RESEARCH ARTICLE

Hospitalized Infants With Medical Complexity Experience Slow Acquisition of Gross Motor Skills

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ABSTRACT

OBJECTIVES: The progression of infant gross motor development during an acute hospitalization is unknown. Understanding gross motor skill acquisition in hospitalized infants with complex medical conditions is necessary to develop and evaluate interventions that may lessen delays. Establishing a baseline of gross motor abilities and skill development for these infants will guide future research. The primary purposes of this observational study were to: (1) describe gross motor skills of infants with complex medical conditions ($n = 143$) during an acute hospitalization and (2) evaluate the rate of change in gross motor skill development in a heterogenous group of hospitalized infants with prolonged length of stay ($n = 45$).

METHODS: Gross motor skills in hospitalized infants aged birth to 18 months receiving physical therapy were evaluated monthly using the Alberta Infant Motor Scale. Regression analysis was completed to assess rate of change in gross motor skills.

RESULTS: Of the 143 participants, 91 (64%) demonstrated significant motor delay at initial evaluation. Infants with prolonged hospitalization (mean 26.9 ± 17.5 weeks) gained new gross motor skills at a significant rate of 1.4 points per month in Alberta Infant Motor Scale raw scores; however, most (76%) continued with gross motor delays.

CONCLUSIONS: Infants with complex medical conditions admitted for prolonged hospitalization frequently have delayed gross motor development at baseline and have slower than typical acquisition of gross motor skills during hospitalization, gaining 1.4 new skills per month compared with peers acquiring 5 to 8 new skills monthly. Further research is needed to determine effectiveness of interventions designed to mitigate gross motor delay in hospitalized infants.

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Ms Pflock conceptualized and designed this study, trained physical therapy staff in assessment of participants and organized recruitment of participants, organized and completed data collection, analysis, and interpretation, drafted the initial manuscript, reviewed and revised the manuscript, and approved the final manuscript for submission; Dr Fragala-Pinkham contributed to design of the study, participated in analysis and interpretation of collected data, critically reviewed and revised the manuscript, and approved the final manuscript for submission; Dr Shulman contributed to design of the study, participated in analysis and interpretation of collected data, critically reviewed and revised the manuscript, and approved the final manuscript for submission; and Ms Babcock contributed to design of the study, assisted in collection and organization of data, critically reviewed and revised the manuscript, and approved the final manuscript for submission.

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Infants and children with complex conditions are spending more time in the hospital.[1] In the United States between 2010 and 2020, 5.4 million children were hospitalized at 49 children's hospitals; children with complex chronic conditions accounted for 45.7% of these encounters.[2] Children with medical complexity, as defined by Cohen et al, have significant health care needs, chronic conditions, functional limitations, and high projected use of health resources that may include frequent or prolonged hospitalizations.[3] Infants and children with complex medical conditions, including prematurity[4,5] and congenital heart disease,[6–8] are at risk for developmental delay, and hospitalization further increases this risk, especially when admissions are frequent or prolonged.

During hospitalization, infant developmental needs are often overlooked to focus on acute medical needs. The hospital environment contributes to delayed development as opportunities for natural movement, play, and exploration are limited.[9] Environment can have a significant impact on infant development, and infants have the greatest opportunity for development in their natural environments (eg, home, daycare).[10] Hospitalized infants are not within their natural environment, spending most of their time supine in a crib instead of in caregivers' arms or participating in age-appropriate floor play, limiting opportunities for exploration essential for motor learning. The presence of lines, tubes, and restraints (ie, joint immobilizers, hand mittens) further restrict movement.[9] For example, elbow immobilizers and hand mittens prevent infants from bringing their hands to midline to grasp, explore objects, and self-soothe. Critically ill infants or those undergoing invasive procedures may experience prolonged mechanical ventilation, medical sedation, and paralysis further limiting gross motor exploration, motor learning, and strengthening necessary to facilitate acquisition of gross motor skills.[9]

Developmental delay in infants with complex conditions following acute hospitalization is well-documented.[5–9,11,12] General recommendations to combat delays include close medical monitoring and rehabilitation following hospitalization[5–12]; however, we do not yet understand baseline motor abilities of infants with medical complexity requiring acute hospitalization and how prolonged hospitalization impacts their gross motor skill acquisition. The aims of this study are twofold: (1) describe baseline gross motor abilities of infants with medical complexity who are admitted for acute hospitalization from medical institutions or home and (2) examine changes in infant gross motor abilities during prolonged hospitalization. Understanding the trajectories of gross motor skill development in hospitalized infants with medical complexity is critical because it will allow clinicians to develop and evaluate interventions to mitigate delay and provide a baseline on which to evaluate the effectiveness of these interventions. Although hospitalized children of all ages are at risk for experiencing delays in development, this study aims to focus on infants in an effort to understand how prolonged hospitalization may impact gross motor development during this early period of rapid growth in infancy.

