Baby Observational Selective Control AppRaisal (BabyOSCAR)

Peyton, Colleen; Aaby, David; Barbosa, Vanessa Maziero; Boswell, Lynn; de Regnier, Raye Ann; Bos, Arend F.; Sukal Moulton, Theresa

Published in:
Developmental Medicine and Child Neurology

DOI:
10.1111/dmcn.15925

Received: 10 April 2023 | Accepted: 6 March 2024

DOI: 10.1111/dmcn.15925

ORIGINAL ARTICLE

Baby Observational Selective Control AppRaisal (BabyOSCAR): Scores at 3 months predict functional ability, spastic cerebral palsy distribution, and diagnosis at 2 years

Colleen Peyton[1,2] | David Aaby[3] | Vanessa Maziero Barbosa[4] | Lynn Boswell[5] | Raye-Ann de Regnier[2,5] | Arend F. Bos[6] | Theresa Sukal Moulton[1,2]

[1]Department of Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

[2]Department of Pediatrics, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

[3]Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

[4]Department of Occupational and Physical Therapy, University of Illinois Health

[5]Ann and Robert H. Lurie Children's Hospital, Chicago, IL, USA

[6]Division of Neonatology, Department of Pediatrics, Beatrix Children's Hospital, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands

Correspondence
Colleen Peyton, Department of Physical Therapy and Human Movement Sciences, Feinberg School of Medicine, Northwestern University, 645 N. Michigan Ave., Suite 1100, Chicago, IL 60611, USA.
Email: colleen.peyton1@northwestern.edu

Funding information
National Center for Advancing Translational Sciences, Grant/Award Number: KL2TR001424 and UL1TR001422

Abstract

Aim: To assess the predictive capabilities of the Baby Observational Selective Control AppRaisal (BabyOSCAR) tool, administered at 3 months corrected age, in determining spastic cerebral palsy (CP) outcome, functional abilities, and body topography at 2 years of age or later.

Method: Independent joint motions were measured at age 10 to 16 weeks from video recordings of spontaneous movement using BabyOSCAR in a sample of 75 infants. All included infants had known 2-year outcomes (45 with spastic CP and 30 without CP) including Gross Motor Functional Classification System (GMFCS) levels and CP body distribution. Receiver operating characteristic curves and cut points indicating greatest sensitivity and specificity were generated for predictive performance.

Results: Total BabyOSCAR score was a strong predictor of future outcome of spastic CP (cut score of 22.5, sensitivity = 98%, specificity = 100%, area under the curve = 0.99), and was able to distinguish children classified in GMFCS levels I and II from those in III to V (cut score of 13.5, sensitivity = 92%, specificity = 89%, area under the curve = 0.94). Having an (absolute) asymmetry score on the BabyOSCAR of more than 5 was a predictor of having unilateral CP at age 2 years (sensitivity = 56%, specificity = 100%, area under the curve = 0.86).

Interpretation: BabyOSCAR scores are predictors of diagnosis, body distribution, and future gross motor function in infants with spastic CP at 2 years of age or later.

Selective motor control (SMC) is the ability to move one joint at a time and is difficult for individuals with spastic cerebral palsy (CP).[1] SMC is important for gross and fine motor tasks because people who have decreased SMC have less independence with ambulation[1] and manual abilities.[2] The ability to isolate joint motion reflects the integrity of the corticospinal system, the motor pathway responsible for most skilled movement.[3] The corticospinal tract originates in the primary motor cortex[4] and other corticomotor regions[3] and sends direct motor signals to targeted motor pools in the spinal cord,[3] producing dexterous motion. Early brain injuries that cause spastic CP often include damage to the corticospinal pathways, probably causing motor behavior to be generated from less direct motor pathways.[5] Consequently, movement is less

This original article is commented by Heathcock on pages 1406–1407 of this issue.

Abbreviations: BabyOSCAR, Baby Observational Selective Control AppRaisal; GMA, General Movement Assessment; SMC, selective motor control.

individuated and more grouped muscle activation co-occurs with increased spinal motor firing and spasticity.[6] However, it is not clear when infants who go on to develop spastic CP begin to show signs of diminished SMC.

Observation of spontaneous infant motion has been successfully used in the Prechtl General Movement Assessment (GMA)[7] as a clinical method to detect CP in young infants,[8] and indicates that spontaneous infant motion can reflect neurological functioning. Furthermore, brain injuries that damage the corticospinal pathways result in observable and repetitive clinical patterns in older children and adults such as: (1) stereotyped combinations of joint motions, or synergies;[9] and (2) mirror movements, which are movements that occur simultaneously on both sides of the body.[10] When part of a variable array of spontaneous movement behavior, infants with typical motor development may demonstrate synergistic[11] and mirrored movements;[12] however, spontaneous behavior that is predominantly lacking in individual joint motion may indicate early signs of diminished SMC.[13] Notably, the isolation of individual joint motion can be observed during spontaneous infant behavior and may indicate an early expression of corticospinal connectivity. Therefore, the quantification of these observable behaviors can add clinical value as a non-invasive biomarker and prognostic indicator.

