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Update on the EMI for Infants and Toddlers

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Abstract

Universal screening and progress monitoring measures are increasingly of interest to early interventionists who make decisions about the services provided to young children. A measure of infant-toddlers' growth in early movement, the *Early Movement Indicator (EMI)*, was reported in 2002. However, the EMI has remained an experimental measure based on a small sample and not used broadly by practitioners in real-world programs. We addressed this limitation by advancing knowledge the EMIs scalability through a website and improved psychometrics in a large sample. Results indicated that the EMI was (a) scalable evidenced by a large volume of early childhood staff users in programs in five states with 628 children and 2,258 individual EMI assessments, (b) sensitive to growth over time, (c) comprised of a complex continuum of skill development, and (d) influenced by moderators (i.e., home language, Individual Family Service Plan [IFSP] status). Implications for research and practice are discussed.

Keywords

assessment, screening, adaptive, development, infancy, motor/movement, intervention strategies, progress monitoring

Movement is a critical factor in brain development and codevelops with cognition and language (Iverson, 2010; Leonard & Hill, 2014). Reports indicate that movement mediates exploration of the environment which, in turn, is related to more enhanced and differentiated early cognitive development (Roebers et al., 2014; Thelen & Smith, 1996), improved language (Abney, Warlaumont, Haussman, Ross, & Wallot, 2014), social development (Libertus & Needham, 2011, and later school readiness (Campos et al., 2000; Zelazo, Carter, & Reznick, 1997), all of which increase likelihood of high school completion (Brooks-Gunn, Guo, & Furstenberg, 1993). Without measures to monitor early development, delays in movement skills often go undetected until school entry (Goyen & Lui, 2002).

Movement opens the door for a young child to transition from solitary play to group play at home and school settings (Adolph & Franchak, 2017). Engagement in play activities (e.g., playing catch, running, skipping) facilitates much of a young child's learning and development. The ability to move fluently also plays a role in health promotion, helping maintain adequate levels of physical activity, particularly in children predisposed to weight gain, such as those with Down Syndrome (DS; W. Brown et al., 2009; W. Brown et al., 2016). Taken together, children's growth in lower and upper body movement is of paramount importance to participation in social and learning activities as well as maintaining overall health.

Reports indicate that movement concerns in young children are associated with three predominant factors: (a) injuries and neurological conditions (e.g., Cerebral Palsy), (b) developmental disabilities (e.g., DS, Autism Spectrum Disorder [ASD]), and (c) pervasively restricted movement opportunities (Roeber, Tober, Bolt, & Pollak, 2012). For example, Su et al. (2017) reported that 45% of preterm infants studied longitudinally indicated either deteriorating or delayed movement skills. Children with DS are often delayed but acquire movement skills in the same sequence as typically developing children (Tudella, Pereira, Basso, & Savelsbergh, 2011). Other reports indicated that children with DS and ASD acquired movement skills faster in infancy but slowed down through 6 years of age (Ming, Brimacombe, & Wagner, 2007; Ozonoff et al., 2008; Palisano et al., 2001). Children who have experienced limited movement opportunities in their caregiving (e.g., restrictions on physical movement because of safety, hygienic, or other reasons) also may be delayed (Rosenberg & Smith, 2008). Reports also indicate that some children

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acquire atypical, adaptive skills to meet their needs, for example, rolling rather than crawling across the floor (Leitschuh, Haring, & Dunn, 2014).

Eligibility versus Short-Term Growth Measurement

The assessment of young children's movement for eligibility for early intervention services under the Individuals With Disabilities Education Act (IDEA, 2004) traditionally has been the role of movement experts—occupational (OT) and physical therapists (PT). For this purpose, standardized, norm-referenced tests are often used, for example, the *Vineland Adaptive Behavior Scales* (motor skills subscale; Sparrow, Cicchetti, & Balla, 2005), *Movement Assessment Battery for Children* (T. Brown & Lalor, 2009), *Bayley Scales of Development* (Bayley, 2006; motor scale) and the *Peabody Scales of Motor Development* (Folio & Fewell, 2000).

However, when the goal is to evaluate short-term growth in movement in response to intervention, assessment information is needed with actionable implications for improving movement function in natural environments (e.g., home or child care center). In this context, traditional standardized measures offer limited support (Kirshner & Guyatt, 1985; Palisano et al., 2001). For example, many standardized measures are recommended for re-administration only every 6 months, which is not timely or frequent enough to inform intervention decisions. Experts other than early childhood practitioners (OTs and PTs) are needed to administer and interpret the measurement outcomes. These measures are often not sensitive to growth in the intervention skills targets provided by caregivers, home visitors, and parents in a progress monitoring scenario. An additional concern with traditional measures is their lack of utility in real-world infant-toddler settings (Akers et al., 2015; Azzi-Lessing, 2011; Bruder, Dunst, Wilson, & Stayton, 2013). Early educators, caregivers, parents, and OTs/PTs also need a measurement approach that supports their collaboration in making intervention decisions (Division for Early Childhood, 2014; Head Start, 2015; National Association for the Education of Young Children [NAEYC], Distance Education Council [DEC], & National Head Start Association [NHSA], 2013).

Another need for short-term measures of growth in movement is intervention research. Riethmuller, Jones, and Okely (2009) reported finding only 17 studies that rigorously evaluated movement interventions. Half were implemented in child care or school settings delivered by teachers, researchers, and students. Only three studies involved parents in the home. Thus, there is a need for measurement of new interventions implemented by teachers and parents intended to improve motor/movement skills in settings were children live and play.

