

Qualitative Analysis of a Pediatric Strength Intervention on the Developmental Stepping Movements of Infants With Down Syndrome

**L. Kristi Sayers, Jo E. Cowden, Maria Newton,
Barbara Warren, and Bobby Eason**
University of New Orleans

The purpose of this study was to describe the developmental stepping movements of 5 infants with Down syndrome who participated in a pediatric strength intervention. Pretest and posttest data were collected with the Hawaii Early Learning Profile Strands, Battelle Developmental Inventory, and specially designed gait analysis. An 8-week individualized pediatric strength intervention was implemented according to theoretical principles of progressive interactive facilitation (Cowden, in press). Posttest data and the Snyder-McLean (1987) intervention developmental quotient suggested an increase in the subjects' rates of motor development during intervention as compared to their lifetime rates prior to intervention. One subject showed increased rate and distance, 2 subjects acquired independent upright locomotion, and 1 subject established independent sitting movements and creeping patterns. One subject was unable to complete the study.

It is customary to define the transitional period from infancy to toddler, or early childhood, along the time line during which the infant acquires walking skills (McGraw, 1932). The acquisition of independent upright locomotion is of such significance to future development that it is a common test item on most formal developmental assessment instruments used with young children (Bayley, 1993; Brigance, 1978; Rogers & D'Eugenio, 1981). Basic independent upright locomotion is fundamental to later development of perceptual motor skills that affect one's opportunities for learning and socializing, as well as motor skills needed for participation in play and physical activities (Bertenthal & Campos, 1987; Campos, Svejda, Campos, & Bertenthal, 1982; Gustafson, 1984; Parker, Bronks, & Snyder, 1986; Rosenbloom, 1971; Seefeldt, 1980).

Research has reported delayed acquisition of motor skills by infants with Down syndrome when compared to their nondisabled peers (Sherrill, 1993; Ulrich, Ulrich, & Collier, 1992). Nondisabled infants typically develop the ability to walk

The authors are with the Department of Human Performance and Health Promotion, University of New Orleans, Lakefront Campus, New Orleans, LA 70148.

between 9 and 17 months of age; however, infants with Down syndrome do not typically acquire this skill until 13 to 48 months of age (Carr, 1970; Donoghue, Kirman, Bullmore, Laban, & Abbas, 1970; Hall, 1970; Henderson, 1986; Parker & Bronks, 1980; Ulrich & Ulrich, 1993). Previous research attributes the delayed motor development of infants with Down syndrome to the characteristics of the disability. Prior studies have assessed the following traits of Down syndrome: reduced brain weight (Crome, Cowie, & Slater, 1966), delayed postural reactions (Halcy, 1986; Rast & Harris, 1986), delayed primitive reflexes (Cowie, 1970; Henderson, 1985), heart and respiratory problems (Dyer, Gunn, Raugh, & Berry, 1990), obesity (Henderson, 1986), hypotonia (Ulrich & Ulrich, 1993), and joint laxity (Livingstone & Hirst, 1986). Dyer et al. (1990) reviewed literature that addressed several characteristics of development in children with Down syndrome, including neuromotor delays, hypotonia, primitive reflexes, energy level, and congenital heart disease.

Theoretical approaches to treating individuals with abnormal motor development have been dominated by the neuro-based approaches: neurodevelopmental (Bobath, 1966; Bobath & Bobath, 1964), neurophysiological (Rood, 1956), neurobehavioral (Ayres, 1972, 1974, 1980), and neuromuscular (Voss, 1976). However, in the 1980s, Thelen (1986) began describing a dynamic systems approach as a functional theory which does not assume that all traditional principles of motor development adequately explain the process of sequential motor development and control. Thelen, Kelso, and Fogel (1987) proposed a systems approach that addresses movement as an emergent phenomenon that does not develop solely from cognitive status or neural maturation but rather is a blending of various contributing elements such as perceptual structures, cognitive abilities, maturation of the motor cortex, and the infant's control of energy provided to a particular system. Specific contentions of the dynamic systems approach included the following: Moving and developing organisms are complex and cooperative systems, moving and developing systems are self-organizing in nature, skill development occurs in an asynchronous and nonlinear manner, and shifts from one qualitative behavioral mode to another are often discontinuous (Thelen et al., 1987). Thelen's (1986) research of 7-month-old infants demonstrating step patterns when placed upright on a moving treadmill supported the contention that neural maturation must combine with balance, postural stability, strength, and environmental contexts.

Ulrich et al. (1992) and Ulrich and Ulrich (1993) suggested that independent upright locomotion of infants with Down syndrome does not depend on a maturation of neural commands. When 11-month-old infants with Down syndrome were supported upright on the belt of a motorized treadmill, they demonstrated alternating stepping patterns. The data from these studies proposed that neurological and kinesthetic step-patterning abilities exist in infants with Down syndrome at 11 months of age. Ulrich et al. (1992) and Ulrich and Ulrich (1993) concluded that the delayed motor development in infants with Down syndrome may be attributed to a combination of existing congenital deficits. They suggested that the more prominent rate-limiting factors that prevent infants with Down syndrome from walking closer to the mean walking age of nondisabled infants may be a lack of leg

strength and stability during dynamic balance. Therefore, there seems to be a need for research studies that analyze intervention programs whose focus is the increase of muscle tone and strength as well as postural stability in infants with Down syndrome.

For the purposes of this study, a proposed theory of intervention, termed *progressive interactive facilitation* (Cowden, in press), has been developed as a more definitive approach to the structure and development of specific motor skills to promote independent upright locomotion in infants and toddlers with multisystem delays. The theoretical foundation for progressive interactive facilitation (Cowden, in press) was based on a thorough review of relevant literature (Ayres, 1972, 1974, 1980; Bobath, 1966; Bobath & Bobath, 1964; Gesell, 1939; Hebb, 1949; Knott & Voss, 1968; Piaget, 1952, 1954, 1962; Rood, 1956; Thelen, 1986; Voss, 1976). A system of postulates was formulated that comprises this theory: (a) combined emphasis of neurodevelopmental patterning and proprioceptive stimulation through specific repetitive activities; (b) sequential interactive progression of exercises to facilitate the development of muscle tone, strength, and balance; (c) intersensory modality activation of motor output and feedback response; and (d) task analysis approach to equilibrium and balance. Progressive interactive facilitation (Cowden, in press) emphasizes the following intervention principles: (a) increase or decrease of muscle tone to facilitate effective movement; (b) inhibition of primitive reflexes; (c) reciprocal innervation; (d) neurodevelopmental repetitive patterning of movements; (e) stimulation of automatic equilibrium reactions; (f) tactile stimulation for warm-up, flexibility, range of motion, and relaxation; (g) positioning for increasing muscle tone, strength, and balance of specific muscles; (h) coordination of stability and mobility; (i) resistance training; (j) exercise sequences, repetitions, and sets; (k) frequency, duration, and rest; (l) overload, progression, and maintenance; and (m) dynamic action and adaptation.

