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The complementary roles of the motor optimality score and Hammersmith infant neurological examination

Aysu Kahraman [a,*], Ayşe Numanoğlu Akbaş [b], Özge Çankaya [c]

[a] Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Sıhhıye, Ankara, 06100, Turkey
[b] Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Balıkesir University, Balıkesir, 10145, Turkey
[c] Faculty of Gülhane Physiotherapy and Rehabilitation, Health Sciences University, Ankara, 06100, Turkey

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ABSTRACT

Objective: It is recommended that General Movements Assessment, Hammersmith Infant Neurologic Examination (HINE) and magnetic resonance imaging be used together for the early identification of infants at risk for neurodevelopmental problems. This study aimed to investigate the agreement and relationship between the Motor Optimality Score-Revised (MOS-R) and HINE.

Methods: MOS-R and HINE were performed on the same day in 79 infants with corrected ages between 9 and 17 weeks. The agreement between the two scales was analyzed by intraclass correlation coefficient (ICC) test and the correlation was analyzed by Spearman correlation coefficient.

Results: The median (interquartile range 25–75) gestational age and birth weight of the infants were 36 (30–39) weeks and 2340 (1400–3095) grams respectively. There was moderate agreement (ICC = 0.627) and high correlation ($p < 0.001$, $r = 0.744$) between MOS-R and HINE global scores.

Conclusion: Despite the results, the two assessment tools assess both overlapping and distinct components of infants' development and should be considered complementary. Using them together will provide a more comprehensive insight into infants' body functions and neurodevelopmental risk.

1. Introduction

The first years of life are a unique period for neuroplasticity [1]. Detection of infants at risk for neurodevelopmental disorders as early as possible is very important to benefit from this unique period of neuroplasticity through early intervention [2]. Numerous assessment tools have been developed for this purpose, including the Prechtl Qualitative General Movements Assessment (GMA) and the Hammersmith Infant Neurological Examination (HINE). It is recommended that GMA (98 % sensitivity), HINE (90 % sensitivity) and magnetic resonance imaging (86 %–89 % sensitivity) be used together for the early identification of infants at risk for neurodevelopmental problems [3–6].

A predictive, discriminative and observational tool, the Motor Optimality Score-Revised (MOS-R) is a detailed version of the GMA [7]. While the GMA focuses solely on fidgety movements (FM), the MOS-R evaluates in detail the FM, concurrent other motor repertoire (swipes, kicking, hand-to-hand contact, foot-to-foot contact, rolling to side, etc.) and posture of an infant (body symmetry, head centered etc.) between 9 and 20 weeks post-term age [7]. FM are continuous, small-amplitude, moderate-speed movements of shoulders, wrists, hips, and ankles in all directions and of variable accelerations in typically developing infants at 3–5 months post-term age [7]. These movements serve as a significant marker for predicting neuromotor development during the early months of life [8,9]. The evaluation of FM, concurrent motor repertoire and posture together, which documents small changes, provides a more accurate prediction of later neurological impairments [7]. Research has shown that the motor repertoires of infants with problems such as cerebral palsy (CP), Down syndrome, torticollis, spinal muscular atrophy, or autism differ from those of typically developing infants, highlighting the prognostic value of the MOS-R in identifying atypical development [7,10–13].

HINE is a fast to administer, easy to perform, norm-referenced neuromotor assessment tool that helps in the early identification of preterm and term infants at risk for neurologic problems between 2 and 24 months of age [4,14]. This tool is accessible to all clinicians and is appropriate for the follow-up of infants through sequential examinations. A global HINE score of less than 56 at three months of age has demonstrated high sensitivity and specificity (90 %) in predicting the

* Corresponding author.
E-mail addresses: aysum@hotmail.com (A. Kahraman), aysenumanoglu@gmail.com (A. Numanoğlu Akbaş), ozgemuezzinoglu@gmail.com (Ö. Çankaya).

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subsequent development of CP [15].

