
Systematic Review of Interventions Used in Occupational Therapy to Promote Motor Performance for Children Ages Birth–5 Years

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MeSH TERMS

- early intervention (education)
- evidence-based practice
- motor skills
- occupational therapy
- psychomotor performance
- treatment outcome

We examined the research evidence for interventions used in occupational therapy to promote the motor performance of young children ages 0–5 yr. We identified 24 trials, Levels I–III, that met our review criteria. The studies fell into three categories: (1) developmental interventions for infants (ages 0–3 yr), (2) interventions for young children with or at risk for cerebral palsy (CP), and (3) visual–motor interventions for preschool children (ages 3–5 yr). Developmental interventions showed low positive short-term effects with limited evidence for long-term effects, and findings on the benefits of neurodevelopmental treatment were inconclusive. Interventions using specific protocols for children with CP resulted in positive effects. Visual–motor interventions for children with developmental delays (ages 3–5 yr) resulted in short-term effects on children’s visual–motor performance. Of the intervention approaches used in occupational therapy, those that embed behavioral and learning principles appear to show positive effects.

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Because motor performance is essential to the young child’s ability to participate in play, self-care, and social interaction, occupational therapy practitioners often emphasize motor development in their interventions with young children. As development unfolds, the infant first demonstrates his or her cognitive ability through fine motor skills (e.g., reaching, grasping, and interacting with objects), and the infant’s first type of play is sensory–motor exploration.

Young children (ages 0–5 yr) who receive occupational therapy services in early childhood settings can have a variety of diagnoses or risk factors. Children who exhibit neuromotor impairments or motor delays affecting occupational performance may or may not have a medical diagnosis, and unlike older children, delays in developmental milestones alone can qualify them for services (Early Intervention Program for Infants and Toddlers With Disabilities, 2011; Individuals With Disabilities Education Improvement Act of 2004). Among infants and children at risk, those born preterm or at low birthweight often demonstrate delayed motor performance (Barrera, Kitching, Cunningham, Doucet, & Rosenbaum, 1991), and the smallest infants are at greatest risk for poor motor outcomes (Farooqi, Hägglöf, Sedin, & Serenius, 2011).

Although early intervention services for low-birthweight preterm infants can ameliorate impairments and prevent developmental delays, longitudinal studies have demonstrated that preterm infants remain at risk for cerebral palsy (CP), developmental coordination disorders, and learning disabilities (Marlow, Wolke, Bracewell, & Samara, 2005; Orton, Spittle, Doyle, Anderson, & Boyd, 2009). The rate of CP is 25 to 30 times higher in infants of very low birthweight than in infants of typical birthweight (Wilson-Costello, Friedman, Minich, Fanaroff,

& Hack, 2005). Young children diagnosed with CP experience significant limitations in sensory–motor play, adult and peer interaction, and activities of daily living (ADLs). These infants are often limited in mobility and can miss opportunities to explore their environment. They are also at risk for developing secondary problems (e.g., spasticity, contractures, stiffness, failure to grow, visual–motor limitations) that can further delay developmental progress. A child who is limited in independent interactions with toys, objects, and environments may also become passive and socially isolated (King et al., 2003).

Goals of early intervention are to minimize the developmental delay, remediate the impairment, and support family functioning (Blauw-Hospers & Hadders-Algra, 2005; Rosenbaum, King, Law, King & Evans, 1998). As members of the early intervention team, occupational therapists provide individualized interventions to promote motor performance, reduce the level of motor impairment, and increase the child's participation in play and ADLs.

Most interventions to remediate motor impairments in young children emphasize developmental approaches and learning principles. In the 1960s and 1970s, Bobath and Bobath (1984) formulated a set of principles that became known as neurodevelopmental treatment (NDT; Butler & Darrah, 2001). The purpose of NDT for children with CP is to reduce abnormal movement patterns and encourage normal purposeful movement (Mayo, 1991). In recent years, occupational therapy approaches for children with CP and other neurological disorders have expanded to become comprehensive interventions that embrace the implications of neuroplasticity (O'Brien & Williams, 2010), theories on how children learn (Taub, Ramey, DeLuca, & Echols, 2004), understanding of environment–person interactions (Law et al., 2011), dynamic systems theory (Case-Smith, Law, Missiuna, Pollock, & Stewart, 2010), and appreciation of play as a context for child development (Parham, 2007). The focus appears to have shifted from improving specific motor skills that follow the normal developmental sequence to promoting functional outcomes such as play and social interaction (Darrah et al., 2011; O'Brien & Williams, 2010). Early intervention programs also emphasize coaching models that support family well-being and educate parents on caring for a young child with specific needs (Rosenbaum et al., 1998).