By utilizing the progressive overload principle of strength training, we determined that the presence of ankle weights would provide light resistance, proprioceptive sensations, and additional sensory motor feedback sensations to the muscles as they contracted and relaxed during facilitated movements. Therefore, the neurological and sensory input and hands-on kinesthetic patterning (passive assistance through range of motion) would increase infant motor skills that lead to the ability to perform independent upright locomotion. Thus, this study provides baseline descriptive and exploratory case study data with suggestions on how increased leg strength and postural stability may promote independent upright locomotion in infants with Down syndrome.

The purpose of the present study was to implement and describe the changes of a pediatric strength intervention (PSI) on the developmental stepping movements of infants with Down syndrome.

Method

Subjects

A nonrandom purposive sampling design (Kerlinger, 1973) was used to select 2 female and 3 male infants with Down syndrome. Detailed medical histories were obtained for each subject, and a physician's consent was required for participation. The subjects attended a university-based 8-week motor development clinic where graduate-level adapted physical education students served as teachers. Table 1 provides pretest descriptive data of the participants. All subjects had been diagnosed

with Down syndrome subtype trisomy 21. Four of the subjects lacked independent walking skills. One subject had recently acquired independent upright locomotion. A variance in age (in months) was sought to represent a range of developmental abilities.

Multiple Case Reports

Case Study 1. At pretest, Subject 1, a female, was 31 months of age. Her medical history included a premature birth (4 weeks early) by Caesarean section and a 1-week stay in the Neonatal Intensive Care Unit (NICU). She had no reported history of seizure disorder. Cardiac problems included atrial septal defect and patent ductus arteriosus, now closed. Previous surgeries included insertion of two sets of drainage tubes in her ears and removal of her adenoids. She had no known visual, auditory, or skeletal problems. There was a possibility of hypothyroidism. Her mother reported that she began independently walking approximately 2 months prior to pretest. Subject 1 attended a daycare program at the local Association for Retarded Citizens (ARC) 2–3 days per week. She received speech therapy twice a week.

Case Study 2. At pretest, Subject 2, a male, was 22 months of age. His medical history included a normal and timely delivery with no reported complications. He had a resolved seizure disorder that occurred from 6 to 11 months of age. Subject 2 had not experienced any cardiac problems. He had a dislocated elbow and fractured humerus at 14 months of age; both healed naturally without a cast. At pretest, his visual diagnosis included myopia; however, he did not receive eyeglasses until the eighth week of the intervention. His auditory history included insertion of drainage tubes in his ears. At pretest, Subject 2 was rolling but not crawling. He began rolling at 3 months of age and continued until he was placed on Acthar Gel H.P. seizure medication (a steroid) at 7 months of age. His mother reported that he began rolling again at 10 months of age. At pretest, Subject 2 could pull to a sitting position with assistance. If he was

Table 1 Pretest Descriptive Data of Participants

| Subject | Gender | Age (months) | Height | | Weight | | Means of locomotion |
|---------|--------|-----------------|--------|-------|--------|------|---|
| | | | (cm) | (in.) | (kg) | (lb) | |
| 1 | Female | 31 | 78.7 | 31 | 12 | 26.5 | Walking |
| 2 | Male | 22 | 83.8 | 33 | 9.08 | 20 | Rolling |
| 3 | Female | 18 | 73.7 | 29 | 8.1 | 18 | Creeping/ cruising |
| 4 | Male | 38 | 69.5 | 27.5 | 11.3 | 25 | Creeping/ bunny-hopping/ stepping |
| 5 | Male | 22 | 78.7 | 31 | 9.9 | 22 | Scotting/ cruising |

placed in a sitting position, he could maintain balance in sitting. Subject 2 participated in several programs offered at the local ARC. His home-based program included weekly visits from a parent trainer who monitored therapy programs prescribed during monthly visits with his physical, occupational, and speech therapists. In addition, he attended a monthly 1-1/2-hour "play-group" session at the ARC.

Case Study 3. At pretest, Subject 3, a female, was 18 months of age. Her medical history included a normal and timely delivery; however, she was placed in NICU for 10 days. Subject 3 had no history of a seizure disorder. Prior to posttest, Subject 3 was diagnosed with patent ductus arteriosus (which may require future surgery) and ventricular septal defect, which appeared to be closing naturally. She had drainage tubes inserted in her ears. There were no reports of visual or skeletal problems. At pretest, she avoided placement on her knees and would continually "bear walk" with locked elbows and knees and her back arched. Her mother reported that acquisition of this skill occurred at 10 months of age. She could stand alone and cruise furniture. Within the preceding 3 months she had taken two independent steps on three separate occasions. At pretest, Subject 3 received physical, occupational, and speech therapy twice a month at the local ARC. During the seventh week of the intervention, she began receiving speech and occupational therapy 3 days a week.

Case Study 4. At pretest, Subject 4, a male, was 38 months of age. His medical history included a late delivery of 2-1/2 to 3 weeks. He was in NICU for 2-1/2 weeks. Subject 4 had no reports of a seizure disorder. Cardiac conditions at birth included arterial septal defect and patent ductus arteriosus, now closed. His surgeries consisted of insertion of tubes in his ears and insertion of a chest tube at birth to drain the chest cavity. Subject 4 was diagnosed as legally blind and wore eyeglasses. He was fitted for bifocals during the intervention but had not received them at the time of posttesting. There were no reported hearing or skeletal problems. Respiratory problems consisted of frequent infections and asthma. At pretest, Subject 4 displayed a creep that combined the four-point creep with the "bear walk"; one knee touched the surface and the other externally rotated in a locked position without touching the surface. He began bunny-hopping at 2 years of age. He began to rise to standing from a chair at 3 years of age. At pretest, he could take four to eight independent steps 8 to 12 times a day. Subject 4 received early intervention at the local United Cerebral Palsy Center. He saw speech, occupational, and physical therapists weekly. In addition, he received private occupational therapy twice a week.

Case Study 5. Subject 5 was unable to complete the study.

Design

Researchers should acknowledge the individual characteristics of subjects when designing treatment programs (Bouffard, 1993; Bryk & Raudenbush, 1988) and then use the subjects as a unit of analysis in order to describe and explain the variability in response to treatment (Bouffard, 1993). Once individual responses to the treatment have been described, similarities among individuals can be determined and applied to theoretical propositions (Bouffard, 1993; Thorngate, 1986; Valsiner, 1986).

The data in this study were qualitatively analyzed utilizing a case study format. Because there were multiple subjects for whom a case study was written, an exploratory multiple-case study design was chosen. Each case study used an embedded approach due to the use of several subunits of analysis.

Evaluation Measurements

According to Yin (1989), "A major strength of case study data collection is the opportunity to use many different sources of evidence" (p. 96). Each form of assessment was used in pilot tests to ensure appropriate methodology. All forms of pretest and posttest data collection were obtained during the week prior to and the week following intervention. Based on pretest data, an 8-week individualized pediatric strength intervention (PSI) program was designed for each subject.

To ensure procedural accuracy during data collection, this study followed guidelines given for utilizing judgment-based assessment (Fleischer & Ogonosky, 1990; Neisworth & Bagnato, 1988). The evaluation instruments were selected or designed to ensure adequate representation of the subject's gross motor skills as well as confidence level of the instruments and data sources. Following are the names of the evaluation instruments and the applicable subsections of each instrument. The formal evaluation instruments provided data that reported the subjects' current gross motor age. In addition to these instruments, forms and charts were designed to collect more specific data on selected components of independent up-right locomotion.