There are differences between the two assessment tools in terms of methodology and purpose of use. The MOS-R is primarily utilized for its predictive value as a motor marker for various types of CP [7]. The HINE is a neurological examination developed to systematically characterize the infant nervous system [14]. While the MOS-R places primary emphasis on the observation of movements, in the HINE, movements play a much smaller role in the overall assessment. On the other hand, direct cranial nerve testing, reflexes and reactions are included in the HINE but are given very little attention in the MOS-R. Furthermore, in MOS-R, the infant is not stimulated, repositioned, or touched in any way, whereas in HINE, the infant's responses to various systematic manipulations are observed [7,14].

Determining the relationship between MOS-R and HINE may provide insights into their potential interchangeability. Utilizing either of the two assessment tools offers advantages in terms of efficiency and effort, as well as the flexibility to select a tool based on the specific circumstances of the infant and the examiner. For this reason, the aim of this study was to investigate the agreement and relationship between the MOS-R and the HINE, which are used to predict the infants at risk for neurodevelopmental problems.

2. Methods

This retrospective cross-sectional study was approved by Balıkesir University Health Sciences Non-Interventional Research Ethics Committee with decision number 2023/99. Informed consent was obtained from the parents of each participant.

2.1. Participants

The inclusion criteria were as follows; infants admitted to Sivas Cumhuriyet University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Pediatric Rehabilitation Unit for neurodevelopmental follow-up and early intervention from January 2021 to August 2022; with a suitable video recording for the MOS-R performed at corrected ages of 9 to 17 weeks; and for whom the HINE was also performed on the same day. Infants with video recordings shorter than 3 min or of insufficient quality for reliable MOS-R assessment, or those for whom the HINE could not be fully performed on the same day as the MOS-R, were excluded from the study. Clinical and demographic characteristics of infants were obtained from infant files and are presented in Table 1.

Since the study had a retrospective design, a power analysis was not performed at the beginning. Post hoc power was calculated with the G*Power Version 3.1.9.7 analyzes program. According to the post hoc power analysis, the ρ value obtained from our study was 0.770, the sample size was 79, and the probability of error was set as 0.05. Under these conditions the power (1- β) of the study was found to be 0.999.

2.2. Assessment tools

2.2.1. Motor Optimality Score-Revised (MOS-R)

According to the MOS-R, the infant's FM (normal 12 points, abnormal 4 points, absent 1 point), age-adequate movement repertoire (maximum 4, minimum 1 point), observed movement patterns (maximum 4 points, minimum 1 point), observed postural patterns (maximum 4 points, minimum 1 point) and movement character (maximum 4 points, minimum 1 point) are evaluated. The scores of the infant in these five subcategories are summed to calculate the MOS-R, which can be a maximum of 28 and a minimum of 5 points [7]. The score of MOS-R between 25 and 28 was determined as optimal, 20–24 as mildly reduced, 9–19 as moderately reduced, and 5–8 as severely reduced [7,9]. Absence of FM, MOS-*R* $\leq$ 14 and/or cramped-synchronised movement character indicate that the infant should certainly receive early intervention with high suspicion of CP [7].

Table 1
Characteristics of the infants (n = 79).

	Infants (n = 11) ≤ 28 weeks	Infants (n = 31) 29–36 weeks	Infants (n = 37) ≥ 37 weeks
Gender, n (%)	7 (9.4) F 4 (5.4) M	9 (11.4) F 22 (27.8) M	18 (22.8) F 19 (24) M
Gestational age (week) median (interquartile range 25–75)	26 (25–28)	33 (30–34)	39 (38–40)
Birth weight (gram) median (interquartile range 25–75)	850 (660–1150)	1690 (1400–2150)	3150 (2935–3535)
Postterm age of infants at study (week) median (interquartile range 25–75)	12 (11−13)	12 (10−13)	12 (10–13)
Twin, n (%)	0 (0)	10 (12.7)	2 (2.5)
Respiratory distress syndrome, n (%)	8 (10.1)	9 (11.4)	0 (0)
Sepsis, n (%)	3 (3.8)	1 (1.3)	4 (5)
Hypoxic ischemic encephalopathy, n (%)	0 (0)	0 (0)	8 (10.1)
Preeclampsia, n (%)	3 (3.8)	2 (2.5)	0 (0)
Intraventricular hemorrhage, n (%)	7 (8.9)	5 (6.3)	1 (1.3)
Congenital muscular dystrophy, n (%)			1(1.3)
Down syndrome, n (%)		1(1.3)	1 (1.3)
Metabolic disease, n (%)			2 (2.5)
Obstetric brachial plexus injury, n (%)			3 (3.8)
Torticollis, n (%)			3 (3.8)

