Object Permanence and the Relationship to Sitting Development in Infants With Motor Delays

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Purpose: This study examines object permanence development in infants with motor delays (MD) compared with infants with typical development (TD) and in relation to sitting skill.

Methods: Fifty-six infants with MD (mean age = 10 months) and 36 with TD (mean age = 5.7 months) were assessed at baseline and then at 1.5, 3, and 6 months postbaseline. A scale was developed to measure object permanence (Object Permanence Scale [OPS]), and the Gross Motor Function Measure sitting subsection (GMFM-SS), and the Bayley Scales of Infant and Toddler Development, 3rd Edition (Bayley-III) were administered.

Results: Interrater reliability of the OPS was excellent and correlation between the OPS and Bayley-III cognitive scores was moderately positive. Compared with TD, infants with MD were delayed in development of object permanence but demonstrated increased understanding over time and as sitting skills improved.

Conclusion: In children with MD, object permanence, as quantified by the OPS, emerges in conjunction with sitting skill. (Pediatr Phys Ther 2022;34:309–316)

Key words: motor delay, object permanence, reliability, sitting, validity

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INTRODUCTION

Knowing that objects continue to exist when they cannot be directly observed or sensed is called "object permanence." This fundamental cognitive skill is important for working memory and allows us to form and retain mental representations of objects.[1] For example, when a ball rolls under a couch and out of sight, infants who have object permanence understand that the ball exists. They may persist in attaining the ball by moving their body in various ways to look for and reach it even though it is hidden from view.

As a cognitive construct, object permanence is intimately connected to perceptual motor experiences including object exploration and self-mobility.[2] Object exploration (eg, fingering, grasping, banging, rolling) scaffolds cognitive development by providing information about object properties (eg, shape, color, weight, texture, sound). As infants gain sitting independence, opportunities for object exploration increase, which, in turn, fosters cognitive change.[3,4] For example, 5- to 7-month-old infants demonstrate manual, oral, visual, and coupled (eg, oral-manual and visual-manual) exploration more often while in sitting position than when lying in supine or prone position.[4] Adequate postural control in sitting facilitates infant cognitive development by both freeing hands to manipulate objects and changing visual perspective.[5,6]

Following or coinciding with the emergence of sitting, self-mobility allows further environmental exploration, providing opportunities for the development of object permanence as documented in both infants with typical development (TD) and infants with motor delays (MD).[7] Independent crawling increases spatial awareness and motor search strategies and correlates strongly with object permanence.[7,8] When infants with delayed mobility are provided a mobility device, object permanence is noted to emerge concomitantly.[7] Early mobility (crawling) is also closely tied to increased sitting skill, both in developmental time and in control of one's body.[9] We speculated that budding cognitive constructs may be emerging during the development of sitting as well as with self-mobility. Thus, infants with limited perceptual-motor experience due to early MD prior to crawling or walking may be delayed in developing object permanence, yet no studies explore this potential relationship.

To clinically assess object permanence in infants, manual search is used for objects hidden in various ways. Unlike other laboratory-based methods, such as eye-tracking or violation of expectation techniques, manual search does not require specialized laboratory equipment, improving clinical feasibility. However, manual search requires motor skills that may be impaired or unavailable to young infants with MD. Infants begin to recover a fully hidden object between 8 and 10 months of age, when self-mobility is emerging.[10] Moore and Meltzoff[11] observed that 8.75-month-old infants with TD succeeded on a partial occlusion task by removing the obstruction to uncover the object, but they failed on a total occlusion task. Manual search tasks have been used to assess object permanence in infants with developmental delays, but their use has been limited to infants older than 18 months with developmental delays due to very low birth weight[12,13] or autism.[14] The motor demands of manual search (eg, postural orientation, grasping, and removing the obstruction) may prevent young infants with TD or those with MD from successful search strategies even though they may understand object permanence, as shown by studies involving eye-tracking and violation of expectation techniques.[15,16]