METHODS

Setting and Study Design

This prospective observational study was conducted at Boston Children's Hospital (BCH), a pediatric acute care hospital with more than 400 inpatient beds. Hospitalized infants are routinely referred to physical therapy (PT) when there are concerns for developmental delay or risk of delay during admission. This study was approved by the BCH institutional review board, and a waiver for consent was provided as completion of the Alberta Infant Motor Scale (AIMS) is part of routine physical therapy care.

Participant Inclusion Criteria

Inpatients from all medical and surgical units aged birth to 18 months referred for PT evaluation were included. Participants were excluded if they: (1) did not receive PT services after initial PT evaluation; (2) were anticipated to have a short length of stay (<1 month) because they would be discharged before the monthly reevaluation; (3) were unable to maintain a calm and awake state for proper assessment; or (4) AIMS assessment was medically contraindicated (eg, sternal precautions preventing prone positioning, unstable vital signs, intubation/sedation).

Procedures

The AIMS was administered at the initial PT evaluation and repeated every month for participants who met inclusion criteria at PT reevaluation to track change in motor skill development over time because infants are typically expected to gain new skills on the AIMS each month. If the AIMS could not be completed at the monthly reevaluation because of medical complications, participants were eligible to participate at subsequent reevaluations when appropriate. When participants were discharged from the hospital or reached the age of 18 months, the AIMS was no longer administered.

Before the start of this study, all inpatient physical therapists were trained by the primary investigator in the use of the AIMS. Training included a presentation on administering the items and scoring the AIMS. Afterward, clinicians practiced administering the AIMS with observation and guidance by a clinician experienced with AIMS administration until deemed competent. As the study progressed, new staff members were trained by clinicians who had previously demonstrated competency in administering the AIMS.

Physical Therapy Evaluation

Participants were evaluated by a physical therapist within 24 hours of referral. The initial PT evaluation included a chart review and examination of active movement, range of motion, infant state, tolerance to position changes and handling, and functional mobility. The AIMS is routinely administered to assess gross motor skills during a PT evaluation at BCH. If unable to complete the AIMS during the

initial evaluation, the assessment was completed during a subsequent PT session within 1 week.

As part of the initial PT evaluation, physical therapists developed a plan of care which included treatment goals, interventions, and PT frequency and duration. Therapists considered the participant's baseline developmental skills, medical status, and anticipated medical and developmental prognosis when determining the plan of care. The AIMS provided information about participants' baseline gross motor skills (raw scores) and how their skill level compared with typically developing infants (normative percentile scores). For premature infants, AIMS percentile scores were calculated using corrected age. PT frequency was determined by therapists using guidelines adapted from the American Physical Therapy Association's Section on Pediatrics Fact Sheet: Frequency and Duration of Physical Therapy Services in the Acute Care Pediatric Setting.[13]

Physical Therapy Intervention

PT treatment sessions were provided according to usual care by physical therapists and physical therapist assistants with treatment interventions following the PT plan of care based on evaluation results. Treatment sessions were approximately 15 to 45 minutes in length, depending on the participant's tolerance to intervention. PT interventions primarily included therapeutic activities and therapeutic exercise with a focus on facilitation of gross motor skill development, promotion of state regulation, range of motion, and family education. Although the participants presented with a wide variety of medical conditions, all sessions focused on motor skill acquisition and progression. Treatment was individualized for each diagnosis as needed. For example, an infant born prematurely may have a session targeting state regulation, whereas the session of an infant with a neurologic disorder may focus more on tone management. Caregivers were integrated into treatment sessions whenever possible.

