Contextual risk factors for atypical motor development in infants exposed to poverty: a longitudinal study

Carolina Fioroni Ribeiro da Silva, Ana Luiza Righetto Greco, Afrânio Márcio Corrêa Vieira, Luiza Ribeiro Machado, Giuseppina Sgandurra, Eloisa Tudella

Acta Psychologica 262 (2026) 106054

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Contextual risk factors for atypical motor development in infants exposed to poverty: a longitudinal study

Carolina Fioroni Ribeiro da Silva [a,*], Ana Luiza Righetto Greco [b], Afrânio Márcio Corrêa Vieira [c], Luiza Ribeiro Machado [d], Giuseppina Sgandurra [e,f], Eloisa Tudella [g]

[a] The Institute of Medical Sociology, Department of General Paediatrics, Neonatology and Paediatric Cardiology, Centre for Health and Society, Medical Faculty and University Hospital, Heinrich-Heine-University Düsseldorf, Germany
[b] Department of Physiotherapy, State University Of Goias, Brazil
[c] Department of Statistic, Universidade Federal de São Carlos, São Carlos, São Paulo, Brazil
[d] Institute of Health Sciences, Federal University of Jataí, Goiás, Brazil
[e] Department of Developmental Neuroscience, IRCCS Fondazione Stella Maris, Pisa, Italy
[f] Department of Clinical and Experimental Medicine, University of Pisa, Pisa, Italy
[g] Department of physiotherapy, Universidade Federal de São Carlos, São Carlos, São Paulo, Brazil

ARTICLE INFO

Keywords:
Infant
Motor Skills
Child Development
Socioeconomic Factors
Poverty
Social Determinants of Health
Risk Factors
Longitudinal Studies
Cerebral palsy

ABSTRACT

Background: Children raised in socioeconomically disadvantaged environments experience poorer health outcomes than their more advantaged peers. Evidence examining infancy, a period of intense neuroplasticity, remains limited.

Objective: To identify (i) the specific domains of motor development and the assessment time points during follow-up in which infants exposed to poverty score lower than their non-exposed peers; and (ii) contextual risk factors associated with atypical motor development.

Methods: This prospective, longitudinal study included 50 infants exposed to poverty (Exposed Group, EG) and 38 infants not exposed. Motor development was assessed using the Infant Motor Profile (IMP). Multiple linear and logistic regressions with backward selection were conducted with Generalized Estimating Equations.

Results: At six months, EG infants had significantly lower scores in variation, fluency, and total IMP. At seven months, they showed significantly lower scores in fluency. The main risk factor for atypical motor development was male sex (odds ratio [OR] = 2.57; 95 % confidence interval [95 % CI]: 1.28–5.17) and single-parent status (OR = 1.23; 95 % CI: 1.08–1.75). Protective factors included a higher number of fine motor toys (OR = 0.84; 95 % CI: 0.74–0.97) and age at time of assessment. Older infants demonstrated a higher IMP score (OR = 0.34; 95 % CI: 0.24–0.49) as part of the expected developmental progression.

Conclusions: Six months may represent a sensitive period for motor development among infants exposed to poverty. Cohabiting caregivers and access to fine motor toys appear to be protective factors against atypical variation, indicator associated with central nervous system impairments.

1. Introduction

Infancy is a highly sensitive period for motor development, influenced by both protective and risk-related environmental factors (Black et al., 2017). Contextual risks include poverty, limited maternal education, restricted physical space, and reduced access to toys and stimulation (Da Rocha Neves et al., 2016; Koutra et al., 2012; Pereira et al., 2016). Although the impact of environmental factors is well recognized, longitudinal studies examining these contextual risks remain limited, particularly those focusing on specific domains of motor development. Most existing research has focused on infants exposed to biological risks such as prematurity, low birth weight, or hospitalization (Pridham et al., 2002; Saccani et al., 2013; Wang et al., 2010), or has relied primarily on parent-reported questionnaires (Bishwokarma et al., 2022). Given the