Early Movement Indicator (EMI)

The EMI is an example of a measure that provides the early educator/interventionist/home visitor with the means to universally screen and monitor progress in the growth of movement skills not readily available in traditional measures. "The EMI is focused on movement skills (not motor ability) that are alterable in response to interventions" (Greenwood & Carta, 2010, p. 78). The EMI can be used quarterly for universal screening or progress monitoring of children and monthly for children receiving targeted interventions. This kind of frequent, brief measurement of short-term (e.g., monthly or quarterly) growth in movement skills might be particularly useful for early educators and interventionists working with the child and family to improve functional movement skills who are monitoring progress and updating Individual Family Service Plan (IFSP) goals (*Advisory Committee on Head Start Research and Evaluation*, 2012; Bagnato, Neisworth, Salvia & Hunt, 1999).

The EMI is one of four Individual Growth and Development Indicators (IGDIs; Carta, Greenwood, Walker, & Buzhardt, 2010). The EMI (Greenwood, Luze, Cline, Kuntz, & Leitschuh, 2002) is a play-based measure of how a child actually moves in standard authentic contexts as compared with reports by a parent or teacher. The EMI is accessible and supported by an online web application wherein early educators learn, manage, collect, report, and make data-based decisions given child progress data (Greenwood, Carta, Walker, & Buzhardt, n.d.).

Key Movement Skills

Five EMI key skills were identified and operationalized for measurement based on a conceptual review of the literature followed by validation with criterion measures of movement and motor ability (Greenwood & Carta, 2010; Greenwood et al., 2002). The EMI measures postural, locomotion, and object control skills. These skills are Transition in Position (postural movement); Grounded and Vertical (locomotion); and Throw/Roll and Catch/Trap (object control). These skills represent a continuum of movement skill acquisition expected for children 6 to 36 months of age. These key skills were further operationalized by their composite, a single indicator of rate of Total Movement (Greenwood & Carta, 2010).

Administration and Scoring

The EMI is administered during a 6 min, semi-structured, play-based session with a familiar adult. The majority of EMI assessments conducted in this study occurred in the child's home (65%), a child care program (35%), or in other locations (0.6%, e.g., grandparents' home, etc.). The EMI may be scored live during the administration or later by a video recording by a trained and certified coder (see below for description of certification). EMI score sheets are available from the IGDI website. Recording the occurrence of child's movement key skills during the play session involves a simple tally of one per occurrence leading to a session total frequency count for key movement skills. These frequency data are entered into the password-protected website wherein all data for a particular program are securely managed. These data from each new session are added to each child's cumulative record by date. Individual and group reports of children's movement may be created in several forms as graphical displays and summary tables.

EMI Toys and Materials

The EMI consists of two equivalent toy sets (Forms A vs. B). Each set comprises a flexible, nylon pop-up, enclosure and a selection of blocks and balls (Greenwood & Carta, 2010). Each enclosure, for example, a bus or hut, is characterized by a door that children can walk or crawl through. Children may stand up in the enclosures, open and close the nylon doors, and look out of and in to the enclosure. Rubber blocks and ball in each set of various sizes, colors, and shapes can be rolled or thrown in and out of the enclosure, which encourages movement in and around the toy. All toys were selected because they evoked movement rather than sitting and exploration (Greenwood et al., 2002). The blocks and balls could be easily cleaned with antiseptic wipes and large enough to avoid becoming a choking hazard.

Testing Accommodations

The EMI administration allows for specific adaptations to ensure children are not disadvantaged due to diversity in language, vision, hearing, or physical disabilities (Americans With Disabilities Act, 1990; Walker & Buzhardt, 2010). The administration and scoring of the child's skills requires adults who speak the child's language(s) (including sign language or picture communication systems). Introductory experiences with the EMI format can be used with children with hearing or vision impairment using guided prompts and practice with the play partner. Toys may be placed within reach of the child. Children using postural or stability supports (braces, scooters), or assistive strategies may be included. For children who use alternative or compensatory movement replacement strategies to meet their needs, such as rolling across the floor rather than walking, interpretation of just the relevant EMI key skills scores is recommended. For example, young children with disabilities that impede or do not permit vertical locomotion, vertical locomotion should not be interpreted in lieu of focus on the other relevant key skills. Grounded locomotion may be a replacement for walking. If developing vertical locomotion skills is a targeted goal for a child (e.g., learning to use crutches, artificial limbs, etc.), then the vertical locomotion key skill becomes a valuable tool for measuring progress toward this goal.

EMI Training and Certification

Infant/toddler service providers (assessors) learned to administer and score the IGDIs through a combination of didactic training, online resources, and scoring practice. IGDI staff conducted an on-site workshop in which service providers learned to administer the EMI, score assessments, and interpret results for intervention decision making. Trainees were certified and ready to collect data after passing two benchmarks: coding of two EMI assessments in which their coding was within at least 85% agreement of a master coding, and a demonstration using the correct EMI administration steps (80% correct) during either a live or video-recorded assessment. If the trainee did not achieve these benchmarks at first attempt, they consulted their local certified EMI trainer for suggestions and corrective feedback on additional attempts until reaching the criterion.