In this study, MOS-R was evaluated from a 3–5 min long video of each infant taken while lying supine and without any stimulation during an active, awake period between 9 and 17 weeks of corrected age [7]. The assessments were performed by a pediatric physiotherapist with advanced GMA course certification (first author). Twenty randomly selected videos were rescored by the same examiner two months later to assess intra-rater reliability for the MOS-R. In this study, intra-rater reliability was excellent for MOS-R ($p < 0.001$, single measures intra-class correlation coefficient (ICC) 0.998 (0.996–0.999)).

2.2.2. Hammersmith Infant Neurological Examination (HINE)

The HINE consists of three subcategories: neurological assessment, motor milestones and behavior. Only the neurological assessment was used in this study. The neurological assessment, which is a scorable subcategory, consists of 26 items including cranial nerve functions (maximum score: 15), posture (maximum score: 18), movement (maximum score: 6), tonus (maximum score: 24) and reflexes (maximum score: 15) [14]. Each item is scored between 0 and 3 and the scores are summed to obtain a global score which can range between 0 and 78. For a corrected 3- and 6-month-old infant, a global score of greater than 67 and 70, respectively, is considered optimal, while a global score of 56 and below is considered suboptimal [4,15]. At 3–6 months, infants with Gross Motor Function Classification System (GMFCS) I-II diplegia and hemiplegia usually score between 40 and 60, whereas infants with quadriplegia, GMFCS IV and V, and GMFCS III diplegia score below 40 [14].

In this study, HINE was performed by a pediatric physiotherapist (second author) with a minimum of 10 years of experience in the field, on the same day that the infant videos were recorded. A HINE global score of ≥67 was considered optimal, while a score of ≤57 was classified as suboptimal.

2.3. Statistical analysis

All statistical analyses were performed using “IBM® SPSS © 25 software”. The normality of continuous variables was examined using visual and analytical methods. Descriptive statistics were expressed as

median, minimum and maximum for non-normally distributed numerical variables, and as number and percentage for categorical variables. The Mann-Whitney *U* test was used to compare non-normally distributed numerical data groups. The agreement between the two assessment tools was evaluated using ICC. The single measures ICC with 95 % confidence intervals was used to interpret the data. The ICC values were interpreted as follows: values below 0.50 were considered poor, between 0.50 and 0.75 as moderate, between 0.75 and 0.90 as good, and above 0.90 as excellent [16]. The relationship between MOS-R and HINE global score was analyzed using Spearman correlation coefficient. Correlation coefficient between 0.30 and 0.50 was determined as low level relationship, 0.50–0.70 as moderate level relationship, 0.70–0.90 as high level relationship, and 0.90–1.00 as very high level relationship [17]. The statistical significance level was set at $p < 0.05$.

3. Results

A total of 79 infants, including 34 (43 %) girls and 45 (57 %) boys, were included in the study. Among them, 1 (1.3 %) had congenital muscular dystrophy, 2 (2.6 %) had Down syndrome, 3 (3.8 %) had torticollis, 3 (3.8 %) had obstetric brachial plexus injury, and 2 (2.5 %) had a metabolic disorder. The clinical and demographic characteristics of the infants are presented in Table 1.

