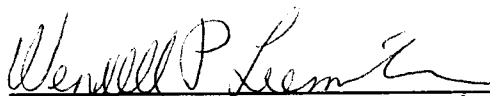


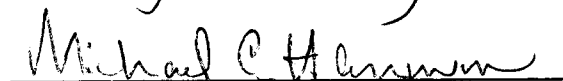
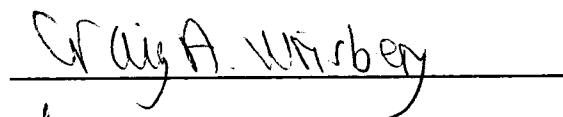
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AMBULATORY STATUS OF CHILDREN WITH CEREBRAL PALSY:
A RETROSPECTIVE STUDY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert C. Barnhart

August, 1992

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DEDICATION

..."whatever you do, do all to the glory of God." This thesis is dedicated to the glory of God, who has given life to all, both weak and strong.

ACKNOWLEDGEMENT

I would like to thank my wife, Sandra, for her support, love and encouragement during my studies. I would also like to thank my major professor, Dr. Wendell Liemohn for his guidance, ideas and availability at a moments notice. Heartfelt thanks also to the other members of my committee, Dr. Craig Wrisberg and Dr. Mike Hannum for their time and comments. I would also like to thank Dr. Joan Henry, formerly of the Bristol Township School District for her continual encouragement over the last seventeen years and Dr. Dennis O'Connell of The University of Texas Health Science Center at San Antonio for his friendship and for passing his desire on to me to be both a consumer and a producer of research. Finally, I would like to thank my families Mr. and Mrs. Richard E. Barnhart and Mr. and Mrs. T.A. Finch, for their love and support.

ABSTRACT

The purpose of this study was to examine the relationship between: (a) non-ambulatory status of children with spastic quadriplegia (SQ) and spastic diplegia (SD) at age 4 years with current ambulatory status and (b) non-ambulatory status among these children at age 7 years and ultimate development of independent ambulation. The physical therapy records of 26 students with a diagnosis of SQ or SD who met criteria to be included in the study were reviewed. Of the 21 children with SQ who were non-ambulatory at age 4 years, all continued to be non-ambulatory at 7 years and are currently non-ambulatory. Of the five children with SD who were non-ambulatory at age 4 years, two were non-ambulatory at 7 years and three are currently non-ambulatory. The two children with SD who were non-ambulatory at age 7 continue to be non-ambulatory. The results appear to indicate: (a) a relationship between non-ambulatory status at age 4 years and ultimate non-ambulatory status for children with SQ (b) no relationship between non-ambulatory status at 4 years and ultimate ambulatory status for children with SD and (c) remote prospects for the development of independent ambulation in children with SQ who are non-ambulatory at age 7 years. Further study is needed to determine whether children with SD who are non-ambulatory at 7 years ever acquire independent ambulation.

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CHAPTER 1

INTRODUCTION AND PURPOSE

Of the approximately 42 million Americans affected with neurological or communicative disorders, 750,000 (1.7%)¹ have a diagnosis of cerebral palsy. Cerebral palsy (CP) is defined as a non-progressive disorder of movement and posture secondary to an insult to the brain occurring^{2,3,4,5,6} prenatally, perinatally, or postnatally. The incidence of CP is estimated to be 1 out of every 500^{3,7,8,9} school-age children. The incidence of CP has not decreased over the last 10 years and may even be^{10,11} increasing.

CP is a disorder that affects the entire development of⁶ a child. However, the effect CP has on a child's motor development separates this disorder from other^{4,5,9,12,13} developmental and congenital problems.

The one developmental milestone which parents appear to focus on regardless of the neurological status of a child,^{14,15} is independent ambulation. Therefore, the diagnosis of CP in a child poses an immediate question among parents regarding the prognosis of independent^{5,12,16,17,18} ambulation. The question of independent ambulation is also a concern for physical therapists

who treat the child with cerebral palsy. Physical therapists are responsible for helping develop motor goals for the child with cerebral palsy and must know when independent ambulation is no longer an appropriate goal. Furthermore, as a result of Public Law (P.L.) 94-142, physical therapists have become members of the educational team of the child with cerebral palsy. Since P.L. 94-142 mandates an appropriate education for the child with special needs, the need to know when independent ambulation is no longer an appropriate goal becomes even more important for physical therapists.

Because the question of independent ambulation is a concern of both parents and physical therapists, the research questions of this thesis correspond to this concern and are presented as follows:

- (a) Is non-ambulatory status at age 4-years related to the ultimate ambulatory status of a child with spastic quadriplegia?
- (b) Is non-ambulatory status at age 4-years related to the ultimate ambulatory status of a child with spastic diplegia?
- (c) If a child with spastic quadriplegia is non-ambulatory at age 7-years does independent ambulation develop?
- (d) If a child with spastic diplegia is non-ambulatory at age 7-years does independent ambulation develop?

Formal Statement of Hypothesis

In the present study, a non-experimental retrospective approach was used in an attempt to test the following hypotheses:

- (a) There is no relationship between non-ambulatory status at age 4-years and ultimate ambulatory status in children with spastic quadriplegia.
- (b) There is no relationship between non-ambulatory status at age 4-years and ultimate ambulatory status in children with spastic diplegia.
- (c) There is no relationship between non-ambulatory status at age 7-years and ultimate ambulatory status in children with spastic quadriplegia.
- (d) There is no relationship between non-ambulatory status at age 7-years and ultimate ambulatory status in children with spastic diplegia.

CHAPTER 2

REVIEW OF LITERATURE

Types and Classifications of Cerebral Palsy

Seven types of CP are widely recognized; the types are spastic, athetoid, rigid, ataxic, tremor, atonic, and mixed. Mixed CP is further divided into spastic-athetoid, rigid-spastic, and spastic-ataxic. Spastic CP is the most frequently occurring type (91%).