Occupational therapists also provide services to children (ages 3–5 yr) with developmental delays who attend early childhood programs. These services include direct and consultative services (Davies & Gavin, 1994) and can be provided one-on-one or to small groups of children (Case-Smith & Holland, 2009). The child's

sensory–motor and visual–motor skills are often the focus of occupational therapy services (Case-Smith, 2000). De-Gangi, Wietlisbach, Goodin, and Scheiner (1993) defined the primary therapeutic approaches used with preschool children to improve sensorimotor skills as (1) perceptual–motor strategies, (2) sensory integrative therapy, and (3) NDT, acknowledging that these approaches are often combined and blended in the intervention sessions. Because a primary focus of early childhood programs is to prepare the child for school, the occupational therapist's goals and interventions typically emphasize preliteracy, prewriting, self-care, and behaviors appropriate for a kindergarten setting.

In the past 20 yr, practitioners, agency administrators, and government funding agencies have championed the importance of early intervention and early childhood services (Blauw-Hospers & Hadders-Algra, 2005; Hanft & Anzalone, 2001; Shonkoff & Meisels, 2000). Professionals and families have embraced the promise of early intervention because they more fully understand neuroplasticity and the potential of a highly responsive nervous system in the first 5 yr of life (Shonkoff & Philips, 2000). Despite the compelling nature of these theories, evidence for the effectiveness of early interventions has been inconclusive, and a body of rigorous clinical trials has not yet been established (Anttila, Suoranta, Malmivaara, Mäkelä, & Autti-Rämö, 2008).

Early intervention and early childhood systems serve a broad scope of children, including those undiagnosed but at high risk for disability (e.g., born preterm at low birthweight) and those with developmental delays but no diagnosis. The aim of early intervention services is to enhance developmental skills and prevent disability; this aim becomes more focused on preliteracy and school readiness skills as the child reaches ages 4 and 5 yr. As members of interdisciplinary teams, occupational therapists have primary roles in early intervention and early childhood programs. One focus of their services is the child's motor function as an essential component of participation in ADLs, play, and social relationships. The goal of this systematic review was to answer the following research question: What is the evidence for the effectiveness of interventions within the scope of occupational therapy to improve motor performance in children birth to age 5 yr?

Method

This review was completed as part of the American Occupational Therapy Association's (AOTA's) Evidence-Based Practice Project. See Arbesman, Lieberman, and Berlanstein (2013) for specific information about the methodology. The original question for this study was

broader in scope, that is, to review interventions that promote children's preliteracy skills. In consultation with the project administrators, the research question was subdivided into two questions, including one regarding the focus of this article, motor performance outcomes. The original search used the following databases: Medline, CINAHL, PsycInfo, ERIC, Cochrane Database of Systematic Reviews, Campbell Collaboration, and OTseeker. Search terms included *infants, newborn, premature, preschool children, toddlers, young children, child development, activities of daily living, adaptive equipment, early childhood intervention, early intervention, fine motor skills learning, gross motor, gross motor skill learning, haptic perception training, hand skills, handwriting, imitative behavior, kinesthetic perception training, manipulation skills, motor activity, motor processes, name writing, occupational therapy, perceptual learning, perceptual motor learning, perceptual motor processes, preemergent writing, physical development, play, posture balance, postural control, posture, psychomotor, psychomotor performance, self care, sensory integration, sensory processing, shoulder control, skill learning, space perception, spatial ability, transition, visual motor, visual perception, visual-perceptual skills, and visual spatial ability.*

The studies included in this review met the following criteria: intervention within the occupational therapy scope of practice, participants children age birth to 5 yr at risk for or with a developmental delay or disability, peer-reviewed literature written in English, and articles published within the past 20 yr. Only studies at evidence Levels I, II, or III were included. The studies were originally reviewed by the second and third authors (Frolek Clark and Schlabach) with a team of occupational therapy students. When the research question was revised, a second search using the same terms and criteria and focused on recent trials was completed. The first author (Case-Smith) rereviewed all of the studies, confirmed the levels of evidence, and revised the evidence table that guided the development of this article. All authors participated in a process of synthesizing the studies to identify themes and to distill the salient findings across studies.

Results

A total of 24 articles met the criteria and were included in the review. Of these, 16 were Level I, 7 were Level II, and 1 was Level III. The studies fell into three primary categories and described six types of intervention (see Supplemental Table 1, available online at <http://ajot.aotapress.net>; navigate to this article, and click on "Supplemental Materials"). The themes for the studies were as follows:

- Developmental play-based interventions for infants at risk (5 studies)

- Interventions for young children with or at risk for CP (15 studies)
- Visual-motor interventions for preschool children with developmental delays (4 studies).