The Object Permanence Scale (OPS) was developed as part of a longitudinal study, in which the early motor skills of sitting and reaching were targeted as foundational motor skills necessary for learning early cognitive constructs such as object permanence.[17] Because there was no existing clinical tool to measure gradual changes in object permanence performance, our research team developed the OPS based on their extensive clinical and research experience in infant development. Primary investigators with more than 30 years of clinical early intervention experience and 20 years of research experience in MD and developmental psychology reviewed the literature and other standardized tests to develop the instrument. The purpose of this study was to first determine interrater reliability and validity of the OPS as a clinical tool suitable for early intervention and, second, to determine how object permanence develops over time in infants with MD as compared with infants with TD. We were interested in whether there is a positive relationship between the emergence of object permanence in infants with MD and emerging sitting development. The validity of the OPS

was examined with (1) the relationship of the OPS to another measure of cognitive ability (cognitive domain of the Bayley Scales of Infant and Toddler Development, 3rd Edition [Bayley-III[18]]); and (2) a comparison of OPS scores between infants with TD and infants with MD (known groups method). The known groups method is demonstrated when a test can discriminate between a group of individuals with a particular trait and a group with no trait.[19] We hypothesized that infants with MD would demonstrate delayed performance on the OPS when compared with infants with TD. We also hypothesized that object permanence in infants with MD, even though delayed compared with infants with TD, would improve over time in relation to sitting development.

METHODS

Design

This longitudinal, prospective cohort study is a component of 2 larger studies.[17,20] Infants with MD and with TD were assessed 4 times over 6 months: at baseline, 1.5, 3, and 6 months postbaseline. For both groups, the common inclusion criterion was sitting skill (sit propped on arms for at least 3 seconds), which creates a skill-held-constant design with sitting ability as the common factor. The skill-held-constant design or also referenced as the ability-held-constant design is a specialized developmental research design that allows researchers to investigate the relative importance of maturation and specific experiences.[21] Unlike the age-held-constant design that assesses infants at a specific age, the skill-held-constant design recruits infants based on a skill or an experience, so that infants of various ages may be included. Ethics approval was obtained from the Institutional Review Boards at Duquesne University and Virginia Commonwealth University.

Participants

Fifty-six infants with MD and 36 infants with TD were included in the study. The infants with MD were recruited from 5 regions in the United States (Pennsylvania, Virginia, Delaware, Nebraska, and Washington) for a longitudinal randomized controlled trial.[17] Infants with MD were eligible if they were (1) 7 to 16 months of age (corrected for prematurity), (2) able to sit propped on their arms for at least 3 seconds but unable to independently transition in and out of sitting, and (3) demonstrating gross MD at least 1 SD below the age-group mean on the gross motor domain of the Bayley-III. Infants were excluded if they were blind or had a progressive disorder. Infants born full-term with TD were recruited from the community in Richmond, Virginia, for a longitudinal observational study.[20] Infants with TD were eligible if they were (1) 7 months old or younger, (2) able to sit propped on their arms for at least 3 seconds but unable to independently transition in and out of sitting, and (3) without major health concerns, birth complications, or developmental/ MD evidenced by scores on the gross motor domain of the Bayley-III that were within 1 SD or above the mean. All parents provided written informed consent.

Table 1 provides demographic information for the infants and families in both groups. Infants with MD (23 boys, 33 girls)

TABLE 1
Demographic Characteristics of Infants With MD and Infants With TD[a]

	Infants With MD n = 56 (%)	Infants With TD n = 36 (%)
Age at baseline, months[b]		
Mean (SD)	10.23 (2.63)	5.68 (0.79)
Minimum-maximum	7.00-16.00	4.00-6.90
Sex		
Boy	23 (41.1)	17 (45.9)
Girl	33 (58.9)	20 (54.1)
Race		
Asian	4 (7)	0 (0)
African American or Black	7 (13)	4 (11)
White	40 (71)	27 (75)
Multiracial	5 (9)	3 (8)
Other		2 (6)
Severity		
Mild	28 (50)	N/A
Moderate	12 (22)	
Severe	16 (29)	
Income		
$0 to $15 000	7 (13)	4 (11)
$15 000 to $24 999	2 (4)	2 (5)
$25 000 to $34 999	2 (4)	0 (0)
$35 000 to $44 999	6 (11)	1 (3)
$45 000 to $59 999	1 (2)	2 (5)
$60 000 to $79 999	5 (9)	5 (14)
>$80 000	33 (59)	22 (61)
Missing		1 (3)
Parent education (mother/father)		
Some high school or less	1 (2)/4 (8)	2 (5)/1 (3)
High school graduate or GED	7 (13)/10 (19)	2 (5)/5 (14)
Some college or trade school	8 (15)/7 (13)	3 (8)/2 (5)
College graduate	22 (40)/14 (27)	7 (19)/13 (35)
Postgraduate degree	16 (29)/15 (29)	23 (62)/15 (41)
Missing	1 (2)/2 (4)	0/1 (3)