CP is sub-classified based on the distribution of tone throughout the body. Diplegia refers to entire body involvement with legs more involved than the arms and all children with diplegia are spastic. In quadriplegia the entire body is affected. Unlike children with diplegia, children with quadriplegia can have athetoid, ataxic, flaccid, rigid, or mixed as well as spastic muscle tone. Children with hemiplegia have only one side of their body affected. Their muscle tone is usually spastic although a few cases of athetoid hemiplegia have been reported. Monoplegia is rare and involves only one extremity, usually an arm. Paraplegic CP is even more rare and involves only the legs.

Generally, the prognosis for independent ambulation

among children with spastic hemiplegia is thought to be
12,16,18,20,21
good. A good prognosis for independent
18,20
ambulation is also true for children with ataxia. A
poor prognosis for ambulation is given to children with
20
rigidity or flaccidity. The prognosis for independent
ambulation in children with spastic diplegia and
quadriplegia is more difficult to make because of the great
18,20
diversity of motor handicaps in these children.

Subjects in the current study were children with a
diagnosis of CP with spastic diplegia or spastic
quadriplegia. Developmental histories for these children
were acquired from the children's physical therapy files in
the Knox County Schools.

Effect of the problem

CP is probably the most common pediatric neurological
6
diagnosis referred to pediatric physical therapists.
Therefore, an accurate prognostic indicator of independent
ambulation in children with spastic diplegia or spastic
quadriplegia could be very helpful to physical therapists
in determining appropriate treatment goals. Knowing at what
age ambulation may no longer be a priority goal for a
non-ambulatory child would be very helpful to physical
therapists. Parents, physicians, teachers and other
professionals concerned with the welfare of these children

could also find the information useful for developing realistic expectations for the child's future functional status.

Characteristics of Spastic Diplegia and Spastic Quadriplegia

Children with spastic CP usually have increased deep tendon reflexes, a tendency to develop contractures and orthopedic deformities, and generally have delays in adaptive, social, language, and gross and fine motor skills.^{6,12,22} A child with spastic CP will have stereotypical patterns of postures and movements and primitive and tonic reflexes may be present.^{6,12,23} These children will also have poor development of the "postural reflex mechanism".⁶ The normal postural reflex mechanism enables humans to move efficiently and safely against gravity. It consists of normal postural tone , reciprocal innervation, and the large number of patterns of position and movement that are common to all humans.²²

Righting, equilibrium, and protective extension reactions may be poorly developed or even absent in children with CP.²³ Righting reactions provide humans a sense of head position in space, the alignment of head and neck with the trunk, the alignment of trunk and limbs, head

control, and rotation within the body axis. Equilibrium reactions are compensatory reactions resulting from stimulation of the labyrinths when the center of gravity is changed.²⁴ Righting and equilibrium reactions are the two main automatic reactions in the postural reflex mechanism. Protective reactions allow the body to protect itself from falling.²⁵ The protective reactions consist of two phases: (a) extension of the arms, wrist, and fingers towards the ground and (b) weight bearing on the extended arm and hand.²⁶

Children with spastic diplegia have more involvement in their trunks and lower extremities than in the arms and face and as a result their gait will be more affected than their hand skills.^{6,9,12} As infants they characteristically have tightness of their hip adductors, general spasticity of their legs; and visual, oral-motor, and speech difficulties.^{6,12}

Children with spastic quadriplegia are at greater risk for mental retardation, seizures, vision and hearing impairments than are children with spastic diplegia.^{6,12} Like children with spastic diplegia, these children have total body involvement but their arms are equally or even more involved than their legs. Because their high muscle tone can dominate their postures and movements, they may have little ability to move against gravity.⁶ Muscle

tone is often asymmetric in these children, causing secondary orthopedic deformities. A greater percentage of children with spastic quadriplegia tend to be non-sitters and non-ambulators when compared to children with spastic diplegia.¹² Because of their increased muscle tone and subsequent movement impairments, children with spastic diplegia and spastic quadriplegia are at risk for gait deficits and decreased ambulation ability.

Etiology of Cerebral Palsy

In 1862, Dr. William John Little described 47 children with muscle rigidity and hypothesized an abnormal birth process^{8.9} as the cause of the rigidity. More than 100 years after Little's observation, there is still relatively little known about the etiology of CP. Presently asphyxia, prematurity, and postnatal complications are hypothesized etiologies; their relationship will be discussed in this section.

In a retrospective study of 331 mixed race and 175 white children with CP, Arens found an exceedingly high incidence of CP among mixed raced children.²⁷ The author concluded that poor socioeconomic conditions may play a part in the etiology of CP. The same conclusion was made by Dale and Stanley in their epidemiological study of CP in

Western Australia. An interesting finding by Arens and associates was that many infants with abnormal birth histories have little or no impairment in later life.²⁷ This has been substantiated by the studies that follow. In their analysis of data from the National Institute of Neurological and Communicative Disorders and Stroke Collaborative Perinatal Project (NCP), Nelson and Ellenberg discovered that only 28% of mothers and infant pairs with the highest risk for complications produced a child with CP.¹¹ They also discovered most mothers with identified risk factors (mental retardation, proteinuria in late pregnancy, etc.) did not have a child with CP. In another study, of 45 patients with severe or variable fetal heart rate deceleration during labor, only one patient was diagnosed as "abnormal."⁸ The National Institute of Health Report on Causes of Mental Retardation and Cerebral Palsy also concluded that the majority of children with risk factors at birth later demonstrated no evidence of neurological dysfunction.²⁹

Many authors have associated low birth weight (LBW), prematurity and asphyxia with a greater incidence of CP.^{1,3,5,8,9,34} However, based on the data from NCP, Nelson and Ellenberg down played the importance of asphyxia as an etiological agent of CP. Only 21% of all cases of CP had one sign of asphyxiation.¹¹ Possibly one

explanation for the few cases of asphyxia is that during the years the data from the NCPP were collected (1959-1966), the procedure used to identify asphyxia in newborns was not as accurate as it is now, and many children with asphyxia may have gone undetected.⁹ When Apgar scores of children in the NCPP were analyzed, 57% of the children who survived with scores of 0-3 at 20 minutes were later diagnosed as having CP. An Apgar score of 0-3 at 20 minutes is associated with severe asphyxia.¹³ On the other hand, Apgar scores of 0-3 at 5 minutes were poor^{8,13} predictors of cerebral palsy. In fact, 75% of the cerebral palsy cases in the NCPP study had Apgars of 7 or more at 5 minutes.¹¹ Thus it would appear severe asphyxia (apgar of 0-3 at 20 minutes) may be an etiological indicator of cerebral palsy.