The studies and key findings are summarized for each of the themes in the sections that follow.

Developmental Play-Based Interventions for Infants at Risk

Five studies examined the effects of developmental interventions; 2 were systematic reviews, and 3 were randomized controlled trials (RCTs). Two of the developmental interventions were combined with other play-focused strategies (e.g., aquatic therapy, parent education). In these approaches, therapists analyze the child's developmental level, encourage the next steps in play activities, and provide opportunities for the infant to transfer newly learned skills. With an understanding of the child's emerging skills, the therapist provides appropriate supports to promote the child's mastery of new skills. Often, therapists apply physical and social scaffolding to support the child's performance at a higher level, reinforce the child's efforts, and gradually fade supports (Case-Smith et al., 2010; Casey & McWilliam, 2011).

In an RCT of a developmental motor program for Thai infants (Lekskulchai & Cole, 2001), 84 preterm infants at risk for motor delays were randomly assigned to a therapy or control group. The intervention was a home program of 12 activities updated at 1, 2, and 3 mo adjusted age. At 4 mo adjusted age, the infants who received the home program scored significantly higher on the Test of Infant Motor Performance (Campbell, Kolobe, Wright, & Linacre, 2002) than those in the control condition and were similar to a group of infants who were not at risk.

The effects of another home-based therapy program emphasizing motor play on mother-child interaction and motor performance were analyzed in a sample of 38 mothers and infants with motor delays (Chiarello & Palisano, 1998). Infants (mean age = 19 mo) and mothers in the intervention group ($n = 19$) received five parent education sessions that included modeling activities to promote fine and gross motor skills in the context of positive, encouraging interactions; the control group ($n = 19$) received only usual care. Ratings using videotapes of mother-infant play showed that the interactions for both the control and the intervention groups were primarily positive and similar to each other (although mothers who participated in the intervention more appropriately held their infants).

McManus and Kotelchuck (2007) also involved families in a nonrandomized trial to examine the effects of aquatic therapy on young children (mean age = 15.8 mo) with a variety of motor disabilities. The intervention group received 36 wk of aquatic therapy (specific resistive movements in a pool) provided by an occupational therapist and physical therapist as a supplement to home-based occupational and physical therapy. The comparison group received only home-based occupational and physical therapy. Using the Mullen Scales of Early Learning (Mullen, 1995), the children who received aquatic therapy improved significantly more in functional mobility. McManus and Kotelchuck suggested that aquatic therapy is a community-based option that appears to benefit children's motor function.

Two systematic reviews examined the effects of early intervention services on motor outcomes. Blauw-Hospers and Hadders-Algra (2005) examined the effects of early intervention on motor development in infants ages birth to corrected age of 18 mo. Of the 34 studies reviewed, 17 examined neonatal interventions and 17 examined interventions implemented post-neonatal intensive care unit (NICU). For the NICU interventions, 7 of 17 studies (2 Level I and 5 Level II) had significant positive effects on motor development. The Newborn Individualized Developmental Care and Assessment Program (Als et al., 1994) had short-term effects on motor development, but long-term effects have not been found. Most interventions applied after the neonatal period were home-based and resulted in infants making limited motor gains. In 24 of 34 studies, parents were incorporated into the intervention; in 19, the parents were the focus of the intervention. Only 4 of 17 studies demonstrated a positive effect on motor development. These studies investigated developmental programs or specific motor training (e.g., treadmill training). Blauw-Hospers and Hadders-Algra concluded that the optimal interventions for motor development vary according to the age of the child and that the current approaches have minimal evidence in support.

Orton et al. (2009) concurred with these findings. They investigated the effects of early intervention programs on cognitive and motor development of preterm infants, with interest in both short-term (infancy) and long-term (school-age) outcomes. Of the 17 motor outcome studies, 8 with sufficient data analysis for meta-analysis showed a low effect (standardized mean difference = 0.07, $p = .18$) that was not significant. Of the remaining 9 studies, only 1 had a positive effect (i.e., Lekskulchai & Cole, 2001). Orton et al. concluded that the meta-analysis found no beneficial impact on motor outcomes at infancy or

school age; however, because the interventions and measures were heterogeneous, the meta-analysis results should be viewed cautiously.

Interventions for Young Children With or At Risk for Cerebral Palsy

Occupational therapy is a primary intervention for children with CP, who often receive therapy services throughout early childhood. A range of interventions have been developed and tested, with varying levels of efficacy. We identified 15 studies of interventions for CP, 12 Level I and 3 Level II. One systematic review examined the effectiveness of upper-limb interventions for children with hemiparetic CP; the remaining studies examined the effects of NDT, constraint-induced movement therapy (CIMT), conductive education (CE), and context-focused intervention.