FM was present in 55 (69.6 %) infants, abnormal in 3 (3.8 %) infants and absent in 21 (26.6 %) infants. There were 16 (20.3 %) infants with optimal MOS-R scores (Table 2). The MOS-R had a median of 23 (IQR: 13–24).

According to HINE, 30 (37.9 %) infants had an optimal global score (67 or more) (Table 2). The median HINE global score of infants was 64 (IQR:52–71).

Among the 20 (25.3 %) infants identified as high risk for CP according to MOS-R (≤ 13), 6 (7.6 %) exhibited HINE global scores within the normal range (51–69). Additionally, of the 25 (31.6 %) infants identified as high risk for CP according to HINE global score (≤ 56), 7 (8.9 %) demonstrated mildly reduced MOS-R (20–24).

All HINE subcategory scores were higher when FM was present than when it was absent, and in optimal MOS-R compared to suboptimal MOS-R (Table 3).

Moderate agreement was found between MOS-R and HINE global score ($p < 0.001$, single measures ICC = 0.627 (0.473–0.745)). In addition to the high-level positive correlation ($p < 0.001$, $r = 0.744$) between the two assessment tools, significant positive correlations were also observed between their subcategories — except for the correlations between movement character and posture, as well as movement character and tone (Table 4).

4. Discussion

This study investigated the agreement and relationship between MOS-R and HINE, which are used to predict the infants at risk for neurodevelopmental problems. The present study results indicate that the two assessment tools exhibit moderate agreement and a high correlation.

In a study conducted by Harpster et al., the associations between early structural MRI, the HINE, and the GMA were examined in infants born very preterm [18]. The authors reported that there was a low correlation between HINE and GMA and these two tests cannot be used interchangeably because they evaluate different structures. Similarly, the systematic review by Novak et al. emphasized that GMA and HINE assess different aspects of early neurological function and should be interpreted together rather than separately when predicting cerebral palsy, given their differing sensitivity and specificity profiles [19]. Unlike the previous study, the present study used MOS-R, which is a detailed version of GMA. HINE and MOS-R do not evaluate the same parameters, although there is some overlap (such as posture and character of movement) [7,14]. The MOS-R is predominantly affected by FM (12 of the maximum score of 28). The HINE global score is predominantly influenced by muscle tone. Therefore, using both assessment tools together can provide a more comprehensive understanding of an infant's various body functions and structures. Nonetheless, the moderate agreement and high correlation between MOS-R and HINE, along with the high HINE scores observed when FM is normal or MOS-R is optimal, suggest that they may yield similar results in predicting neurodevelopmental problems.

In our study, seven infants with a high risk of CP according to HINE had mildly reduced MOS-R. This finding suggests a potential contradiction between the two assessment tools. Previous studies have indicated that premature infants exhibit lower HINE scores compared to term infants [20–22]. The majority of participants in our study were preterm infants. These infants likely exhibited low HINE scores, resulting in their classification as high risk for CP. Therefore, the findings of our study, which explored the relationship between MOS-R and HINE scores, may not be applicable to infants across all gestational ages.

A systematic review found that FM evaluated by Prechtl's GMA may play an important role in predicting CP, but caution should be taken against false positive and false negative results, and it is more appropriate to use it together with other clinical evaluation methods rather than alone [5]. During the 6–9 week period, FM may be sporadic and age-appropriate for this specific timeframe. This is relevant to our study because we included postterm 9-week-old infants, who are at the lower limit of the MOS-R age range. At this age, FM may not yet have emerged sufficiently, and due to these age-specific limitations, MOS-R scores may underestimate the infant's true abilities. Therefore, a second video and a follow-up MOS-R assessment in the following weeks may be needed to minimize the risk of false outcomes. When only a single MOS-R evaluation is possible, supplementing it with HINE can help reduce error and provide a more reliable evaluation.