Abbreviations: MD, motor delays; N/A, not applicable; TD, typical development.
[a] The values indicate mean (SD).
[b] Significant group difference, $P < .01$.

were between the ages of 7 and 16 months (mean: 10.23 months, SD: 2.63 months) at baseline. Infants with MD were classified by the level of MD, based on a scale incorporating Gross Motor Functional Classification System levels, Manual Ability Classification Scale, distribution of motor deficit (eg, quadriplegia, hemiplegia), and active movement (gestalt observation of low/medium/high spontaneous movement including arm movement), which varied from mild (50%) to severe (29%). Infants with TD (17 boys, 20 girls) were between the ages of 4 and 6.9 months (mean: 5.68 months, SD: 0.79 months) at baseline. In both groups, most of the infants were White and more than 80% of the parents had greater than a high school education. The median income bracket was higher than the national median household income in the 5 states.[22] Infants with MD had a significantly higher mean age at baseline compared with infants with TD ($t_{62.18} = 12.75$; P value less than .01). No differences were found between infants with TD and MD for sex, race, income (below or above poverty line), and parent education (college degree or not).

Tests and Measures

Two experts in infant development extracted tasks with differing levels of difficulty from developmental studies on object permanence with infants developing typically and infants born preterm.[18,23-25] After consultation with a developmental assessment expert and item verification by a group of 4 experts with more than 20 years of clinical and research experience each, 7 tasks were selected and incorporated into an ordinal level assessment tool. Object permanence from minimal to advanced skills is rated on the OPS on a scale of 0 to 10, with 10 reflecting the highest level of performance (Table 2). The OPS begins with early motor skills related to object permanence (eg, looking at an object, tracking a slowly moving object) and gradually progresses to higher levels (eg, finding a partially and completely covered object, finding an object after visible displacements). During the test, infants sit on the floor in front of a table. If an infant cannot maintain a sitting position through the test, the infant sits in a supportive chair. The assessor begins the OPS with task 1 and continues until the infant reaches a score of 10 or he or she meets the ceiling criterion (failure on 2 consecutive tasks). The time required to complete the OPS varies from 1 to 10 minutes depending on child's ability. In most cases, it takes less than 5 minutes. For this cohort, the OPS was performed with all infants at each of the 4 visits to examine how object permanence develops in infants with MD in comparison with infants with TD across time.

The Bayley-III[18] is a standardized, norm-referenced test designed to assess development of infants and toddlers aged 1 to 42 months. The Bayley-III assesses 5 developmental domains: cognitive, language, motor, social-emotional, and adaptive behavior. Only cognitive and motor domains are reported here. The Bayley-III assesses cognition in a variety of tasks—such as exploring toys, object permanence tasks, means-end skills, and relational play—with different difficulty levels. The motor domain includes fine motor and gross motor subtests that assess performance in a variety of motor activities, such as reaching for blocks, turning book pages, sitting, or walking. Test results yield standardized scores for each domain (eg, scaled score, composite score). Reliability and validity of the Bayley-III are considered good (test-retest reliability: cognitive: $r = 0.81$, motor: $r = 0.83$; interrater reliability: cognitive: $r = 0.81$, motor: $r = 0.83$).[18] In this study, composite scores of the motor and cognitive domains at baseline in infants with MD were used to determine MD (inclusion criteria) and evaluate the relationship with the OPS scores, respectively.