Sakzewski, Ziviani, and Boyd's (2009) meta-analysis of therapy for children with hemiparesis (also termed *unilateral CP*) included 20 studies, 13 trials, and 7 systematic reviews that met their criteria. The studies included children of all ages; however, in most studies a portion of the sample were young children (<5 yr). Outcome measures included motor performance, progress on individualized goals, and self-care skills. The interventions used by occupational therapists fell into three categories: NDT, CIMT, and bimanual therapy. The meta-analysis revealed that children who received NDT improved in dissociated movements and individualized goals but not in motor function. CIMT and bimanual therapy are both intensive therapies for children with unilateral CP in which therapists use motor learning and behavioral (shaping) theories. CIMT trials have produced moderate to large treatment effects (see the next section); however, the measures often lack evidence of reliability and validity (Hoare, Imms, Carey, & Wasiak, 2007). The bimanual intensive treatment produced small effects. This meta-analysis set the stage for later trials comparing CIMT and bimanual interventions for children with unilateral CP (e.g., Sakzewski et al., 2011).

Neurodevelopmental Treatment. Six trials—five in the 1990s—of NDT with young children have been completed. The goal of NDT is to inhibit the abnormal movement patterns often observed in spastic CP and to increase normal movement patterns. Treatment involves extensive handling and positioning that the therapist performs with the child and encourages parents to implement at home (Law et al., 1991). This therapeutic approach has been widely used by occupational therapists in services for children with CP.

Mayo (1991) completed an RCT examining the effects of NDT with a sample of 29 infants ages 7–18 mo

with severe or moderate involvement. The infants who received the intensive NDT, compared with the basic NDT (a home program), demonstrated more improvement in aggregate scores for motor development that included both normal and abnormal movements. Also in the 1990s, researchers from Canada (Law et al., 1991, 1997) completed two trials examining the effects of casting and NDT on young children with CP. They combined NDT handling techniques with inhibitive casting of the wrist. In the first study (Level I), 79 children were randomized to regular or intensive NDT with or without casting. The children who received intensive NDT plus casting improved more in quality of movement but were no different in hand function (i.e., specific hand skills). Law et al. (1991) stated that this trial was underpowered, and they implemented a similar trial that was published in 1997. The second randomized trial of preschool children (ages 18 mo–4 yr) used a crossover design with a washout period to compare NDT with casting with regular occupational therapy. Although the children received more NDT intervention (24 sessions) compared with regular occupational therapy (9 sessions), the children did not differ in hand function or quality of movement postintervention. Both groups of children made highly significant gains in hand function and quality of movement during the intervention period; however, Law et al. (1997) could not attribute these improvements directly to intervention because they did not have a control group.

Two RCTs of NDT were completed with infants at risk for CP (i.e., infants born preterm or exhibiting motor development delays; see Wilson-Costello et al., 2005). Girolami and Campbell (1994) evaluated the effects of NDT with a group of at-risk (i.e., low birthweight) preterm infants. Nine preterm infants (34–35 wk gestational age) received NDT and 10 received nonspecific handling (for the same amount of time); 8 full-term infants received no intervention. These infants participated in 14–28 sessions within 7–17 days. NDT sessions had no effect on neonatal behaviors and responsiveness; however, the infants who received NDT exhibited more antigravity movements. In a repeated-measures randomized study, Arndt, Chandler, Sweeney, Sharkey, and McElroy (2008) compared the effects of NDT ($n = 5$) with those of parent–infant play ($n = 5$) on gross motor skills in infants with postural and motor dysfunction. Both protocols consisted of 10 one-hr sessions over 15 days. The 5 infants who received NDT improved significantly more in gross motor function than the infants who received parent–infant play. These studies (Arndt et al., 2008; Girolami & Campbell, 1994) did not in-

clude follow-up measures; therefore, whether the gains were retained is not known.

In a systematic review of NDT, Brown and Burns (2001) found 16 trials of NDT (12 of 16 were Level II evidence) that met their criteria. Of these, 14 included young children, ages 5 yr or younger, and 7 had been published since 1990. In the 10 studies sampling children with CP, 6 demonstrated benefit and 4 did not. Of the 6 studies of high-risk infants, 1 supported the use of NDT and 5 did not. Brown and Burns concluded that the evidence for benefit from NDT is mixed and that the findings for the efficacy are inconclusive.

