

Neurodynamics derived from early clinical electroencephalography predict neurodevelopmental function in infants with cerebral palsy



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Background and Objectives

Infants with cerebral palsy (CP) have impairments in movement, balance, and posture associated with static brain injuries often sustained before or surrounding birth. CP is primarily a clinical diagnosis, but there has been great interest in developing objective biomarkers to predict prognosis and guide early interventions. Neonates with neurological concerns often receive clinical electroencephalography (EEG) as standard-of-care. We assessed if neonatal EEG corresponded with standardized evaluations, Hammersmith Infant Neurological Examination (HINE) and the Bayley Scale of Infant & Toddler Development, 3rd edition (BAYLEY), in the first three years of life in children with CP.

Materials and Methods

Study Design

Retrospective cohort study

Study Participants & Setting

24 children with CP and neonatal EEG at a tertiary care pediatric hospital. EEG recordings were preprocessed and analyzed for absolute band power, phase-lag index connectivity (PLI), and entropy-based dynamic features (spectral entropy, spectral flatness, fractal dimension, median frequency). Uncorrected **Pearson's correlation coefficients** were calculated from EEG features (yearly average and over-time slope) and clinical measure subscales.

Results – Pearson's Correlation Coefficient

Figure 1. Availability and sampling times of clinical EEGs and clinical evaluations by the Hammersmith Infant Neurological Examination (HINE) and the Bayley Scale of Infant & Toddler Development (BAYLEY) from 24 children with cerebral palsy.

Table 1.1. Correlation coefficients of prior to 1 year of age **EEG power spectral band averages** and clinical outcome scores prior to 1 year of age (upper panel), at 1 year of age (lower panel). * denotes p-value<0.05. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

HINE scaled scores prior to 1 year of age (n=8)						
Subscales Band	Asymmetry	Movements	Nerve	Posture	Reflexes	Tone
delta	.66	.15	.59	.57	.31	.47
theta	.20	.25	.71*	.75*	.51	.55
alpha1	.17	.34	.69	.76*	.61	.57
alpha2	.10	.21	.66	.65	.53	.49
beta	.14	.10	.57	.55	.37	.42
gamma	.11	.42	.33	.02	.29	.02

HINE scaled scores at 1 year of age (n=14)				
Subscales Band	Nerve	Posture	Reflexes	Tone
delta	-.59*	.35	-.44	.08
theta	-.62*	.33	-.64*	-.03
alpha1	-.49	.51	-.49	.21
alpha2	-.27	.44	-.46	.22
beta	-.01	.38	-.17	.47
gamma	.11	.05	-.21	.24

Table 1.2. Correlation coefficients of prior to 1 year of age **EEG band power over-time slope** and clinical outcome scores prior to 1 year of age (upper panel), at 1 year of age (lower panel). * denotes p-value<0.05, ** denotes p-value<0.01. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

HINE scale scores prior to 1 year of age (n=5)						
Subscales Band	Asymmetry	Movements	Nerve	Posture	Reflexes	Tone
delta	.92*	.17	.46	.27	.10	.12
theta	.78	.21	.74	.33	.47	.41
alpha1	.78	-.06	.47	-.16	.16	.11
alpha2	.77	.34	.83	.30	.52	.54
beta	.69	.55	.92*	.43	.57	.79
gamma	.66	.57	.95*	.55	.66	.79

HINE scaled scores at 1 year of age (n=10)				
Subscales band	Asymmetry	Cognitive (n=10)	Fine Motor	Gross Motor
delta	-.17	-.12	.75*	.10
theta	-.42	-.22	.89**	.14
alpha1	-.35	-.54	.73*	.04
alpha2	-.19	-.73*	.86**	.17
beta	-.16	-.69*	.31	.52
gamma	-.23	-.62	.04	.56

