
	Rater 1^2	Rater 2^2	Rater 3^2
Rater 1^2	...	80% $\cong \gamma \cong$ .87	87% $\cong \gamma \cong$ .99
Rater 2^2	...	...	90% $\cong \gamma \cong$ .93
Rater 3^2	...	...	...

Note: Superscripts designate first^1 or second^2 stage categorization.

of PNF for each of the 5 major body parts under investigation, based on the text by Knott and Voss (1968).

Since the data consisted of unordered categorical variables, the percentages of agreement on the subjective decisions were calculated. Interjudge agreements on subjective decisions made from film using percentages of agreement were limited, but included is 71.79% (Wild, 1937). The criteria in earlier studies upon which the subjective decisions were made appeared less involved with respect to describing the overt segmental relationships of the contributing body parts during a selected segment of the performance cycle. Also, fewer numbers of body part movement relationships were described in fewer planes of movement. Therefore, conformity appeared to be relatively easier to obtain when compared to the present study. The present study assessed more body parts throughout the entire performance cycle and used a more difficult criterion; namely, the joint actions in three planes for one major body part, to assess the movement patterns of each of five major body parts. It seemed justifiable, therefore, to expect percentages of agreement of .67 or above for the MMP identification as an acceptable objectivity criterion.

Each of the four judges independently identified the presence of the MMP for 30 trials, randomly selected from the data. After 20 different trials were analyzed by each of the 3 RPT and 60 different trials were analyzed by the investigator, the 30 trials were re-analyzed by all the raters for the presence of MMP. The preparatory phase was randomly selected to be used to calculate percentages of agreement for reliability and objectivity. Since the number of

PNF pattern choices, other pattern choices and no perceptible movement choices numbered 74 on the checklist, the variables used to calculate the reliability and objectivity had to be limited. For this reason, it was decided jointly by the investigator and the dissertation chairperson to use the most frequently observed PNF pattern for each of the major body parts. Since the data revealed stability in this area across all judges, the same patterns were used for all judges. The PNF patterns used for calculating the reliability and objectivity included flexion rotation left for the head and neck, extension rotation right for the upper trunk, D1 extension for the left arm, D2 flexion for the right arm and extension rotation right for the lower trunk. (See Table 4.17)

The intrajudge consistency based upon the replication of the presence of five selected MMP during the preparatory phase for the five major body parts ranged from 67% to 97% (Table 4.4). The intrajudge percentages of agreement for the head and neck were 83%, 73%, 67% and 83%. The intrajudge percentages of agreement for the upper trunk were 90%, 90%, 93% and 70%. The percentages of agreement for the right (throwing) arm were 93%, 90%, 83% and 87%. And finally, the percentages of agreement for the lower trunk were 83%, 97%, 97% and 87%.

The interjudge consistency or observer objectivity across the same five variables during the preparatory phase for the five major body parts ranged from 46% to 93%. The interjudge percentages of agreement for the head and neck from the four judges were 53%, 70%, 73%, 63%, 46% and 70%. The interjudge percentages of agreement for

Table 4.4.--Rater objectivity and reliability for mass movement pattern assessment displayed in percentages of agreement.

Rater Reliability	Variables				
	Head & Neck	Upper Trunk	Left Arm	Right Arm	Lower Trunk
Rater 1	83	90	67	93	83
Rater 2	73	90	90	90	97
Rater 3	67	93	93	83	97
Rater 4	83	90	70	87	87
Rater Objectivity	**Variables**				
	Head & Neck	Upper Trunk	Left Arm	Right Arm	Lower Trunk
Percentages of agreement between 4 raters on 5 variables	53	90	83	83	73
	70	87	70	90	80
	73	87	73	83	70
	63	90	87	87	93
	46	90	90	87	77
	70	87	77	87	77

the upper trunk from the four judges were 90%, 87%, 87%, 90%, 90% and 87%. The interjudge percentages of agreement for the left arm from the four judges were 83%, 70%, 73%, 87%, 90% and 77%. The interjudge percentages of agreement for the right arm from the four judges were 83%, 90%, 83%, 87%, 87% and 87%. The interjudge percentages of agreement for the lower trunk from the four judges were 73%, 80%, 70%, 93%, 77% and 77%.

The observer consistency met the criterion set. In all cases the MMP ratings were the result of repeated, independent viewings; therefore, the results can be considered relatively free of observer variability and relatively objective.

The observer objectivity met the criterion set (67%) for four of the five major body parts. The exceptional body part was the head and neck. Three of the six interjudge percentages of agreement for the head and neck were less than 67%, they included 46%, 53% and 63%. The four other major body parts met the criterion set. These percentages of agreement ranged as follows: 87% to 90% for the upper trunk, 70% to 90% for the left arm, 83% to 90% for the right arm and 70% to 93% for the lower trunk. Although all of the major body parts did not meet the criterion set for observer objectivity, the results of those that did can be considered relatively free of observer variability and therefore, relatively objective.