Prematurity and/or low birth weight appears to be an accurate prognostic indicator for CP. Once labor begins, a gestational age of less than 32 weeks is a powerful predictor of CP.¹¹ Presently there is uncertainty whether preterm infants are at greater risk because of the factors causing a premature birth or complications secondary to a preterm birth.¹³ As many as 50% of all low birth weight infants experience brain hemorrhage postnatally.¹³ However, when data from the NCPP were analyzed, 67% of the children with CP weighed 2500 grams or more at birth.¹¹

How accurate was Little when he related an abnormal birth process with a high incidence of CP? Data from the NCPP study have shown no factors in labor or delivery were accurate predictors of CP.¹¹ In order for a perinatal factor to be considered a cause of CP, the factor must be analyzed independently of any other complication. For example, breech births are often identified as a risk factor for CP; however, breech presentations are considered more powerful predictors.^{9,11} For infants weighing more than 2500 grams the risk of CP related to perinatal complications is less than 2%.¹¹ When the 10 highest risk factors were present at the onset of labor, those infants at the highest risk were responsible for only 34% of the cases of CP.¹¹

Prematurity and severe asphyxia at birth appear to be high risk factors for CP; however little is presently known about the etiology of these events.⁸ Spastic diplegia appears to be related to the problems surrounding a premature birth while spastic quadriplegia is frequently related to birth asphyxia or a grade 3-4 intraventricular hemorrhage.^{6,13} Table 1 contains a list of currently known risk factors and the approximate contribution of each to the current number of CP cases; it must be interpreted

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TABLE 1: DISTRIBUTION OF CAUSES IN CEREBRAL PALSY

Causes	Percent
1. Low birth weight, pre-term birth	35% to 40%
2. Perinatal asphyxia in term infants	25% to 30%
3. Congenital and perinatal infections (CMV, rubella, toxoplasma, neonatal meningitis)	5% to 10%
4. Intrauterine ischemic events	5% to 10%
5. Congenital brain anomalies not evident on clinical examination	5% to 10%
6. Perinatal metabolic conditions other than asphyxia (hyperbilirubemia, hypoglycemia, hyperosmolarity, amino acid disorders)	5%
7. Genetic origin	2% to 5%

in light of the fact that many risk factors interact with each other.

Because of recent developments in neonatal medicine, the conclusions from the data in the NCPP may no longer be applicable. Data from recent births needs to be analyzed and compared with the data from the NCPP to evaluate whether or not the conclusions from the NCPP are still warranted.

Development of Gait

Gessell stated that the normal child does not need to be taught to walk because the urge to assume upright posture and step forth is part of development.¹⁶ This discussion of the development of gait will include the determinants of mature gait, characteristics of the toddler gait, prerequisites of the developmental skills for gait, and pre-gait developmental skills CP may interfere with that ultimately may affect the child's future ambulation status. Table 2 includes a brief summary of common developmental milestones identified by various authors.

The determinants of mature gait are cadence, step length, walking velocity, duration of single limb support,³⁰ and the ratio of pelvic span to ankle spread.³⁰ These components of mature gait usually are present in a child between the ages of 3 and 3 1/2 years.^{30,31} In order for

TABLE 2: AGES OF SELECTIVE DEVELOPMENTAL MILESTONES BY AUTHOR

Authors	Head Control	Rolling Prone- Supine	Rolling Supine- Prone	Sitting	Assume Sitting	Walking
Ill'worth ³⁹	5 mn	6 mn	7 mn	8-9 mn	10 mn	13 mn
Largo ⁴⁰	-----	5.3 mn M	6.8 mn M	--	9.5 mn M	13.4 mn M
		5.4 mn F	6.4 mn F		9.1 mn F	13.5 mn F
Bayley ⁴¹	-----	--	6.4 mn	5.9 mn	--	11.7 mn
Neligan ⁴²	-----	--	--	9.3 mn	--	18.4 mn
Lowrey ⁴³	-----	--	--	10 mn	--	15 mn
Sutherland ³⁰	-----	--	--	6 mn	--	15 mn
Burnett ³³	-----	--	--	6.25 mn	--	12.6 mn
Tachjian ³¹	-----	--	--	6 mn	--	15 mn
Bly ²⁴	6 mn	5 mn	6 mn	8 mn	7-9 mn	--
Gessell ⁴⁴	5 mn	--	6 mn	9 mn	10 mn	15 mn

M = Male, F = Female

mature gait to develop, a number of skills during the first year of life must occur. A child's motor skills develop in a cephalo-caudal and a proximal-distal direction; therefore, the development of head and neck control is an important milestone to evaluate in any child with ambulation problems.^{15,24} Normal head control consists of the ability to extend in prone, flex in supine, and laterally flex against gravity in sidelying.²⁴

The development of the Landau reflex is another important early foundation for independent ambulation. The Landau can be seen when the child is held suspended in prone and neck and spinal extension and often hip extension occur.²⁴ The child may also demonstrate the influence of the Landau when placed prone by engaging in "swimming."²⁴ Lack of adequate extensor tone in attempted standing could be a result of an absent or poorly developed Landau reaction.¹⁵ The Landau has been found to be absent in children with tonic reflexes and marked flexor spasticity; these are common characteristics of children with CP.²⁶