* Corresponding author at: Heinrich Heine University Düsseldorf (HHU), Centre for Health and Society (CHS), Moorenstraße 5 40225 Düsseldorf, Germany.
E-mail addresses: Carolina.Fioroni@uni-duesseldorf.de (C. Fioroni Ribeiro da Silva), analuiza.rig@gmail.com (A.L.R. Greco), afranio@ufscar.br (A.M.C. Vieira), luiza.ribeiromachado@gmail.com (L.R. Machado), g.sgandurra@fsm.unipi.it (G. Sgandurra), etudella@ufscar.br (E. Tudella).

https://doi.org/10.1016/j.actpsy.2025.106054
Received 6 February 2025; Received in revised form 3 November 2025; Accepted 1 December 2025
Available online 3 December 2025

complexity of contextual influences, findings regarding their effects on motor development can vary across studies (Domagalska-Szopa et al., 2022).

Among environmental factors, poverty is a global concern. It is associated with malnutrition, exposure to violence, illicit drug use, and limited parent-infant interaction (Rocha et al., 2020; Walker et al., 2011). Worldwide, an estimated 1.43 billion children live in poverty based on the international poverty line of US$6.85 per person per day. Among them, approximately 829 million children survive on less than US$3.65 per day, and 333 million live in extreme poverty, earning less than US$2.15 per day, according to the latest reports from the World Bank (World Bank, 2020) and the United Nations International Children's Emergency Fund (2025). About 67 % of children in extreme poverty reside in Sub-Saharan Africa, with another 18 % living in South Asia (World Bank, 2020). Brazil ranks among the world's most unequal countries, where the wealthiest 10 % earn 29 times more than the poorest 50 % of the population (Chancel et al., 2022). In Brazil, 44.7 % of children live in poverty (< US$5.50 per day), and 12.7 % of the total population lives in extreme poverty (Salata et al., 2022).

Poverty and inequality are linked to changes in central nervous system (CNS) structures and functions, beginning prenatally and persisting throughout life (Fernald & Gunnar, 2009; Hair et al., 2022). Infants from low socioeconomic backgrounds exhibit global reductions in brain volume and cortical gyrification (Blair & Raver, 2016). Chronic stress and limited stimulation can disrupt the hypothalamic-pituitary-adrenal axis, increasing the risk of physical and mental health disorders (Fernald & Gunnar, 2009). Empirical studies also demonstrate that children living in poverty experience delays in language, social, gross motor, and fine motor skills (Bishwokarma et al., 2022). At six months, infants living in poverty performed fewer functional reach movements than preterm infants in the sample (Araújo Rohr et al., 2021). In contrast, infants from higher socioeconomic backgrounds show more advanced motor, cognitive, and language development, likely due to greater opportunities for interaction and exploration (Tella et al., 2018). Additionally, access to sanitation, clean water, and higher parental education are predictors of developmental outcomes in early childhood (Sania et al., 2019).

A comprehensive approach to assessing motor development requires tools that extend beyond simple milestone checklists. The Infant Motor Profile (IMP) provides detailed information across five domains: variation, adaptability, symmetry, fluency, and performance (Hadders-Algra & Heineman, 2021; Heineman et al., 2008, 2011; Heineman et al., 2010). This tool has primarily been applied to infants exposed to biological risks, such as those at very high risk for cerebral palsy, where developmental trajectories have predicted later outcomes, including cognitive and behavioral disorders (Coxon et al., 2023; Straathof et al., 2022). However, to date, the IMP has not been utilized to investigate the impact of poverty on motor development.

Therefore, the present study had three aims. First, to identify which motor domains (variation, adaptability, fluency, symmetry, and performance) and at which assessment time points infants exposed to poverty score lower compared with their non-exposed peers. Second, to examine the associations between contextual factors and motor development. Third, to identify potential contextual risk and protective factors for atypical motor development.