Hawaii Early Learning Profile (HELP) Strands

- Weight-bearing in standing
- Mobility/transitional movements
- Reflexes/reactions/responses
- Standing
- Walking/running
- Climbing
- Stairs
- Riding a tricycle
- Balance beam

Battelle Developmental Inventory (BDI)

- Muscle control
- Body coordination
- Locomotion

Gait Analysis Form

- Height of step
- Stride length
- Width of stationary base of support

Progressive Model of Infant Stepping Movements

- Step initiation phase
- Foot placement to stance
- Swing phase

Growth Charts

- Height (centimeters/inches)
- Weight (kilograms/pounds)

PSI Performance Charts

- Exercise
- Frequency
- Sets
- Reps

HELP Strands. The Hawaii Early Learning Profile (HELP) Strands is a curriculum-based assessment tool for children from birth through 3 years that was designed for teacher administration (Parks, 1992). The HELP Strands delineates small increments of change in motor skill development. HELP Strands scores provided a very descriptive profile of the subjects' motor levels and served as weekly documentation of the effectiveness of the PSI. At pretest and posttest, each subject's teacher administered the Gross Motor section of the HELP Strands.

Battelle Developmental Inventory. The Battelle Developmental Inventory (BDI) is a standardized and norm-referenced assessment battery of developmental skills in children from birth through 8 years (Guidubaldi, Newborg, Stock, Svinicki, & Wnek, 1988). Previous studies have indicated that the standard error of measurement and the test-retest coefficients support the high reliability (met or exceeded .85) of the instrument (Newborg, Stock, Wnek, Guidubaldi, & Svinicki, 1984, 1988). The BDI was selected for two reasons: (a) The standardized developmental age could be applied to the Snyder-McLean procedural formula for analyzing norm-referenced data, and (b) accuracy of test administration was increased by utilizing a certified BDI examiner with a Master of Education degree in adapted motor development. The examiner was not aware of the specific intervention programs.

Gait Analysis. Using the Panasonic SVHS Reporter Model AG-450 video camera, we videotaped the subjects as they walked on the specially designed 5 cm × 5 cm grid platforms the length of a set of pediatric aluminum parallel bars (170 cm × 38 cm × 49.5 cm). One grid served as a platform deck and one stood upright for lateral viewing. Two views were recorded: one with the camera lateral to the parallel bars a distance of 197 cm and one with the camera posterior to the parallel bars a distance of 114 cm. At pretest and posttest, three gait trials were videotaped of the subject walking the length of the parallel bars: one without the subject wearing ankle weights and one with the subject wearing appropriate weights. At pretest, each subject wore 1/4-lb (0.11-kg) weights. At posttest, the subjects wore the weights they used during the last week of the PSI.

Prior to videotaping, anatomical markings were made on each subject with a black washable Crayola marker to ensure consistency during data analysis. The knee was marked at the crease of the femur where the femur joins the fibula and tibia, and the hip was marked at the head of the femur where it fits into the acetabulum. A piece of black electrical tape was placed on the outside of each subject's shoes to mark the lateral malleolus base of the fifth metatarsal and the medial malleolus base of the first metatarsal. Bracelets of black yarn were tied around the wrist to show arm, hand, and wrist movements.

A Panasonic video cassette recorder Model AG-7300 and a Panasonic color video monitor Model CT-1331Y were used to print five selected intervals of each of the following gait components: height of the step, stride length, and width of the stationary base of support. The height of the subject's step was measured according to the height of the knee lift as seen on the upright grid. The stride length was measured from the heel of the back shoe to the toe of the stepping shoe as seen on the platform grid. The width of the stationary base of support was measured from the inside midfoot of one shoe to the inside midfoot of the other shoe. Separate measurements were taken with each foot forward. Five measurements of the selected intervals for each of the three gait components were calculated and averaged by three experienced observers. The three observers' averages were then calculated to give an averaged measurement for each gait component.

Progressive Model of Infant Stepping Movements. The gaits of 3 nondisabled toddlers, ages 10, 13, and 18 months, were videotaped using the same procedures. An observational comparison was made of the gaits of these nondisabled toddlers and the gaits of the subjects with Down syndrome. The obvious differences in the gaits of the typical children and the gaits of the subjects with Down syndrome established the need to develop the Progressive Model of Infant Stepping Movements.

The Progressive Model of Infant Stepping Movements was designed specifically for this study and was based on previous research (Auxter, Pyfer, & Huettig, 1993; Sherrill, 1993; Ulrich et al., 1992). The format allowed a panel of observers to record descriptive information about the gait phases (i.e., step initiation, foot placement to stance, and swing phase) of the following five step types: shuffle, waddle, single, beginning alternate, and alternate. Identification of step types was made according to the following definitions: (a) *shuffle*, both feet are alternately shuffled forward as they maintain contact with the surface, (b) *waddle*, trunk leans to the side of the body from which alternating forward steps are taken in a waddling manner, (c) *single*, steps occur in a single manner from only one side of the body, (d) *beginning alternate*, steps occur in an alternating manner from one foot to the other with slight forward movement, and (e) *alternate*, steps occur in an alternating manner from one foot to the other with good forward movement.

Growth Charts. Pretest and posttest measurements of each subject's height (in centimeters and inches) and weight (in kilograms and pounds) were plotted on the Physical Growth NCHS Percentiles (Ross Laboratories, 1982a, 1982b). The percentile score compared each subject's height and weight to those of typical children of the same age. The subject's height was measured while the subject lay straight in supine on a flat surface. The tape measure was taken from the top of the subject's head to the sole of his or her foot. The subject was fully clothed when weighed. The same scales were used at pretest and posttest.

PSI Performance Charts. At each weekly motor clinic, the investigator wrote each subject's new and individualized PSI prescription on the PSI performance charts. The format required the parents and teachers to document the frequency, sets, and repetitions as they were actually performed under the original prescription. This documentation, in conjunction with the weekly updates on the HELP Strands and judgment-based assessment made by the primary investigators, was used to prescribe a new PSI and to determine which ankle weights the subject utilized during the videotaped gait analysis.

Intervention Procedures

Based on pretest scores, an initial individualized home-based PSI was prescribed for each subject. According to case study protocol (Yin, 1989), the intervention followed the theoretical premises of progressive interactive facilitation (Cowden, *in press*). Ankle weights had been used with children with Down syndrome at previous motor clinic sessions and were determined to be both safe and appropriate for these subjects. Each subject's physician granted approval for participation in a strength intervention that utilized ankle weights.

Before the intervention began, the parents and graduate-level adapted physical education teachers were given very specific written and verbal guidelines for implementing the intervention. These guidelines included the following: maintaining proper body alignment during the exercises, properly adapting the necessary home equipment, allowing the subject to put forth exerted effort during the movements, providing an atmosphere of fun and play during the implementation of the exercises, following the child's lead without continuously targeting a particular muscle group, and remaining committed to performing the prescribed intervention weekly.