4.3 Stability of Mass Movement Patterns

4.3.1 Stability of MMP Across the Developmental Stages--Testing Hypothesis 1

The major question of this study was whether the mass movement patterns remained the same across the five developmental stages. It had been decided apriori that support for the concept of MMP consistency would exist if at least 50% of each rater's patterns were MMP of PNF. Hypothesis 1 had predicted this would occur.

The data (Table 4.5) indicated that the MMP were consistent in 4 of the 5 major body parts across all four raters for all three phases of the throwing performance. The exceptional major body part was the left arm. It met the consistency criterion for 2 of 4 raters for all three phases of the throw and for another rater across two of the throwing phases. However, for one rater, the left arm did not meet the criterion of consistency for any of the three phases of the throw. Therefore, with the exception of the left arm, the major body parts met the criterion for consistency of the MMP.

Hypothesis 1 was partially supported. While one major body part did not meet the criterion for consistency, the other four did for all raters across all phases of the throw.

4.3.2 Stability of the Modal MMP Across the Developmental Stages Testing Hypothesis 2

Another significant question of this study was whether the modal MMP for each major body part would remain constant across the five developmental stages of throwing. The criterion measure of 50%

TABLE 4.5.--Percentage of occurrence for mass movement patterns observed across the development stages.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	95	96	98	100	100	100	100	86	95	88	100
Upper trunk	94	98	100	94	98	98	96	99	98	96	100	100
Left arm	46	75	60	98	44	74	75	95	44	61	46	91
Right arm	67	88	70	91	60	70	68	92	60	85	90	93
Lower trunk	84	85	95	92	94	95	94	88	94	98	100	88
Number of subjects (N)	50	51	50	91	50	51	50	91	50	51	50	91

was used to determine support for Hypothesis 2. Hypothesis 2 had predicted that the modal MMP would show consistency.

The data (Table 4.6) indicated that the modal MMP were consistent in 4 of the 5 major body parts across all four raters for all three phases of the throwing performance. The exceptional major body part was the head and neck. It met the consistency criterion for 2 of the 4 raters across all three phases of the throw, for the third rater across two phases, and for the fourth rater across one phase. Therefore, with the exception of the head and neck, the major body parts met the criterion for consistency of the modal MMP.

Hypothesis 2 was partially supported. As in the support of Hypothesis 1, four of the major body parts met the criterion for consistency of the modal MMP for all raters across all phases of the throw.

4.3.3 Stability of the MMP Within the Five Developmental Stages--Testing Hypothesis 3

A third question of this study was whether the MMP occurred within the five developmental stages. Again, if 50% or more of the patterns observed were MMP, support for the concept of MMP consistency would exist. Hypothesis 3 had predicted that this would be true.

The data (Tables 4.7-4.11) indicated that the MMP were consistent in 4 of the 5 major body parts across all four raters within stage 1. This within stage stability was exhibited for all 3 phases of the throw. The exceptional major body part was the left arm. It met the consistency criterion for 2 of the 5 raters for all 3 phases,

Table 4.6.--Percentage of occurrence for modal mass movement patterns observed across the developmental stages.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	65	38	70	85	84	92	73	83	59	46	40	81
Upper trunk	80	76	79	93	80	80	85	84	91	92	90	84
Left arm	91	60	69	67	68	61	64	64	87	71	54	73
Right arm	96	81	96	80	87	94	81	78	94	85	91	94
Lower trunk	74	67	72	81	71	81	88	92	89	80	89	95
Number of subjects (N)	50	51	50	91	50	51	50	91	50	51	50	91

Table 4.7.--Percentage of occurrence for mass movement patterns observed within Stage 1.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	78	67	91	100	100	100	100	83	93	85	100
Upper trunk	85	92	100	81	92	91	89	95	100	100	100	100
Left arm	22	64	38	89	33	64	71	96	57	69	70	92
Right arm	75	92	67	100	65	100	83	96	65	81	100	92
Lower trunk	73	93	73	72	88	83	80	71	73	100	100	90
Number of subjects (N)	15	13	13	23	15	13	13	23	15	13	13	23

Table 4.8.--Percentage of occurrence for mass movement patterns observed within Stage 2.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	100	100	100	100
Upper trunk	75	100	100	100	100	100	100	100	100	100	100	100
Left arm	0	0	43	100	0	33	80	100	0	67	22	60
Right arm	0	50	33	64	25	33	38	45	0	80	88	70
Lower trunk	0	100	100	100	33	100	100	90	33	100	100	60
Number of subjects (N)	3	3	6	10	3	3	6	10	50	51	50	91