In summary, given the need for individual measures of growth in movement that practitioners can use, we sought to provide new information on the use of the EMI to inform the practice of movement assessment in early intervention, update the original benchmark trajectories informed by a large sample of children measured by program staff, evaluate the construct validity of the EMI relative to a conceptual framework of movement skills development, and rule out potential sources of measurement bias (moderators) relative to children's sociodemographics, culture/home language, and disability characteristics (American Psychological Association, 2013; Greenwood & McConnell, 2011). Thus, the following research questions were addressed:

Research Question 1: Was use of the EMI scalable by practitioners in early childhood programs measured in terms of the volume of individual child data collected by practitioners in the number of programs, regions, states, children, and occasions?
Research Question 2: Was the EMI's Total Movement trajectories sensitive to growth over time?
Research Question 3: Did patterns of growth in the EMI Key Skills benchmark trajectories reflect a continuum of change?
Research Question 4: Was children's growth in Total Movement moderated by their demographic characteristics (i.e., gender, home language, and IFSP status)?

Method

Participants

Programs. Fifteen early childhood programs in 12 zip code areas and six states adopted use of the EMI for screening,

Table 1. Children's Sociodemographics.

Variable	*M*	*SD*	Minimum	Maximum	*N*	%
Number of children					628	
Age in months	18.0	9.5	6.0	36.0		
Gender, % Male					317	50.5
Gender, % Female					311	49.5
Home language, % English					373	59.4
Home language, % Spanish					223	35.5
Home language, % Other					32	5.1
IFSP, % No					533	84.9
IFSP, % Yes					60	9.5
IFSP, % Yes (with movement concerns)					35	5.6
Total					628	100.0

Note. IFSP = Individual Family Service Plan.

intervention decision making, progress monitoring, and evaluation.

Programs described themselves as Area Education Agencies (5), Part C infant/toddler IDEA programs (4), Family Centers (3), Early Head Start (EHS) (1) and Community Child Care (1) who commenced using the EMI sometime within the 7-year period ending in 2015. The program models were Home (7), Home and Center (6), and Center only (2). This resulted in 2,258 EMI assessments for analysis, including 198 (9% of 2,258) collected in the original EMI development (Greenwood et al., 2002).

Children. Infants/toddlers between 6 and 36 months of age at start participated ($N = 628$; see Table 1). The mean age of children at the start of the project was 18 months, with a range of 6 to 36 months ($SD = 9.5$ months). The number of boys and girls was nearly evenly split at 50%. About 85% of children were from disadvantaged backgrounds based on the low-income eligibility requirements of EHS and included 15% of children with IFSPs (see Table 1). In total, 35 (37%) of the 95 children with IFSPs had a movement concern identified. The majority home language reported was English (59%), followed by Spanish (36%) and other languages (5%).

Assessors. The EMI was adopted for use by the program's administration. In total, 94 participating assessors/coders conducted quarterly EMI assessments with children enrolled in the program as part of their standard services for families. The roles of these staff members included child care teachers and early interventionists (e.g., physical or OTs, Early Childhood Special Educators, home visitors).

Measurement Procedures

Scalability. Scalability refers to the ease that an evidence-based practice and its implementation support system can grow in size under a full implementation scenario (Fixsen, Naoom, Blase, Friedman, & Wallace, 2005; Milat, Bauman, & Redman, 2015). Included in the scalability concept are the drivers of implementation that include the necessary personnel structures, delivery venues and training supports, digital data infrastructures, resources, and management systems needed to promote and support use at scale. We selected indicators of the success of the EMI implementation from the online system reflecting some of these drivers, including volume of use in terms of programs, staff, and geographical diversity in the United States. Because the online system was first and foremost a service provided to programs, and not research, we did not include more extensive information on the sociodemographics of the assessor staff, the child's socioeconomic status (SES), or other research related measures collected outside of the website.

Because use of the EMI required an information profile be created for each program, director, assessor, and child within the web application, it was possible to pull descriptive data on scale of use. At the program level, information was provided identifying the program name, address, zip code, and contact information. The director also selected which of several IGDI's to be used (i.e., the EMI). Thereafter, the program director was responsible for registering the names and contact information of all staff members that would be using the EMI and supervise their implementation. At the staff level, practitioners entered children's identifying information, including zip code, birthdate, and date of enrollment into the early childhood program. At the child level, variables included in the online measurement system were the child's birthdate, age at EMI assessment, gender, home language, IFSP status (yes/no), and a text field for describing the domain of concern (e.g., movement, language delay, etc.) given that the child had an IFSP.

Child characteristics/moderators. A standard set of child-level variables in the online data system were used to examine the question of children's characteristics as moderators of EMI performance outcomes. These variables were gender

(Male, Female), home language (English, Spanish, Other), and IFSP status (No, Yes) drawn from each child's profile. Gender and home language were considered potential sources of measurement bias. IFSP status, however, was considered a potential construct validity question regarding the claim that children with IFSPs would demonstrate comparatively lower EMI performance that children without IFSPs. It was also possible to refine the IFSP variable by separating it into two subgroups: IFSP and no movement concern versus IFSP with a movement/motor concern.

EMI reliability. The EMI as previously described was used. While recommended, assessors did not participate in pairwise interobserver agreement checks on a regular basis because of time and resource limitations. Staff instead recalibrated scoring reliability annually using a standard EMI assessment video as part of meeting a fidelity of implementation standard. Assessors reviewed the original EMI scoring instruction documents and then observed and scored the video. These scorings were compared with a standard scoring. Re-certification required at least an 85% overall score and the certification procedures previously described were followed.

Percentage observer agreement was computed by dividing the smaller value into the larger value times 100. Agreement was defined as perfect or within a count of 1, otherwise disagreement was counted. Results for a sample of 102 separate scorings indicated a mean agreement score of 89.5%, ranging from 30.1% to 100.0%. Agreement on the individual behaviors ranged from 70.9% for catching/trapping to 74.7 % for throwing/rolling. These data included all scorings of coders recertifying as well as first time learners of the system.