The intervention utilized PSI exercises based on the concept of "specificity of skill," a kinesiological analysis of head-to-toe development of specific muscle groups (Cowden, *in press*). The parents and teachers were given written and pictorial descriptions of the PSI exercises and a demonstration of the procedures and administrative techniques. In addition, the purpose of each exercise was explained to the parents and teachers. Instructions for the exercises were appropriately modified for each subject. During the 8-week intervention, a new PSI was prescribed each week based on the teacher's weekly HELP Strands assessments, the child's PSI performance chart, informal evaluative comments from the parents and teachers, and judgment-based assessments (Fleischer & Ogonosky, 1990; Neisworth & Bagnato, 1988). Each new PSI was designed to promote the subject's normal, sequential motor development based on his or her strengths and needs. A balance of current skills and progressive challenges encouraged each subject's advancement to subsequent levels of motor development.

After receiving initial explanations and guided examples of their child's exercises, the parents and teachers demonstrated their understanding of the techniques for implementing their child's PSI. In addition to the subject performing the PSI with his or her teacher at the weekly motor sessions, the parents were asked to help their child perform the entire PSI three different days during the upcoming week. The parents documented the frequency, intensity, and duration of each home-based exercise on the PSI performance chart. Weekly telephone calls were made to the parents of each subject to monitor the implementation of the home-based PSI. At the motor clinic sessions, the parents were often asked to demonstrate with their child the procedures they had followed at home with a particular exercise.

Data Analysis

Data analysis strategies included a comparison of pretest and posttest scores. The Snyder-McLean (1987) procedural formula for determining an intervention developmental quotient was calculated to assess the rate of change each subject exhib-

ited during the intervention. In addition, three analytical case study strategies suggested by Yin (1989) (i.e., cross-case analysis, time-series analysis, and pattern-matching analysis) were applied to the data analysis.

Intervention Developmental Quotient

In reporting the measurable benefits of the 8-week intervention employed through this study, there was a need to accommodate for (a) normal growth and developmental changes that may have occurred through an increase in chronological age and maturation and (b) any formal or informal teaching or therapy that was conducted outside the study. In evaluating the data analysis methods of previous studies (Bagnato & Neisworth, 1980; Bailey & Bricker, 1985; Garwood, 1982; Sheehan & Keogh, 1982; Wolery, 1983; Wolery & Dyk, 1985) in which early intervention programs were implemented, Snyder-McLean (1987) concluded, "It has become common practice in early intervention evaluation research to use the child's own preintervention data as the control against which his or her performance is compared following intervention" (p. 254). Most current research evaluations of early intervention programs are designed around a pretest/intervention/posttest model that uses standardized, norm-referenced assessment instruments. Each subject's pretest developmental level or rate of development during intervention (the subject's "developmental change") is used to evaluate the effectiveness of the intervention (Snyder-McLean, 1987).

Snyder-McLean (1987) suggested a procedural formula for calculating the intervention developmental quotient (DQ) as a means of quantifying the rate of progress a subject demonstrates during an early intervention program, thus demonstrating the effectiveness of the early intervention program. The intervention DQ can be contrasted to the child's preintervention rate of development determined by the pretest DQ ($DQ = \text{developmental age} / \text{chronological age}$). The pretest DQ is actually a lifetime DQ reflecting the child's entire lifetime of learning (Snyder-McLean, 1987). This formula has been applied to early intervention studies to account for maturation, increasing chronological age, and outside therapies (Fewell & Oelwein 1991; Snyder-McLean, 1987). At this time, the Snyder-McLean (1987) method has been found to be the best means for measuring change in development of the individual child.

Case Study Analytic Strategies

Because a multiple-case study approach was utilized, a cross-case analysis was made of the single-case interpretations. The embedded design of the study allowed the cases to be compared for each subunit of analysis.

The time-series analysis allowed the data to be recorded over a period of time (i.e., over the 8-week PSI). Pretest and posttest scores were analyzed, and the specificity of skill and progressive facilitation of each subject's PSI were documented on the PSI performance charts. In addition, each subject's pretest DQ and intervention DQ were compared.

When the pattern-matching strategy is used, "several pieces of information from the same case may be related to some theoretical proposition" (Yin, 1989, p. 33). The results of the multiple case studies and cross-case analysis may be compared with the theoretical foundations of the study, that is, progressive interactive

facilitation (Cowden, in press). In addition, this theoretical construct can be compared and contrasted with other hypotheses or theories reported in the literature.

Results and Discussion

For the purposes of this article, the data will be presented in a cross-case manner utilizing the time-series approach. Thus, the individual scores collected over a period of time using multiple subunits of analysis will be compared across the cases. In addition, the pattern-matching strategy will be developed.

HELP Strands

The investigator administered the HELP Strands at random to determine percentage of agreement among selected teachers and the investigator. There was 100% agreement on the performance levels of the subjects.

Table 2 provides each subject's pretest and posttest HELP Strands ceiling scores (the highest level for which performance was given full credit). At pretest, each subject had accomplished the peak developmental level assessed within the prone, supine, sitting, and antigravity responses subsections. Likewise, the jumping subsection was not addressed, as none of the subjects were able to perform any of the strands within this subsection.

The HELP Strands scores presented the pretest and posttest motor development skill levels of the subjects. Therefore, as the subjects acquired new motor

Table 2 Pretest and Posttest Ceiling Scores (in months) on the Gross Motor Section of the Hawaii Early Learning Profile Strands

| Subsection | Subject 1 | Subject 2 | Subject 3 | Subject 4 |
|---------------------------------|------------------|-----------|----------------|------------------|
| Weight-bearing in standing | 11.5-14 | —, 6-10.5 | 11.5-14 | 11-13, 11.5-14 |
| Mobility/transitional movements | 13-15 | 5-6, 6-8 | 13.5-15, 13-15 | 11.5-13.5, 13-15 |
| Reflexes/reactions/responses | 9-11 | 7-8 | 9-11, 12-15 | 12-15 |
| Standing | 23-25.5, 30-33 | — | 20-22 | —, 16-17 |
| Walking/running | 17-18.5, 34.5-36 | — | —, 17-18.5 | — |
| Climbing | 18-21 | — | —, 18-21 | — |
| Stairs | 15-18, 24-25.5 | — | 15-18, 24-25.5 | — |
| Catching/throwing | 16-22 | — | —, 15-18 | — |
| Riding a tricycle | 18-24 | — | — | — |
| Balance beam | 24-26, 30-32 | — | — | — |

Note. Dashes indicate the subject's inability to perform any of the strands within this subsection. Commas separate pretest and posttest scores.

skills during the PSI, their HELP Strands scores improved. At posttest, Subject 1 improved in the following subsections: standing, walking/running, stairs, and balance beam. Subject 2 acquired skills up to the 6- to 10.5-month range in the weight-bearing in standing subsection and the 6- to 8-month range in the mobility and transitional movements subsection. His posttest score for the reflexes/reactions/responses subsection remained in the 7- to 8-month range. Increased posttest scores were noted for Subject 3 in the following subsections: reflexes/reactions/responses, walking/running, climbing, stairs, and catching/throwing. Posttest improvements for Subject 4 included weight-bearing in standing, mobility and transitional movements, and standing.