To measure early SMC in infants, we have designed a clinical tool called the Baby Observation of Selective Control AppRaisal (BabyOSCAR)[14] which uses only clinical observation, and can be used concurrently with other infant observational neurological assessments.[7] The BabyOSCAR was designed to measure an infant's capacity to isolate joint movements and record the presence of synergies and mirror movements (in the absence of joint isolation). The aim of this study was to determine the predictive performance of the BabyOSCAR (tested at 3 months corrected age) to outcome at 2 years of age or later in a sample of children with and without spastic CP.

What this paper adds

- Decreased independent joint movement at 3 months predicts spastic cerebral palsy (CP) at 2 years.
- Baby Observational Selective Control AppRaisal (BabyOSCAR) scores ≤13 are predictive of Gross Motor Function Classification System (GMFCS) levels III to V.
- BabyOSCAR scores of 14 to 22 are predictive of GMFCS levels I and II.
- A BabyOSCAR total asymmetry score >5 predicts unilateral CP.
- Stereotyped movements are more prominent in those who will be diagnosed with spastic CP at 2 years.

METHOD

Participants

Children included in the study had at least one video of spontaneous movements recorded between 10 weeks and 16 weeks corrected age, a known 2-year-old outcome of either a diagnosis of CP or no CP, and written permission (from infants' guardians) for use of videos in a research study. Among the children with CP, inclusion criteria, measured at 2 years of age or later, were (1) having a spastic (only) type of CP, (2) a known topography of CP (including paretic side in cases of unilateral CP), and (3) known Gross Motor Functional Classification System (GMFCS) level. Infants were excluded from the study if they had an orthopedic condition that prevented joints from moving independently or were diagnosed with either dyskinetic CP or a mixed dyskinetic and spastic CP type.

Written consent was provided by the guardians of the infants for recording, storage, and scientific use of video data. Medical, demographic, and 2-year outcome data were collected from all participating centers from research data and medical records. Infant data were collected with institutional review board approval from four sites conducting longitudinal research on infant development and GMA and included: (1) Northwestern Memorial Hospital, Chicago, IL, USA; (2) Lurie Children's Hospital, Chicago, IL, USA; (3) University of Chicago Comer Children's Hospital, Chicago, IL, USA; and (4) Beatrix Children's Hospital, Groningen, the Netherlands.

BabyOSCAR

The BabyOSCAR is a clinical assessment that evaluates an infant's capacity for isolating joint motion. An isolated movement is defined as joint motion that occurs in absence of movement at other joints in the same limb, and without mirroring with the opposite side of the body. A score of 1 is given for each instance of isolated joint motion seen in the right and left sides of the body. The total BabyOSCAR score is the sum of all joint motions that were scored a 1 on the left and right sides of the body. The total BabyOSCAR score points range from 0 to 32.[14] If an individual joint motion is not observed, the scorer provides a score of 0 and selects one (or more) of the following options why the joint motion is not isolated: (1) movement is part of a synergy pattern, (2) movement is mirrored, (3) hypokinetic (movement does not occur during observation period), or (4) moves with other joint.[14] An asymmetry score is then calculated by subtracting the total number of joints with individual movements on the left (upper and lower extremities) from the corresponding total for the right (upper and lower extremities).[14] Videos were scored using the BabyOSCAR tool by at least two raters. In the case of disagreement in scoring (above a

given scoring threshold), an additional rater was used as a tie-breaker. The total time it takes to score the BabyOSCAR is between 10 minutes and 15 minutes.[14]

Video recordings

Infants between 10 weeks and 16 weeks corrected age were filmed in the supine position during active movement while in a calm and alert state. Pacifiers were removed and infants were filmed so that fingers and toes were visible throughout recording. All videos were originally recorded and scored using the GMA.[7] Videos that were originally longer than 1 minute were edited to 1 minute in length. The 1-minute clips were used in the BabyOSCAR analysis.

Statistical analysis

Statistical analyses were conducted using R version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria). Sample characteristics were summarized as either *n* (%) or as median and interquartile range (IQR), as appropriate. We used Wilcoxon rank sum and χ^2 tests to determine characteristic differences among children with and without CP.

We generated receiver operating characteristic curves to evaluate the diagnostic performance of BabyOSCAR scores (total, leg, and arm) in determining presence or absence of CP. The R package pROC was used to determine optimal cut points using the Youden index,[15] defined as the greatest combined sensitivity and specificity. Receiver operating characteristic curves were also used to determine optimal cut points to distinguish between (1) children classified in GMFCS levels I and II and children classified in GMFCS levels III to V (BabyOSCAR total score, $n = 45$) and (2) the number of asymmetries for children with or without unilateral CP (BabyOSCAR asymmetry score, $n = 75$). When calculating receiver operating characteristic curves for children with or without unilateral CP, the symmetry score used was an absolute value of the differences between the two sides of the body.

We added the total number of times that synergy and mirror movements were attributed to scores of '0' at a joint (maximum count of 32). Then, we used Poisson regression to model the association between the total number of synergies and mirror movements among three groups with confirmed functional ability at age 2 years or later: (1) those without CP, (2) those classified in GMFCS levels I and II, and (3) those classified in GMFCS levels III to V. We report incident rate ratios from the Poisson regression models. A two-tailed *p*-value of 0.05 or less defined statistical significance.