We hypothesized, first, that infants exposed to poverty would exhibit lower motor development scores, particularly in the domain of variation, across all assessment points. Second, we hypothesized that poverty, as measured by the Poverty Income Ratio (PIR) (Karlamangla et al., 2010), would be negatively associated with motor development domains, reflecting the reduced opportunities for stimulation typically found in lower socioeconomic environments.

2. Material and methods

2.1. Experimental design and ethical aspects

This was an observational, longitudinal, and prospective study, approved by the Human Research Ethics Committee (CAAE: 04097718.9.0000.5504;number 3,203,794) of the Federal University of São Carlos and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all infants' caregivers. The study was designed following the recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (Von Elm et al., 2008).

2.2. Participants

The ideal sample size is five to ten times the number of independent variables (Chen & Kang, 2014). The data were collected between March 2018 and March 2020 in a medium-sized city in São Paulo (state), Brazil. Participants were identified through medical records from the public maternity hospital and basic health centers.

The eligibility criteria included term-born infants (≥ 37 weeks of gestation), of both sexes, aged three to eight months (Organização Mundial da, 2016). They were divided into two groups: Exposed Group (EG), which included infants exposed to poverty and classified as having low socioeconomic status; and Comparison Group (CG), which included infants not exposed to poverty. The socioeconomic status of infants was measured by the PIR, i.e., the ratio between family income and poverty level by geographic area (Karlamangla et al., 2010; Zare et al., 2022). According to Article 18 of Decree No. 9396 of 2018, the poverty level by geographic area was Brazilian Real 178.00 per month per person (Brasil, 2018).

The exclusion criteria included complications during the (a) prenatal period (intrauterine growth restriction); (b) perinatal period (anoxia, hypoxia, Apgar <7, low birth weight); (c) or postnatal period (neuromotor, musculoskeletal, auditory, visual, sensory deficits, genetic syndromes, and congenital heart disease).

2.3. Motor development

The dependent variables in this study were the motor development domains (variation, adaptability, symmetry, fluency, performance, and total IMP score) expressed as percentiles and categorical IMP variables (atypical or typical variation; atypical or typical adaptability; low or adequate fluency score; asymmetry; low or adequate performance score; very low or low or adequate total IMP score) (Hadders-Algra & Heineman, 2021) (Table 1). The IMP is an instrument that assesses both gross and fine motor development, both qualitatively and quantitatively. The IMP consists of 80 items, organized in the following domains: (a) variation (25 items); (b) adaptability (15 items), assessed only from six months old; (c) symmetry (10 items); (d) fluency (seven items); (e) performance (23 items); and finally, (f) total score (covering all IMP domains) (Hadders-Algra & Heineman, 2021; Heineman et al., 2008; Heineman et al., 2010).

Motor development assessments were conducted monthly in the infants' homes to ensure an ecologically valid approach. A qualified and experienced physiotherapist administered the IMP. Assessments were paused if the infant became unsettled or uncooperative. All sessions were video-recorded, coded, and anonymized. Subsequently, three trained raters, who were blinded to the group assignment, independently scored the IMP video assessments. The inter- and intra-rater reliability was calculated using the Intraclass Correlation Coefficient ($ICC_{[3,4]}$) for each IMP domain (significance level of 5 %). The blinded raters presented Cronbach's alpha ≥0.90; ICC ≥ 0.80. Across raters, ICC and Cronbach's alpha were ≥ 0.74, indicating good reliability (Bland & Altman, 1997; Koo & Li, 2016).

Table 1
Categorical outcomes of the Infant Motor Profile (IMP), adapted from the manual of IMP (Hadders-Algra & Heineman, 2021).