An additional check was made on the reliability of EMI Total Movement scores by testing the difference between mean estimates based on a random split-half division of the records, groups A versus B. While the mean scores ranged from 13.4 to 25.0 across videos indicating different test cases, there were no differences between split-half scores (α, $p = .05$) within each video. The size of the overall mean differences were smaller than 1 per min between videos, and only 0.5 responses per minute with all videos combined.

Statistical Analysis

The total EMI assessments completed were screened for outliers (N = 2,282). In total, 24 (1.0%) were identified falling more than +3.0 *SD* above mean and removed, leaving N = 2,258 assessments included in analyses. The mean number of observations collected per child was 3.6, ranging from 1 to 15 occasions. Simple descriptive statistics, mean (*M*) and standard deviation (*SD*) were used to address the scalability research question. To address the questions about children's movement growth trajectories, multilevel growth curve modeling (MGCM) was used (Snijders & Bosker, 2012). MGCM was appropriate because it computes an equation (model) to the raw data over time that describes its prototypical growth curve trajectory across the 6- to 36-month age span. The linear form of the statistical model requires two parameters, an intercept and slope to define a trajectory in graphical space. A curvilinear form of the model adds an acceleration parameter that defines bend in the curve. Together, these parameters define the shape of the growth curve that best fits the raw data that is either accelerating or decelerating over time. An advantage of MGCM is that the intercept value, can be determined at any one age at the discretion of the researcher. We computed the intercept at 36 months of age because it is an endpoint for children exiting IDEA Part C (Infant/Toddler) services and a transition point for the onset of Part B (Preschool) services. This value is helpful in establishing one's level of movement proficiency relative to normative benchmarks at this age, the impact of Part C, and/or the need for Part B services.

Levels in the EMI data addressed in the models were EMI assessments nested within children within programs using child age in months as the time variable of interest. A preliminary step in the analyses involved testing for the correct shape of the trajectory (i.e., linear vs. quadratic). We used the quadratic model, because the chi-square test of nested models indicated significant improvement in the fit of the linear model (χ = 123.07, $p < .01$).

To address sensitivity to growth in the Total Movement trajectory (Research Question 2), we calculated benchmark growth trajectories representing the mean trajectory as well as the −1.5 and –1.0 and +1.5 *SD* trajectories over the age span. These benchmarks are helpful when deciding whether or not an individual child's growth is falling within or outside of the range of expectation for their chronological age (Greenwood et al., 2010). In this growth model, we were interested in the parameters representing the means of intercept, slope and acceleration rate across all individuals, that is, γ_{00}, γ_{10}, and γ_{20}, respectively (Equation 1):

$$\begin{aligned} y_{ij} &= \beta_{0j} + \beta_{1j}\text{Age}_{ij} + \beta_{2j}\text{Age}_{ij}^2 + e_{ij} \\ \beta_{0j} &= \gamma_{00} + u_{0j} \\ \beta_{1j} &= \gamma_{10} + u_{1j} \\ \beta_{2j} &= \gamma_{20} + u_{2j} \end{aligned} \qquad (1)$$

To address the Key Skills trajectories (Research Question 3), separate growth models were computed for each individual skill intended to reveal shape of each skill over time and to compare features of all in comparison to a theoretical continuum of growth in movement proficiency. For example, we expected to see grounded locomotion (crawl, a more basic, early EMI skill) peak and then plateau at approximately 12 months, in covariation with the onset and growth of vertical locomotion (a more advanced skill). We hypothesized growth in transitions in position to precede growth in ground locomotion, preceding growth in vertical locomotion, preceding growth in throws/rolls, and preceding growth in catches/traps.

To address Research Question 4, the moderating variables were added as cross-level interactions with the growth and intercept parameters in the multilevel growth models (see Equation 2):

$$\begin{aligned} y_{ij} &= \beta_{0j} + \beta_{1j}\text{Age}_{ij} + \beta_{2j}\text{Age}_{ij}^2 + e_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01}\text{Moderator}_j + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11}\text{Moderator}_j + u_{1j} \\ \beta_{2j} &= \gamma_{20} + \gamma_{21}\text{Moderator}_j + u_{2j} \end{aligned} \quad (2)$$

The key parameters of interest in this model were those associated with moderators, that is, γ_{01}, γ_{11}, and γ_{21}, which were referred to as cross-level interaction effects (see Table 4). These parameters represent the differences in intercepts, slopes, and acceleration rates, respectively, between two groups defined by the Moderator (i.e., gender, IFSP status, or home language status). Because it was possible to improve the precision of the IFSP question by separating the IFSP status of children into subgroups that were differentiated by whether or not movement domain concerns were expressed in the IFSP, an additional model was computed using: IFSP = none; IFSP = yes, but *without movement concerns*; and IFSP = yes, *with movement concerns* as fixed effects.

Results

Was Use of the EMI in Early Childhood Programs Scalable?

Overall, use of the EMI was scalable given the number and range of adopting early childhood programs in diverse geographical locations implemented by trained staff supported by the website and online data management system (see Table 2). In total, 15 community-based early childhood programs used the EMI and contributed child data through the efforts of 94 staff members who administered, collected, scored, and entered the EMI data. The total number of children with EMI data used in analyses was 628 with a total of 2,258 EMI completed assessments. The number of EMI assessments at each month of age (6–36 months) ranged from 41 to 86 with the overall rate of Total Movement growing from a mean of 2.8 (*SD* = 2.8) per min at 6 months to 14.0 (*SD* = 6.3) per min at 36 months (see Table 2). Children were not assessed on all occasions because they entered and left programs at different ages and for different reasons (e.g., moved in or away, aged out, etc.).