Battelle Developmental Inventory

At both pretest and posttest, a certified examiner individually administered and scored a BDI gross motor developmental age for each subject. The BDI examiner did not participate in the interventions. To establish intrarater reliability, pretest assessments of the BDI were conducted on two different occasions. The pretest data from the two administrations were correlated to determine agreement between the results. The time between the two testing sessions did not exceed 5 days. Using the Pearson product-moment correlation, the intrarater reliability was calculated at .99. A cross-case analysis of the subjects' BDI motor scores and developmental age is presented in Table 3.

In contrast to the HELP Strands, the BDI test items represent very large increments of motor skill acquisition. Therefore, the increases in BDI scores represent the acquisition of developmental milestones during the PSI. In addition to improvements within the subsections of the motor domain, each subject's developmental motor age increased during the PSI.

Gait Analysis

Table 4 gives pretest and posttest measurements for each subject's height of step, stride length, and width of stationary base of support, without ankle weights.

Table 3 Pretest and Posttest Scores (in months) on the Motor Domain of the Battelle Developmental Inventory

| Subject | Muscle control | Body coordination | Locomotion | DA |
|------------|----------------|-------------------|------------|----|
| 1 Pretest | 12-17 | 18-23 | 18-23 | 16 |
| 1 Posttest | 12-17 | 18-23 | 18-23 | 17 |
| 2 Pretest | 6-11 | 0-5 | 0-5 | 5 |
| 2 Posttest | 6-11 | 6-11 | 6-11 | 8 |
| 3 Pretest | 6-11 | 6-11 | 12-17 | 11 |
| 3 Posttest | 12-17 | 12-17 | 18-23 | 15 |
| 4 Pretest | 6-11 | 6-11 | 18-23 | 13 |
| 4 Posttest | 12-17 | 12-17 | 18-23 | 17 |

Table 4 Pretest and Posttest Measures of Gait Components (in cm) Without Ankle Weights

| Subject | Height of step | | Stride length | | Width of stationary base of support | |
|-----------|----------------|-------|---------------|-------|-------------------------------------|-------|
| | Left | Right | Left | Right | Left | Right |
| 1 Pretest | 17.3 | 15.2 | 37.9 | 38.6 | 16.3 | 16.0 |
| Posttest | 15.8 | 16.0 | 40.9 | 40.4 | 11.7 | 15.2 |
| 2 Pretest | — | — | — | — | — | — |
| Posttest | — | — | — | — | — | — |
| 3 Pretest | 15.8 | 13.2 | 28.5 | 19.1 | 8.1 | 8.9 |
| Posttest | 12.5 | 11.4 | 28.5 | 24.6 | 16.8 | 14.0 |
| 4 Pretest | 17.5 | 21.1 | 29.0 | 34.3 | 8.4 | 9.4 |
| Posttest | 23.9 | 24.4 | 37.1 | 33.8 | 13.7 | 11.9 |

Note. Dashes indicate the subject’s inability to exhibit the skill components of this measurement.

Table 5 Pretest and Posttest Measures of Gait Components (in cm) With Ankle Weights

| Subject | Height of step | | Stride length | | Width of stationary base of support | |
|-----------------------------|----------------|-------|---------------|-------|-------------------------------------|-------|
| | Left | Right | Left | Right | Left | Right |
| 1 Pretest (0.11 kg, 1/4 lb) | 14.0 | 16.5 | 32.8 | 39.4 | 14.5 | 17.3 |
| Posttest (0.45 kg, 1 lb) | 16.5 | 14.2 | 38.6 | 35.8 | 9.1 | 13.7 |
| 2 Pretest | — | — | — | — | — | — |
| Posttest | — | — | — | — | — | — |
| 3 Pretest (0.11 kg, 1/4 lb) | 11.9 | 13.5 | 28.7 | 26.2 | 4.1 | 4.8 |
| Posttest (0.34 kg, 3/4 lb) | 12.2 | 15.0 | 30.2 | 24.9 | 13.2 | 10.2 |
| 4 Pretest (0.11 kg, 1/4 lb) | 19.6 | 19.6 | 22.4 | 32.8 | 14.2 | 13.5 |
| Posttest (0.45 kg, 1 lb) | 20.6 | 26.4 | 30.2 | 37.3 | 9.1 | 9.1 |

Note. Dashes indicate the subject’s inability to perform this gait component.

Across the subjects, no apparent pattern of increase or decrease could be noted for width of stationary base of support. There was an apparent increase in stride length and height of step across the subjects. Table 5 gives pretest and posttest measurements exhibited while subjects were wearing the ankle weights.

Subjects 1, 3, and 4 performed very specific exercises that utilized ankle weights to strengthen the muscles used in independent upright locomotion. As the

subjects' independent upright locomotion became more advanced (according to the Progressive Model of Infant Stepping Movements), their gait components changed in relation to the gait patterns they exhibited at pretest. The ankle weights increased 3/4 lb to 1 lb (0.34 kg to 0.45 kg) for Subjects 1 and 4 and 1/2 lb to 3/4 lb (0.23 kg to 0.34 kg) for Subject 3. The posttest measurements taken while the subjects were wearing ankle weights also revealed individual variations with the cross-case patterns that indicated increases in height of step and stride length and decreases in width of stationary base of support. Thus, the lack of established consistency for the subjects (with and without ankle weights) may be attributed to their various developmental ages, the presence of hypotonia, the progressive nature of their gaits from those of a wide base and high guard to patterns that are more typical of a mature gait, and the proprioception from the ankle weights. The measured gait component variations agree with the differentiations among previous research studies on the gait components of nondisabled beginning walkers (Bril & Breniere, 1993; Shirley, 1931; Statham & Murray, 1971; Sutherland, Olshen, Cooper, & Woo 1980).

Progressive Model of Infant Stepping Movements

Three adapted physical education teachers served as observers and viewed the beginning segments of each subject's pretest and posttest videotaped gaits (without ankle weights). The panel was in 100% agreement on the identification of each subject's pretest and posttest step types. The characteristics of each subject's gait and overall step types were identified according to the Progressive Model of Infant Stepping Movements.

The overall pretest and posttest step types of the subjects, according to the Progressive Model of Infant Stepping Movements, are presented in Table 6. The step types progress from shuffle to alternate. Therefore, the achievement of a more

Table 6 Pretest and Posttest Identification of Step Types According to the Progressive Model of Infant Stepping Movements

| Subject | Shuffle | Waddle | Single | Beginning alternate | Alternate |
|-----------|---------|--------|--------|---------------------|-----------|
| 1 Pretest | | x | | | |
| Posttest | | | | | x |
| 2 Pretest | — | — | — | — | — |
| Posttest | — | — | — | — | — |
| 3 Pretest | | | x | | |
| Posttest | | | | | x |
| 4 Pretest | | | x | | |
| Posttest | | | | | x |

Note. x identifies the subject's step type. Dashes indicate the subject's inability to perform the necessary skills for this step type.

adultlike or mature step pattern was considered an improvement in the independent upright locomotion of these subjects.