Outcome Measures

The AIMS assesses gross motor development in infants aged birth to 18 months. The test is performed primarily through observation of an infant's motor skills in each developmental position, with only a few items requiring handling to complete the item (eg, sitting or standing with support at the trunk). This is an ideal assessment to be performed in the inpatient setting because it requires minimal handling, equipment, and time to complete. The AIMS has 4 subscales consisting of positioning in supine, prone, sitting, and standing with a total of 58 individual items. Infants receive 1 point for each skill acquired with a maximum score of 58 points. The total raw score is used to obtain a normative percentile score, allowing the infant's motor skills to be compared with same-aged peers, using corrected age for premature infants. Percentile scores 2 SDs below the mean (<2.3 percentile) are considered "abnormal," whereas scores between 1 and 2 SDs below the mean (2.3–15.9 percentile) are considered "suspicious" for atypical motor development.[14] The AIMS has good concurrent validity with the Bayley Scales of Infant Development[15] and Peabody Developmental Gross Motor Scales-2.[16] The AIMS has good interrater reliability when used by experienced clinicians, trained students, or early intervention providers.[15–17] Although there are other outcome measures available to assess infant gross motor skills, they are more labor intensive, requiring more time, equipment, and space that is not feasible in the inpatient setting. In addition, outcome measures used to assess function and mobility in the acute setting are designed for adults and older children, making them inappropriate to assess infants' functional skills.

Participant Demographics

In addition to AIMS scores, descriptive data including age, sex, and diagnoses as well as hospital length of stay and PT frequency were recorded. Participants in the study met the criteria for the definition of children with medical complexity[8] with diagnoses affecting multiple systems of the body. For the purposes of this study and to more precisely describe the infants observed, participants were grouped into diagnostic categories based on the primary diagnosis or system involvement at admission as noted in the medical record. This was completed by the first author and reviewed by the other authors. The participants were divided into 2 categories to describe the reason for hospital admission: (1) surgical and (2) medical. The participants were admitted to BCH from another medical facility or from home.

Data Analysis

Data were entered into Excel and analyzed with SAS version 9.4 (The SAS Institute, Cary, NC). Independent samples *t* tests were used to compare diagnostic groups, sex, and prematurity groups on age and AIMS outcomes. Because interval level scores (scaled scores) are not provided by the AIMS assessment and most participants did not have a change in percentile score throughout hospitalization, normative percentile scores could not be used to track change in motor skills over time for this population. Total raw AIMS scores were used instead to track gross motor change during hospitalization. Improvement per month of treatment was estimated using a linear regression procedure (SAS Proc Genmod) appropriate for repeated measures on participants. The following variables were included in the model: sex, prematurity (yes/no), baseline age, and primary reason for hospital admission (medical versus surgical). Sex and prematurity are known to have an impact on gross motor development.[4,18,19] Preterm males are noted to have increased incidence of poor motor outcome when compared with preterm females,[18] and premature infants have delayed gross motor development compared with same-age peers.[4,19]

Primary reason for hospital admission was selected as a variable because we hypothesized that surgical procedures might have a greater impact on motor skills because of greater restrictions in movement in the postoperative recovery period. Typically developing infants acquire skills at a slower rate as they age; therefore, we hypothesized that baseline age would also be a factor because older infants with medical complexity and baseline motor delays would also acquire skills at a slower rate and therefore show greater delays as they age.

RESULTS

Participant Characteristics

Participant characteristics are presented in Table 1. Between April 2016 and June 2018, 143 participants were evaluated with the AIMS at least once during hospitalization. Age at first AIMS administration ranged from 1 to 17 months. Most participants were admitted for a surgical intervention (n = 88, 62%) and cardiac diagnoses were the most common primary diagnosis at admission (n = 35, 24%). The mean ± SD hospital length of stay was 14.9 ± 14.3 weeks, ranging from 0.3 to 99.6 weeks.

Forty-five participants (31.5%) repeated the AIMS assessment during the same admission. Participants without a repeated AIMS assessment (n = 98, 68.5%) were lost to follow-up for the following reasons: (1) unanticipated discharge from the hospital before the 1 month reevaluation (n = 73, 74.5%) or (2) change in medical status affecting their ability to participate in the AIMS (n = 25, 25.5%). Five participants were lost to death during the course of the study. Despite 4 of the participants aging out of the AIMS at 18 months, no participants in this study achieved the maximum score on the AIMS (58 points) at any time point. The mean hospital length of stay for those with repeat AIMS assessment was 26.9 weeks, SD ± 17.5 (range, 6.6–99.6). The majority of participants (n = 30, 67%) received PT services at a frequency of 2 times per week, ranging from twice per month to 3 times per week. On average, 34% (mean 7.3, SD ± 6.0) of all scheduled PT appointments were cancelled most commonly because of the participant sleeping or being unavailable resulting from medical intervention, acute illness, or caregiver deferral to let the infant rest.