Was the Total Movement Benchmark Trajectories Sensitive to Growth Over Time?

Similar to the original report (Greenwood et al., 2002), the new trajectories also were accelerating negatively; that is, increasing rapidly, slowing later, and reaching an inflection point (see Figure 1). The fitted mean growth model was 13.5 total movements per min (tm/min; mean intercept at 36 months of age), –0.118 (linear slope), and −0.016 (acceleration). All three values were significantly greater than zero. In this sample of *N* = 628 children, the mean values along the total movement trajectory were 2.7, 10.5, and 13.5 tm/min at the sixth, 18th, and 36th months of age, respectively. These same values on the original trajectory (Greenwood et al., 2002) were similar at 0.50, 7.9, and 13.8 tm/min at the sixth, 18th, and 36th months of age (*N* = 29 children).

Separating the overall Total Movement trajectory into *SD* bands for intervention decision making purposes, produced four Total Movement rate benchmark trajectories with mean intercepts of 20.2, 14.1, 8.6, and 6.5 tm/min for the +1.5 *SD, M*, –1.0 *SD*, and −1.5 *SD* trajectories, respectively. Comparisons between the shapes of these four benchmark trajectories key differences emerged. For children in the −1.0 *SD* trajectory below the mean, early acceleration was comparatively slower and trending downward sooner compared to the mean trajectory (see Figure 1). This same pattern was more extreme in the −1.5 *SD* trajectory. In contrast, for the children in the +1.5 *SD* trajectory above the mean, growth was higher and rapid at 6 months and but accelerated slowly through 36 months of age compared with the mean trajectory, where children continued to accelerate and did not reach an inflection point.

Did Patterns of Growth in EMI Key Skill Benchmark Trajectories Reflect a Continuum?

Individually, each of the Key Skill trajectories depicted differences at age of onset, increasing and some waning in rate of occurrence over time (see Table 3 and Figure 2). At 6 months of age, Transitional Movement and Grounded Locomotion were in use, with Transitional Movement at a much higher rate. By 8 months, Vertical Locomotion and Throw-Roll movements were beginning to grow. Growth curved for Transitional Movement, Vertical Locomotion, and Throw/Catch, accelerating negatively over time. Growth in Grounded Locomotion after a fast start was slow and linear over time. By 36 months, the rates of all five skills had increased substantially in frequency, with Transitional Movement, Vertical Locomotion, Throw-Roll, Grounded Locomotion, and Catch trap, in order of highest to lowest. The slowest growing key skills were Catch/Trap and Grounded Locomotion (Figure 2; Table 3).

Taken together, the ages at onset and shapes of growth reflected a complex picture of a continuum in that multiple

Table 2. Number of Early Movement Indicator Assessments by Age and Total Movement *M, SD*.

	EMI		
Months	Assessments	*M*	*SD*
6	70	2.8	2.8
7	51	2.5	2.0
8	41	4.2	3.1
9	62	5.0	3.5
10	75	6.2	4.9
11	58	7.5	4.9
12	56	7.4	4.1
13	72	8.6	4.5
14	77	9.2	4.4
15	72	9.8	5.1
16	76	10.3	5.5
17	79	10.8	4.6
18	63	12.3	5.9
19	68	11.7	6.0
20	73	11.4	5.4
21	86	12.3	5.4
22	57	11.4	5.3
23	91	12.0	4.8
24	64	11.9	4.5
25	72	12.8	6.7
26	81	12.7	4.8
27	67	12.5	5.0
28	60	12.8	6.2
29	83	13.0	4.7
30	72	12.8	5.9
31	55	13.2	6.8
32	75	13.8	5.5
33	74	14.5	6.9
34	68	14.3	5.7
35	54	12.6	5.0
36	57	14.0	6.3
37	42	13.4	4.5
38	40	14.4	4.5
39	17	14.4	9.8
40	26	14.3	5.7
41	9	10.3	3.3
42	15	11.7	5.3
Total	2,258		
M	10.7		
SD	5.6		
Minimum	0		
Maximum	33		

Note. n = 628 children. Assessments after removal of 24 outliers. EMI = Early Movement Indicator.

skills were nearly always in the repertoire with each changing differentially adding to overall proficiency in movement. This was in contrast to a simple stair stepping continuum—wherein one skill started and ended and another skill began. Instead, Vertical Locomotion soon exceeded Grounded Locomotion over the age range, as expected and did not drop from the repertoire. In another case, Transitional Movement emerged early, grew over time, but was never exceeded by Vertical Locomotion in children this age.

Was Growth in Total Movement Moderated by Children's Characteristics?

Results were comparisons made between the values of each moderating variable. Value 1 of the three moderators were Females, English home language, and no IFSP status and their interactions, respectively. The contrasting value of the moderators were males, IFSP status, and Spanish–Other home language. For the purpose of interpreting growth effects, the first three growth parameters (intercept, age, age^2) of each moderator were for the value 1 comparisons only (see Table 4). Thus, the last three growth parameters of each moderator in Table 4 indicated the between values differences, or the influence of the moderator on explaining growth in the mean Intercept (36 months), the linear slope (Age × effect), and acceleration (Age^2 × effect).