Results

HINE scaled scores prior to 1 year of age (n=8)						
Subscales Band	Asymmetry	Movements	Nerve	Posture	Reflexes	Tone
delta	.03	-.56	-.95**	-.71*	-.50	-.85**
theta	-.06	-.57	-.95**	-.76*	-.50	-.89**
alpha1	.02	-.60	-.92**	-.64	-.43	-.81*
alpha2	-.17	-.65	-.86**	-.71*	-.45	-.86**
beta	-.41	-.42	-.49	-.68	-.26	-.68
gamma	-.45	.07	.39	-.03	.22	.10

BAYLEY scaled scores 1 year of age (n=14)			
Subscales Band	Asymmetry	Cognitive	Fine Motor
delta	.10	.66**	.49
theta	-.47	.28	.29
alpha1	-.33	.41	.27
alpha2	-.50	.25	.26
beta	-.07	-.54*	.02
gamma	.12	-.38	.02

Table 2.1. Correlation coefficients between prior to 1 year of age EEG connectivity band average and clinical outcome scores prior to 1 year of age (upper panel), at 1 year of age (lower panel). * denotes p-value<0.05, ** denotes p-value<0.01. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

Table 2.2. Correlation coefficients between EEG Band Connectivity Slope and BAYLEY subscale scores at 1 year of age. * denotes p-value<0.05, ** denotes p-value<0.01. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

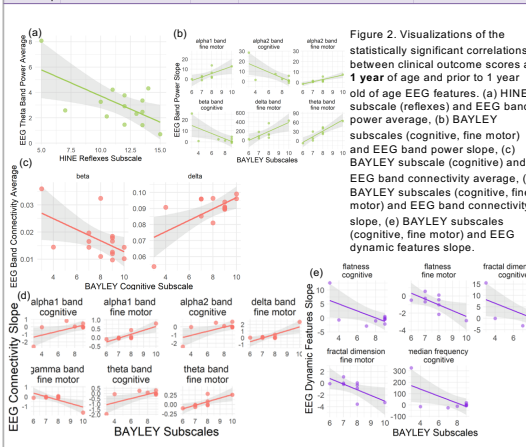
BAYLEY scaled scores 1 year of age (n=9)						
Subscales Band	Cognitive (n=10)	Fine Motor	Language Composite	Language Total	Language Expressive	Language Receptive
delta	.54	.80*	-.21	-.20	-.16	-.23
theta	.70*	.77*	.43	.44	.49	.36
alpha1	.65*	.83**	.08	.09	.13	.04
alpha2	.68*	.65	.33	.34	.37	.28
beta	.28	-.65	.44	.43	.41	.42
gamma	.18	-.75*	.34	.33	.30	.35

Table 3.1. Correlation coefficients of prior to 1 year of age EEG dynamic feature average with HINE subscale scores prior to 1 year of age. * denotes p-value<0.05, ** denotes p-value<0.01. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

HINE scaled scores prior to 1 year of age (n=8)						
Subscales Feature	Movements	Nerve	Posture	Reflexes	Tone	Total
Entropy	-.61	-.80*	-.74*	-.44	-.89**	-.80*
Flatness	-.56	-.87**	-.80*	-.48	-.86**	-.82*
HFD	-.46	-.80*	-.77*	-.45	-.76*	-.75*
MedFreq	-.60	-.84**	-.70	-.42	-.86**	-.78*

Table 3.2. Correlation coefficients of prior to 1 year of age EEG dynamic feature slope with HINE and BAYLEY subscale scores at 1 year of age. * denotes p-value<0.05. Multiple comparisons were not corrected. Some other correlations are worth reporting within the sample.

HINE scaled scores prior to 1 year of age (n=5)				
Subscales Feature	Movements	Nerve	Posture	Tone
Entropy	-.38	.54	-.34	.36
Flatness	-.86	.47	.29	.24
HFD	-.40	-.06	.51	-.08
MedFreq	-.37	.60	-.27	.45



Conclusions and Significance

Early clinical EEGs demonstrate predictive value for neurological and developmental outcomes prior to 1 year and during 1 year of age in infants diagnosed with CP. Quantitative analysis of available clinical EEGs months prior to any structured clinical evaluations may inform prognosis and/or referral early intervention.

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