Table 4.9.--Percentage of occurrence for mass movement patterns observed within Stage 3.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	75	100	100	100
Upper trunk	100	100	100	94	100	100	91	100	88	100	100	100
Left arm	38	50	50	94	28	57	50	95	12	60	58	100
Right arm	67	100	80	100	54	83	71	100	69	71	83	95
Lower trunk	83	100	100	95	100	100	90	93	67	80	100	87
Number of subjects (N)	6	5	8	15	6	5	8	15	6	5	8	15

Table 4.10.--Percentage of occurrence for mass movement patterns observed within Stage 4.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	93	100	80	100
Upper trunk	100	100	100	100	100	100	100	100	100	94	100	100
Left arm	45	71	62	96	33	74	85	93	36	62	60	92
Right arm	71	94	100	100	65	60	71	100	93	94	100	96
Upper trunk	85	91	100	96	100	94	100	86	91	100	100	95
Number of subjects (N)	16	16	15	23	16	16	15	23	16	16	15	23

Table 4.11.--Percentage of occurrence for mass movement patterns observed within Stage 5.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	86	90	82	100
Upper trunk	100	100	100	100	100	100	100	100	100	93	100	100
Left arm	63	88	83	92	80	100	87	96	14	50	12	96
Right arm	68	87	72	88	64	67	73	94	83	84	86	100
Lower trunk	100	62	100	100	100	100	100	100	100	100	100	91
Number of subjects	11	11	10	20	11	11	10	20	11	11	10	20

for 1 of the raters for 2 of the 3 phases and for 1 of the raters for 1 of the phases.

The data (Table 4.8) indicated that the MMP for stage 2 was the least consistent according to the criterion measure of all five developmental stages. The MMP were consistent in only 2 of the 5 major body parts across all raters for all 3 phases. The MMP were consistent for one other major body part across 3 of the 4 raters for all three phases. The most inconsistent major body parts during stage 2, in reference to the presence of MMP, were the left and right arm. For 2 of the raters each arm met the consistency criterion only once out of the three phases. For one rater the right arm only failed to meet the criterion measure during one of the phases. For the other raters neither the left nor right arm or the lower trunk met the criterion measure during any of the phases.

The data (Tables 4.9-4.11) indicated that the presence of MMP was consistent in 4 of 5 major body parts across all raters for all phases of the throw during each of stages 3, 4 and 5. The only major body part which did not display consistency was the left arm. Three of the four raters detected consistency for all major body parts for all phases for stages 3, 4 and 5 with one exception. One of the three raters noted that the left arm, during one phase of stage 5, did not meet the consistency criterion. Data of the fourth rater indicated that only in 2 of the phases in stage 5 was the MMP consistency criterion met.

Hypothesis 3 was partially supported for 4 out of 5 major body parts during stages 1, 3, 4 and 5. It was also partially supported for 2 out of 5 major body parts during stage 2. The left arm was inconsistent with respect to the occurrence of MMP during stages 1, 3, 4 and 5. Both the left arm and right arm were inconsistent for 3 out of 4 of the raters during stage 2.

4.3.4 Stability of the Modal MMP Within the Five Developmental Stages--Testing Hypothesis 4

Another question of this study was whether the modal MMP remained the same within the five developmental stages. If 50% or more of the patterns observed represented the modal MMP for that particular major body part during that phase, support for the concept of a modal MMP consistency would exist. Hypothesis 4 predicted this would occur.

The data (Tables 4.12-4.16) indicated that the modal MMP were consistent in 3 out of 5 major body parts during stage 1 for all raters for all three phases of the throw. Exceptions to this included one phase by one rater for the left arm and one phase by a different rater for the head and neck. Therefore, stage 1 was consistent with two exceptions.

Stage 2 data (Table 4.13) indicated that modal MMP consistency existed across 3 of the 4 raters on 3 of the 5 major body parts. Exceptions were indicated for the head and neck during 1 phase for 1 rater and for the left arm for another rater during a different phase. The other of the four raters only found consistency in 3 of the 5 major body parts during 1 of the 3 phases of the throwing performance.

Table 4.12.--Percentage of occurrence for modal mass movement patterns observed within Stage 1.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	73	54	100	80	75	90	100	87	60	50	18	83
Upper trunk	91	67	70	88	100	90	100	76	91	92	90	86
Left arm	100	55	67	71	75	22	60	54	75	89	86	88
Right arm	100	100	100	92	91	100	90	89	100	77	92	88
Lower trunk	88	69	75	85	100	100	88	93	100	83	90	94
Number of subjects (N)	15	13	13	23	15	13	13	23	15	13	13	23

Table 4.13.--Percentage of occurrence for modal mass movement patterns observed within Stage 2.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	100	100	100	100
Upper trunk	75	100	100	100	100	100	100	100	100	100	100	100
Left arm	0	0	43	100	0	33	80	100	0	67	22	60
Right arm	0	50	33	64	25	33	38	45	0	80	88	70
Lower trunk	0	100	100	100	33	100	100	90	33	100	100	60
Number of subjects (N)	3	3	6	10	3	3	6	10	3	3	6	10