Domain	Categorical outcomes	Definition
Variation	Typical (≥15th percentile); Atypical (<15th percentile)	Variation reflects the infant's repertoire of movement patterns. Typical variation indicates a broad and age-appropriate repertoire, while atypical variation denotes a reduced or stereotyped repertoire.
Adaptability	Typical; Atypical	Adaptability reflects the ability to select motor strategies appropriate to the task and environment, assessed from 6 months of age. Typical adaptability indicates that adaptive strategy selection is present, whereas atypical adaptability indicates that the infant fails to select the most efficient strategies.
Fluency	Adequate; Low	Fluency reflects the smoothness and coordination of movements. An adequate fluency score indicates smooth and coordinated movements, whereas a low fluency score indicates fragmented or tremulous movements.
Symmetry	Symmetry; Asymmetry	Symmetry reflects the presence or absence of stereotyped asymmetries. A classification of symmetry indicates age-appropriate motor behavior, whereas asymmetry indicates clear lateral biases in posture or movement.
Performance	Adequate; Low	Performance reflects the achievement of gross and fine motor milestones. An adequate performance score indicates age-appropriate milestone attainment, whereas a low performance score indicates delayed or reduced attainment.
Total IMP score	Adequate (≥15th percentile); Low (5th–15th percentile); Very low (<5th percentile)	The total IMP score provides a summary across all domains. An adequate score reflects typical overall motor development, while low or very low scores indicate an increased risk for neuromotor disorders.

2.4. Covariates

The covariates were measured using the adapted Sociodemographic Questionnaire (Araújo Rohr et al., 2021) and the Brazilian version of the Affordances in the Home Environment for Motor Development-Infant Scale (AHEMD-IS) questionnaire (Caçola et al., 2011; Caçola et al., 2015). Both instruments were administered through interviews with the infants' caregivers, which served as an icebreaker and helped establish closer contact with the families. The AHEMD-IS assesses the home environment (Caçola et al., 2015), including evaluations of physical space, variety of stimuli, and the quantity of gross and fine motor toys available at home. The AHEMD-IS domains were measured via caregiver report. Physical space refers to the adequacy and safety of indoor and outdoor areas available for the infant's motor exploration (e.g., open floor space, room size, and accessibility). Variety of stimuli refers to the diversity of sensory and motor experiences provided in the home, including opportunities for varied positions, exposure to different textures, and interactive play. The quantity of gross and fine motor toys refers to the number of age-appropriate toys that support the development of large-muscle movements (gross motor toys) and fine-motor coordination (fine motor toys) (Caçola et al., 2015). The AHEMD-IS categorizes these domains as less than adequate (LQA), moderately adequate (MA), adequate (A), or excellent (E). In addition, the AHEMD-IS gathers information on the type of residence (e.g., apartment or house), the number of adults, and the number of children living in the home. Maternal and paternal education was analyzed as a continuous variable and coded according to the International Standard Classification of Education. Education levels were then categorized as low (<3), intermediate (3 or 4), or high (5 to 8) (Schneider, 2013).

The adapted Sociodemographic Questionnaire (Araújo Rohr et al., 2021) collects information on the following covariates: sex (female, male); age of the infant (in months); current weight (in grams); maternal age (in years); civil status (cohabitating caregivers, single-parent); the number of the mother's children; and group (EG, CG).

2.5. Statistical analyses

Statistical analyses were performed using RStudio (Team, 2016) and supervised by a senior statistician (A.M.C.V). Descriptive statistics were used to summarize the characteristics of the study population. Continuous variables were reported as means ± standard deviation, categorical variables as counts and percentages (n, %), and discrete quantitative variables (e.g., number of adults, rooms, or children in the residence) as medians (minimum–maximum). Group comparisons were conducted using tests appropriate for the distribution and homogeneity of the data, such as independent samples *t*-tests or Mann–Whitney tests. Multiple comparisons and analysis of the models' covariance structure were carried out using multiple linear and logistic regression analyses. All regression analyses were performed using Generalized Estimating Equations (GEE). The initial set of variables included infant sex, infant age (months), birth weight, maternal age, maternal education, civil status, number of children, type of residence, number of adults and rooms in the household, PIR, and the AHEMD-IS classifications (physical space, variety of stimulation, fine motor toys, and gross motor toys).