Another precursor of independent locomotion is spontaneous kicking which develops at about 1 month and peaks at 5 to 7 months of age.³² The reciprocal leg movements seen in spontaneous kicking are an example of reciprocal leg movements that occur in all nonhandicapped children.¹⁴

The ability to weight shift is an extremely important component of normal motor development; and head lifting in the neonatal period is the first step in its achievement.^{24,31} Five-month-old infants, while prone on their elbows, are able to reach forward with one arm while maintaining weight bearing on the opposite arm.²⁴ One reason infants can achieve this skill is the development of the body righting on head reaction which allows them to laterally flex their head and spine away from the weight bearing surface causing their weight bearing side to elongate, an important skill in the development of reciprocal ambulation.^{15,24}

The development of segmental rolling allows the shoulders and pelvis to move independently of each other.¹⁵ In mature rolling supine to prone, the weight bearing side will elongate and the weight bearing leg extends, adducts, and internally rotates; concurrently, the non-weight bearing leg will flex, abduct, and externally rotate.²⁴ Segmental rolling allows the lower extremities to develop movements independent of each other. This is important because the pattern the legs assume during rolling is very similar to the pattern they assume in gait. During gait the weight bearing hip extends and the non-weight bearing hip flexes.³⁰

Segmental rolling is also a precursor skill for

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the assumption of sitting or standing from supine.

Between the ages of 6 to 10 months the infant is able to sit independently (Table 2). Independent sitting requires good trunk control including equilibrium and protective reactions.^{15,24} Once increased trunk control is developed, the baby's legs are used less often for stability and can now begin to move independently of the body.^{4,24} The good head and trunk control needed for sitting also permits the infant's upper extremities to move independently from the rest of the body. This is important for future reciprocal ambulation.

Between the ages of 7 to 10 months the infant will begin to pull to standing (Table 2). Around 11 months trunk and leg control are sufficient for independent standing.²⁴ Initially, the child uses a wide base of support to help maintain standing balance.²⁴ By 12 months equilibrium reactions are present in all positions except standing. At this time the child may attempt to walk with support.^{24,30,31} This initial wide base of support also occurs in early gait.^{14,30,31,33} Independent ambulation generally appears between 13 to 15 months. The infant gait is characterized by a wide base, high cadence (180 steps/minute), decreased stance phase, hip and knee flexion during stance, decreased ankle control, and absence of reciprocal swing in the arms.^{14,30,31} As the child's control and balance improve, walking slowly becomes more

adult-like. The base of support narrows, hip and knee extension increases, cadence decreases, single limb stance increases, walking velocity increases, and heel strike and reciprocal arm movements appear.^{14,30,31} When a child is between 5 and 7 years old, a mature gait pattern is present.^{14,30}

In summary, the development of mature ambulation in a child begins at birth and continues until the child is approximately 7 years old. Several early developmental milestones appear to play an important role in the development of gait. Since the child develops in a cephalo-caudal direction, the development of good head control is important. Walking involves weight shifting from one leg to the other; therefore, the ability to weight shift and elongate on the weight bearing side is essential. The influence of the Landau reflex on the development of adequate spinal and hip extension is important in the development of the upright position. However, the development of extension needs to be balanced by adequate flexor control.^{6,24} The development of good sitting balance is needed for good trunk control during gait. Once the shoulders, arms, trunk, pelvis, and hips can move independently of each other reciprocal gait is possible.

Prognostic Indicators of Independent Ambulation in Children With Cerebral Palsy

Researchers have been interested for many years in being able to predict future potential based on certain "signs" during infancy. Because of the importance attached to independent ambulation, there has been a great deal of interest in identifying developmental skills that will reliably predict future ambulatory status in children with CP. In one of the earliest studies, Beals evaluated surgical and nonsurgical factors that might influence ambulation in 93 children with spastic paraplegia and diplegia whose ambulatory status at age 7 years was known.³⁴ Developmental information at 3 years of age was gathered from each of the children's medical records. The information was then scored based on a nonstandardized motor test used at the author's medical clinic. This score, which could range from 0 to 36, represented the severity index for each child which later was correlated with the child's ultimate ambulatory status. Sixty children had a severity index of 12 or more; all of these children were independent in ambulation by age 7 years. Fourteen children had indexes of 10 and 11; eight of these were independent in ambulation and six ambulated with crutches. Nineteen children had an index of less than 10; ten of these children walked with crutches and nine were

non-ambulatory. All children with an index above 9 were at least crutch walkers; those who had indexes below 4 were ultimately non-ambulatory. Beals concluded: (a) motor performance in children with spastic diplegia reached a plateau at 7-years-old, (b) all children who became independent ambulators did so by 6-years-old, while the ability to ambulate with crutches can be achieved as late as 10-years-old, and (c) motor development seems to decelerate in children with spastic diplegia between the ages of 6 and 7-years-old.

The study by Beals had several shortcomings including a failure to provide minimal parameters in the definition of free or independent ambulation. For example, it is possible that if a patient could walk two feet, that was considered free ambulation. The amount of physical therapy each child received was not mentioned. Finally, an uncontrolled bias may have been present in this study; in order to be included, a detailed developmental history had to be part of each of the children's medical records. Of the 1371 patients followed by the authors, only 93 met these criteria. Since the medical records of the 93 children involved in the study were more detailed, these children quite possibly could have had better medical care and follow-up than those subjects in the original subject pool.

In a study of 336 institutional clients at a hospital for the mentally retarded, delays in walking were seen in 129 subjects with CP.¹⁷ The ages of the subjects were between birth and 15-years-old. The age each subject first ambulated was recorded from hospital records or gathered from parental interviews. Intelligence levels were determined from the latest psychological assessment and current ambulatory status were determined by visual observation. The authors discovered 48% of the hospital population was non-ambulatory and only 9% of the subjects with CP could walk. All the subjects who walked after 7 years of age were severely retarded except those with CP. The subjects with CP also had the highest mean age of walking. A number of criticisms can be made of this study; principally the lack of specific information regarding: (a) case definition of CP, (b) reliability data regarding the method of diagnosis of CP, (c) the length of residence, and (d) expectations placed upon each subject to walk. With respect to the later, it is very possible that subjects with cerebral palsy could walk but were not given the opportunity because staff were afraid they might fall and injure themselves.