Results indicated no significant moderation of children' growth in Total Movement by Gender or IFSP status (Yes vs. No) or their interaction at $\alpha = .05$. However, when the IFSP analysis included information on an expressed movement concern, the difference was significant (Estimate = −3.78, $SD = 0.68$, $t = -5.54$, $p < .01$). Children with IFSP movement concerns were lower in Total Movement rate at 36 months of age ($M = 9.4$ tm/min) versus those with an IFSP but without a movement concern ($M = 13.8$ tm/min). Children's home language was a significant moderator. Children whose home language was Spanish or Other than English attained a significantly higher rate of Total Movement at 36 months of age: $M = 15.4$ per min compared to $M = 12.4$ for English only (Estimate = 2.95, $SE = 0.74$, $t = 3.988$, $p < .001$).

Discussion

The purpose was to advance what we know of the EMI's use and psychometrics in a web-supported implementation by early childhood adopters as part of their regular program of services. Strengths were several, including the much larger sample relative to the original (Greenwood et al., 2002), use by early childhood staff in authentic settings rather than researchers, analyses accounting for the multilevel nature of the data, updated benchmarks for individual response to intervention decisions, new data on the shape and sequence of movement skills development, and child characteristics influencing measurement of growth in movement.

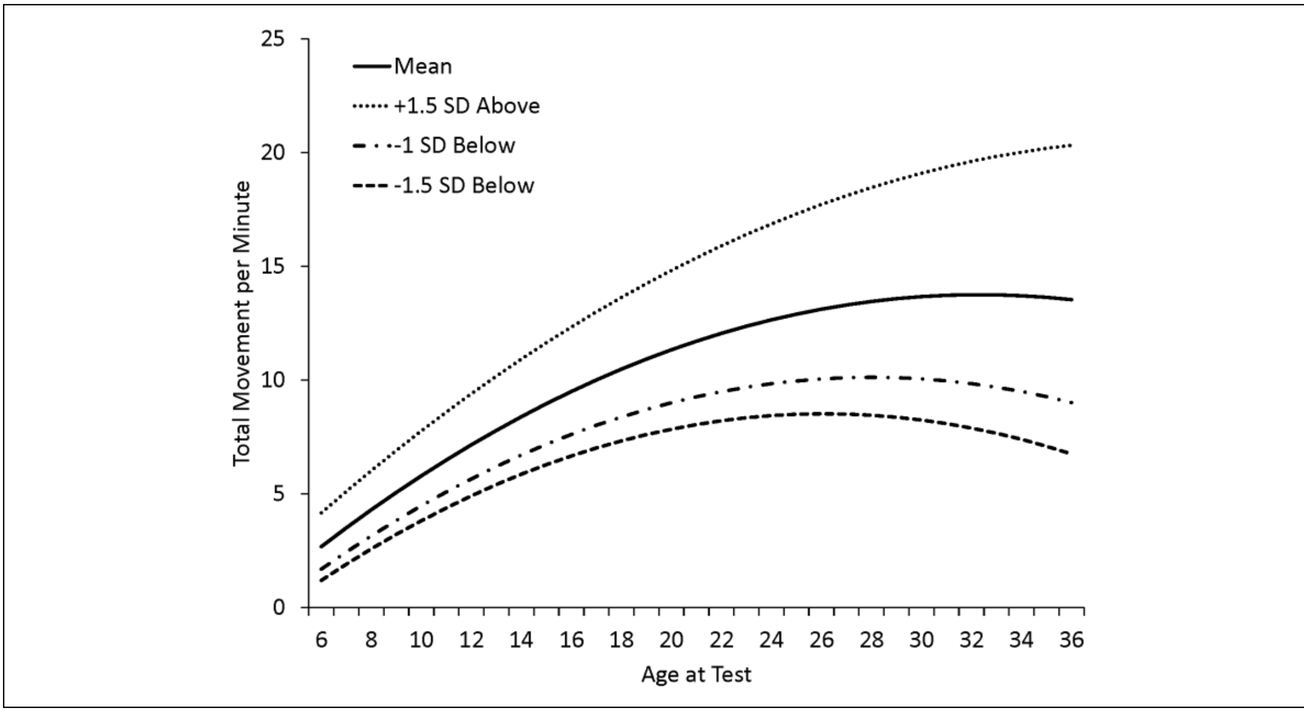

Figure 1. EMI *M*, and *SD* trajectories (intercept centered at 36 months).
Note. EMI = Early Movement Indicator.

Table 3. EMI Key Skills Growth Models.

Model	Intercept	Age (centered at 36 months)	Age^2 (centered at 36 months)
Transitional movement			
Estimate	5.293	−0.024	−0.005
SE	0.194	0.025	0.001
t	27.337	−0.937	−6.600
p	<.01	.349	<.01
Grounded locomotion			
Estimate	1.372	0.017	—
SE	0.140	0.005	—
t	9.818	3.249	—
p	<.01	.001	—
Vertical locomotion			
Estimate	3.444	−0.72	−0.007
SE	0.379	0.021	0.001
t	6.456	−4.948	−11.679
p	<.01	<.01	<.01
Throwing/rolling			
Estimate	2.130	−0.022	−0.003
SE	0.284	0.016	0.000
t	7.497	−1.395	−7.416
p	<.01	.163	<.01
Catching/trapping			
Estimate	0.481	0.013	—
SE	0.119	0.005	—
t	4.024	2.647	—
p	<.01	<.01	—

Note. EMI = Early Movement Indicator.