RESULTS

We included videos of 75 total infants (30 without CP, 45 with CP) which are summarized in Table 1. Among infants without CP, half were born preterm (<37 weeks gestational age). The median gestational age was lower in the group of infants with CP than in those without CP (Table 1). The median gestational age was 27 weeks (IQR 25–31) in the group of infants with CP, compared with 36.5 weeks (IQR 33–39) in the group of infants without CP (Table 1).

Predictive validity of BabyOSCAR and CP

The BabyOSCAR scores at 3 months corrected age (total, leg, and arm) had excellent predictive validity (Table 2 and Figure 1) in determining children who did and did not have spastic CP at 2 years of age or later. For example, an optimal cut point total score of not more than 22 predicted spastic CP with 98% sensitivity and 100% specificity. Among children with CP, total BabyOSCAR score (measured at 3 months corrected age) also showed predictive validity in distinguishing those classified in GMFCS levels I and II from those in GMFCS levels III to V at 2 years or later (Table 2). Total asymmetry score (absolute value), measured at 3 months corrected age, had a strong diagnostic accuracy for unilateral CP at 2 years of age or later (Table 2 and Figure 1).

Synergies and mirror movements

The total number of synergies observed at 3 months corrected age differed among groups of children (classified at age ≥2 years) without CP, classified in GMFCS levels I and II, and in GMFCS levels III to V (no CP mean = 0.4, SD = 0.9; GMFCS levels I and II mean = 6.1, SD = 4.2; GMFCS levels III–V mean = 10.4, SD = 8.7; Figure 2), with children without CP having the least number of synergies observed and children classified in GMFCS levels IV and V having the highest number. The incidence rate of the number of synergies noted (during the 1-minute recording at 3 months corrected age) differed significantly among all groups tested ($p < 0.001$). Children classified at 2 years or later in GMFCS levels III to V had 26.0 times the incidence rate of having synergies (at 3 months corrected age) compared with children without CP at 2 years or later (95% confidence interval [CI] 14.6–46.3) and 1.7 times the incidence rate of having synergies (at 3 months corrected age) compared with children classified at 2 years or later in GMFCS levels I and II (95% CI 1.4–2.1). Children classified at 2 years or later in GMFCS levels I and II had 15.3 times the incidence rate of having synergies (at 3 months corrected age) compared with children without CP at 2 years of age or later (95% CI 8.4–27.6).

Similarly, the total number of mirror movements observed at 3 months corrected age was least in the children without CP (mean = 0.2, SD = 0.5) and higher in GMFCS level groups classified at 2 years of age or later (GMFCS levels I and II mean = 0.9, SD = 1.8; GMFCS levels III–V mean = 2.5, SD = 3.8; Figure 2). The incidence rate of mirror movements noted in a 1-minute video recording (at 3 months corrected age) differed significantly among all groups (at ≥2 years:

TABLE 1 Participants' characteristics among a sample of 75 infants with and without CP.

Demographics	Infants without CP ($n=30$)	Infants with CP ($n=45$)	p
Born preterm (<37 weeks)	15 (50)	36 (80)	0.01[a]
Median gestational age, weeks (IQR)	36.5 (33–39)	27 (25–31)	<0.001[b]
Median corrected age at BabyOSCAR film, weeks (IQR)	13 (12–14)	12 (12–13)	0.05[b]
CP subtype			
Bilateral CP		29 (64)	
Unilateral CP		16 (36)	
Unilateral CP paretic side			
Left		8 (50)	
Right		8 (50)	
GMFCS level			
I		14 (31)	
II		5 (11)	
III		5 (11)	
IV		10 (22)	
V		11 (24)	
Brain injury subtype[c]			
Grade I and II IVH		2 (4)	
Grade III IVH		5 (11)	
PVHI		9 (202)	
PVL		15 (33)	
NE		3 (7)	
Ischemic stroke		3 (7)	
Other[d]		6 (13)	

Data are *n* (%) unless otherwise stated.

Abbreviations: BabyOSCAR, Baby Observational Selective Control AppRaisal; CP, cerebral palsy; IQR, interquartile range; IVH, intraventricular hemorrhage; NE, neonatal encephalopathy; PVHI, periventricular hemorrhagic infarction; PVL, periventricular leukomalacia.

[a]χ^2 test.

[b]Wilcoxon rank sum test.

[c]Two participants were missing brain injury subtype.

[d]Other: encephalomalacia, occipital atrophia, posthemorrhagic hydrocephalus, ventriculomegaly.

TABLE 2 Predictive validity of BabyOSCAR at 3 months and 2-year outcome among 75 infants.