Bleck conducted a study to identify prognostic indicators for locomotion in children with CP.¹⁶ Seventy-three children with a diagnosis of CP, suspected CP, and delayed motor development were examined and

received follow-up therapy from 1958 to 1973. The ages of the children at the first examination were 10 to 54 months. Only four children were under 6-years-old when the study was completed. In order to be included in the study, each child had to be non-ambulatory at the first examination. One point was given for the presence of each of the following reflexes: (a) asymmetrical tonic neck reflex (ATNR), (b) symmetrical tonic neck reflex (STNR), (c) moro, (d) neck-righting, and (e) extensor thrust. One point each was given for the absence of the foot placement and parachute reaction. Thus, each child could have a total score of 0 through 7 based on the number of reflexes present or absent. The author found that, of 49 children with a total score of zero, 46 were ambulatory. Ambulation was defined as the ability to walk independently for at least 15 meters over level surfaces, with or without crutches. All seven of the children who had a total score of one were ambulatory, although five ambulated with crutches. Sixteen of 17 children who scored 2+ were non-ambulatory and they were either diagnosed with spastic or tension athetoid quadriplegia. Of the children who walked, 36 did so by age 4 years. Five children walked between the ages of 6 and 7 years and eight of the 14 who walked after age 5 years had a previous history of orthopedic surgery. The average ages of walking for those

who attained this skill were: (a) spastic hemiplegia - 27 months, (b) spastic diplegia - 47 months, and (c) triplegia, quadriplegia, athetoid, and ataxia - 54 months. Based on the data collected, Bleck concluded that the evaluation of postural and tonic reflex activity provided a good prognostic indicator for future ambulation with children who have CP and that the development of walking after age 7 years in non-ambulatory children with CP is remote. Unfortunately this study also had a number of variables that did not appear to be controlled and that could have biased the results. These included an absence of explicit criteria for assignment of children to the different types of CP and to the ambulator or non-ambulator groups. Also the definition of walking did not describe functional ambulation.

A similar study investigating the presence or absence of reflexes as predictors for future motor functioning was completed by Molnar and Gordon.¹⁸ They also studied the age independent sitting developed as a predictor of future ambulation status. Two hundred and thirty-three children with a diagnosis of CP had their motor development evaluated at 12, 18, 24, and 48 months of age. Each of the children were followed until they reached 11-years-old. The reflexes evaluated were: (a) moro, (b) ATNR, (c) STNR, (d) tonic labyrinthine (tonic lab), (e) positive supporting, and (f) the presence of predominate extensor patterns in

the lower extremities when in ventral suspension. Of the 233 children in the study, 184 (ages 3 to 11 years) were ambulatory and 49 (ages 8 to 11 years) were non ambulatory and were not expected to walk independently. Independent ambulation was defined as the ability to walk outdoors with or without the use of braces or crutches. Molnar and Gordon concluded: (a) all congenital hemiplegics walked by age 3 years, (b) all eventual ambulators sat independently by age 4 years, (c) all children with CP who sat independently by age 24 months eventually ambulated, (d) those children with CP not sitting by 24 months, but whose suppression of primitive reflexes occurred between ages 18 and 24 months would probably be able to walk, (e) 71% of the children with spastic quadriplegia eventually ambulated and, (f) 86.5% of the children with spastic diplegia eventually ambulated. Similar criticisms applied to the previous studies reviewed can also be applied to Molnar and Gordon's study. These include (a) lack of good case definition and diagnostic criteria and (b) insufficient identification of which categories of children received therapy and which did not.

Shapiro et al, analyzed the medical records of 152 profoundly mentally retarded individuals to identify factors that might affect the ability to walk. ³⁵ Subjects were assigned to one of six groups: (a) profound mental retardation (PMR) with no other neurological disability, (b) PMR with seizures, (c) PMR and CP, (d) PMR and

associated genetic syndrome, (e) PMR with sensory deficits, and, (f) PMR secondary to acquired or degenerative diseases. Walking was defined as the ability to take six or more steps independently. Diagnosis of CP was determined by the presence of abnormal tone or posture, disordered movement, contractures, obligatory primitive reflexes, and pyramidal tract signs. If group (f) were excluded from data analysis, 53% of the subjects with PMR walked independently. However, only 10% of the subjects with PMR and CP ambulated. The median age of acquisition of ambulation in the subjects with PMR and CP was 63.5 months. The authors concluded that basic neurological integrity, not cognitive ability, is the important determinant in acquisition of ambulation.

Several criticisms can be made regarding this research project. The definition of walking as the ability to walk six steps independently is not functional. Data collection on each subject was done only to age 7 years; any individuals who acquired ambulation later were not noted in the study.

Babell-Ribera studied the rates and patterns of postural development in 50 children with CP to determine whether a reliable prognostic indicator for future ambulatory status could be developed.³⁶ All the children in the study were diagnosed as having CP between the ages of 6 and 18 months. These children were followed up for 4

to 16 years past diagnosis and all received physical until they were 5 to 6-years-old. The motor milestones evaluated in each child were: (a) placed sitting with pelvis support (b) placed sitting maintained with arm support (c) sitting from prone (W-sits) (d) symmetrical crawling (e) sitting from supine and (f) predominate pattern of reciprocal crawling. The attainment of these milestones was "correlated" with eventual ambulation patterns. Ambulation was classified as exercise ambulator, household ambulator low endurance, household ambulator high endurance, and community ambulator. After the data were collected and analyzed, the author concluded that the available motor control at ages 1 1/2 to 2 1/2 years was a predictor of future motor control. For example, all the children who were able to reciprocally crawl between the ages of 1 and 2 1/2 years eventually became community ambulators. Children who were only prop sitting (sitting with arm support) at ages 1 1/2 to 2 years were exercise ambulators. Like the study done by Molnar and Gordon, Badell-Ribera discovered that the majority of children with spastic diplegia attained some form of ambulation. Similar to previous studies reviewed, this study did not provide criteria for the diagnosis of CP. Unlike the other studies, specific definitions for the type of ambulation observed were given in the current study.