Apaydın et al. reported that the predictive power of magnetic resonance imaging, HINE and GMA are the gold standard for the detection of CP and neurodevelopmental delays in infants with hypoxic-ischemic encephalopathy treated with hypothermia [23]. It was also found that the sensitivity and specificity for the two scales were approximately similar (83.3 %, 87.8 % for HINE and 83.3 %, 100 % for GMA, respectively) in determining the diagnosis of CP at two years of age. The similarity in sensitivity and specificity may indicate that MOS-R has a stronger predictive value because it assesses certain factors that are also included in HINE and fully incorporates the GMA. Although our study identifies a high level of correlation between HINE and MOS-R, long-term follow-up of infants were not available. Therefore, studies comparing the predictive value of MOS-R and HINE are still needed to make definitive recommendations.

These two assessment tools each have distinct advantages and disadvantages. In addition to contributing to the early prediction of CP, both the MOS-R and HINE are effective tools for assessing infants with conditions such as genetic problems, musculoskeletal deformities or cardiac defects [10–13,24]. Therefore, in busy clinical settings, their applicability increases the demand for trained and experienced

Table 2
Distribution of MOS-R and HINE scores.

	Infants (n = 79), n (%)	HINE ≥57 score, n (%)	HINE ≥67 score, n (%)
Optimal MOS-R (25–28 score)	16 (20.2)	16 (20.2)	13 (16.5)
Mildly reduced MOS-R (20–24 score)	39 (49.4)	32 (40.5)	16 (20.2)
Moderately reduced MOS-R (9–19 score)	16 (20.2)	6 (7.6)	1 (1.3)
Severely reduced MOS-R (5–8 score)	8 (10.1)	0 (0)	0 (0)

HINE: Hammersmith Infant Neurologic Examination, MOS-R: Motor Optimality Score-Revised.

Table 3
Distribution of HINE Subcategories Scores According to MOS-R Range and FM.

		Normal and abnormal FM	FM absent	Optimal MOS-R (25–28 score)	Suboptimal MOS-R (≤24 score)
Cranial nerve functions	Median (IQR)	13 (11–15)	11 (7.5–13)	15 (13–15)	13 (11–14)
	p value	0.002*		0.001*	
Posture	Median (IQR)	12 (10–14)	6 (4–9)	13 (11–15)	10 (6.5–12)
	p value	<0.001*		<0.001*	
Movement	Median (IQR)	4 (3–5)	1.5 (1–3.5)	5 (5–6)	4 (2–4)
	p value	<0.001*		<0.001*	
Tonus	Median (IQR)	20 (18–21)	9.5 (8.5–14.5)	20 (19–22)	18 (12.5–20)
	p value	<0.001*		0.006*	
Reflexes	Median (IQR)	8 (7–9)	4 (2.5–6)	9 (8–9)	7 (5–8)
	p value	<0.001*		0.001*	
HINE global score	Median (IQR)	66.5 (59–71)	42 (35–52)	72 (68.5–73.5)	60 (47–67)
	p value	<0.001*		<0.001*	

FM: Fidgety Movements, HINE: Hammersmith Infant Neurologic Examination, IQR: interquartile range (25th–75th percentiles), MOS-R: Motor Optimality Score-Revised.
* $p < 0.05$.

Table 4
The relationship between HINE, MOS-R, and their subcategories.