The Gross Motor Function Measure (GMFM)[26] is a reliable and valid standardized measure designed to evaluate change in gross motor function over time. Although the GMFM was originally designed for children with cerebral palsy, it has been validated for use with children with developmental delays secondary to diagnoses such as Down syndrome[27] and brain injury.[28] The GMFM consists of 88 items grouped into 5 dimensions: (1) lying and rolling [17 items], (2) sitting (20 items), (3) crawling and kneeling (14 items), (4) standing (13 items), and (5) walking, running, and jumping (24 items). Items are each scored on a 4-point ordinal scale (0-3). In this study, the sitting subsection score (GMFM-SS, score range: 0-60) at each of the

Task Description	Score
1. Hold a toy at infant's eye level. Make sure that the infant is looking at the toy. Move the toy to the left and right sides of the infant (at least 45°) and observe whether the infant is tracking the toy.	*Score of 0*: Infant does not look at the toy when given visual cue or auditory cue to follow toy. *Score of 1*: Infant looks at the toy in one location, then shifts gaze to new location to find the toy when the toy is moved 45° to side or vertically. *Score of 2*: Infant reorients body part other than head to gaze at moved toy when toy shifted in space as in previous item. *Score of 3*: Infant reorients body posture to follow moving toy of interest.
2. Place a wide nontransparent container in front of the infant and then place a toy inside the container. Make sure that the infant looks at the toy and put the toy in the container. 3. Put one washcloth on the table. Show the toy to the infant and make sure that the infant is watching the toy. Hide the toy completely under the washcloth. Observe whether the infant retrieves the toy by pulling the washcloth off. If the infant does not do this, repeat the same procedure with the half of the toy visible from underneath the washcloth. 4. Put 2 identical washcloths on the table (not overlapping). Show the toy to the infant and make sure that the infant is watching. Hide the toy under one of the washcloths. Observe whether the infant retrieves the toy by pulling off the washcloth. 5. Put 2 identical cups on the table side by side. Show the toy to the infant and make sure that the infant is watching. Hide the toy under one of the cups. Observe whether the infant finds the toy. Perform the task 2 times (once under each of the left and right cups). If the infant failed on either side, perform the task again for both sides. 6. Put 2 cups on the table side by side. Show the toy to the infant and make sure that the infant is watching. Hide the toy under one of the cups. Reverse the cups while the infant is watching. Observe whether the infant looks for the toy. Perform the task 2 times (left and right). If the infant failed on either side, perform the task again for both sides. 7. Put 2 cups on the table side by side. Show the toy to the infant and make sure that the infant is watching. Hide the toy under one of the cups. Remove the toy and hide it under the other cup while the infant is watching. Observe whether the infant looks for the toy. Perform the task 2 times (left and right). If the infant failed on either side, perform the task again for both sides.	*Score of 4*: The infant looks inside of the container and attempts to retrieve the toy dropped inside. *Score of 5*: Pulls cloth off the toy after watching cloth being placed and the toy partially visible. *Score of 6*: Pulls cloth off the toy after watching the toy being slid under cloth. *Score of 7*: Pulls cloth off the toy after watching cloth being placed and toy completely covered, with identical cloth nearby. *Score of 8*: Infant finds toy hidden under 1 of 2 cups. *Score of 9*: Infant finds the toy while hidden 1 of 2 cups when the cups are reversed after the toy is hidden. *Score of 10*: Double visual displacement used as the toy is hidden under one cup, removed and hidden a second time under the second cup.

[a]The materials for the assessment: 1 table and 1 chair, 1 small toy, 1 wide nontransparent container (5-in high), 2 identical washcloths (8 in × 8 in), and 2 identical nontransparent cups.

4 visits was used to determine whether the emergence of object permanence in infants was related to sitting development.

Procedures

Infants were assessed at baseline and then at 1.5, 3, and 6 months postbaseline. At the baseline visit, parents completed a family demographic questionnaire. The OPS and GMFM-SS were performed with all infants at each of the 4 visits. The Bayley-III was administered to all infants but only at the baseline, 3-month, and 6-month visits. The 1.5-month visit did not include the Bayley-III assessment in the interest of time for both the family and the assessors because it was not an end point for that outcome measure. All assessments were administered by trained researchers and videotaped either in infants' homes or daycare setting. Trained, blinded assessors viewed the videos and scored the OPS, Bayley-III, and GMFM-SS. For scoring the newly developed OPS, a graduate research assistant (primary rater) was trained by an expert rater, a pediatric physical therapist with more than 30 years of clinical and research experience who participated in the selection of OPS tasks. Training lasted until the agreement in scoring between the 2 raters reached at or above 80% on 4 videos. After reaching high agreement on

4 consecutive videos, the primary rater scored the OPS videos. To determine interrater reliability of the OPS, a postdoctoral researcher who was also a pediatric physical therapist was trained by the expert rater and rescored 30 randomly selected videos.