Table 4.14.--Percentage of occurrence for modal mass movement patterns observed within Stage 3.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	75	100	100	100
Upper trunk	100	100	100	94	100	100	91	100	88	100	100	100
Left arm	38	50	50	94	28	57	50	95	12	60	58	100
Right arm	67	100	80	100	54	83	71	100	69	71	83	95
Lower trunk	83	100	100	95	100	100	90	93	67	80	100	87
Number of subjects (N)	6	5	8	15	6	5	8	15	6	5	8	15

Table 4.15.--Percentage of occurrence for modal mass movement patterns observed within Stage 4.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	93	100	80	100
Upper trunk	100	100	100	100	100	100	100	100	100	94	100	100
Left arm	45	71	62	96	33	74	85	93	36	62	60	92
Right arm	71	94	100	100	65	60	71	100	93	94	100	96
Lower trunk	85	91	100	96	100	94	100	86	91	100	100	95
Number of subjects (N)	16	16	15	23	16	16	15	23	16	16	15	23

Table 4.16.--Percentage of occurrence for modal mass movement patterns observed within Stage 5.

Major Body Part	Preparatory Phase				Propulsive Phase				Follow-Through Phase			
	Rater				Rater				Rater			
	1	2	3	4	1	2	3	4	1	2	3	4
Head and neck	100	100	100	100	100	100	100	100	86	90	82	100
Upper trunk	100	100	100	100	100	100	100	100	100	93	100	100
Left arm	63	88	83	92	80	100	87	96	14	50	12	96
Right arm	68	87	72	88	64	67	73	94	83	84	86	100
Lower trunk	100	62	100	100	100	100	100	100	100	100	100	91
Number of subjects (N)	11	11	10	20	11	11	10	20	11	11	10	20

Stage 2 data (Table 4.13) indicated that modal MMP consistency existed across 3 of the 4 raters on 3 of the 5 major body parts. Exceptions were indicated for the head and neck during 1 phase for 1 rater and for the left arm for another rater during a different phase. The other of the four raters only found consistency in 3 of the 5 major body parts during 1 of the 3 phases of the throwing performance.

Stage 3 data (Table 4.14) indicated that modal MMP consistency existed in 3 of the 5 major body parts for all raters across all phases. Exceptions were indicated for the left arm during 1 phase for 1 rater and for the head and neck during 1 phase for another rater.

Stages 4 and 5 also indicated that modal MMP consistency existed in 3 of the 5 major body parts for all raters across all phases. Two of the four raters indicated consistency across all 5 major body parts for all the phases. However, one of the other two raters only found inconsistency in the head and neck during 2 phases for both stages 4 and 5. The other rater found inconsistency in 2 phases for the left arm and 1 phase for the head and neck of the stage 4 performances and 1 phase for the left arm during stage 5.

Hypothesis 4 was partially supported for 3 out of 5 major body parts during stages 1, 3, 4 and 5. It was also partially supported for 3 of the 5 major body parts by 3 of the 4 raters during stage 2. Again the left arm and head and neck were the major body parts in which consistency of the modal MMP was lacking.

4.3.5 Phasic Relationships of MMP

The final question of this study was to identify the modal MMP which emerged in each phase of the throwing performance. The modal MMP was identified as the most frequently occurring MMP of each phase, by each rater, for each major body part.

The data (Table 4.17) indicated that the modal MMP for each phase were consistently the same for all raters. The modal MMP will be identified by phase in the following order: head and neck, upper trunk, left arm, right arm, and lower trunk. For the preparatory phase the following modal MMP emerged; flexion/rotation left, extension/rotation right, D/extention, D2 flexion, and extension/rotation right, respectively. The modal MMP for the propulsive phase included: extension/rotation right, flexion/rotation left, D1 flexion, D2 extension and flexion/rotation left respectively. Finally, the modal MMP for the follow through phase were comprised of extension/rotation right, flexion/rotation left, D1 extension, D2 extension and flexion/rotation left, respectively.

4.4 Discussion

4.4.1 The Number, Age, Stage and Sex of the Subjects

Research on throwing in the literature of motor development has generally supported two findings on the overarm throw. One, that the maturity of the performance increases with age, and two, that males generally have been in advance of females with respect to the maturity of the performance. The present study also concurs with both of these findings.

Table 4.17.--Modal mass movement patterns showing phasic relationships.