Constraint-Induced Movement Therapy. Five published reports of three trials (Level I) of CIMT with young children with hemiparesis or unilateral CP were identified. In CIMT, the child's less affected arm is constrained, and occupational or physical therapists provide activities using motor learning theory and motor shaping principles to encourage improved function in the affected arm. CIMT protocols include intensive therapy (e.g., 2–6 hr/day) and application of constraint (e.g., using casts, splints, mitts) to the less affected arm.

Willis, Morello, Davie, Rice, and Bennett (2002) examined the effects of CIMT using casting of the less affected limb (without shaping procedures) for 1 mo while the children (ages 1–8 yr) attended standard therapy ($n = 12$ in casted group; 13 in control group). This study, compared with the others selected for review, did not include intensive therapy. The children were evaluated immediately after 1 mo of casting or control and 6 mo later. The control group entered the casting condition at 6 mo. Children whose less affected arm was casted demonstrated improved fine motor skill for the affected arm compared with children in the control condition, and this improvement was maintained at 6 mo. Parents reported improvement in the children's daily living skills after the casting procedure.

In an RCT using a crossover design, Taub et al. (2004) and Deluca, Echols, Law, and Ramey (2006) examined the effects of CIMT on 18 children with CP and asymmetric involvement (mean age = 41.5 mo). Occupational or physical therapists provided 6 hr of intensive motor-shaping therapy for 21 consecutive days during which time the child wore a full cast on the less affected arm. After the casting condition, the children exhibited increased frequency and quality of use of the affected arm on the Pediatric Motor Activity Log and new motor patterns and classes of functional activity on the Emerging Behaviors Scale (Deluca et al., 2006; Taub et al., 2004). Quality of movement did not show significant changes when groups were compared. A more

recent trial (Aarts, Jongerius, Geerdink, van Limbeek, & Geurts, 2010) tested modified CIMT (CIMT combined with bimanual training), in which children with unilateral spastic CP (ages 2.5–8 yr) pretended to be pirates. In this intervention, children ($n = 28$) received functional training during 3-hr sessions, 3 days/wk for 8 wk. During the first 6 wk, the less affected arm was constrained, and during the final 2 wk, children participated in bimanual play and self-care without constraint. The usual-care group ($n = 24$; mean age = 5.1 yr) received regular therapy (1.5 hr/wk). The children who received modified CIMT improved significantly more on the Assisting Hand Assessment (Krumlinde-Sundholm, Holmefur, & Eliasson, 2007; 13% improvement) and ABILHAND-Kids (Arnould, Penta, Renders, & Thonnard, 2004; 36% improvement) than the children in usual care (who improved 5% on each assessment). These researchers suggested that the meaningful and challenging environment (pretending to be pirates) provided the children with playful and interesting activities that motivated their improved function.

Aarts, Jongerius, Geerdink, van Limbeek, and Geurts (2011) conducted a secondary analysis of these results. In this analysis, they examined how improvements in spontaneous use of the affected limb during play and self-care activities were established using the video observations and measurements of passive and active range of motion of the affected arm. The children with baseline poor manual ability appeared to be the best responders to CIMT. Although the children improved in how they used the affected arm, they did not improve in automaticity or strength. Thus, CIMT interventions improve quality and frequency of hand use but have limited effects on duration of use or increased automaticity. The CIMT studies with young children corroborated studies of older children (e.g., Charles, Wolf, Schneider, & Gordon, 2006; Sakzewski et al., 2011) demonstrating positive effects of CIMT.

Conductive Education. Two trials (one Level I and one Level II) examined the effects of CE on young children with CP. CE originated in Hungary and uses a master conductor to administer the program (Reddihough, King, Coleman, & Catanese, 1998). In CE programs, groups of children form social units that together perform activities designed to improve their control of functional movements. The conductor and therapists lead the children in goal-directed and highly structured tasks, give specific verbal cues for movements, and use specific equipment (e.g., ladders and chairs). Activities use rhythm, songs, or rhymes to facilitate movements. The two studies selected were completed by the same Australian team. In the

initial study, Catanese, Coleman, King, and Reddihough (1995) compared 34 children (ages 4–7 yr), 17 who received CE and 17 who attended preschool and received individualized physical therapy. After 26 wk of intervention, the CE group improved more in gross and fine motor skills and ADLs. In a later study, Reddihough et al. (1998) analyzed the effects of CE on 34 children (ages 12–36 mo) who were randomly assigned to CE (76 hr over 6 mo) or a control condition of usual care (80 hr of occupational and physical therapy over 6 mo). The CE group demonstrated greater gains in cognition, and the control group demonstrated greater gains in behavior and organization. Both groups also improved in gross motor skills, with no difference between groups. The authors concluded that children in both conditions improved, with no difference between CE and standard therapy. These studies offer weak evidence for the benefits of CE.