Data Analysis

Descriptive statistics were used to report characteristics of the participants and scores for the OPS. Demographic comparisons between groups were completed with χ^2 and t test analyses for nominal and interval-level measures, respectively. Interrater reliability was determined using the intraclass correlation coefficient (ICC: 2,1). For concurrent construct validity evidence, we examined the correlation between the OPS and the Bayley-III cognitive composite scores in infants with MD. We used Bayley cognitive score as a criterion because the OPS assessed the cognitive construct of object permanence understanding. Because the OPS score is ordinal data, the Spearman ρ statistic was calculated. To determine whether object permanence in infants with MD was delayed compared with infants with TD, the OPS scores between the 2 groups were compared first using the Mann-Whitney U test (nonparametric test

	Infants With Motor Delays			Infants With Typical Development			
	N	Mean (SD)	Minimum-Maximum	N	Mean (SD)	Minimum-Maximum	P
Baseline	56	4.9 (2.8)	0-10	34	4.5 (1.5)	1-7	.277
1.5 mos	51	5.7 (2.7)	0-10	35	5.4 (1.8)	2-9	.307
3 mo	51	6.0 (2.7)	0-10	33	6.2 (2.0)	2-10	.981
6 mo	49	6.4 (2.5)	1-10	32	7.4 (1.8)	4-10	.075

to compare differences between 2 independent groups). The Friedman test (nonparametric alternative to the 1-way analysis of variance with repeated measures) was conducted for each group to examine whether there were changes in OPS scores over time. If the Friedman was significant, Wilcoxon signed rank test with Bonferroni correction confirmed where the differences occurred. Finally, to examine the relation between sitting skills and object permanence in infants with MD, the correlation between the OPS and the GMFM-SS scores was examined using the Spearman ρ statistic. Data were analyzed using SPSS Statistics version 25 (Armonk, New York). An α level of 0.05 was the criterion for significance.

RESULTS

Descriptive statistics of the OPS scores are shown in Table 3. When infants enrolled in the study, the development of object permanence skills varied from 0 (no response to a moving object) to 10 (find an object after double visible displacements). On average at baseline, infants in both groups noticed the disappearance of a toy and attempted to retrieve the toy dropped inside a container (OPS score of 4). The scores on the OPS increased in both groups over 6 months. On average, at the 6-month follow-up assessment, infants with MD were able to find a toy completely covered with a washcloth (OPS score of 6). Infants with TD were able to go a step further and find a toy completely covered in 1 of 2 identical washcloths (OPS score of 7).

Interrater Reliability and Validity

The ICC (2, 1) was 0.92 (95% confidence interval: 0.84-0.96), indicating excellent interrater reliability for the OPS scoring. The correlation between the OPS and the Bayley-III cognition scores in infants with MD, r (54) was 0.554 (P value less than .001), indicating moderate to good relationship.[19] The results of the Mann-Whitney U test showed that the OPS score did not differ between infants with MD and infants with TD at any of the 4 assessment visits (P value greater than .05). However, as infants entered the study when they had the ability to sit, infants with MD were significantly older than infants with TD (mean age at baseline = 5.7 months in infants with TD and 10.2 months in infants with MD, P value less than .001, Table 1). The finding suggests that development of object permanence as well as emergence of sitting was delayed by approximately 5 months in infants with MD compared with infants with TD.

Progression of Object Permanence in Infants With MD as Compared With Infants With TD

The Friedman test had a significant increase in OPS score over time: for infants with MD, χ^2 (3, n = 47) = 19.91, P value less than .001, and for infants with TD, χ^2 (3, n = 29) = 24.86, P value less than .001. For each group, 6 pairwise comparisons were completed using Wilcoxon tests with the Bonferroni correction (comparison-wise α, 0.05/6 = 0.008). The comparisons between baseline and 3 months and baseline and 6 months were significant in both groups (Figure 1). The results show that object permanence skills in infants with MD, even though delayed, improve over time in a parallel pattern to those of infants with TD.