TABLE 1 Participant Demographics

Characteristic	All Participants (n = 143)	Participants With More Than 1 AIMS Assessment (n = 45)
Sex (male), n (%)	87 (61%)	26 (58%)
Baseline age, mo	6.4 ± 3.9	6.7 ± 3.7
Min-max	0.5–16.0	1.0–14.0
Admission reason, n (%)		
Medical	55 (38%)	15 (33%)
Surgical	88 (62%)	30 (67%)
Prematurity, n (%)	44 (31%)	15 (33%)
Primary diagnosis at admission, n (%)		
Cardiac	35 (24%)	10 (22%)
Gastrointestinal	31 (22%)	13 (29%)
Respiratory	23 (16%)	4 (9%)
Esophageal/airway disorders	18 (13%)	5 (11%)
Oncology/immunodeficiency	17 (12%)	8 (18%)
Organ transplant	6 (4%)	3 (7%)
Other	13 (9%)	5 (11%)
Length of stay, wk	14.9 ± 14.3	26.9 ± 17.5
Min-max	0.3–99.6	6.6–99.6
Baseline AIMS raw scores	12.3 ± 9.9	12.2 ± 9.5
Final AIMS raw scores	N/A	18.2 ± 13.0

Values are represented as mean ± SD unless noted otherwise. Baseline age represents the age (mo) at which the participant first completed the AIMS assessment. Repeat participants include those who completed the AIMS at more than 1 time point during the same admission. Other diagnoses include neurologic, metabolic, orthopedic, genetic, and urologic conditions.
Abbreviations: AIMS, Alberta Infant Motor Scale; min-max, minimum-maximum; N/A, not available.

Baseline AIMS Scores

At initial AIMS administration, 64% (n = 91) of participants scored 2 SDs below the mean for their age group with a normative score of <2.3%, placing them in the "abnormal" motor performance category, which is indicative of significant gross motor delay. Of these 91 participants who scored in the "abnormal" category, 60% (n = 55) were male, 58% (n = 53) were admitted for a surgical procedure, and 26% (n = 24) were premature. The most common primary diagnosis at admission for those with "abnormal" scores was cardiac (n = 26, 29%), followed by gastrointestinal (n = 17, 19%). Thirty-three participants' (23%) scores were in the "suspicious" motor performance category at 2.3 to 15.9 percentile. The remaining 19 (13%) participants scored above the 16th percentile at the initial completion of the AIMS, placing them within the "normal" category for motor development. Of the 19 participants who scored in the "normal" category, 68% (n = 13) were ≤3 months old, 63% (n = 12) were male, and 47% (n = 9) were premature. Thirteen (68%) of those with a "normal" score were admitted for a surgical procedure and gastrointestinal was the most common primary diagnosis at admission (n = 9, 47%).

Gross Motor Skill Acquisition During Hospitalization

Change in gross motor skills during hospitalization was examined for participants with more than 1 AIMS administration (n = 45). Gross motor classifications based on scores at the first and final AIMS assessment are shown in Fig 1. Baseline age (months) was associated with higher AIMS raw scores and for every month