BabyOSCAR score category	Predicted outcome	Optimal cut point	Sensitivity (%)	Specificity (%)	NPV (%)	PPV (%)	AUC
BabyOSCAR scores: diagnosis of spastic CP ($n=75$)							
Total	Spastic CP	≤22	98	100	97	100	0.99
Leg	Spastic CP	≤8	97	93	91	98	0.97
Arm	Spastic CP	≤10	76	100	73	100	0.94
BabyOSCAR scores: GMFCS level among infants with spastic CP[a] ($n=45$)							
Total	GMFCS levels III–V	≤13	92	89	89	92	0.94
BabyOSCAR asymmetry scores: unilateral CP[b] ($n=75$)							
Total asymmetry	Unilateral CP	>5	56	100	89	100	0.86
Leg asymmetry	Unilateral CP	>1	69	88	91	61	0.80
Arm asymmetry	Unilateral CP	>1	81	75	94	46	0.81

Abbreviations: AUC, area under the curve; BabyOSCAR, Baby Observation Selective Control AppRaisal; CP, cerebral palsy; GMFCS, Gross Motor Functional Classification System; NPV, negative predictive value; PPV, positive predictive value.

[a]Children classified in GMFCS levels III–V were compared with children classified in GMFCS levels I and II.

[b]Children with unilateral CP were compared with a grouping of children with no CP and with bilateral CP.

children without CP, children classified in GMFCS levels I and II, children in GMFCS levels III–V; $p < 0.001$). Children in GMFCS levels III to V (at ≥2 years) had 15.0 times the incidence rate of having mirroring at 3 months corrected age compared with children without CP at 2 years or later (95% CI 6.0–37.2) and had 2.6 times the incidence rate of mirror movements at 3 months corrected age compared with children classified in GMFCS levels I and II (at ≥2 years; 95% CI 1.6–4.4). Also, children classified in GMFCS levels I and II (at ≥2 years) had 5.7 times the incidence rate of having mirror movements at 3 months corrected age compared with children without CP (at ≥2 years; 95% CI 2.1–15.3).

DISCUSSION

The BabyOSCAR score, tested at 3 months corrected age, was an excellent predictor of spastic CP at 2 years of age or later, and was predictive of future motor performance in children with spastic CP. Using a cut point of BabyOSCAR total score of not more than 22 (at 3 months corrected age) predicted spastic CP at 2 years of age or later with 98% sensitivity and 100% specificity. In addition, the BabyOSCAR asymmetry score measured at 3 months corrected age was useful in predicting CP topography, especially in differentiating those with unilateral CP at 2 years of age or later.

Importantly, this tool was designed and validated to be used with infants (between 10 weeks and 16 weeks corrected age) with a high chance of having spastic CP. We have chosen to validate this tool only for children with spastic CP because the ability to isolate joint movements is a key feature of spastic CP in children and adults contributing to challenges in gait,[1,16] reaching, grasping, and fine or dexterous motor control.[2,6] A higher total BabyOSCAR score (indicating more observed instances of independent joint control) was related to more independent functional motor performance, as is seen in the relationship between instances of SMC and GMFCS level in children and adults with spastic CP.[1,16–18]

Because this sample of infants was used to validate BabyOSCAR as being able to discriminate among infants with and without later CP, we only included infants who at 2 years of age or later either had a known diagnosis of CP or were known not to have CP. This selection bias has the potential to inflate the predictive abilities found in this sample as we have not included any children whose 2-year outcomes were not known in advance. We will next prospectively test the predictive abilities in a sample of infants whose outcomes are not yet known. Nevertheless, in clinical practice, we recommend that this tool is used primarily for children with the highest possibility of having a diagnosis of spastic CP, and not as a screening tool. Therefore, we recommend that this tool is used after other currently recommended tests[19] that can more quickly screen and distinguish children with and without CP in infancy, such as the Prechtl GMA.[7] The BabyOSCAR concept was created using video recordings made from the GMA, and therefore can be used as an additional measure in cases where infants have absent fidgety movements[20] and/or neuroimaging findings that suggest a high chance of having an eventual diagnosis of spastic CP. Specifically, this tool may also be useful in infants with known unilateral brain injury because infants with unilateral CP are more likely to have normal GMA than those with bilateral CP.[21] In fact, 12% of infants with unilateral CP (11 out of 92) had normal fidgety movements among a large cohort ($n = 468$) of infants with CP.[21] For these infants, the BabyOSCAR may be a useful prognostic indicator, signaling an earlier referral to intervention, with perhaps earlier targeted treatment to body regions found to have less SMC.

While we designed the BabyOSCAR to be used in clinical practice, the implementation and clinical use is yet to be determined. While we have created a comprehensive manual[14] to explain how to score the BabyOSCAR, we do not yet know whether the manual alone will be sufficient for clinicians to accurately use the BabyOSCAR or whether it will require additional training of clinicians and researchers interested in using it. We plan to next test this in samples of clinician learners. Nevertheless, we have learned that SMC in infants is observable at 3 months corrected age.

The BabyOSCAR was designed by using similar items to tests that currently measure SMC (Selective Control Assessment of the Lower Extremity[22] and Test of Arm Selective Control[2]) and contrasts with their methods for evaluation. Unlike the Selective Control Assessment of the Lower Extremity[22] and the Test of Arm Selective Control,[2] where SMC is measured by asking the person to move in response to a verbal command, the items in BabyOSCAR are measured through observation of spontaneous movement. Observation of spontaneous infant movement has been used reliably in the Prechtl GMA[7] for several decades, with the highest sensitivity in predicting CP in the young infant.[8] While observation of spontaneous movement is a new way to interpret SMC, it allows us to interpret the behaviors in young infants of all abilities, regardless of the ability to follow directions.