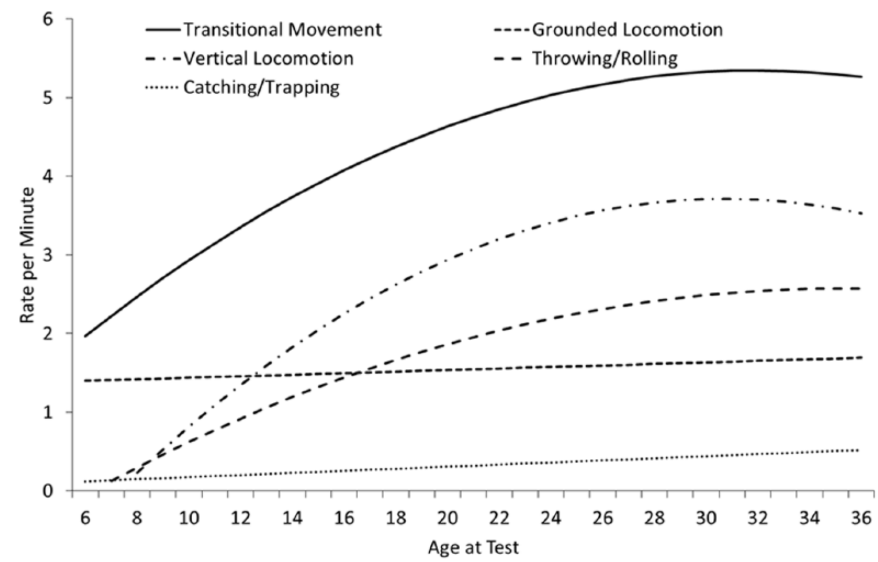

Figure 2. Early movement key skill elements fitted growth trajectories for all children.

Table 4. Growth Curve Modeling Results for the Early Movement Indicator.

	Model											
	Gender				Language				IFSP status			
	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
Intercept	11.297	0.835	13.524	<.01	11.018	0.719	15.323	<.01	12.312	0.678	18.172	<.01
Age (centered at 36 months)	−0.108	0.062	−1.744	.08	−0.153	0.058	−2.655	<.01	−0.127	0.048	−2.670	.010
Age^2 (centered at 36 months)	−0.016	0.002	−8.232	<.01	−0.017	0.002	−9.658	<.01	−0.016	0.001	−11.203	<.01
Contrast value	0.029	0.721	0.040	.97	2.605	0.743	3.505	<.01	−1.403	0.989	−1.418	.16
Age × effect	−0.035	0.088	−0.402	.69	0.128	0.091	1.409	.16	0.032	0.126	0.255	.80
Age^2 × effect	−0.001	0.003	−0.431	.67	0.004	0.003	1.276	.20	0.000	0.004	0.106	.92

Note. The contrast values were as follows: Gender = Female, where 0 = *Female*, and 1 = *Male*; Language = English, where 0 = *English* and 1 = *Spanish*; and IFSP= No IFSP where *No IFSP* = 0 and *IFSP* = 1. IFSP = Individual Family Service Plan.

Results indicated that the EMI had achieved a degree of scalability demonstrated by the number and diversity of programs, multiple U.S. locations, staff, children enrolled, and number of EMI assessments. These findings were consistent with those of the Early Communication Indicator (ECI), another IGDI widely used by early childhood programs (Greenwood, Buzhardt, Walker, Howard, & Anderson, 2011). Growth in Total Movement was similar in shape to that originally reported for the EMI's Total Movement trajectory (Greenwood et al., 2002). Total movement rate grew rapidly, slowed and plateaued over the age range (a negative acceleration). This shape was more extreme for children in the −1.0 and −1.5 *SD* benchmark trajectories who slowed earlier and maintained lower levels longer than children in the mean and +1.0 *SD* trajectories. These findings were consistent with similarly shaped trajectories reported by Palisano and colleagues (2001) in children with DS.

We were able to test the hypothesis reflected in the EMI conceptual framework that posited that postural development (transition in position) would proceed locomotion (grounded, vertical) and proceed object control (throw/catch, roll/trap). Based on literature review (Greenwood et al., 2002), this developmental sequence was largely confirmed in the present findings. At 6 months, the only skills occurring with any frequency were Transition in Position and Grounded Locomotion. With increasing age, rapid growth was seen in Vertical Locomotion, with slowing in Grounded Locomotion, and increasing Throwing/Rolling. Catching/Trapping was lowest at start and remained the slowest developing of all. This was an important check on the construct validity of the EMI and whether or not measurement of growth in movement skills was in agreement with theory and empirical findings.

With respect to moderators of growth in movement skills, the original study reported no differences in EMI Total Movement rate by gender or IFSP status (Greenwood et al., 2002). This also was the case in this larger sample. However, when IFSP was disaggregated to include a confirmed movement concern or not, IFSP with concerns did significantly moderate Total Movement rate. Children with IFSP movement concerns were lower at 36 months than children (a) without an IFSP or (b) with an IFSP but no movement concerns. This supported a divergent validity relationship between children's clinical versus nonclinical movement status detectable by the EMI. We did not interpret this finding as a measurement bias issue because all children participated in EMI administrations and all children's data were included in the overall analyses and benchmark estimates.

Although there is a substantial literature addressing the association between motor development, language, and cognition in young children (e.g., Iverson, 2010; Libertus & Violi, 2016), the specific developmental pathways between these have yet to be fully understood (Adolph & Franchak, 2017). We hypothesized that we would not find home language differences and movement behaviors in our sample because of the language accommodations included in the EMI administration procedures. We were therefore surprised that home language moderated Total Movement at 36 months. Children whose home language was Spanish/non-English had significantly higher Total Movement rates than children speaking English at home (see Table 3). These children started with higher movement skills, grew at similar rates as the other children, and ended higher at 36 months, suggesting unknown influences at start that maintained growth.