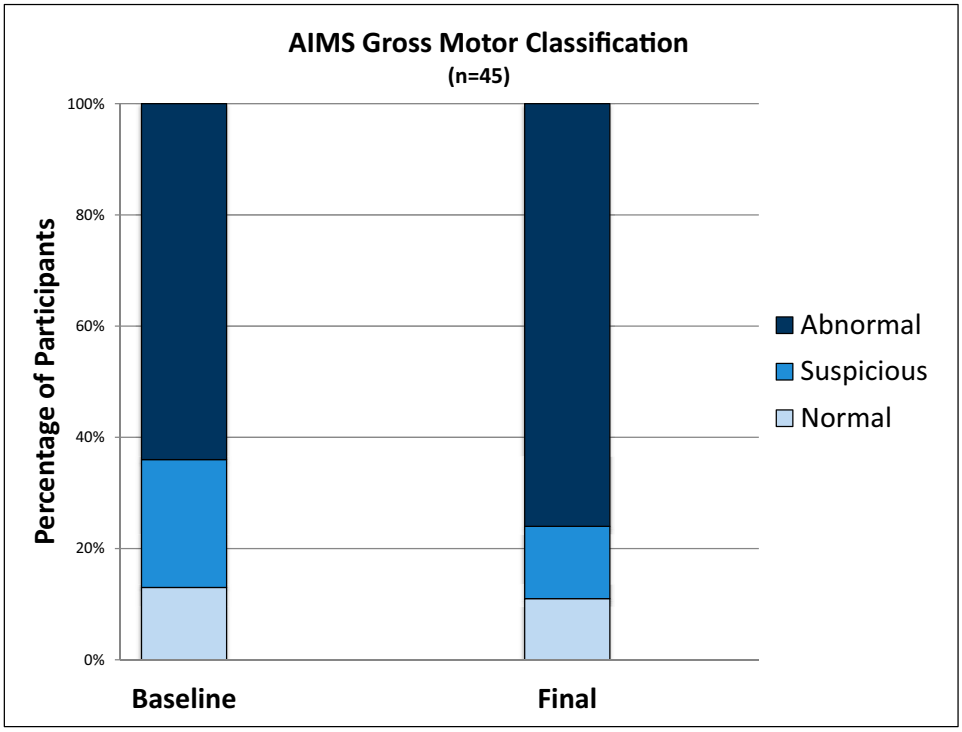

FIGURE 1 Repeat participants AIMS baseline and final gross motor classification. AIMS classifications for 45 participants with AIMS reassessments based on percentile scores: abnormal: ≤2 SDs below the mean; suspicious: <2 but >1 SD below the mean; normal: <1 SD below, equal to, or above the mean.

increase, raw AIMS scores increased by 1.6 points (95 confidence interval, 0.83–2.4; $P <$ .0001). When controlling for reason for hospital admission (medical versus surgical), prematurity (yes/no), and sex, the estimated improvement in AIMS raw scores was +1.4 points per month (95 confidence interval, 0.6–2.2; $P = .0007$), indicating that 1.4 new gross motor skills were acquired each month.

When looking at performance of individuals included in the study, 14 (31%) participants' raw AIMS scores declined upon reevaluation with score decline associated with acute illness with or without intubation ($n = 7$) including cardiac arrest, sepsis, and respiratory compromise, or surgical procedure ($n = 4$). Three participants had decreased scores that could not be linked to specific events.

DISCUSSION

To the authors' knowledge, this is the first observational study to describe infant gross motor performance and skill acquisition during an acute hospitalization. In line with previous research of infants with cardiac conditions and prematurity,[4–9] many (64%) participants showed significant gross motor delay at initial evaluation, scoring in the abnormal range on the AIMS. Results from this study suggest that hospitalized infants with a variety of complex medical conditions are at risk for significant developmental delay and acquire gross motor skills at a slower rate during hospitalization, highlighting the need for additional research on promoting gross motor development both during and after acute hospitalization.

Along with significant delays at baseline, the majority of participants showed slow acquisition of gross motor skills during hospitalization. When controlling for age, sex, prematurity (yes/no), and admission reason (medical versus surgical), participants demonstrated statistically significant increases in AIMS raw scores at a rate of 1.4 points (ie, 1.4 gross motor skills) per month during admission. Although this is a statistically significant improvement, this rate of development is much slower compared with the rate of gross motor skill acquisition in typically developing infants. There is a flattening of the percentile curves on the AIMS at 15 months indicating that infants with typical development (≥50th percentile) are expected to achieve all 58 skills as early as 15 months and no later than 18 months of age.[14] Inspection of the slopes of the AIMS normative percentile curves shows that gross motor skills increase by 3 to 8 skills per month from birth to 15 months in typically developing infants; thus, the increase of 1.4 skills per month observed in this study is at least twice as slow as their typically developing peers. Given the medical acuity and complexity of participants in this study, the observed slower acquisition of motor skills is not surprising.

Of concern, more infants presented with "abnormal" development on the AIMS at their final assessment (76%) compared with

baseline (64%) (Fig 1). This suggests that although infants show small gains on the AIMS during hospitalization, motor skill acquisition continues to lag as the infant ages in the hospital environment, leading to more notable delays over time. Finally, 14 (31%) infants with repeated assessments showed a regression in motor skills during hospitalization highlighting the need for interventions to improve developmental outcomes.