Major Body Part	Preparatory Phase	Propulsive Phase	Follow-Through Phase
Head and neck	Flexion/rotation left	Extension/rotation right	Extension/rotation right
Upper trunk	Extension/rotation right	Flexion/rotation left	Flexion/rotation left
Left arm	D-1 extension	D-1 flexion	D-1 extension
Right arm	D-2 flexion	D-2 extension	D-2 extension
Lower trunk	Extension/rotation right	Flexion/rotation left	Flexion/rotation left

Since the major question of this study was to determine the stability and phasic relationships of the MMP of PNF during the throwing performance, the age of the subjects was not a critical factor. However, a representative and equivalent number of both males and females within each of the five stages of development was of paramount importance. An attempt to ensure this situation was made by screening all subjects prior to the filming. Ten males and ten females of various ages between 2 and 16 years of age were identified for the study. However, after the majority of subjects had been filmed, it was discovered that the stage of development for several subjects had changed. This required the recruitment of 7 additional male and 3 female subjects for stage 2 and 5 additional male subjects for stage 3.

In spite of the additionally recruited subjects, the final numbers of male and female subjects was less than had been anticipated for stages 2 and 3. The fact that so many subjects changed stages of development within stages 2 and 3 led the investigator to suggest that perhaps stages 2 and 3 are more transitory stages than the others. The small number within each age, by sex, also prevented the test of significant differences between the sexes, within the various stages.

Another factor influenced the loss of subjects to some extent. A number of subjects anticipated the command to throw and therefore had partially completed their preparatory phase before the cameras had attained their required frames per second. This resulted in the loss of 19 subjects. Fortunately, this occurred in only 2 subjects at stage 2 and 1 subject at stage 3.

4.4.2 Reliability-Observer Objectivity: Stage Classifications

The rationale for using the five developmental stages of throwing chosen in this study was based on knowledge that they were modifications of those identified by Wild (1937, 1938). Although there are no substantiated stages of throwing, Wild's work remains the most definitive investigation to date.

4.4.3 Reliability-Observer Objectivity: MMP Classifications

Originally, the seven major body parts identified in Knott and Voss (1968) were chosen to be assessed for MMP of PNF in this study. Unfortunately, the legs had to be eliminated because the time to assess all of the MMP became prohibitive. The extreme difficulty of the leg assessment led to an excessive involvement of the raters and the project would have been in jeopardy if some reduction of their involvement had not been negotiated. Even with the present time requirements four of seven physical therapists discontinued the study.

The most difficult aspect of the MMP assessment for the legs was attempting to determine the joint actions while the legs were supporting the body's weight. The physical therapists were accustomed to assessing the MMP for the leg as a pendulum, swinging freely at the limp joint. Initially, the leg assessment alone required 50% of the time for the total body part assessment. Regretfully, the legs were eliminated from the assessment in order to preserve the remainder of the study.

A major concern in motor development research has been the cursory and nondescript nature of the movement patterns in studies which have attempted to identify fundamental motor skills. In an attempt to accomodate these concerns, this study made an attempt to identify the stability of the MMP for the majority of contributing body parts throughout the entire performance cycle. Therefore, the contributing major body parts were assessed for the presence of MMP throughout all the phases of the performance cycle.

One can only speculate with regard to the reasons for the raters' failure to meet the criterion set for observer objectivity for the head and neck. Perhaps the movements of the head and neck were subtle and therefore, more difficult to detect. Perhaps the head and neck as a body part displayed more variable movements than other body parts because the eyes were attempting to focus in various ways during a performance. Perhaps the eyes provided a misleading cue to the raters as they tried to assess the movement patterns of the head and neck. Perhaps there were more variable movements which occur in the head and neck as a result of the lack of instructed movement pattern cues. Whatever the reason, the head and neck emerged as a major body part which was difficult to assess with respect to its movement patterns during the overarm throwing performance.

4.4.4 Stability of MMP Across the Developmental Stages

The major question of this study tested the stability of the MMP across the five developmental stages of throwing. The data indicated that only the left arm failed to meet the criterion set for stability. However, when the phases were analyzed, the majority of movement patterns that were observed represented one or more of the component patterns of the modal MMP which emerged for that phase. In other words, in those cases when the criterion was not met, the movement patterns that were observed were components of the modal MMP for that particular major body part during that particular phase. To be considered a MMP, all three components had to be observed as contributing to the movement patterns. Even though the movement patterns which emerged could not be considered MMP, the majority of joint actions comprising the emerging movement patterns were components of the MMP which represented that particular major body part during that particular phase.

4.4.5 Stability of Modal MMP Across the Developmental Stages

The fact that the modal MMP for each of the three phases for all four raters was similar suggested an inherent consistency displayed by the MMP. However, the modal MMP for the head and neck failed to meet the criterion set for stability. As speculated earlier, perhaps the head and neck display more variability in movements, since this body part generally has been neglected in studies of movement. Instruction cues for this body part also seemed limited in texts describing movement. In general, the head and neck have received limited emphasis in studies on movement. Perhaps this has led to more experimentation on the part of performers and, therefore, more variability in the movement patterns displayed by this body part throughout the throwing performance.