Seventy-four children with a diagnosis of CP were

followed up until they were 8-years-old by Watt et al .
All were graduates of a neonatal intensive care unit.
Follow-up visits occurred at 12, 24, 42, and 96 months of age. Four sets of information were recorded at each visit: (a) age of independent sitting, (b) clinical type of CP, (c) primitive reflexes present, and (d) absence of postural reflexes. Independent sitting was defined as the ability to maintain a free sitting position for an indefinite period of time. The clinical types of CP described were: (a) spastic hemiplegia, (b) spastic diplegia, (c) spastic quadriplegia, (d) athetosis, (e) ataxia, (f) hypotonia, or (g) uncertain. Primitive reflexes recorded were: (a) ATNR, (b) STNR, (c) moro, (d) tonic lab, (e) neck righting reflex, and (f) extensor thrust. Postural reactions recorded were the presence or absence of the foot placement and parachute reactions. At age 8 years, the ambulatory status for each child was determined. Children were described as community ambulators or non-ambulators. Community ambulation was defined as the ability to walk for 15 meters over level surfaces with or without bracing or upper extremity aides. Non-ambulation was defined as household or exercise ambulator. At age 8 years, 47 of the 74 children were community ambulators. Of those 47, only five walked requiring bracing or upper extremity aides. Twenty-seven children were described as non-ambulators. Five of the 27 were household ambulators, two used manual

wheelchairs, six used power wheelchairs, and 14 children just sat in their wheelchairs. All of the children with spastic hemiplegia walked by age 8 years. Ninety percent of the children with spastic diplegia walked at age 8 years. None of children with spastic quadriplegia walked. The authors found no significant difference between the ambulatory group and the non-ambulatory group with regard to neonatal variables with the exception of neonatal seizures. Seventy-four percent of the non-ambulatory children had seizures during the neonatal period. Only 38% of the ambulatory children had neonatal seizures. There was no significant difference in ambulatory status between those who had surgery and those who did not. There was also no significant difference between those who had physical therapy and those who did not. Only one child who sat after age 2 years eventually ambulated. Obligatory persistence of any one of the four primitive reflexes at age 2 years was also a good predictor of non-ambulatory status at age 8 years. The definition of community ambulation can be questioned since the ability to ambulate 15 meters over level surfaces was never determined to be a good indicator of the ability to actually ambulate in the community.

Research studying prognostic indicators for independent ambulation in children with CP has been reviewed. Similar conclusions among the studies reviewed were found. These conclusions were: (a) all children with spastic hemiplegia

eventually walk, (b) the majority of children with a diagnosis of spastic diplegia eventually walk, (c) children with a diagnosis of CP have delayed acquisition of ambulation regardless of the type of CP, and (d) acquisition of ambulation after age 7 years is remote in children with a diagnosis of CP. Similar weaknesses were discovered for each study. These weaknesses included (a) no case definitions for CP, (b) numerous uncontrolled variables that could influence the results, and (c) nonfunctional definitions for independent ambulation. Because of the weaknesses of the studies reviewed, further research is warranted to determine prognostic indicators of independent ambulation in children with spastic diplegia and spastic quadriplegia CP. Table 3 provides a summary of the weaknesses and conclusions of the studies reviewed.

TABLE 3: SUMMARY OF STUDIES REVIEWED

AUTHOR	N	PT	AMB	CP	MAJOR FINDINGS
Beals 1966	93	N	N	SD	motor plateau by 7 years, independent walking by 6 years
Donaghue et al 1970	129	N	N	NC	delays in acquiring walking for children with CP
Bleck 1975	73	N	N	SH SD Q	development of gait after 7 years remote
Molnar & Gordon 1976	233	N	Y	SH SD Q	all hemis walking by 3 yrs, all walkers sitting by 4 yrs 71% SQ ambulating
Shapiro et al 1979	152	N	N	NC	neuro integrity of child used as determiner of ambulation potential
Babell- Ribera 1985	50	Y	Y	SD	majority of children with SD attain some form of ambulation
Watt et al 1989	74	Y	N	SH SD Q	all SH walking all SD walking by 8 yrs no Q walking

PT = amount of services each subject received recorded

AMB = functional definition of ambulation given

CP = type of cerebral palsy studied

N = no

Y = yes

SH = spastic hemiplegia

SD = spastic diplegia

Q = quadriplegia of all types

NC = type of cerebral palsy studied not mentioned in article

CHAPTER 3

METHOD

Subjects

Permission was granted by the Knox County Schools and the University of Tennessee Committee on Research Participation to review the physical therapy records of students who are currently receiving physical therapy through the Knox County Schools. (The Appendix contains copies of permission letters.) All physical therapy records of students who are not involved in the Knox County School's pre-school program were reviewed by the author.

Procedure

Criteria selected for inclusion in the study were (a) documented diagnosis of cerebral palsy made by at least one physician, (b) type (spastic) and distribution (diplegia or quadriplegia) of muscle tone agreed upon by one physician and one physical therapist or by 2 physical therapists, (c) student age of at least 8-years, (d) documented evidence of non-ambulatory status at age 4-years, (e) documented ambulatory status at age 7-years, (f) documented current ambulatory status.

The following information was recorded on those subjects who met inclusion criteria: (a) diagnosis, (b) distribution and type of muscle tone, (c) years of physical therapy received (d) ambulatory status at age 4 and 7 years, and (e) current ambulatory status. Subjects were considered independent ambulators if ambulation was their primary means of mobility and a wheelchair was never used. To qualify for independent ambulation status use of^{16,37} crutches, walkers and/or braces was allowed. Subjects were considered non-ambulators if they were household or exercise ambulators or used wheelchairs for³⁷ mobility.