This observational study of infants with medical complexity who received PT an average of 2 times per week as a part of usual care suggests that future research is needed to determine if changes in PT dosing or treatment models can improve gross motor development during acute hospitalization. Examining environmental modifications to the inpatient setting and caregiver coaching are treatment strategies to be explored. Systematic reviews by Morgan et al[20,21] demonstrate the potential benefits of environmental modification and parental training for motor development in outpatients with cerebral palsy that may be adapted for acute care. Environmental modifications to support development could include the following: (1) limiting use of line protection devices (eg, joint immobilizers, mittens) when the infant is awake and supervised; (2) removing blanket nesting during wake periods; (3) providing mats at bedside to allow for floor play; and (4) providing benches or other equipment for older infants to engage in assisted standing play. Coaching models are a common method of caregiver instruction in early intervention programs[22]; however, there is no available research on the effectiveness of developmental coaching models for caregivers and staff in acute care settings. Coaching in the acute care setting may involve scheduled sessions with caregivers including family, nurses, and child life specialists for education on handling skills and positioning to facilitate gross motor development.

Many factors may contribute to the observed gross motor delay in hospitalized infants that cannot be attributed to hospitalization alone. First, many participants had complex medical conditions with multisystem involvement and may eventually be diagnosed with a developmental or genetic condition, placing them at increased risk for delayed development regardless of hospitalization. Second, specific acute medical conditions and surgical interventions experienced during hospitalizations also delay development. Examination of how such events affect gross motor development was beyond the scope of this initial study but could be explored in much larger, multicenter samples. Finally, as previously noted, the hospital environment also limits movement and gross motor experiences, further contributing to the slow progression of skills.

Participants who were included in the study were referred to PT, evaluated, and determined to require PT services. Those infants who were excluded from the study did not receive PT services, possibly resulting from lack of delays or because they were unable to participate in the assessment because of medical status or inability to maintain a calm state. With this exclusion criteria, there is a possibility of selection bias because those with limited or no delays or those with extreme sickness were not included in the study.

The variables used in this study included prematurity as a dichotomous variable. Although degree of prematurity has differing levels of developmental impact based on weeks of gestation, our sample size was too small to evaluate different groups according to severity of prematurity. In addition, we did not consider length of stay as a variable and we acknowledge that this may influence motor delay; however, because of our small sample size, we did not have enough power to analyze this variable. In future studies, length of stay and prematurity as a continuous variable should be evaluated to determine their impact on gross motor development in hospitalized infants with medical complexity.

All participants included in this study were receiving PT services an average of 2 times/week, which could influence outcomes. Although this study is observational by design, PT is a treatment that can influence developmental outcomes. It is unknown to what extent PT services influenced the participants' observed developmental progression. Understanding the impact of PT interventions and dosing were beyond the scope of this study, but the current study establishes a baseline of anticipated motor skill acquisition on the AIMS (1.4 skills per month) in hospitalized infants with medical complexity that can be used for comparison in future research evaluating the effectiveness of PT intervention for mitigating developmental delay. This observational study lacks a control group and changes in gross motor skills cannot be attributed to PT intervention. Despite this, our study design provides rich, real-life data on motor skills of hospitalized infants that could not be obtained in a traditional controlled trial. Participants were categorized based on primary diagnosis at admission, as noted in the medical record without the use of a validated algorithm for diagnostic categorization, impacting the ability to generalize the results to specific diagnostic groups in the acute setting. The heterogeneity of the diagnoses presented in this study is a representation of the real-life caseload of infants who are receiving physical therapy in a specialized pediatric hospital. This is an important first step in observing motor development in hospitalized infants and leads the way for future researchers to explore changes in individual diagnostic groups as defined by validated algorithms.

CONCLUSIONS

This study adds to the evidence on gross motor development of infants with medical complexity who are hospitalized and receiving inpatient PT services. Sixty-four percent of hospitalized infants with medical complexity receiving PT demonstrated abnormal gross motor development that worsened with prolonged length of stay. Hospitalized infants in this observational study acquired 1.4 gross motor skills per month on the AIMS regardless of age, sex,

diagnosis, admission reason, and prematurity status, compared with the expected 3 to 8 skills gained per month in typically developing infants. Future research should evaluate the impact of additional motor development focused PT interventions on motor skill acquisition in hospitalized infants with medical complexity compared with usual care.

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