Context-Focused Intervention. A recent RCT examined the effects of child-focused versus context-focused intervention on functional performance in young children with CP. Law et al. (2011) randomized 128 children with CP (mean age = 3 yr, 6 mo) into child-focused intervention with an emphasis on improving performance or into context-focused intervention with an emphasis on adapting the context to enable more function. In the child-focused approach ($n = 71$), the therapists identified the impairments and provided therapy to remediate and practice specific movements. In the context-focused intervention ($n = 57$), the therapists emphasized changing tasks and environment rather than the child. Using dynamic systems theory, the environment was modified to challenge the child and allow the child to problem solve how to reach the activity's goal (Darrah et al., 2011). Children in both groups made gains (effect sizes for self-care and mobility ranged from .22 to .26). Children younger than age 4 yr showed significantly more improvement than children older than age 4 yr. Assessments for self-care, mobility, social function, and gross motor function at 6 and 9 mo postintervention (18–19 therapy sessions) were no different for the two groups. These two approaches are generally combined in occupational therapy; this study suggests that both can contribute to improvement in functional performance for children with CP.

Visual–Motor Interventions for Preschool Children With Developmental Delays

Occupational therapists apply perceptual–motor and visual–motor interventions to promote preschool children's prewriting skills. Visual–motor skills appear to be an

important precursor to writing and in the young child are highly correlated with handwriting (Case-Smith, 1996; Dankert, Davies, & Gavin, 2003; Tseng & Murray, 1994). Four studies (3 Level II and 1 Level III) examined the effects of occupational therapy on visual–motor skill development in preschool children with visual–motor delays.

In a nonrandomized cross-over design, DeGangi et al. (1993) tested the effects of a child-centered versus a therapist-directed approach on visual–motor skills in 12 children (mean age = 53 mo). The children exhibited delays in fine motor skills, sensory processing, or motor planning. In the child-centered intervention, the child was allowed to explore his or her environment, dyadic interaction was emphasized, and the child selected the activity with therapist guidance. In the therapist-directed intervention, the sequence of activities was predetermined, and the therapist directed the activities and taught specific skills. Each child received 8 wk of one condition, was tested, and then received 8 wk of the other approach. The children in the therapist-directed intervention improved more in gross motor skills and functional skills. The children in the child-centered intervention improved more in fine motor skills. Behavior, attention, and play skills did not differ between groups. DeGangi et al. suggested that these two approaches are generally combined and that temperament, behavior, and affect may determine a child's response to one therapy rather than the other.

In a second study that investigated the effects of service delivery method, Davies and Gavin (1994) compared the effects of individualized therapy services with those of group or consultation therapy services for preschool children with developmental delays. Using a sample of 18 preschool students with disabilities, they found that the children in the consultation model made similar gains on the developmental motor scales as the children who received individual therapy. Their gains in fine and gross motor skills were similar to those made by typical children (i.e., standard scores did not differ preintervention to postintervention). As in the previous study, clinicians often combined individualized therapy and group sessions in service delivery.

In a later study, Dankert et al. (2003) studied the effect of 1 yr of occupational therapy services on visual–motor skill development in a sample of preschool children with developmental delays ($n = 12$) compared with two comparison groups of children without developmental delays (one that received the intervention [$n = 16$] and one that received no intervention [$n = 15$]). An occupational therapist provided the intervention,

which comprised fine motor, gross motor, and visual–motor activities. The children with delays who received intervention improved significantly pre- to posttest in visual–motor integration skills. These gains were larger (effect size = 1.15) than the gains made by the children without developmental delays who did not receive therapy (effect size = 0.16); they also made gains when standard (age-adjusted) scores were used. In a one-group pretest–posttest study, Case-Smith (2000) also examined the effects of occupational therapy services on fine motor and visual–motor outcomes. Using a sample of 44 children (mean age = 57 mos) with fine motor delays, the outcomes of 9 mo (23 sessions) of occupational therapy services were measured. Intervention comprised consultation (16%), individual sessions (62%), and group sessions (52%). The participants made statistically significant gains in manipulation, motor accuracy, fine motor, and visual–motor skills (d s = 1.83–2.13). The use of play and peer interaction within the therapy sessions predicted fine motor and visual–motor outcomes. This group of occupational therapy studies investigated service delivery models, including group versus individualized and child-centered versus therapist-directed. Although this group of studies had lower rigor (Levels II and III); the occupational therapy models demonstrated positive effects on fine motor and visual–motor performance in preschool children with mild to moderate disabilities.