Data Analysis

Means, ranges and standard deviations were calculated for the ages and number of years of physical therapy received by the subjects.

CHAPTER 4

RESULTS

Two hundred and ninety-six students' physical therapy records were reviewed; only 26 of those 296 students met criteria for inclusion in the study. The most common reasons for exclusion were (a) wrong diagnosis, (b) student was independent in ambulation at age 4-years, and (c) inability to determine student's ambulation status from records (either status was not provided or records were incomplete or missing for ages 4 and 7 years). Table 4 provides a summary of the data gathered from each student's record.

Means, ranges and standard deviations for age and number of years of physical therapy received by each student are presented in Table 5. The mean age of subjects with spastic quadriplegia was greater ($\bar{X}=13.9$ vs. $\bar{X}=10.9$ years) and they had received on the average more years of physical therapy than the subjects with spastic diplegia ($\bar{X}=10.5$ vs. $\bar{X}=8$ years).

Data describing the type of cerebral palsy in relationship to ambulatory status at ages 4 years, 7 years, and current are presented in Table 6. Twenty-one students with spastic quadriplegia were included in the study. All

TABLE 4: DATA GATHERED FROM SUBJECTS (N=26)

SUBJECT NO.	SEX	DX	AGE	YEARS PT	AS4	AS7	CAS
1	F	SD	8.8	5	NA	NA	NA
2	M	SD	10.0	5	NA	NA	NA
3	F	SD	13.5	11	NA	IA	IA
4	F	SD	14.3	11	NA	IA	NA
5	M	SD	18.1	I	NA	IA	IA
6	M	SQ	9.2	7	NA	NA	NA
7	M	SQ	9.5	6	NA	NA	NA
8	M	SQ	9.7	8	NA	NA	NA
9	F	SQ	10.7	10	NA	NA	NA
10	M	SQ	10.9	9	NA	NA	NA
11	F	SQ	11.6	10	NA	NA	NA
12	M	SQ	11.10	6	NA	NA	NA
13	F	SQ	12.1	8	NA	NA	NA
14	F	SQ	13.1	I	NA	NA	NA
15	F	SQ	13.1	7	NA	NA	NA
16	M	SQ	13.11	11	NA	NA	NA
17	F	SQ	14.1	6	NA	NA	NA
18	M	SQ	14.1	10	NA	NA	NA
19	M	SQ	14.9	I	NA	NA	NA
20	F	SQ	15.8	12	NA	NA	NA
21	M	SQ	15.11	14	NA	NA	NA
22	F	SQ	16.9	14	NA	NA	NA
23	M	SQ	17.2	16	NA	NA	NA
24	F	SQ	19.3	16	NA	NA	NA
25	F	SQ	19.5	15	NA	NA	NA
26	F	SQ	21.6	14	NA	NA	NA

F=female

M=male

SD=spastic diplegia

SQ=spastic quadraplegia

I=data incomplete from file

AS4=ambulatory status at age 4 years

AS7=ambulatory status at age 7 years

CAS=current ambulatory status

NA=non-ambulatory

IA=independent ambulator

TABLE 5: CHARACTERISTICS OF THE SAMPLE (N=26)

Characteristics	Number
Number of subjects with spastic quadriplegia	21
female	10
male	11
Number of subjects with spastic diplegia	5
female	3
male	2
Average age of subjects with spastic quadriplegia	13.9 years
Age range of subjects with spastic quadriplegia	9.2 to 21.6 years
Standard Deviation	3.48 years
Average age of subjects with spastic diplegia	10.9 years
Age range of subjects with spastic diplegia	8.8 to 18.1 years
Standard Deviation	3.69 years
Average number of years of physical therapy received by subjects with spastic quadriplegia	10.5 years
Range of years of physical therapy received by subjects with spastic quadriplegia	6 to 16 years
Standard Deviation	3.50 years
Average number of years of physical therapy received by subjects with spastic diplegia	8 years
Range of years of physical therapy received by subjects with spastic diplegia	5 to 11 years
Standard Deviation	3.46 years

TABLE 6: TYPE OF CEREBRAL PALSY IN RELATION TO AMBULATORY STATUS AT FOUR YEARS, SEVEN YEARS AND PRESENT

Ambulation Status	Ambulatory			Non-ambulatory	
	N	N	%	N	%
At 4 years					
diplegia	5	0	0	5	100
quadriplegia	21	0	0	21	100
At 7 years					
diplegia	5	3	60	2	40
quadriplegia	21	0	0	21	100
Present status					
diplegia	5	2	40	3	60
quadriplegia	21	0	0	21	100

21 (100%) of these students were non-ambulatory at age 4 years and continued to be non-ambulatory at age 7 years and at their current age. Since 100% of the students who were non-ambulatory at ages 4 and 7 years continued to be non-ambulatory currently, statistical analysis was not performed on these data.

Only five students with spastic diplegia were included in the study. Five (100%) of these students were non-ambulatory at 4-years. Two of the five (40%) were non-ambulatory at 7-years and currently, three of the five students (60%) were non-ambulatory. Because of the small sample size, statistical analysis was not performed on this data. Two of the students with spastic diplegia who were non-ambulatory at 7-years continue to be non-ambulatory presently. One student who was ambulatory at 7-years is now non-ambulatory. This student continues to use crutches for household ambulation but uses a wheelchair for long distance and community mobility.