4.4.6 Stability of the MMP Within the Five Developmental Stages

As was the case for the stability of the MMP across the developmental stages, the stability within the stages failed to meet the criterion measure for the left arm in the majority of cases. The reason for this lies with the interpretation of the movement pattern components by each of the raters. However, as in the stability across the stages, the movement patterns displayed were comprised of joint actions, the majority of which represented components of the modal MMP for that particular body part.

Stage 2 was the stage within which the least stability was displayed by the MMP. One possible reason for this could be the small number of subjects represented in stage 2. Again, as in the case with the left arm mentioned earlier, when other movement patterns were indicated, the majority of the joint actions identified were components of the modal MMP for that particular body part.

4.4.7 Stability of the Modal MMP Within the Five Developmental Stages

As indicated in the test for Hypothesis 2, the stability of the modal MMP across the developmental stages failed to meet the criterion set for the head and neck. This same outcome resulted regarding the stability of the modal MMP within the developmental stages. As speculated previously, there may be several reasons for this increased variability, including limited descriptive information and, therefore, limited instructional cues, which perhaps has resulted in increased experimentation on the part of performers.

Stage 2 again represented the stage that displayed the least stability of the MMP for the major body parts. Again, this may be due to the limited number of subjects who displayed stage 2 behavior.

4.4.8 Phasic Relationships of MMP

Perhaps the most important finding of the study, beside the overall stability displayed by the MMP was the identification of the modal MMP which emerged for each major body part during each phase of the throwing performance. Studies which have dealt with the description of movement have generally been too nondescript about how the movement was to be performed. The MMP which emerged for each major body part may assist in providing a guideline for the teacher of movement by suggesting a movement pattern to be expected throughout the performance. It should be remembered that the modal MMP which emerged were the same for all raters, by major body part within each phase.

Careful analysis of the modal MMP represented by phase and major body part in Table 4.17 suggests that some of the movement patterns do not change between phases. The movement patterns for four of five major body parts remains the same between the propulsive and follow-through phases. However, the movement patterns of the left arm did change between these two phases.

4.4.9 Other Observations

Some other observations evolved throughout the progress of the study. The range of motion for the same movement pattern appeared to increase as the maturity of the performance increased, i.e. stage 1 to stage 5. The number of contributing major body parts also appeared to increase as the maturity of the performance increased. For example, in stage 1 a typical performer may have had 3 or 4 major body parts contributing to the movement, whereas a typical stage 3 performer may have had 5 or 6 major body parts contributing to the performance.

Another trend emerged which suggested that the more mature performers displayed more than one movement pattern for a single major body part during one phase of the throwing performance. This phenomenon was especially true for subjects in stages 4 and 5. For example, one rater identified 2 subjects in stage 4 with 2 patterns for the left arm and 2 subjects in stage 5 with 2 patterns for the left arm, all of these during the preparatory phase.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The purpose of this study was to determine the stability and phasic relationships established by the MMP of PNF throughout the developmental sequence of the forceful overarm throw in children. The data consisted of simultaneous, two-view, 16 mm films of each subject performing one trial of a forceful overarm throw. A group of 91 boys and girls between 2 and 16 years of age were the subjects in the study. The subjects were mainly middle class, white, and threw with their right hands. Each subject was filmed individually while throwing a tennis ball as hard as possible against a brick wall.

The data reduction consisted of two procedures, each of which required a group of raters or judges. One procedure required that the 91 trials be classified into the developmental stages of throwing by a panel of three raters. The other procedure required that the data be assessed for the presence of the MMP of PNF by a panel of judges. Rater objectivity and reliability was determined for both groups of raters, based upon the assessment and reassessment of 30 randomly selected subjects.

The interrater gamma coefficients for the stage recategorizations ranged from .87 to .99. The intrarater consistency ranged from gammas of .96 to 1.00 for the 3 stage raters. The interrater percentages of agreement based upon the modal MMP of each major body part during the preparatory phase ranged from 46% to 93%. The intra-rater consistency for the MMP raters ranged from 67% to 97%.

An acceptable objectivity criterion was set at a gamma of .85 or above for the stage categorizations and at a percentage of agreement of 67% for the MMP categorizations. Based upon these criterion, the stage rater's objectivity and reliability met the criterion. The MMP rater's reliability met the criterion. However, their objectivity met the criterion for only four of the five major body parts.

The major question of this study was whether the MMP of PNF were consistent across the five developmental stages of throwing. It was hypothesized that this would occur. It was also hypothesized that the MMP would demonstrate stability within the developmental stages and that the modal MMP would display stability across and within the developmental stages. The criterion set for support for these hypotheses was 50% or more of occurrence. All four hypotheses were partially supported. The data indicated that the MMP and the modal MMP were consistent across the developmental stages in 4 of 5 major body parts. The data also indicated that the MMP and the modal MMP were consistent within the developmental stages in 4 of 5 and 3 of 5 major body parts, respectively.