Continuous outcomes (e.g., IMP scores) were analyzed using GEE linear models with an identity link, while categorical outcomes (e.g., typical vs. atypical variation) were analyzed using GEE logistic models with a logit link. Variable selection was performed using a backward stepwise method, with a significance level set at $p < 0.05$. (Hardin & Hilbe, 2002; Liang & Zeger, 1986; Ziegler, 2011). The GEE approach uses only cases with complete data (McPherson et al., 2013; Supplementary Material, Table S1). No additional procedures were applied to handle missing data.

To evaluate model fit, we used the Quasi-likelihood under the Independence model Criterion and pseudo-R^2 (Pan, 2001; Rouam et al., 2011).

3. Results

1.1. Participants

In total, 59 infants participated at three months of age (CG = 24; EG = 35); 88 at four months (CG = 38; EG = 50); 68 at five months (CG = 31; EG = 37); 62 at six months (CG = 30; EG = 32); 29 at seven months (CG = 13; EG = 16); and 28 at eight months (CG = 12; EG = 16). The main reasons for dropout varied between groups. In the EG, many families relocated or changed phone numbers without notification; some later reported legal issues, including cases where the father had fled prison. In the CG, data collection began later, and participation was interrupted due to coronavirus disease 2019-related social isolation measures and inadequate video recordings (Supplementary Material, Fig. S1).

Infants in the EG had a significantly lower maternal age (Cohen's r = 0.50); different civil status distribution (Cohen's r = 0.25); lower PIR (Cohen's r = 0.82); lower maternal (Cohen's r = 0.88) and paternal

(Cohen's r = 0.52) education; more children living in the residence (Cohen's r = 0.40); lower birth weight (Cohen's d = 0.41); less variety of stimulation (Cohen's d = 0.51); fewer fine motor toys (Cohen's r = 0.30) and gross motor toys (Cohen's d = 0.94); and a lower total AHEMD-IS score (Cohen's r = 0.49) (Table 2). Regarding home-environment classifications, 38.0 % of infants in the EG were in the LQA category versus 21.1 % of the CG for variety of stimulation; 78.0 % versus 63.2 % for fine motor toys; 88.0 % versus 52.6 % for gross motor toys; and 76.0 % versus 34.2 % for the total score (Table 2).

3.1. Motor development

At six months, infants in the EG had significantly lower scores in variation (Cohen's r = 0.39), fluency (Cohen's r = 0.26), and the total IMP score (Cohen's d = 0.89). At seven months, infants in the EG had significantly lower scores in fluency (Cohen's r = 0.36) (Table 2). By the end of follow-up, infants in the EG did not differ significantly in any other motor development domains (Table 3). The individual trajectories of the motor development domains, represented by graphs, showed greater variability in the EG at six and seven months of age (Supplementary Material, Fig. S2).

3.2. Associations between contextual factors and motor development

The main contextual factors negatively associated with motor development domains in the fully adjusted multiple linear regression model were male sex (β = −3.10; 95 % confidence interval [CI]: −3.37 to −0.77) and the number of adults living in the residence (β = −0.79; 95 % CI: −1.14 to −0.32), both within the performance domain. The main contextual factors associated with higher scores were infant age at assessment (β = 6.81; 95 % CI: 6.28 to 7.34) for performance; living in a house (β = 3.76; 95 % CI: 1.43 to 6.09) for fluency; number of children (β = 1.76; 95 % CI: 0.11 to 3.41) for adaptability; cohabitating caregivers (β = 0.91; 95 % CI: 0.05 to 1.78) for symmetry; maternal education (β = 0.42; 95 % CI: 0.07 to 0.77) for variation; and quantity of gross motor toys (β = 0.41; 95 % CI: 0.04 to 0.79) for fluency (Table 4).

3.3. Risk factors for presenting atypical motor development

The multiple logistic regression results corroborated the multiple linear regression findings. For variation, the contextual risk factor was male sex (odds ratio [OR], 2.57; 95 % CI: 1.28 to 5.17) and single-parent status (OR, 1.23; 95 % CI: 1.08 to 1.75). Protective factors against atypical variation included access to fine motor toys (OR, 0.84; 95 % CI: 0.74 to 0.97) and infant age at assessment (OR, 0.34; 95 % CI: 0.24 to 0.49) (Table 5).