The overall goal of the PSI programs for Subjects 1, 3, and 4 was the acquisition and refinement of independent upright locomotion skills. The identification of the sequential step types in the model documented the subjects' acquisitions of progressive gaits. The data suggested very few variations among the gait phases of the subjects with like step types.

Growth Charts

An increase in height and weight is expected over an 8-week period for children of these ages. The Physical Growth NCHS Percentiles (Ross Laboratories, 1982a, 1982b) for normal development compare the subject's height and weight to expected values for his or her sex and age. The pretest and posttest data are presented in Table 7. Each subject did increase in height and weight. However, the subjects did not have the short stature and increased body weight that have typically been associated with children with Down syndrome. The below-normal weights of these infants with Down syndrome can be attributed to their below-normal heights and hypotonicity. The commonly recognized "chubbiness" of infants with Down syndrome may be due to hypotonicity rather than higher than average body weight.

Intervention Developmental Quotient

The subjects' pretest DQs and intervention DQs are presented in Figure 1. A posttest improvement in motor skills was reflected in increased BDI posttest scores. Subjects 2, 3, and 4 acquired several gross motor abilities during the 8-week PSI. Therefore, these subjects' intervention DQs were much higher than their pretest DQs. The increase in the rate of development during intervention, as compared to the subjects' lifetime rates of development (pretest DQ), suggests the effectiveness of the individualized PSI procedures. Because Subject 1 had acquired independent upright locomotion just prior to pretest and her gross motor attainments were related to improvements within independent upright locomotion skills, her interven-

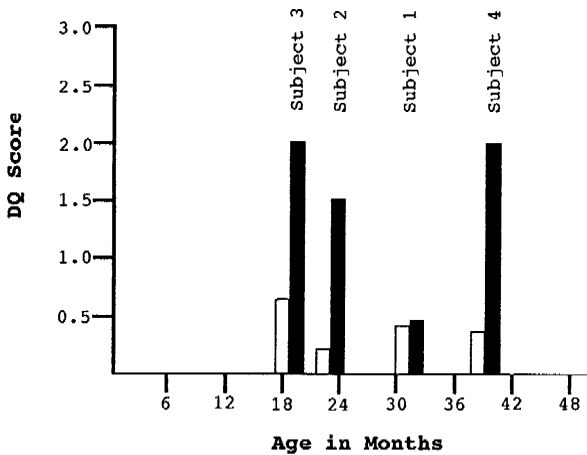
Table 7 Pretest and Posttest Measures of Height and Weight

| Subject | Weight (kg) | Height (cm) |
|-----------|-------------|-------------|
| 1 Pretest | 12.0 | 78.7 |
| Posttest | 12.7 | 81.3 |
| 2 Pretest | 9.08 | 83.8 |
| Posttest | 11.1 | 84.2 |
| 3 Pretest | 8.1 | 73.7 |
| Posttest | 8.8 | 76.2 |
| 4 Pretest | 11.3 | 69.5 |
| Posttest | 12.7 | 72.4 |

tion DQ was closer to her pretest DQ. For this subject, the curriculum-based assessment (the HELP Strands) provided a more accurate documentation of the small increments of skill development that she obtained.

Pediatric Strength Intervention

Each subject progressed through sequential, more challenging PSI exercises. This progression relied on increased developmental motor skills that were targeted through the specificity of skill design of the intervention. This approach facilitated acquisition of increased balance, muscle tone, and strength in specific muscle groups utilized during independent upright locomotion. Considering the presence of hypotonicity in these subjects, the progression to more advanced levels of exercise using heavier ankle weights demonstrated increases in balance, muscle strength, and endurance. This progression agrees with previous research studies that have noted the prerequisites of strength and balance for acquisition of independent upright locomotion (Bobath & Bobath, 1964; Bril & Brenier, 1993; Clark, Whittall, & Phillips, 1988; Cowden, in press; Gesell, 1939; Murray, 1967; Sutherland et al., 1980; Thelen, 1986; Thelen & Cooke, 1987; Thelen, Ulrich, & Jensen, 1989). In addition, the effectiveness of an individualized intervention utilizing the parents as



Note: □ = Pretest DQ
 ■ = Intervention DQ

| | <u>Pretest DQ</u> | <u>Intervention DQ</u> |
|-----------|-------------------|------------------------|
| Subject 1 | .48 | .50 |
| Subject 2 | .23 | 1.50 |
| Subject 3 | .61 | 2.00 |
| Subject 4 | .34 | 2.00 |

Figure 1 — A comparison of pretest DQs to intervention DQs.

administrators or teachers agrees with previous research on early intervention programs for infants with Down syndrome (Block, 1991; Esenther, 1984; Harris, 1980; Hartley, 1986).

Pattern-Matching

One of the pattern-matching strategies includes replication of a proposed pattern or theoretical construct across multiple cases (Yin, 1989). The theoretical foundation for this study was progressive interactive facilitation (Cowden, in press). The neurodevelopmental approach to the PSI emphasized sequential strength-building movements, proprioceptive stimulation, and repetitive activities that utilized light resistance to promote muscle tone, strength, and balance. The theoretical pattern was replicated across all 4 subjects.

The principles of progressive interactive facilitation (Cowden, in press) supported the dynamic systems approach (Thelen, 1986; Thelen et al., 1987) through the emphasis on internal developments that promote emerging developmental patterns. In addition, progressive interactive facilitation also supported an interaction of these internal processes with external environmental stimulation to facilitate the emergence of functional patterns of independent movement. This theoretical approach to a PSI for infants with Down syndrome supported previous research (Ulrich & Ulrich, 1993; Ulrich et al., 1992) which suggested that the rate-limiting factors affecting the achievement of independent upright locomotion by infants with Down syndrome may not be a lack of neural pattern-generating substrate but a lack of leg strength and balance.

Quality of the Study

In analyzing the results of the study, it is appropriate to judge the quality of the case study research design with suggested case study criteria (Yin, 1989). Construct validity was established by following operational case study protocol to collect specific sets of data measurements and included a review by key adapted physical activity professionals of the case study procedures utilized in the study. These professionals felt that the methodology, design, and quality of the study were extremely strong. The internal validity of the study was increased by applying pattern-matching and time-series analytic strategies to the selected assessments. The external validity of the study was increased through the multiple-case replication of the progressive interactive facilitation theory (Cowden, in press). The reliability of the study was increased by carefully following case study protocol (Yin, 1989) and documenting the implementation of the methods and procedures throughout the study.

Conclusions

The exploratory multiple-case embedded case study design recognized the importance of evaluating subjects with like diagnoses on an individual basis. The implementation of a systematically monitored home-based intervention program that utilized parent involvement contributed to the success of the intervention. The length

of the intervention (8 weeks) allowed time for developmental changes to occur, with consideration being given to the decreased rate of motor development in infants with Down syndrome.