	MOS-R	Fidgety Movement	Age-adequate movement repertoire	Observed movement patterns	Observed postural patterns	Movement character
HINE global score	p < 0.001* r = 0.744	p < 0.001* r = 0.630	*p* < 0.001* *r* = 0.458	p < 0.001* *r* = 0.450	p < 0.001* *r* = 0.617	*p* = 0.0154* *r* = 0.272
HINE-Cranial nerve functions	p < 0.001* *r* = 0.491	p = 0.003* r = 0.341	*p* = 0.003* *r* = 0.341	*p* = 0.008* *r* = 0.303	p < 0.001* *r* = 0.425	*p* = 0.022* *r* = 0.264
HINE-Posture	p < 0.001* *r* = 0.719	p < 0.001* *r* = 0.602	p < 0.001* *r* = 0.460	p < 0.001* *r* = 0.461	p < 0.001* *r* = 0.626	*p* = 0.119 *r* = 0.150
HINE-Movement	p < 0.001* *r* = 0.751	p < 0.001* *r* = 0.627	p < 0.001* *r* = 0.531	p < 0.001* *r* = 0.415	p < 0.001* *r* = 0.499	*p* = 0.001* *r* = 0.387
HINE-Tonus	p < 0.001* *r* = 0.623	p < 0.001* *r* = 0.699	*p* = 0.004* *r* = 0.329	p < 0.001* *r* = 0.487	p < 0.001* *r* = 0.506	*p* = 0.214 *r* = 0.145
HINE-Reflexes	p < 0.001* *r* = 0.710	p < 0.001* *r* = 0.698	p < 0.001* *r* = 0.402	p < 0.001* *r* = 0.420	p < 0.001* *r* = 0.554	*p* = 0.013* *r* = 0.287

HINE: Hammersmith Infant Neurologic Examination, MOS-R: Motor Optimality Score-Revised.
* $p < 0.05$.

healthcare professionals to administer them effectively. Compared to the HINE, the MOS-R requires significantly less time to complete, offering benefits in terms of time efficiency and workforce management [4,7]. Additionally, the MOS-R can be administered using home video recordings, providing a practical alternative for infants who face barriers such as medical fragility or transportation difficulties that may prevent them from attending their three-month follow-up visits [25]. In contrast, the HINE evaluates an infant's responses to movements elicited under various conditions, which may make it less suitable for medically fragile infants [4]. Moreover, since it includes components such as reflexes and postural reactions, it cannot be fully administered via remote assessment [26]. While the MOS-R offers greater flexibility, it is only valid for infants under five months of age, making the HINE more advantageous for assessing older infants [4,7]. However, the MOS-R presents certain challenges, such as the need for multiple scorers in complex or ambiguous cases and the requirement to recalibrate gestalt-based scoring [7].

This study has several limitations. First, due to its retrospective design, we were unable to perform a follow-up video to determine whether FM appeared in the following weeks in infants who showed absent FM at 9 weeks of age. Second, both MOS-R and HINE assessments were conducted by a single evaluator. Although intra-rater reliability was examined for MOS-R, these results may not be generalizable to other evaluators. Moreover, the retrospective design made it impossible to assess inter-rater reliability for HINE. Third, the lack of long-term developmental outcomes for the infants limits the generalizability of the findings. Therefore, studies with larger sample sizes and long-term follow-up data are needed.

5. Conclusions

Moderate agreement and a strong correlation were found between the results of the two assessment tools in identifying the need for early intervention in infants at risk for neurodevelopmental problems. Despite these results, the tools assess both overlapping and distinct components of infants' development and should be considered complementary. Using them together will provide a more comprehensive insight into infants' body functions and neurodevelopmental risk. If it is not feasible to use both tools together is not possible, the choice between them should consider their different purposes, methods, and the particular situation of both the infant and the examiner.

Ethic statement

This retrospective cross section study was approved by Balıkesir University Health Sciences Non-Interventional Research Ethics Committee with decision number 2023/99. Informed consent was obtained from the parents of each participant.

CRediT authorship contribution statement

Aysu Kahraman: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Ayşe Numanoğlu Akbaş:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Özge Çankaya:** Writing – review & editing, Methodology, Investigation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data are available from the corresponding author upon reasonable request.