For the performance domain, no contextual risk factors were identified. However, living in a house was a protective factor (OR, 0.15; 95 % CI: 0.04–0.64), corresponding to an approximately 6.66-fold lower risk of low performance (Table 5). Logistic regression was not performed for adaptability, symmetry, and total IMP score because the frequency of atypical or low scores was too small relative to normative data from the Dutch population (Supplementary Material, Table S2).

4. Discussion

4.1. Main findings

The first hypothesis was supported: Infants exposed to poverty showed lower motor development scores at six and seven months of age. At six months, differences were significant in variation, fluency, and the total IMP score. By seven months, only fluency remained significantly lower. These findings highlight six months as a sensitive period for motor development.

Table 2
Characterization of the infants' variables.

Variables	Categories	CG (n = 38)	EG (n = 50)	95 %CI	P value
Maternal age, years [mean ± SD]	–	[31.97 ± 7.47]	[24.35 ± 7.70]	−10.77 to −5.02	**<0.01**
Civil status n (%)	Cohabitating	35 (92.0)	36 (72.0)	−0.36 to −0.03	**0.01**
	Single-parent	3 (7.9)	14 (28.0)		
PIR [mean ± SD]	–	[7.62 ± 10.04]	[1.12 ± 0.67]	−7.99 to −2.95	**<0.01**
Maternal education n (%)	Incomplete primary education	0 (0.0)	13 (26.0)	−3.34 to −2.23	**<0.01**
	Complete primary education	0 (0.0)	7 (14.0)		
	Incomplete high school	0 (0.0)	30 (60.0)		
	Complete high school	26 (68.4)	0 (0.0)		
	Higher education or more	12 (31.6)	0 (0.0)		
Paternal education n (%)	Incomplete primary education	1 (2.6)	11 (22.0)	−2.96 to −1.39	**<0.01**
	Complete primary education	0 (0.0)	6 (12.0)		
	Incomplete high school	9 (23.7)	13 (26.0)		
	Complete high school	18 (47.4)	10 (20.0)		
	Higher education or more	9 (23.6)	0 (0.0)		
	Uninformed	1 (2.6)	10 (20.0)		
Number of adults in residence {median (min–max)}	–	{2.00 (1–3)}	{2.00 (1–6)}	−0.04 to 0.91	0.09
Number of children living in residence {median (min–max)}	–	{1.00 (1–3)}	{3.00 (1–6)}	0.25 to 0.55	**<0.01**
Number of children {median (min–max)}	–	{1.00 (1–3)}	{2.00 (1–6)}	−0.03 to 0.98	0.19
Number of rooms in residence {median (min–max)}	–	{2.00 (1–3)}	{2.00 (1–5)}	−0.38 to 0.18	0.22
Type of residence n (%)	Apartment	7 (18.4)	3 (6.0)	−0.01 to 0.25	0.07
	Home	31 (81.6)	47 (94.0)		
Sex n (%)	Female	18 (47.4)	21 (42.0)	−0.16 to 0.26	0.61
	Male	20 (52.6)	29 (58.0)		
Gestational age, weeks [mean ± SD]	–	[38.97 ± 1.21]	[39.88 ± 1.08]	−0.37 to 0.88	0.15
Birth weight gramms [mean ± SD]	–	[3380.45 ± 300.02]	[3240.88 ± 364.40]	−300.83 to −299.10	**0.04**
Apgar 1′ [mean ± SD]	–	[9.03 ± 0.42]	[8.35 ± 1.16]	−91.54 to −95.12	0.14

(continued on next page)

Table 2 (*continued*)