Because we found less independent joint motion in infants with spastic CP in early infancy (3 months corrected age), the use of the cut point scores we have found in our study may help to guide clinical decision-making at a time of great plasticity of the nervous system. Having a total score of not more than 13 was predictive of GMFCS levels III to V, scores between 14 and 22 were predictive of having GMFCS levels I and II, and having a score of more than 5 asymmetries was predictive of unilateral CP; these cut point scores may be useful in considering functional motor prognosis and treatment planning in children with spastic CP. Additionally, we decided to analyze and report the predictive validity of the BabyOSCAR total score, leg score, and arm score in this paper because Rasch analysis of test validity suggested that leg and arm scores measured separate and complementary constructs.[23] In practical and clinical use of the tool, we recommend recording arm and leg scores, and using the total and asymmetry scores for prediction, intervention referral, and planning because of their higher sensitivity and specificity for gross motor function and topography of CP.

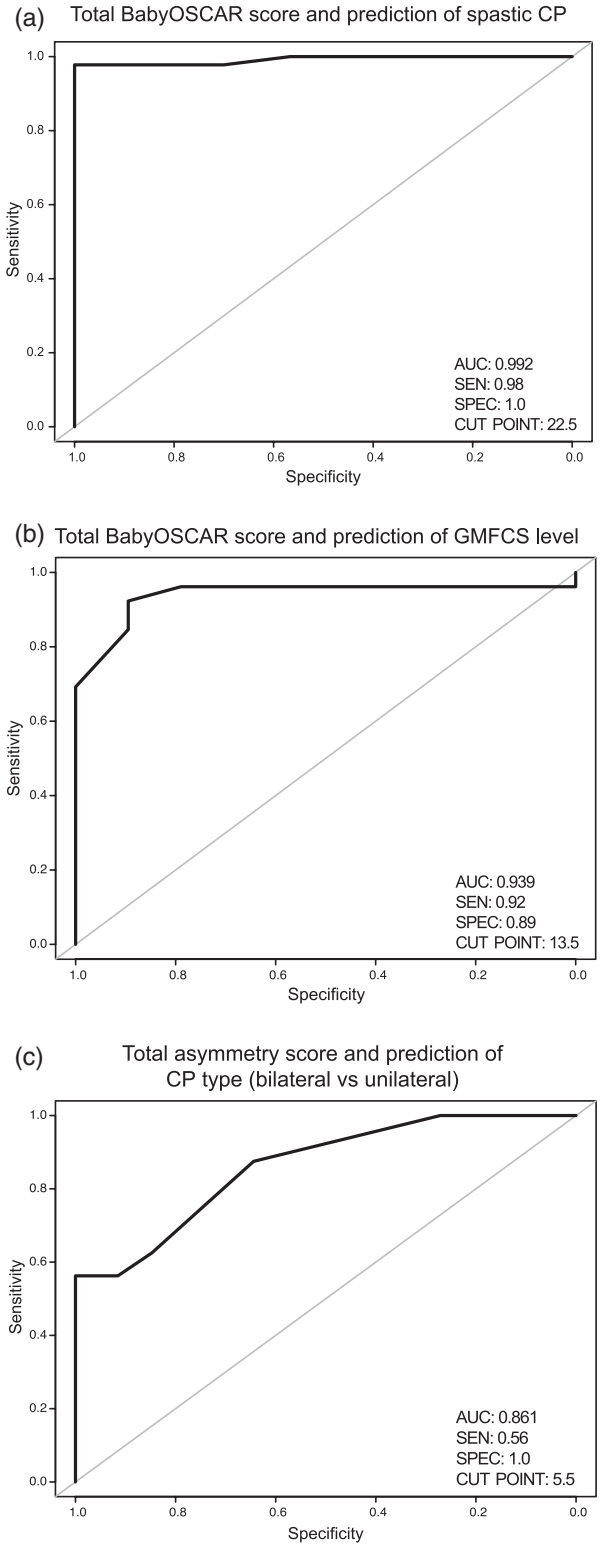

FIGURE 1 ROC curves for: (a) total BabyOSCAR score and prediction of spastic CP among all 75 infants; (b) total BabyOSCAR score and prediction of GMFCS levels III, IV, and V among 45 infants with spastic CP; and (c) total BabyOSCAR asymmetry score and prediction of unilateral CP among all 75 infants. Asymmetry score is calculated using an absolute value. AUC, area under the curve; BabyOSCAR, Baby Observational Selective Control AppRaisal; CP, cerebral palsy; CUT POINT, optimal identified cut point GMFCS, Gross Motor Functional Classification System; ROC, receiver operating characteristic; SEN, sensitivity; SPEC, specificity.