Progression of Object Permanence in Relation to Sitting Development in Infants With MD

The results of Spearman ρ statistic showed significant correlations between OPS and GMFM-SS scores with r ranging from 0.584 to 0.715 (P value less than .001) at all 4 assessment visits. The OPS scores increased as sitting skill increased in infants with MD (Figure 2).

DISCUSSION

The results support that the OPS is a reliable and valid measure for the cognitive construct of object permanence. A significant and positive correlation of the OPS scores
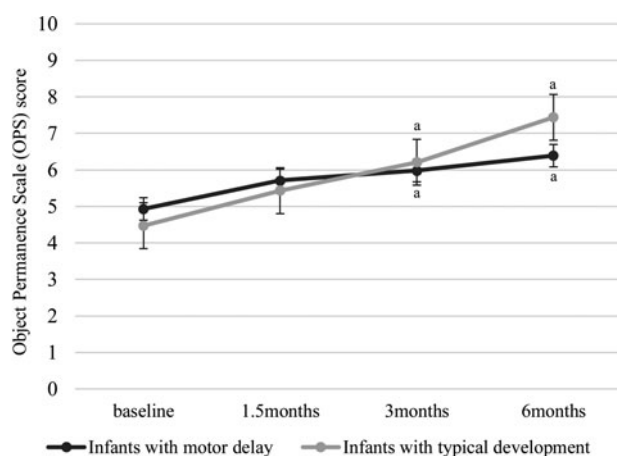

Fig. 1. Progression of object permanence in infants with motor delays as compared with infants developing typically. [a]Significantly higher OPS score compared with baseline score (P < .008). Bars represent standard errors of the mean.
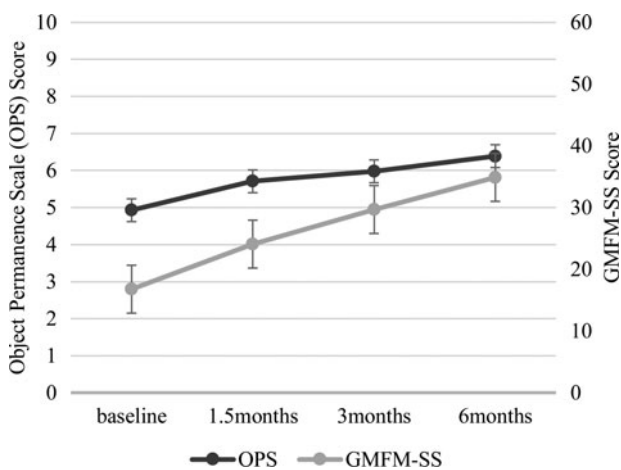
Fig. 2. Progression of object permanence in relation to sitting development in infants with motor delays. GMFM-SS indicates Gross Motor Function Measure sitting subsection. Bars represent standard errors of the mean.

with the Bayley-III cognition scores and the delayed performance on the OPS observed in infants with MD support the validity of the OPS. In Table 3, the mean OPS scores gradually increased over 6 months and individual infants' OPS scores covered the full range of scores with a maximum value of 10 and a minimum value of 0. These findings suggest that the OPS can capture minimal to advanced object permanence skills in infants with MD and TD, which supports the construct validity of the OPS. Our hypothesis that infants with MD will demonstrate delayed development of object permanence when compared with infants with TD was supported. The OPS scores were not different between groups; infants with MD, however, were approximately 5 months older than infants with TD at each assessment point.

In this skill-held-constant design, infants with and with no MD developed beginning object permanence skills as sitting emerged. Although each child has a unique developmental trajectory, infants with TD learn to sit between 4 and 8 months. During that time period, infants anticipate the trajectory of a moving object and understand that objects continue to exist when occluded by other objects.[16,29,30] As expected, infants with TD were between 4 and 7 months of age (mean = 5.7 months) when they entered the study at the onset of sitting. They tried to retrieve a toy, which was dropped inside of a container by looking inside of the container, turning or shaking the container, and/or reaching for the toy (task for OPS score 4). This indicates that the infants anticipated the trajectory of the dropped toy and predicted the landing position. Looking in the correct location for the toy, when the infant was unable to track the toy continuously, indicates an understanding of the toys' continued existence, even when momentarily unseen.