Variables	Categories	CG (*n* = 38)	EG (*n* = 50)	95 %CI	*P* value
Apgar 5′ [mean ± SD]	–	[9.97 ± 0.18]	[9.71 ± 0.47]	−0.33 to −0.33	0.10
Length at birth, centimeters [mean ± SD]	–	[49.03 ± 1.76]	[48.47 ± 1.66]	−5.58 to −5.76	0.07
HC at birth, centimeters [mean ± SD]	–	[34.59 ± 1.29]	[34.12 ± 1.31]	−0.34 to −0.33	0.64
AHEMD-IS Physical space score [mean ± SD]	–	[2.66 ± 1.52]	[2.43 ± 1.58]	−1.08 to 0.30	0.27
AHEMD-IS Variety of stimulation score [mean ± SD]	–	[11.63 ± 2.06]	[9.82 ± 1.92]	−2.23 to −2.25	**<0.01**
AHEMD-IS Fine motor toys score [mean ± SD]	–	[3.58 ± 2.51]	[1.89 ± 1.41]	−2.05 to −2.09	**<0.01**
AHEMD-IS Gross motor toys score [mean ± SD]	–	[2.51 ± 2.32]	[1.45 ± 1.51]	−2.59 to −0.77	**<0.01**
Total AHEMD-IS score [mean ± SD]	–	[20.39 ± 4.86]	[15.61 ± 3.34]	−6.46 to 6.53	**<0.01**

Notes: Continuous variables are expressed as [mean ± SD], categorical variables as n (%) and discrete variables as {median (min–max)}. Bold values denote statistically significant differences. Abbreviations: SD, standard deviation; CI, confidence interval; CG, comparison group; EG, exposed group to poverty; PIR, poverty income ratio; HC, head circumference; AHEMD-IS, Affordances in the Home Environment for Motor Development – Infant Scale (Caçola et al., 2011; Caçola et al., 2015).

4.2. Comparison with previous studies

Low scores in variation and in the total IMP score may be explained by the home environments of infants exposed to poverty. In this study, infants exposed to poverty showed lower PIR, lower maternal and paternal education levels, less variety of stimulation, and fewer fine and gross motor toys. A study reported similar findings, with fewer toys in families with low socioeconomic conditions, although they did not find significant differences in the variety of stimulation (Freitas et al., 2013). Limited parental education also restricts access to information on how to support motor development effectively (Saleem et al., 2021).

Infants with adequate opportunities in their home environment tend to develop better gross and fine motor skills (Caçola et al., 2011). Variation is key in motor development: initially through general movements that promote exploration and provide sensory input to shape the CNS, and later by supporting adaptable, goal-directed actions through trial and error (Hadders-Algra, 2018a). Although fluency often attracts the attention of professionals and caregivers, it is not strongly associated with developmental disorders (Hadders-Algra, 2004; Hadders-Algra & Heineman, 2021).

4.3. Mechanisms and interpretation

At six months, infants usually achieve approximately half of the ten major motor milestones studied during the first year (Adolph & Franchak, 2017). They gain head and trunk control, prop themselves in prone, and begin rolling, sitting without support, and crawling. This may explain why six months emerged as a gold period in the present study. Although motor development is not linear (Tupsila et al., 2022), individual trajectories, especially among infants exposed to poverty, showed fluctuations that may reflect adverse factors such as caregiver stress, socioeconomic instability, and neighborhood violence (Wado et al., 2022). Parental education also influences caregiving practices, which may limit stimulation opportunities (Fioroni Ribeiro Da Silva et al., 2022; Fioroni Ribeiro Da Silva et al., 2023).

It is also important to note that dropouts at seven and eight months could have influenced the results. Moreover, repeated assessments may have raised families' awareness of motor development, as caregivers often adopted practices they observed during assessments, such as prone play. We recommend that future studies use larger samples and investigate how repeated follow-up assessments influence parental practices over time.