Another question of this study was to identify the modal MMP which emerged during each phase of the throwing performance. The data indicated that the following modal MMP emerged during the preparatory phase: flexion/rotation left for the head and neck; extension/rotation right for the upper trunk; D1 extension for the left arm, D2 flexion for the right arm; and extension/rotation right for the lower trunk. During the propulsive phase the following modal MMP emerged: extension/rotation right for the head and neck; flexion/rotation left for the upper trunk; D1 flexion for the left arm; D2 extension for the right arm; and flexion/rotation left for the lower trunk. Finally, during the follow-through phase the following modal MMP emerged: extension/rotation right for the head and neck; flexion/rotation left for the upper trunk; D1 extension for the left arm; D2 extension for the right arm; and flexion/rotation left for the lower trunk. The modal MMP which emerged were consistently similar for all four raters. Based upon the apparent stability and inherent consistency displayed by the MMP of PNF in this study, the MMP of PNF or a modification of this system of movement classification may be a viable method for assessing the developmental sequence or stages of motor behavior.

5.2 Conclusions

In this section, conclusions about the two reliability procedures, the phasic relationships of the MMP and the stability of the MMP will be presented separately.

5.2.1 Reliability Procedures

The following conclusions are warranted as a result of the reliability procedures:

1. Four of five major body parts met the acceptable objectivity criterion measure set for the MMP categorizations.

2. All three stage raters met the acceptable objectivity criterion measure set for the stage categorizations.

3. When attempts are made to observe and rate the MMP of PNF of large numbers of children, (e.g., one hundred and ten in this study,) large amounts of time are required. Each subject required a period of time which initially took one hour, but gradually was reduced to fifteen minutes as the rater's efficiency improved.

5.2.2 Phasic Relationships of the MMP

With respect to the phasic relationships of the MMP, the following conclusions seem justified:

1. The modal MMP which emerged for each major body part during each phase of the throwing performance was consistent across the four raters.

2. Four major body parts had the same modal MMP during the propulsive phase and the follow through phase.

5.2.3 Stability of the MMP

The major question of this study was to determine the stability of the MMP of PNF during the developmental sequence of the overarm throw. The following conclusions are warranted as a result of the stability of the MMP:

1. The MMP of PNF displayed stability across the developmental stage of throwing.

2. The modal MMP of PNF displayed stability across the developmental stages of throwing.

3. The MMP of PNF displayed stability within the developmental stages of throwing except for stage 2.

4. The modal MMP of PNF displayed stability within the developmental stages of throwing except for Stage 2.

5.3 Recommendations for Further Research

The following recommendations may be of assistance in pursuing additional research:

1. A definite starting position such as the position of "attention" should be used with each subject to ensure a similar starting point, to save film and to preserve the entire performance on film.

2. A third camera would be helpful in capturing the movement patterns of the body parts on the non-throwing arm side of the body. For example, if three cameras were used one could be set up as a front view camera and two others could be side view cameras set up as the other two points of a triangle. A fourth camera, an overhead camera, could add accuracy to the rotary movements of the head and trunk.

3. A longitudinal study set up to measure the stability of emerging movement patterns would add valuable information to research in motor development.

4. The legs should be included in descriptive studies of movement pattern stability. Perhaps a simplified system of assessing the movement patterns of the legs can be developed to expediate the analysis so that the legs are included in future research.

5. Allow a sufficient time interval between performance commands to prevent anticipation of the start of the performance by the subject.

6. Investigators using these classification techniques should identify a surplus of subjects at each stage prior to the data collection to ensure an adequate sample size. Thus, if the developmental level or stage of performers changes, there will be a sufficient number of subjects available in each of the categories.

7. A combination of qualitative and quantitative data would permit a comparison of the kinematics with the stages and patterns of the descriptive methods.

8. The selection of subjects for future investigations of this nature should be made from normally distributed populations, to eliminate the possible biasing effect that instruction in the motor skills of our culture might have on their performance.

APPENDICES

APPENDIX A

DEVELOPMENTAL SEQUENCE OF THROWING

APPENDIX A

Stage 1 The throwing motion is essentially posterior-anterior in direction. The feet usually remain stationary during the throw. Infrequently, the performer may step or walk just prior to moving the ball into position for throwing. There is little or no trunk rotation in the most rudimentary pattern at this stage, but those at the point of transition between stages one and two may evoke slight trunk rotation in preparation for the throw and extensive hip and trunk rotation in the "follow-through" phase. In the typical stage one the force for projecting the ball comes from hip flexion, shoulder protraction and elbow extension.

Stage 2 The distinctive feature of this stage is the rotation of the body about an imaginary vertical axis, with the hips, spine and shoulders rotating as one unit. The performer may step forward with either an ipsilateral or contralateral pattern, but the arm is brought forward in a transverse plane. The motion may resemble a "sling" rather than a throw due to the extended arm position during the course of the throw.