Discussion

Children with motor delays or disabilities often receive occupational therapy services to promote motor performance and functional outcomes. Our synthesis included 24 studies that reported the effects of interventions within the scope of occupational therapy for infants and young children.

Developmental Interventions for Infants

When providing services to infants and toddlers, developmental approaches in playful contexts are frequently used. Interventions typically involve the caregiver as a participant (e.g., Lekskulchai & Cole, 2001) or as the focus on the intervention (e.g., Chiarello & Palisano, 1998). An understanding of development is essential to designing interventions for all young children; however, designing activities that follow a developmental sequence may not be sufficient to affect clinically significant motor performance outcomes.

Most early motor interventions (e.g., those implemented when in the NICU) demonstrate short-term effects; however, evidence of long-term effects is minimal

or missing. When interventions are applied to preterm infants who are at risk for developmental delays, all infants experience a neuromaturation process that may wash out intervention effects. Outcome measures represent averages for infants with neurological impairment, who may have benefited most from intervention, combined with those for infants who are neurologically intact. When examining motor outcomes of a variety of intervention approaches with infants, Blauw-Hospers and Hadders-Algra (2005) found that only a small portion (4 of 17 studies of intervention implemented post-neonatal period) showed evidence of positive effects. Most of these studies combined developmental approaches with other types of intervention (e.g., NDT, CE). Early developmental interventions demonstrated low effects when motor outcomes were later measured at school age, suggesting that developmental approaches may lack the potency needed to achieve significant effects (Blauw-Hospers & Hadders-Algra, 2005; Orton et al., 2009).

Despite lack of evidence for long-term gains, the benefits of short-term improvements in motor performance should be considered. Although not the focus of this review, researchers have found that when motor performance improves, infants achieve cognitive benefits (e.g., Bushnell & Boudreau, 1993; Orton et al., 2009). For example, when infants with motor delays improve in motor performance or mobility independence, such that they can explore and manipulate their environment, cognitive performance and socialization skills improve (e.g., Butler, 1986; Latash, 2000; Ragonesi, Chen, Agrawal, & Galloway, 2010). Therefore, motor performance improvements can lead to meaningful functional gains in other domains.

Interventions for Children With Cerebral Palsy

Trials of interventions for children with CP demonstrate mixed findings. NDT, despite its wide use by occupational and physical therapists, demonstrates low effects or effects that are similar to those of comparison interventions (Brown & Burns, 2001). As proposed by Bobath and Bobath (1984), when applying NDT, occupational and physical therapists inhibit the child's abnormal muscle tone and guide the child to move in a normal developmental sequence. However, studies have shown that inhibition of tone through handling techniques does not appear to have long-term effects (Law et al., 1991). For certain daily activities, children with CP can be more functional when their movements do not resemble typical patterns. Butler and Darrah (2001) suggested that NDT lacks evidence of positive effects because its principles are based on the assumption that movement links only to the

neural system, and NDT principles do not integrate current understanding of dynamic systems as the basis of movement. To develop an intervention based on principles of dynamic systems theory, Law et al. (2011) designed and tested a context-focused intervention, defined as a "functional, task-oriented and activity focused" approach (Darrah et al., 2011, p. 616). In context-focused intervention, the therapists collaborated with the child's family to modify the tasks and environments in which the child functioned. Therapists encouraged the children to problem-solve new and challenging tasks using their unique (sometimes atypical) skills, accomplishing the task with a combination of mastered and emerging skills. Children used both trial-and-error approaches and "abnormal" movement to accomplish new tasks (Darrah et al., 2011). Children in the context-focused intervention made meaningful functional gains that were similar to those of children in the child-focused intervention. Law et al. (2011) suggested that efficacious interventions for young children with CP combine and balance child performance intervention with contextual adaptations.

Trials of CIMT demonstrate its benefit for young children with unilateral CP. Although our findings are based on only three RCTs, several other trials using older children concur that CIMT is an efficacious intervention (Eliasson, Krumlinde-Sundholm, Shaw, & Wang, 2005; Gordon, Charles, & Wolf, 2006; Gordon et al., 2011; Sakzewski et al., 2011). The active ingredients of CIMT—constraint of the less affected arm and intensive therapy using motor learning principles in functional, meaningful tasks—are both theory and research based (Taub, Uswatte, & Pidikiti, 1999). In CIMT, constraint of the less affected arm forces the child to attend to and rely on the more affected arm, resulting in extensive arm and hand use in everyday tasks. In most trials, the intensive therapy in CIMT ranges from 2 to 6 hr/day, with continuous constraint (i.e., casting) or constraint only during therapy sessions. As defined by Deluca et al. (2006), the child is challenged to attempt a new task with the involved arm that approximates his or her current skills. Attempts to accomplish higher level skills are encouraged and reinforced. Massed practice with fading reinforcement is used; challenging tasks are interspersed with mastered skills.