We explored potential explanations. We ruled out cell-size imbalances in the data matrix regarding age, IFSP status, and Home Language. However, some researchers have reported ethnic differences in reaching movement milestones. For example, Kelly, Sacker, Schoon, and Nazroo (2006) reported that Black Caribbean, Black African, and Indian infants were less likely to show delay in the attainment of gross motor milestones in the first 9 months of life compared with White infants that were not explained by adjustments in a range of explanatory variables that included biological, SES, cultural tradition, and household composition variables, among others (i.e., adult–child interactions). It may be that racial/cultural and social/economic factors like these explain current findings. For example, it is well known that cultural factors affect the opportunities and timing of early language learning and delays in learning to talk (Hoff, 2006). A growing literature addressing the association between bilingual or dual-language development (DLL) and cognitive development (e.g., Bialystok, 2015; Fuligni, Hoff, Zepeda, & Mangione, 2014) may inform how the development of movement, language, and cognition in young children interact/transact to influence growth in one another. Work is emerging on this issue (Iverson, 2010; Walle & Warlaumont, 2015). Collectively, these findings advanced understanding of the development of young children's movement skills, as well as our understanding of how to construct brief, repeatable measures of movement and other early childhood outcomes. The findings contributed to greater understanding of the importance of monitoring motor development in infants and toddlers in the field.

Limitations

While the new estimates of EMI Total Movement and Key Skills were improved in size, authenticity, and diversity of contributing programs, they are not yet nationally representative. Programs contributing data to this report were self-selected, interested adopters from EHS and Part C IDEA (2004) programs and not randomly selected. It was a strength that the programs (a) were geographically diverse, (b) varied in the number of children served, and (c) differed in duration of using the EMI. Inclusion of the data for the original validation (Greenwood et al., 2002) accounted for only 9% of the total number of assessments. We concluded these data were appropriate to boost sample size and also because the small numbers argued against making a statistical comparison to the original.

It was not feasible that two people were present for live agreement checking, in this enterprise, full program scenario, particularly when the EMI was most often administered in the home. Re-scorings of videos in annual calibration agreement checks has been much more feasible. However, the impact on reliability and drift in reliability/scoring accuracy during the interim has yet to be addressed. We were pleased to see that a simple comparison between the original versus new sample findings indicated that Total Movement scores were highly similar at 6, 18, and 36 months of age points, additional evidence that scoring had not drifted. Also, shapes of the Total Movement between original and new sample growth curves were similar, together suggesting a degree of score accuracy/agreement.

Implications for Future Research

A need in future research is an effort to develop more representative EMI growth benchmarks. Traditionally, the development of universal measures for screening and program monitoring has been to grow incrementally, beginning with local program data collection, moving to accumulated wide-scale program data collected via centralized data infrastructures supported by websites (e.g., Kaminski &

Good, 1996). This is in contrast to collections guided by a nationally representative sampling plan as is typically used in standardized test norming. A part of this work should be a comparison of live versus video scoring.

The finding of accelerated EMI growth by children experiencing Spanish and Other home languages was intriguing and our limited explanation of this difference, suggested that research is needed. Such differences are consistent with racial/ethnic and environmental factors (cultural, parenting practices, socioeconomic) that do explain differences in language, cognitive, and academic development. Such research may also explore associations between children's movement development and codevelopment in other domains. The present findings and the advent of the EMI and other IGDIs for infants and toddlers, such as the ECI, provide a stimulus and a method for doing so. IGDI measures combined with latent MGCM techniques research on dual and multiple developmental processes feasible.

Another need is to demonstrate that growth in the EMI is facilitated by interventions and use of the EMI for data-driven decision making, as has been the case with the ECI and use of language promoting strategies in controlled trials (Buzhardt et al., in press). Such studies could profitably be conducted in collaboration with OT/PT and Early Childhood Special Education (ESCE) professionals as part of implementing and monitoring individual children's progress given goals and targets within a child's IFSP. Experimental studies of groups of children receiving alternative movement interventions are needed to add to our knowledge of what works as measured by the EMI.

The EMI's key skills appeared to capture growth well up until 30 months of age, at which time acceleration slowed and a plateau reached. A similar reduction in older children with DS has been reported (Palisano et al., 2001). Research is needed to better understand whether or not this ceiling is a true development outcome or a weakness in the EMI protocol. For example, the EMI's Catching/Trapping movement skills begins early but remains slow growing over time to 36 months. Additional research is needed to improve the EMI's sensitivity to growth.

Implications for Practice

The EMI represents a practical, new support for early educators and interventionists interested in monitoring the development of infant and toddlers' emerging movement skills. It also represents an advance in evidence-based practice, given that local data collected in the course of typical duties with the children are being used for decision making, as opposed to relying only on data collected by researchers or outside assessors. The EMI can be used as part of a multi-tier support system (MTSS) framework to identify children who need more support and monitor progress given interventions as part of the IFSP.

Use of the web-based EMI by both local and distant early childhood programs indicated that new options exist for fulfilling programs' accountability needs for tools and strategies that promote movement outcomes. The improved EMI benchmarks can be used for individual decision making that may include: referral for additional assessment by the PT/OT, collaboration between the PT/OT with parents and early educators in implementing an intervention, or testing new strategies designed to promote the development of movement skills. In conclusion, given the lack of practitioner/program-level movement measures, the need for such measures, and Internet access and scalability, the EMI appears to be a viable alternative.

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