Stage 3 The distinctive pattern in stage three is the ipsilateral arm-leg action. The ball is placed into a throwing position above the shoulder by a vertical and posterior motion of the arm at the time that the ipsilateral leg is moving forward. This stage involves little or no rotation of the spine and hips in preparation for the throw. The follow-through phase includes flexion at the hip joint and some trunk rotation toward the side opposite the throwing.

Stage 4 The movement is contralateral, with the leg opposite the throwing arm striding forward as the throwing arm is moved in a vertical and posterior direction during the "wind-up" phase. There is little or no rotation of the hips and spine during the wind-up phase; thus, the motion of the trunk and arm closely resemble those of stages one and three. The stride forward with the contralateral leg provides for a wide base of support and greater stability during the force production phase of the throw.

Stage 5 The "wind-up" phase begins with the throwing hand moving in a downward arc and then backward as the opposite leg moves forward. This concurrent action rotates the hip and spine into position for forceful derotation. As the contralateral foot strikes the surface the hips, spine and shoulder begin derotating in sequence. The contralateral leg begins to extend at the knee, providing an equal and opposite reaction to the throwing arm. The arm opposite the throwing limb also moves forcefully toward the body to assist in the "equal and opposite" reaction.

APPENDIX B

CHECKLIST: MASS MOVEMENT PATTERNS

APPENDIX B

Subject's Identification number ____ Subject's age ___ Subject's sex ___

Phase of the throw: Preparatory ___ Propulsive ___ Follow-through ___

Throwing arm: Left ___ Right ___ Rater's identification number ___

INDIVIDUAL PATTERNS

HEAD AND NECK		UPPER TRUNK	
1. Flexion/rotation left	___	1. Flexion/rotation left	___
2. Flexion/rotation right	___	2. Flexion/rotation right	___
3. Extension/rotation left	___	3. Extension/rotation left	___
4. Extension/rotation right	___	4. Extension/rotation right	___
5. Rotation left	___	5. Rotation left	___
6. Rotation right	___	6. Rotation right	___
7. Other ________________	___	7. Other ________________	___
8. No perceptible movement	___	8. No perceptible movement	___

UPPER EXTREMITIES

Left Arm		Right Arm	
1. D1 flexion/elbow straight	___	1. D1 flexion/elbow straight	___
2. D1 extension/elbow straight	___	2. D1 extension/elbow straight	___
3. D2 flexion/elbow straight	___	3. D2 flexion/elbow straight	___
4. D2 extension/elbow straight	___	4. D2 extension/elbow straight	___
5. D1 flexion/elbow flexion	___	5. D1 flexion/elbow flexion	___
6. D1 extension/elbow flexion	___	6. D1 extension/elbow flexion	___
7. D2 flexion/elbow flexion	___	7. D2 flexion/elbow flexion	___
8. D2 extension/elbow flexion	___	8. D2 extension/elbow flexion	___
9. D1 flexion/elbow extension	___	9. D1 flexion/elbow extension	___
10. D1 extension/elbow extension	___	10. D1 extension/elbow extension	___
11. D2 flexion/elbow extension	___	11. D2 flexion/elbow extension	___
12. D2 extension/elbow extension	___	12. D2 extension/elbow extension	___
13. Other __________________	___	13. Other __________________	___
14. No perceptible movement	___	14. No perceptible movement	___

Left Shoulder

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Internal rotation ___
6. External rotation ___
7. Other ___________ ___
8. No perceptible movement ___

Right Shoulder

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Internal rotation ___
6. External rotation ___
7. Other ___________ ___
8. No perceptible movement ___

Left Elbow

1. Flexion ___
2. Extension ___
3. Pronation ___
4. Supination ___
5. Other _________________ ___
6. No perceptible movement ___

Right Elbow

1. Flexion ___
2. Extension ___
3. Pronation ___
4. Supination ___
5. Other _________________ ___
6. No perceptible movement ___

Left Wrist

1. Flexion ___
2. Extension ___
3. Radial deviation ___
4. Ulnar deviation ___
5. Other _________________ ___
6. No perceptible movement ___

Right Wrist

1. Flexion ___
2. Extension ___
3. Radial deviation ___
4. Ulnar deviation ___
5. Other _________________ ___
6. No perceptible movement ___

Left Thumb

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Other _________________ ___
6. No perceptible movement ___

Right Thumb

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Other _________________ ___
6. No perceptible movement ___

Left Fingers

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Other ________________ ___
6. No perceptible movement ___

Right Fingers

1. Flexion ___
2. Extension ___
3. Abduction ___
4. Adduction ___
5. Other ________________ ___
6. No perceptible movement ___

LOWER TRUNK

1. Flexion/rotation left ___
2. Flexion/rotation right ___
3. Extension/rotation left ___
4. Extension/rotation right ___
5. Other ________________ ___
6. No perceptible movement ___

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