The data from this study indicated that acquisition of independent upright locomotion in infants with Down syndrome is very individual and is influenced by the many existing congenital deficits and previous medical complications. The rates of development in these subjects agreed with previous research which suggested that infants with Down syndrome develop in a similar sequence but at a slower rate than their nondisabled peers. However, this study suggested a Progressive Model of Infant Stepping Movements as characteristic of the developmental gaits of infants with Down syndrome. The presence of hypotonicity was a major rate-limiting factor in the acquisition of independent upright locomotion by these infants with Down syndrome, as shown by the increased rate of motor development after participating in an intervention that utilized the resistance of ankle weights. In addition to the prerequisites of dynamic and static balance for independent upright locomotion, these subjects needed sufficient extensor and flexor strength in their leg muscles to support their bodies during forward locomotion.

The theoretical basis, progressive interactive facilitation (Cowden, in press), provided a construct for defining the principles and a structure to guide the development of this study and future strength intervention studies for infants and toddlers with hypotonia. Replications of this study are in progress to establish applicability of this theoretical construct; however, increased rates of motor development were documented in each case study. As children with delays and hypotonicity, these subjects needed neurodevelopmental patterning, proprioceptive stimulation, repetition, resistance training, and basic fitness principles to facilitate their motor development.

References

- Auxter, D., Pyfer, J., & Huettig, C. (1993). *Adapted physical education and recreation*. St. Louis, MO: Mosby-Year Book.
- Ayres, A.J. (1972). *Sensory integration and learning disorders*. Los Angeles: Western Psychological Services.
- Ayres, A.J. (1974). *The development of sensory integration theory and practice*. Dubuque, IA: Kendall/Hunt.
- Ayres, A.J. (1980). *Sensory integration and the child*. Los Angeles: Western Psychological Services.
- Bagnato, S.J., & Neisworth, J.T. (1980). The intervention efficiency index: An approach to preschool program accountability. *Exceptional Children*, **46**(4), 264-269.
- Bailey, E.J., & Bricker, D. (1985). Evaluation of a three-year early intervention demonstration project. *Topics in Early Childhood Special Education*, **5**(2), 52-65.
- Bayley, N. (1993). *Bayley Scales of Infant Development* (2nd ed.). San Antonio, TX: Psychological Corp.
- Bertenthal, B., & Campos, J. (1987). New directions in the study of early experience. *Child Development*, **58**, 560-567.
- Block, M.E. (1991). Motor development in children with Down syndrome: A review of literature. *Adapted Physical Activity Quarterly*, **8**, 179-209.

- Bobath, K. (1966). *The motor deficit in patients with cerebral palsy*. London: Spastics International Medical Publications.
- Bobath, K., & Bobath, B. (1964). The facilitation of normal postural reactions and movements in the treatment of cerebral palsy. *Physiotherapy (England)*, **50**, 246-262.
- Bouffard, M. (1993). The perils of averaging data in adapted physical activity research. *Adapted Physical Activity Quarterly*, **10**(3), 371-391.
- Brigance, A.H. (1978). *Brigance Diagnostic Inventory of Early Development*. North Billerica, MA: Curriculum Associates.
- Bril, B., & Breniere, Y. (1993). Posture and independent locomotion in early childhood: Learning to walk or learning dynamic postural control? In G.J.P. Savelsbergh (Ed.), *The development of coordination in infancy* (pp. 337-357). Amsterdam, The Netherlands: Elsevier Science B.V.
- Bryk, A.S., & Raudenbush, S.W. (1988). Heterogeneity of variance in experimental studies: A challenge to conventional interpretations. *Psychological Bulletin*, **104**, 396-404.
- Campos, J., Svejda, M., Campos, R., & Bertenthal, B. (1982). The emergence of self-produced locomotion: Its importance for psychological development in infancy. In D. Bricker (Ed.), *Intervention with at-risk and handicapped infants*. Baltimore: University Park Press.
- Carr, J. (1970). Mental and motor development in young mongol children. *Journal of Mental Deficiency Research*, **14**, 205-220.
- Clark, J.E., Whittall, J., & Phillips, S.J. (1988). Human interlimb coordination: The first 6 months of independent walking. *Developmental Psychobiology*, **21**(5), 445-456.
- Cowden, J.E. (in press). *Pediatric adapted motor development and exercise*. Springfield, IL: Charles C Thomas.
- Cowie, V.A. (1970). *A study of the early development of mongols*. Oxford, UK: Pergamon.
- Crome, I., Cowie, V., & Slater, E. (1966). Statistical note on cerebellar and brain stem weight in mongolism. *Journal of Mental Deficiency Research*, **10**, 69-72.
- Donoghue, E.C., Kirman, B.H., Bullmore, G.H.L., Laban, D., & Abbas, K.A. (1970). Some factors affecting age of walking in a mentally retarded population. *Developmental Medicine and Child Neurology*, **12**, 781-792.
- Dyer, S., Gunn, P., Raugh, H., & Berry, P. (1990). Motor development in Down syndrome children: An analysis of the motor scale of the Bayley Scales of Infant Development. In A. Vermeer (Ed.), *Motor development, adapted physical activity and mental retardation, medicine and sport science* (pp. 7-20). Basel, Switzerland: Karger.
- Esenther, S. (1984). Developmental coaching of the Down syndrome infant. *The American Journal of Occupational Therapy*, **38**(7), 440-445.
- Fewell, R.R., & Oelwein, P.L. (1991). Effective early intervention: Results from the model preschool program for children with Down syndrome and other developmental delays. *Topics in Early Childhood Special Education*, **11**(1), 56-68.
- Fleischer, K.H., & Ogonosky, A.B. (1990). An overview of judgement-based assessment. *Topics in Early Childhood Special Education*, **10**(3), 13-23.
- Garwood, S.G. (1982). (Mis)use of developmental scales in program evaluation. *Topics in Early Childhood Special Education*, **1**(4), 61-69.
- Gesell, A. (1939). Reciprocal interweaving in neuromotor development. *The Journal of Comparative Neurology*, **70**(2), 161-180.
- Guidubaldi, J., Newborg, J., Stock, J., Svinicki, J., & Wnek, L. (1988). *Battelle Developmental Inventory*. Allen, TX: DLM Teaching Resources.
- Gustafson, G.E. (1984). Effects of the ability to locomote on infants social and exploratory behaviors: An experimental study. *Developmental Psychology*, **20**, 397-405.