Furthermore, our analysis revealed a significant correlation between lower BabyOSCAR scores in limbs and subsequent spastic CP body distribution, particularly in comparing paretic and non-paretic limbs.[14] Given this relationship, it is not surprising that our study also identified a predictive association between BabyOSCAR asymmetry scores (at 3 months corrected age) and the later diagnosis of unilateral CP (at ≥2 years). Specifically, while some children with unilateral CP exhibited asymmetry scores of no more than 5, only those with unilateral CP showed asymmetry scores exceeding 5. Therefore, a BabyOSCAR asymmetry score exceeding 5 can help a clinician decide to initiate therapies to affected limbs, such as bimanual[24] or constraint-induced movement therapies, and implement assessments, such as the Hand Assessment of Infants,[25] to evaluate hand function. Additionally, clinicians should consider that an asymmetry score of less than 5, combined with a total BabyOSCAR score of not more than 22, may indicate either unilateral or bilateral CP distribution. These findings align with the predictive ability of the Hammersmith Infant Neurological Examination, where an asymmetry score exceeding 5 was also indicative of unilateral CP.[26] However, it is important to note that the BabyOSCAR score, although having a lower sensitivity (56%) than the Hammersmith Infant Neurological Examination (92%), demonstrates predictive ability at an earlier timepoint in infant development (BabyOSCAR, 3 months corrected age; Hammersmith Infant Neurological Examination, >9 months)[26] and has a different total score range (BabyOSCAR, 32; Hammersmith Infant Neurological Examination, 78).[27] Lower BabyOSCAR scores in a given limb can serve as a valuable indicator for prioritizing specific body structures to enhance independent joint control. Clearly distinguishing between unilateral and bilateral CP distribution may greatly assist families and clinicians in prognostication and targeted treatment planning to optimize the functionality of the most affected limbs.

Interestingly, we also found that the numbers of synergies and mirror movements (measured at 3 months corrected age) were lowest in children without CP and highest in those classified in GMFCS levels III to V, with increased incidence rates of these patterns increasing by GMFCS level group. It should be noted that children without CP may have also demonstrated observed movements that were mirrored or synergistic, but these observations were not reflected in the analysis if they also demonstrated at least an instance of independent joint movement during the period of observation. In other words, infants who had variability in their movement demonstrated a combination of both stereotyped and independent patterns and this variability resulted in a score of 1 at the joint, excluding the possibility of having been counted for mirrored or synergistic movements. Infants classified in GMFCS levels III, IV, and V had less observed capacity to generate independent joint control and were therefore more often categorized as moving in synergistic or mirrored patterns, suggesting that their self-generated movements were more often produced by grouped muscle activity. Taken together, these observations

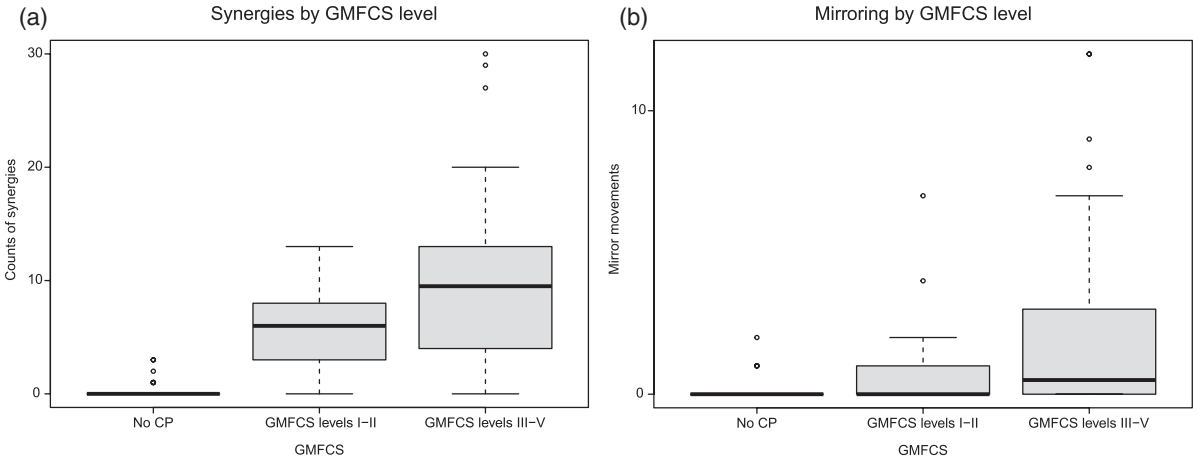

FIGURE 2 Boxplots of counts of (a) synergies and (b) mirror movements noted during a 1-minute video, grouped by Gross Motor Functional Classification System (GMFCS) level among 45 infants with spastic cerebral palsy (CP).

may provide insight about the motor pathways being used to generate movement. Almost three-quarters of infants with spastic CP in our sample ($n = 32$; Table 1) sustained primary injuries to the ventricular or periventricular brain regions, an area of vulnerability for developing corticospinal projections.[28] Injuries to these regions may result in an early upregulation of bulbospinal (e.g. vestibulospinal and reticulospinal) pathways. Bulbospinal projections contribute to grouped movements because they synapse across multiple segments and to both sides of the spinal cord.[3] While the bulbospinal projections contribute to normal movement both in infants[29] and in adults,[30,31] their increased influence may also limit capacity for individual movement as shown here and in other brain injuries.[9]

The BabyOSCAR tool is a promising way to evaluate SMC at an earlier timepoint than has previously been possible. While we are hopeful that this tool may help to inform and guide early interventions, little is known about the capacity to improve SMC when targeting skilled behavior in early infancy. Animal[32,33] and human[34] models suggest that the corticospinal system undergoes significant organization in the first 6 months of life. Because the BabyOSCAR is also predictive of CP topography, we assume that the tool can be used to target specific body regions that are showing less isolated joint motion beginning at 3 months of age.