References

[1] M.V. Johnston, Plasticity in the developing brain: implications for rehabilitation, Dev. Disabil. Res. Rev. 15 (2) (2009) 94–101, https://doi.org/10.1002/ddrr.64.
[2] C. Morgan, L. Fetters, L. Adde, N. Badawi, A. Bancale, R.N. Boyd, et al., Early intervention for children aged 0 to 2 years with or at high risk of cerebral palsy: international clinical practice guideline based on systematic reviews, JAMA Pediatr. 175 (2021) 846–858, https://doi.org/10.1001/jamapediatrics.2021.0878.
[3] M. Bosanquet, L. Copeland, R. Ware, R. Boyd, A systematic review of tests to predict cerebral palsy in young children, Dev. Med. Child Neurol. 55 (2013) 418–426, https://doi.org/10.1111/dmcn.12140.
[4] D.M. Romeo, D. Ricci, C. Brogna, E. Mercuri, Use of the Hammersmith infant neurological examination in infants with cerebral palsy: a critical review of the literature, Dev. Med. Child Neurol. 58 (2016) 240–245, https://doi.org/10.1111/dmcn.12876.
[5] A.K.L. Kwong, T.L. Fitzgerald, L.W. Doyle, J.L.Y. Cheong, A.J. Spittle, Predictive validity of spontaneous early infant movement for later cerebral palsy: a systematic review, Dev. Med. Child Neurol. 60 (2018) 480–489, https://doi.org/10.1111/dmcn.13697.
[6] C. Morgan, D.M. Romeo, O. Chorna, I. Novak, C. Galea, S. Del Secco, et al., The pooled diagnostic accuracy of neuroimaging, general movements, and neurological examination for diagnosing cerebral palsy early in high-risk infants: a case control study, J. Clin. Med. 8 (2019) 1879, https://doi.org/10.3390/jcm811187.
[7] C. Einspieler, A.F. Bos, M. Krieber-Tomantschger, E. Alvarado, V.M. Barbosa, N. Bertoncelli, et al., Cerebral palsy: early markers of clinical phenotype and functional outcome, J. Clin. Med. 8 (2019) 1616, https://doi.org/10.3390/jcm8101616.
[8] C. Einspieler, H.F. Prechtl, Prechtl's assessment of general movements: a diagnostic tool for the functional assessment of the young nervous system, Ment. Retard. Dev. Disabil. Res. Rev. 11 (2005) 61–67, https://doi.org/10.1002/mrdd.20051.
[9] C. Einspieler, R. Peharz, P.B. Marschik, Fidgety movements - tiny in appearance, but huge in impact, J. Pediatr. 92 (2016) S64–S70, https://doi.org/10.1016/j.jped.2015.12.00.
[10] H. Phagava, F. Muratori, C. Einspieler, S. Maestro, F. Apicella, A. Guzzetta, et al., General movements in infants with autism spectrum disorders, Georgian Med. News 156 (2008) 100–105.
[11] D. Herrero, C. Einspieler, C.Y. Panvequio Aizawa, A. Mutlu, H. Yang, A. Nogolová, et al., The motor repertoire in 3- to 5-month old infants with down syndrome, Res. Dev. Disabil. 67 (2017) 1–8, https://doi.org/10.1016/j.ridd.2017.05.006.
[12] A. Kahraman, S. Büğüşan Oruç, D. Erdoğan, A. Mutlu, Analysis of spontaneous movements in infants with torticollis, Pediatr. Phys. Ther. 34 (2022) 17–21, https://doi.org/10.1097/PEP.0000000000000845.
[13] A. Kahraman, A. Mutlu, A. Livanelioğlu, General movements in spinal muscular atrophy type 1, Physiother. Theory Pract. 40 (2024) 1249–1255, https://doi.org/10.1080/09593985.2023.2164842.
[14] D.M. Romeo, M. Cioni, M. Scoto, L. Mazzone, F. Palermo, M.G. Romeo, Neuromotor development in infants with cerebral palsy investigated by the Hammersmith infant neurological examination during the first year of age, Eur. J. Paediatr. Neurol. 12 (2008) 24–31, https://doi.org/10.1016/j.ejpn.2007.05.006.