CHAPTER 5

DISCUSSION

The results of this study appear to support a relationship between ambulation status at age 4-years and ultimate ambulatory status among children with spastic quadriplegia. Therefore, the first hypothesis of this study was rejected. Similar results regarding ultimate ambulatory status in children with spastic quadriplegia were found in the study done by Watt et al.³⁷

However, the results of this study do not appear to support a relationship between ambulatory status at age 4 years and ultimate ambulation status among children with spastic diplegia. Therefore, the second hypothesis of this study was not rejected. However, it is highly possible that the small sample size may have affected the results for the group with spastic diplegia. A small number of children who were diagnosed as having spastic diplegia did not meet the criteria for this study since they were already ambulatory by the time they were age 4-years. Three previous studies found that a number of children with spastic diplegia were ambulating before age 4-years; the first study found 86.5%,^{18,36,37} the second study 20%, and the third study 82%.

The present results did not conform to that of Watt et al, in which 90% of children with spastic diplegia were found to be ambulators by age 8-years.³⁷

Several previous studies concluded that the acquisition of ambulation after age 7-years in children with cerebral palsy is remote.^{16,34,37} Data from the current study seem to support that conclusion, especially when applied to children with spastic quadriplegia. Therefore, the third hypothesis was rejected. Because of the limited sample size of children with spastic diplegia, the fourth hypothesis was not rejected. Further study is warranted regarding this hypothesis. However, the two children with spastic diplegia who were non-ambulatory at 7-years in the present study are currently non-ambulatory.

The current study has several limitations which limit generalizations to the entire population of children with CP. The relatively small sample size of children with spastic quadriplegia and the extremely small sample size of children with spastic diplegia may have affected the results. Variables such as intelligence, orthopedic status, and the presence of seizures have been shown by other studies to have some influence on the acquisition of ambulation among children with CP.^{21,34,35,37} The relationship of these variables to ambulation status was not investigated in the current study. The physical therapy files reviewed did not include complete records or details

regarding these variables. Additional research regarding the relationship of these variables to ambulation status is warranted.

Clinical Implications

The results of the present study suggest that physical therapists may need to carefully reconsider ambulation as a goal for children who have spastic quadriplegia and are non-ambulatory when they are age 4-years or older. Alternative forms of mobility such as power mobility may be a more appropriate and realistic goal for these children. Physical therapists appear to need to keep more detailed records since many of the records reviewed did not include the previously mentioned variables that might influence the acquisition of ambulation among some children with CP. Surprisingly, information describing current ambulatory status was not included in many of the physical therapy records reviewed.

In light of the fact that only eight studies since 1957 could be found in the literature, additional research on prognostic indicators of ambulation for children with CP appears needed. This seems especially true for clinicians attempting to identify prognostic indicators for ambulation in children with spastic diplegia. Since physical therapy

is universally accepted as a primary intervention strategy for the treatment of CP, it is imperative that physical therapists base their goals for children with CP on objective data and research.

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APPENDIX



Knox County
Department of Public Instruction
EARL F. HOFFMEISTER, SUPERINTENDENT

April 22, 1992

Mr. Bob Barnhart
OT/PT Department
Fort Sanders Educational Development Center
501 South 21st Street
Knoxville, Tennessee 37916

Dear Mr. Barnhart:

You are granted permission to conduct your proposed research study entitled, "Current Ambulation Status of Children with Cerebral Palsy Who Were Non-Ambulatory at Age Four Years: A Retrospective Study." In all research studies names of individuals, groups, or schools may not appear in the text of the study unless specific permission has been granted through this office. The principal researcher is required to furnish this office with one copy of the completed research document.

Good luck with your study. Do not hesitate to contact me if you need further assistance or clarification.

Yours truly,

Samuel E. Bratton, Jr.

Samuel E. Bratton, Jr., Coordinator
Research and Evaluation
Telephone: (615) 521-2194

xc: Dr. Jenice Yoder
Mr. Tom Moorehead

Project No. 224

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Research Administration
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DATE: 06/10/92

CRP #: 3812 A

Title: Ambulatory Status of Children with Cerebral Palsy: A
Retrospective Study

✓ Barnhart, Robert C.
Human Perf. & Sport Studies
501 S. 21st St.
Knoxville, TN 37916

Liemohn, Dr. Wendell
Human Perf. & Sport Studies
335 HPER Bldg.
Campus

The project listed above has been certified exempt from review by the
Committee on Research Participation and is approved.

This certification is for a period ending one year from the date of
this letter. Please make timely submission of renewal or prompt
notification of project termination (see item #2 below).

The responsibilities of the project director include the following:

1. Prior approval from the Coordinator of Compliances must be
obtained before any changes in the project are instituted.
2. Submission of a Form D to request renewal, report changes dur-
ing the approval period, or report termination of the project.

We wish you success in your research endeavors.

Sincerely,

Edith M. Szathmary

Edith M. Szathmary
Coordinator of Compliances

cc: Dr. Joan Paul
328 HPER Bldg.

Attachment: Copy of Form A

VITAE

Robert C. Barnhart was born in Fort Lewis, Washington on May 30, 1955. He attended elementary school in the Pennsbury School District (Pennsylvania) and graduated from Pennsbury Senior High School in June, 1973. The following September he entered West Virginia Wesleyan College and in May, 1977 received the degree of Bachelor of Arts in Psychology. In January, 1978 he entered Emory University and received a Certificate in Physical Therapy in May, 1979. He received a Certificate in the Neurodevelopmental Treatment Approach to Cerebral Palsy in August, 1986. In September, 1990 he entered The University of Tennessee, Knoxville and in 1992 received a Master of Science degree in Human Performance and Sports Studies.

He was employed as a physical therapist at The University of Alabama, Tuscaloosa from June, 1979 until June, 1980. From August, 1980 until July 1983 he was a staff physical therapist at Partlow State School and Hospital, Tuscaloosa. From August, 1983 until July, 1984 he was employed as a staff physical therapist at West Alabama Rehabilitation Center, Tuscaloosa. In August, 1984 he moved to Knoxville, Tennessee where he was employed by the Knox County School System as a physical therapist until July, 1992. He is presently employed as a pediatric physical therapist at The Vanderbilt Clinic, Vanderbilt University Medical Center, Nashville, Tennessee.