Interestingly, we found that all infants in our sample, regardless of outcome, had some capacity to isolate a joint independently and no child in our sample had a score of 0 on the BabyOSCAR. It is still unknown whether the young nervous system can recover or maintain the ability to isolate joint motion when targeted treatment is initiated in early infancy. It is possible that, because spasticity is not often present in the newborn infant[35] and develops over time,[36] the ability to isolate joints may become progressively more difficult. Our study is limited in that we only assessed SMC in infancy and therefore cannot compare our results with SMC measures in later childhood such as the Test of Arm Selective Control[2] and the Selective Control Assessment of the Lower Extremity.[22] These important comparisons are needed in future prospective studies to determine the trajectories of independent joint control as the nervous system develops.

Because our findings indicate that observed SMC measured by BabyOSCAR (at 3 months corrected age) is predictive of future functional motor performance, topography, and diagnosis of spastic CP, we hope that the use of this tool can assist with clinical assessment and clinical interventions that target specific behaviors and topography at a time of great potential in the developing neuromotor system.

ACKNOWLEDGEMENTS

We thank the children and their families for their participation. Research reported in this publication was supported, in part, by the National Institutes of Health's National Center for Advancing Translational Sciences, grant number UL1TR001422. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The first author was supported by the National Center for Advancing Translational Sciences, grant number KL2TR001424.

CONFLICT OF INTEREST STATEMENT

Drs. Peyton and Bos are members of the General Movements Trust speaker's bureau.

FUNDING INFORMATION

National Institutes of Health's National Center for Advancing Translational Sciences, grant number UL1TR001422; National Center for Advancing Translational Sciences, grant number KL2TR001424.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Colleen Peyton https://orcid.org/0000-0003-4753-7246
Arend F. Bos https://orcid.org/0000-0002-6103-6125
Theresa Sukal Moulton https://orcid.org/0000-0001-6624-1999