[15] D.M. Romeo, M. Cioni, F. Palermo, S. Cilauro, M.G. Romeo, Neurological assessment in infants discharged from a neonatal intensive care unit, Eur. J. Paediatr. Neurol. 17 (2013) 192–198, https://doi.org/10.1016/j.ejpn.2012.09.006.
[16] T.K. Koo, M.Y. Li, A guideline of selecting and reporting intraclass correlation coefficients for reliability research, J. Chiropr. Med. 15 (2016) 155–163, https://doi.org/10.1016/j.jcm.2016.02.012.
[17] M.M. Mukaka, Statistics corner: a guide to appropriate use of correlation coefficient in medical research, Malawi, Med. J. 24 (2012) 69–71.
[18] K. Harpster, S. Merhar, V.S. Priyanka Illapani, C. Peyton, B. Kline-Fath, N. A. Parikh, Associations between early structural magnetic resonance imaging, Hammersmith infant neurological examination, and general movements assessment in infants born very preterm, J. Pediatr. 232 (2021) 80–86.e2, https://doi.org/10.1016/j.jpeds.2020.12.056.
[19] I. Novak, C. Morgan, L. Adde, J. Blackman, R.N. Boyd, J. Brunstrom-Hernandez, et al., Early, accurate diagnosis and early intervention in cerebral palsy: advances in diagnosis and treatment, JAMA Pediatr. 171 (2017) 897–907, https://doi.org/10.1001/jamapediatrics.2017.1689.
[20] D.M. Romeo, C. Brogna, F. Sini, M.G. Romeo, F. Cota, D. Ricci, Early psychomotor development of low-risk preterm infants: influence of gestational age and gender, Eur. J. Paediatr. Neurol. 20 (2016) 518–523, https://doi.org/10.1016/j.ejpn.2016.04.011.
[21] E.Y.J. Chin, V.R. Baral, I.L. Ereno, J.C. Allen, K. Low, C.L. Yeo, Evaluation of neurological behaviour in late-preterm newborn infants using the Hammersmith neonatal neurological examination, J. Paediatr. Child Health 55 (2019) 349–357, https://doi.org/10.1111/jpc.14205.
[22] H. Paulsen, U.W. Ljungblad, K. Riiser, K.A.I. Evensen, Early neurological and motor function in infants born moderate to late preterm or small for gestational age at term: a prospective cohort study, BMC Pediatr. 23 (2023) 390, https://doi.org/10.1186/s12887-023-04220-w.
[23] U. Apaydın, E. Erol, A. Yıldız, R. Yıldız, Ş.S. Acar, K. Gücüyener, et al., The use of neuroimaging, Prechtl's general movement assessment and the Hammersmith infant neurological examination in determining the prognosis in 2-year-old infants with hypoxic ischemic encephalopathy who were treated with hypothermia, Early Hum. Dev. 163 (2021) 105487, https://doi.org/10.1016/j.earlhumdev.2021.105487.
[24] M. Jackman, C. Morgan, C. Luke, L. Korostenski, K. Zawada, M. Juarez, et al., The predictive validity of HINE, Bayley, general movements and MOS-R in infancy, Early Hum. Dev. 203 (2025) 106226, https://doi.org/10.1016/j.earlhumdev.2025.106226.
[25] L. Adde, K.B. Åberg, T. Fjørtoft, K.H. Grunewaldt, R. Lade, S. Osland, et al., Implementation of remote general movement assessment using the in-motion instructions in a high-risk Norwegian cohort, BMC Pediatr. 24 (2024) 442, https://doi.org/10.1186/s12887-024-04927-4.
[26] T. Schlichting, K. Martins da Silva, R. Silva Moreira, M.V. Marques de Moraes, N.A. Cicuto Ferreira Rocha, R.N. Boyd, et al., Telehealth program for infants at risk of cerebral palsy during the COVID-19 pandemic: a pre-post feasibility experimental study, Phys. Occup. Ther. Pediatr. 42 (2022) 490–509, https://doi.org/10.1080/01942638.2022.2057209.