- Haley, S.M. (1986). Postural reactions in infants with Down syndrome: Relationship to motor milestone development and age. *Physical Therapy*, **66**, 17-22.
- Hall, B. (1970). Somatic deviations in newborn and older mongoloid children: Follow-up investigation. *Acta Paediatrica Scandinavica*, **59**, 199-204.
- Harris, S. (1980). Transdisciplinary therapy model for the infant with Down's syndrome. *Physical Therapy*, **60**(4), 420-423.
- Hartley, X.Y. (1986). A summary of recent research into the development of children with Down's syndrome. *Journal of Mental Deficiency Research*, **30**, 1-14.
- Hebb, D.O. (1949). *The organization of behavior: A neuropsychological theory*. New York: Wiley.
- Henderson, S.E. (1985). Motor skill development. In D. Land & B. Stratford (Eds.), *Current approaches to Down syndrome* (pp. 187-218). London: Holt, Rinehart, and Winston.
- Henderson, S.E. (1986). Some aspects of the development of motor control in Down's syndrome. In H.T.A. Whiting & M.G. Wade (Eds.), *Themes in motor development* (pp. 69-92). Boston: Martinus Nijhoff.
- Kerlinger, F.N. (1973). *Foundations of behavioral research*. New York: Holt, Rinehart, and Winston.
- Knott, M., & Voss, D.E. (1968). *Proprioceptive neuromuscular facilitation: Patterns and techniques* (2nd ed.). New York: Harper & Row.
- Livingstone, B., & Hirst, P. (1986). Orthopedic disorders in school children with Down's syndrome with special reference to the incidence of joint laxity. *Clinical Orthopaedics and Related Research*, **207**, 74-76.
- McGraw, M.B. (1932). From reflex to muscular control in the assumption of erect posture and ambulation in the human infant. *Child Development*, **3**, 291-297.
- Murray, M.P. (1967). Gait as a total pattern of movement. *American Journal of Physical Medicine*, **46**, 290-333.
- Neisworth, J.T., & Bagnato, S.J. (1988). Assessment in early childhood special education. In S.L. Odom & M.B. Karnes (Eds.), *Early intervention for infants and children with handicaps* (pp. 23-49). Baltimore: Brookes.
- Newborg, J., Stock, J., Wnek, L., Guidubaldi, J., & Svinicki, J.S. (1984). *Battelle Developmental Inventory (BDI)*. Allen, TX: DLM/Teaching Resources.
- Newborg, J., Stock, J., Wnek, L., Guidubaldi, J., & Svinicki, J.S. (1988). *Battelle Developmental Inventory (BDI)*. Allen, TX: DLM/Teaching Resources.
- Parker, A.W., & Bronks, R. (1980). Gait of children with Down's syndrome. *Archives of Physical Medicine and Rehabilitation*, **61**, 345-351.
- Parker, A.W., Bronks, R., & Snyder, C.W., Jr. (1986). Walking pattern in Down's syndrome. *Journal of Mental Deficiency Research*, **30**, 317-330.
- Parks, S. (1992). *HELP strands curriculum-based developmental assessment birth to three years*. Adapted from the Hawaii Early Learning Profile. Palo, CA: VORT Corporation.
- Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.
- Piaget, J. (1954). *The construction of reality in the child*. New York: Basic Books.
- Piaget, J. (1962). *Play, dreams, and imitation in childhood*. New York: Norton.
- Rast, M.M., & Harris, S.R. (1986). Evaluation of selected postural reactions and movements of four-month-old infants with Down syndrome. *Developmental Medicine & Child Neurology*, **28**, 84-119.
- Rogers, S.J., & D'Eugenio, D.B. (1981). *Early Intervention Developmental Profile*. Ann Arbor: University of Michigan Press.

- Rood, M.S. (1956). Neurophysiological mechanisms utilized in the treatment of neuromuscular dysfunction. *American Journal of Occupational Therapy*, **10**, 220-224.
- Rosenbloom, L. (1971). The contribution of motor behavior to child development. *Physiotherapy*, **57**, 159-162.
- Ross Laboratories. (1982a). *Physical growth NCHS percentiles birth to 36 months*. Columbus, OH: Author.
- Ross Laboratories. (1982b). *Physical growth NCHS percentiles 2 to 18 years*. Columbus, OH: Author.
- Seefeldt, V. (1980). Development of motor patterns: Implications for elementary school physical education. In G.C. Nadeau (Ed.), *Psychology of motor behavior and sport—1979*. Champaign, IL: Human Kinetics.
- Sheehan, R., & Keogh, B.K. (1982). Design and analysis in the evaluation of early childhood special education programs. *Topics in Early Childhood Special Education*, **1**(4), 81-88.
- Sherrill, C. (1993). *Adapted physical activity, recreation, and sport: Crossdisciplinary and lifespan* (4th ed.). Dubuque, IA: Brown.
- Shirley, M.M. (1931). *The first two years: A study of twenty-five babies* (Vol. I). Minneapolis: University of Minnesota Press.
- Snyder-McLean, L. (1987). Reporting norm-referenced program evaluation data: Some considerations. *Journal of the Division of Early Childhood*, **11**, 254-264.
- Statham, L., & Murray, M.P. (1971). Early walking patterns of normal children. *Clinical Orthopaedics and Related Research*, **79**, 8-24.
- Sutherland, D.H., Olshen, R., Cooper, L., & Woo, S.L.Y. (1980). The development of mature gait. *The Journal of Bone and Joint Surgery*, **62-A**, 336-353.
- Thelen, E. (1986). Treadmill-elicited stepping in seven-month-old infants. *Child Development*, **57**, 1498-1506.
- Thelen, E., & Cooke, D. (1987). The relationship between newborn stepping and later locomotion: A new interpretation. *Developmental Medicine and Child Neurology*, **29**, 380-393.
- Thelen, E., Kelso, J.A.S., & Fogel, A. (1987). Self-organizing systems and infant motor development. *Developmental Review*, **7**, 39-65.
- Thelen, E., Ulrich, B.D., & Jensen, J.L. (1989). The developmental origins of locomotion. In M.H. Woollacott & A. Shumway-Cook (Eds.), *Development of posture and gait across the life span* (pp. 25-47). Columbia: University of South Carolina Press.
- Thorngate, W. (1986). The production, detection, and explanation of behavioral patterns. In J. Valsiner (Ed.), *The individual subject and scientific psychology* (pp. 71-93). New York: Plenum.
- Ulrich, B.D., & Ulrich, D.A. (1993). Dynamic systems approach to understanding motor delay in infants with Down syndrome. In G.J.P. Savelsbergh (Ed.), *The development of coordination in infancy* (pp. 445-459). Amsterdam, The Netherlands: Elsevier Science B.V.
- Ulrich, B.D., Ulrich, D.A., & Collier, D.H. (1992). Alternating stepping patterns: Hidden abilities of 11-month-old infants with Down syndrome. *Developmental Medicine and Child Neurology*, **34**, 233-239.
- Valsiner, J. (1986). Different perspectives on individual-based generalizations in psychology. In J. Valsiner (Ed.), *The individual subject and scientific psychology* (pp. 391-404). New York: Plenum.
- Voss, D.E. (1976). Proprioceptive neuromuscular facilitation: The PNF method. In P.H. Pearson & C.E. Williams (Eds.), *Physical therapy services in the developmental dis-*

- abilities* (4th ed., pp. 223-282). Springfield, IL: Charles C Thomas.
- Wolery, M. (1983). Proportional change index: An alternative for comparing child change data. *Exceptional Children*, **50**(2), 167-170.
- Wolery M., & Dyk, L. (1985). The evaluation of two levels of a center based early intervention project. *Topics in Early Childhood Special Education*, **5**(2), 66-77.
- Yin, R.K. (1989). *Case study research, design and methods* (rev. ed.). Newbury Park, CA: Sage.

Author Note

Appreciation is extended to Dr. Claudine Sherrill, Texas Woman's University, and Dr. Billye Cheatum, Western Michigan University, for graciously serving as external reviewers for this study.