REFERENCES

1. Chruscikowski E, Fry NRD, Noble JJ, Gough M, Shortland AP. Selective motor control correlates with gait abnormality in children with cerebral palsy. Gait & posture 2017; 52: 107–9.
2. Sukal-Moulton T, Gaebler-Spira D, Krosschell KJ. The validity and reliability of the Test of Arm Selective Control for children with cerebral palsy: a prospective cross-sectional study. Developmental Medicine & Child Neurology 2018; 60: 374–81.
3. Lemon RN. Descending pathways in motor control. Annu. Rev. Neurosci. 2008; 31: 195–218.
4. Lemon RN, Griffiths J. Comparing the function of the corticospinal system in different species: organizational differences for motor specialization? Muscle & Nerve: Official Journal of the American Association of Electrodiagnostic Medicine 2005; 32: 261–79.
5. Cahill-Rowley K, Rose J. Etiology of impaired selective motor control: emerging evidence and its implications for research and treatment in cerebral palsy. Developmental Medicine & Child Neurology 2014; 56: 522–8.
6. Sukal-Moulton T, Fowler E. Selective voluntary motor control in children and youth with spastic cerebral palsy. Cerebral Palsy 2020: 2587–610.
7. Einspieler C, Prechtl HF, Bos AF, Ferrari F, Cioni G. Prechtl's method on the qualitative assessment of general movements in preterm, term and young infants. McKeith Press; 2004.
8. Bosanquet M, Copeland L, Ware R, Boyd R. A systematic review of tests to predict cerebral palsy in young children. Developmental Medicine & Child Neurology 2013; 55: 418–26.
9. Sukal-Moulton T, Krosschell KJ, Gaebler-Spira DJ, Dewald JPA. Motor impairments related to brain injury timing in early hemiparesis. Part II: abnormal upper extremity joint torque synergies. Neurorehabilitation and neural repair 2014; 28: 24–35.
10. Kuhtz-Buschbeck JP, Sundholm LK, Eliasson AC, Forssberg H. Quantitative assessment of mirror movements in children and adolescents with hemiplegic cerebral palsy. Developmental Medicine & Child Neurology 2000; 42: 728–36.
11. Thelen E. Developmental origins of motor coordination: Leg movements in human infants. Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology 1985; 18: 1–22.
12. Wolff PH, Gunnoe CE, Cohen C. Associated movements as a measure of developmental age. Developmental Medicine & Child Neurology 1983; 25: 417–29.
13. Fetters L, Sapir I, Chen Yp, Kubo M, Tronick E. Spontaneous kicking in full-term and preterm infants with and without white matter disorder. Developmental Psychobiology 2010; 52: 524–36.
14. Sukal-Moulton T, Barbosa VM, Sargent B, de Regnier RA, Bos AF, Peyton C. Baby Observational Selective Control AppRaisal (BabyOSCAR): convergent validity and reliability in infants with and without spastic cerebral palsy. submitted.
15. Youden WJ. Index for rating diagnostic tests. Cancer 1950; 3: 32–5.
16. Zhou JY, Lowe E, Cahill-Rowley K, Mahtani GB, Young JL, Rose J. Influence of impaired selective motor control on gait in children with cerebral palsy. Journal of Children's Orthopaedics 2019; 13: 73–81.
17. Noble JJ, Gough M, Shortland AP. Selective motor control and gross motor function in bilateral spastic cerebral palsy. Developmental Medicine & Child Neurology 2019; 61: 57–61.
18. Fowler EG, Staudt LA, Greenberg MB. Lower-extremity selective voluntary motor control in patients with spastic cerebral palsy: increased distal motor impairment. Developmental Medicine & Child Neurology 2010; 52: 264–9.
19. Novak I, Morgan C, Adde L, et al. Early, accurate diagnosis and early intervention in cerebral palsy: Advances in diagnosis and treatment. JAMA Pediatrics 2017.
20. Prechtl HFR, Einspieler C, Cioni G, Bos AF, Ferrari F, Sontheimer D. An early marker for neurological deficits after perinatal brain lesions. The Lancet 1997; 349: 1361–3.
21. Einspieler C, Bos AF, Krieber-Tomantschger M, Alvarado E, Barbosa VM, Bertoncelli N, Burger M, Chorna O, Del Secco S, DeRegnier R-A. Cerebral palsy: early markers of clinical phenotype and functional outcome. Journal of clinical medicine 2019; 8: 1616.
22. Fowler EG, Staudt LA, Greenberg MB, Oppenheim WL. Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and interrater reliability of a clinical tool for patients with cerebral palsy. Developmental Medicine & Child Neurology 2009; 51: 607–14.
23. Barbosa VM, Peyton C, Sukal-Moulton T. Baby Observational Selective Control AppRaisal (BabyOSCAR): construct validity and test performance. submitted.
24. Damiano DL, Longo E. Early intervention evidence for infants with or at risk for cerebral palsy: an overview of systematic reviews. Dev Med Child Neurol 2021; 63: 771–84.
25. Krumlinde-Sundholm L, Ek L, Sicola E, Sjostrand L, Guzzetta A, Sgandurra G, Cioni G, Eliasson AC. Development of the Hand Assessment for Infants: evidence of internal scale validity. Dev Med Child Neurol 2017; 59: 1276–83.
26. Hay K, Nelin M, Carey H, Chorna O, Moore-Clingenpeel M, Maitre N, Group NCHED. Hammersmith infant neurological examination asymmetry score distinguishes hemiplegic cerebral palsy from typical development. Pediatric neurology 2018; 87: 70–4.
27. Romeo DMM, Cioni M, Scoto M, Mazzone L, Palermo F, Romeo MG. Neuromotor development in infants with cerebral palsy investigated by the Hammersmith Infant Neurological Examination during the first year of age. European Journal of Paediatric Neurology 2008; 12: 24–31.
28. Bax M, Tydeman C, Flodmark O. Clinical and MRI correlates of cerebral palsy: the European Cerebral Palsy Study. Jama 2006; 296: 1602–8.
29. Rothwell JC. The startle reflex, voluntary movement, and the reticulospinal tract. Supplements to clinical neurophysiology 2006; 58: 223–31.
30. Drew T, Prentice S, Schepens B. Cortical and brainstem control of locomotion. Progress in brain research 2004; 143: 251–61.
31. Prentice SD, Drew T. Contributions of the reticulospinal system to the postural adjustments occurring during voluntary gait modifications. Journal of neurophysiology 2001; 85: 679–98.
32. Martin JH, Friel KM, Salimi I, Chakrabarty S. Activity- and use-dependent plasticity of the developing corticospinal system. Lesions in the Developing Nervous System: Theoretical Considerations, Early Detection and Perspectives for Treatment 2007; 31: 1125–35.
33. Friel KM, Martin JH. Bilateral Activity-Dependent Interactions in the Developing Corticospinal System. The Journal of Neuroscience 2007; 27: 11083–90.
34. Eyre JA, Smith M, Dabydeen L, Clowry GJ, Petacchi E, Battini R, Guzzetta A, Cioni G. Is hemiplegic cerebral palsy equivalent to amblyopia of the corticospinal system? Annals of Neurology 2007; 62: 493–503.
35. Kuban KCK, Allred EN, O'Shea TM, Paneth N, Pagano M, Dammann O, Leviton A, Du Plessis A, Westra SJ, Miller CR. Cranial ultrasound lesions in the NICU predict cerebral palsy at age 2 years in children born at extremely low gestational age. Journal of child neurology 2009; 24: 63–72.
36. Lindén O, Hägglund G, Rodby-Bousquet E, Wagner P. The development of spasticity with age in 4,162 children with cerebral palsy: a register-based prospective cohort study. Acta orthopaedica 2019; 90: 286–91.

How to cite this article: Peyton C, Aaby D, Barbosa VM, Boswell L, de Regnier R-A, Bos AF, et al. Baby Observational Selective Control AppRaisal (BabyOSCAR): Scores at 3 months predict functional ability, spastic cerebral palsy distribution, and diagnosis at 2 years. Dev Med Child Neurol. 2024;66:1521–1528. https://doi.org/10.1111/dmcn.15925