Although infants with MD as they entered the study at the onset of sitting (mean = 10.2 months of age) were approximately 5 months older than infants with TD, their performance on the OPS was similar to the performance of infants with TD. Findings suggest that delayed development of sitting skill may have an effect on the development of object permanence in young infants with MD. Sitting is important to the develop-

ment of object permanence because this vertical position allows a novel and broadened perceptual view of the world, as well as a new play position in which infants can explore and learn about objects in various ways (eg, stacking, putting in and out, putting together and taking apart, covering and uncovering objects).[3,4]

Both infants with and with no MD progressed in object permanence skill over 6 months, yet the slope of progression in infants with MD seemed to decrease around 6 months after baseline (Figure 1). Although there was no statistically significant difference in the OPS score between the 2 groups at the 6-month assessment, on average, infants with MD were able to find a toy completely covered by a washcloth (task for OPS score 6) but not able to find it when an identical washcloth was placed nearby (task for OPS score 7), whereas infants with TD were successful on both tasks. Despite only a 1-point difference on the OPS, it may be clinically meaningful because the more advanced task requires visual attention, quick eye-shifts, coordination of the reaching movement, and working memory to locate the toy.

Infants with MD demonstrated improvement in object permanence over time and in relation to the development of sitting skills (Figure 2). Findings suggest that infants with MD build the object permanence construct as they develop sitting skills and interact with objects. This expands previous research showing the linkage between early mobility skills and cognitive development.[7,31] It further reinforces the theory that cognition is grounded in everyday perceptual-motor experience[32,33] and supports the use of a grounded cognition perspective in early intervention practice and research.[2]

Clinical Implications

As shown by this study as well as in previous research,[5-7] infants with limited perceptual-motor experience, such as those skills needed for sitting, object exploration, and self-mobility, are at risk for cognitive delays, including object permanence. The OPS is an affordable, accessible, easy-to-use tool, which can be implemented with ordinary toys and materials within a brief period. The OPS assesses infants' object permanence from very minimal to advanced skills, so it may be used to monitor progression of object permanence performance. Notably, the OPS is an ordinal but not an interval measure. Because the successive scores may not represent equal increments of skill, users should take care in interpreting scores. The OPS may inform practice and the content or direction of intervention, rather than provide a normative measure of developmental skill. The OPS may be used in an early intervention setting to assess object permanence task performance and to monitor its progression for infants with MD.

Study Limitations and Further Research

This study has several limitations. Although families of infants with MD were from 5 geographic areas in the United States, families of infants with TD were recruited from 1 site. In addition, the sample size was modest, and the families in both groups had higher household incomes than the general population, indicating that they may not be a representative

sample. This study evaluated concurrent construct validity evidence of the OPS only in infants with MD. The 2 groups of infants included in the study were recruited from different studies, and there were insufficient Bayley-III cognitive score data to perform a correlation analysis in infants with TD. Studies involving larger and more diverse samples of families are needed to further validate the findings. All assessments were administered and videotaped by assessors at each of 5 sites and then masked, trained raters viewed the videos and scored for the OPS, Bayley-III, and GMFM-SS. This procedure was used to improve the reliability of scoring for each assessment because, due to the research design, many assessors (2 or more at each site) were involved. However, this assessment procedure may have resulted in an overestimation of interrater reliability of the OPS. The slope of object permanence progression in infants with MD tended to decrease around 6 months after baseline, which may be related to increasing mobility of the TD group and a lag in progression of mobility for the MD group; however, this was not examined for this report. Studies involving long-term follow-up are needed to explore the linkage between MD and object permanence development and determine whether object permanence would be further delayed in infants with MD. Studies involving different settings or intervention programs are needed to determine the effects of early intervention services on the development of object permanence.

WHAT THIS ADDS TO THE EVIDENCE?

Infants with MD are at risk for delayed development of object permanence. The OPS is intended to measure gradual change over time from very minimal to advanced skills in object permanence performance. The results showed that the OPS is a reliable tool that can be implemented with ordinary toys and materials within a brief period. Although delayed compared with infants with TD, infants with MD showed improvement of object permanence across time as sitting skills develop. The OPS may help early interventionists assess object permanence performance and monitor its progression for infants with MD. The skill of sitting appears closely related to the developing cognitive skill of object permanence; thus, interventionists should anticipate the coemergence of these 2 areas and link them during intervention.

ACKNOWLEDGMENTS

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