Although CIMT follows current understanding of motor learning and use of behavioral techniques, protocols for CIMT have not been clearly defined and vary across trials. An emerging type of therapy for children with unilateral CP eliminates the constraint and focuses on bimanual training (Charles & Gordon, 2006; Gordon, Schneider, Chinnan, & Charles, 2007). Bimanual training

appears to have similar efficacy to CIMT but has not yet been tested in young children (Gordon et al., 2007; Sakzewski et al., 2011). In practice and in recent trials, CIMT and bimanual training are combined for a short-term intensive intervention period (e.g., 4–6 wk). The positive effects found in these studies suggest that short-term, intensive periods of intervention may have greater benefit than extended periods of low-dosage therapy 1–2 hr/wk.

Visual–Motor Interventions for Preschoolers

In early childhood programs, occupational therapists apply visual–motor interventions with young children who demonstrate visual–motor or fine motor delays. Generally, therapists use group and individual interventions with consultation focused primarily on pre-writing and writing goals. In the four studies that examined the effects of visual–motor interventions, one was clinic based, three were administered in preschools, and all involved children with a variety of diagnoses and mild to moderate delays in visual–motor skills. Each study demonstrated positive effects on visual–motor skills. A therapist-directed, structured approach can produce greater improvement in gross motor skills, and a child-centered activity approach may result in more fine motor improvement (DeGangi et al., 1993). Two studies suggested that therapy sessions can leverage social elements to motivate the child and result in fine motor or visual–motor gains. Davies and Gavin (1994) found that group or consultation occupational therapy services are as beneficial as individual (one-on-one) sessions. Given that group and individual sessions have equal benefit, decisions about service delivery can be based on the child’s current developmental levels, behavioral issues, and contextual considerations. Case-Smith (2000) found that sessions that included peer interaction and play were related to visual–motor skill improvements. In group intervention sessions, therapists invite children of different performance levels and encourage peers to model for and reinforce the targeted child, to create a playful atmosphere, and to use peer support as a motivator.

Implications for Occupational Therapy Practice

These studies suggest that although the developmental frame of reference is an essential foundation for all practice with children, interventions that are built solely on developmental theory have minimal effects on motor outcomes. Efficacious interventions apply theory-grounded, research-based learning and behavioral techniques. These interventions (e.g., CIMT, context focused) have focused and specified proto-

cols. In trials of these interventions, the measures targeted specific performance components that closely align with the goals and methods of the intervention. In summary,

- Motor interventions that resulted in significant changes in children’s motor performance incorporated use of meaningful play activities (e.g., Aarts et al., 2010), family collaboration (e.g., Law et al., 2011; Reddihough et al., 1998), functional goals (e.g., Deluca et al., 2006; McManus & Kotelchuck, 2007), and social elements (e.g., Aarts et al., 2010; Case-Smith, 2000; Reddihough et al., 1998).
- Successful interventions were based on dynamic systems therapy and motor learning theory, reinforcing the importance of building intervention principles and strategies on research-based theories.
- Using behavioral (e.g., shaping, reinforcement, fading) and learning (e.g., cueing, motivating, scaffolding, presenting a just-right challenge) principles to undergird intervention strategies appears to be more potent than intervention guided solely by developmental and neurodevelopmental theories.

Limitations

This early childhood review was originally broader in scope and was revised to focus on motor outcomes. Although the focus of this review was early intervention, the age range for the children who participated in the studies varied, and some of the studies included children older than age 5. The majority of studies were Level I; however, some of the studies had low sample sizes and investigated short-term interventions, design limitations that can result in low effects and Type II error.

Conclusion

Interventions used by occupational therapists to promote motor performance in children with or at risk for disabilities have mixed evidence for their effectiveness. Interventions that promote normal motor development sequences may miss opportunities to reach the child’s functional goals. Effective interventions apply research-based theories in well-specified intervention protocols. Initial evidence for the effectiveness of interventions using dynamic systems theory and motor learning has been established. Manualized (specified) intervention protocols demonstrate clinically meaningful effects when targeted skills are measured. When occupational therapists adopt the child’s and family’s goals and measure achievement of specific goals, significant effects have resulted. Recent studies using strong research designs have found that

science-based interventions produce important functional gains in children's motor performance. ▲

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