The second hypothesis was partially supported. PIR was not the main contextual factor linked to motor outcomes. Instead, the strongest associations were observed with infant sex and household composition. Male infants had lower scores, consistent with possible biological vulnerability to oxidative stress and brain injury (Netto et al., 2017) and with gendered caregiving practices. Parents may overestimate sons' gross motor abilities and underestimate daughters' abilities (Mondschein et al., 2000), which influence practice opportunities. For instance, parents tend to provide boys with toys for whole-body movement and girls with toys for fine manipulation (Davis & Hines, 2020). These patterns persist through marketing and socialization in later childhood (Davis & Hines, 2020). Female infants in this cohort also showed higher fine motor skills, consistent with findings from other studies at seven months (Dinkel & Snyder, 2020). Other studies, however, did not observe sex differences at 13 months (Saccani et al., 2013) or 18 months (Venturella & Valentini, 2013). Taken together, the evidence suggests an interaction between biology and socially mediated opportunities. Future studies should record the type and frequency of caregiver-initiated motor activities and include measures of parental beliefs so that the independent contribution of social gender bias may be quantified.

A higher number of adults in the household was associated with lower scores, possibly because crowded homes limit safe floor time and opportunities for free exploration. Such conditions can create domestic chaos (Ackerman & Brown, 2010; Dumas et al., 2005), disrupting family routines and exposing children to adversity. Childhood adversity, including maltreatment and household dysfunction, is associated with negative long-term health outcomes (Suglia et al., 2022). In this study, most infants exposed to poverty lived in small homes with one to six adults, and those living in houses rather than apartments had higher motor scores, underscoring the importance of adequate physical space for exploration.

By contrast, a higher number of children in the household was associated with better outcomes, possibly reflecting greater maternal experience or opportunities for interaction. Similar associations have been reported in Brazil (Grunau et al., 2009; Lima et al., 2004; Saccani et al., 2013). However, some studies have found negative associations between older siblings and development (Koutra et al., 2012), suggesting context-dependent effects. Cohabiting caregivers were also associated with better scores compared with single-parent households. Single caregiver status is a known marker of poverty (Vernon-Feagans & Cox, 2013). In addition, it is associated with high levels of stress in the infants (Olsson Mägi et al., 2022). Infant stress impairs their attention, affecting their ability to perform motor and cognitive activities (Brandes-Aitken et al., 2022; Smith et al., 2006). Moreover, we emphasize that infants in the EG group were exposed to additional environmental stressors, as they lived in neighborhoods characterized by high rates of violence and low income (Fundação Maria Cecilia Souto, 2020).

Table 3
Assessments were performed from three to eight months old.

Variables			Infant Motor Profile					
Assessment	Group (n)	Age (months)	Var	Adapt	Flu	Sim	Perf	Total IMP esc
1st	CG (24)	3.06 ± 0.48	86.78 ± 5.60	–	73.35 ± 5.95	98.57 ± 2.90	46.87 ± 3.99	76.35 ± 2.88
(mean ±)	EG (35)	3.02 ± 0.40	84.63 ± 7.38	–	73.14 ± 3.08	98.57 ± 3.45	45.94 ± 4.68	75.60 ± 2.87
	P value	0.14	0.27*	–	0.42	0.48	0.69*	0.66*
	CI 95 %	−0.41 to 0.06	−5.51 to 1.60	–	−2.42 to 2.28	−1.35 to 2.91	−2.91 to 1.97	−2.00 to 1.28
2nd	CG (n = 38)	4.02 ± 0.27	89.35 ± 9.15	–	74.09 ± 5.61	99.00 ± 2.44	52.90 ± 5.41	78.77 ± 3.97
(mean ±)	EG (n = 50)	4.03 ± 0.28	88.66 ± 7.57	–	75.45 ± 5.50	99.00 ± 3.20	52.90 ± 4.16	79.02 ± 3.37
	P value	0.07	0.73*	–	0.84	0.62	0.99*	0.96
	CI 95 %	−0.03 to 0.23	−4.64 to 2.36	–	−1.26 to 3.97	−1.37 to 1.37	−2.23 to −2.33	−1.46 to 1.96
3rd	CG (*n* = 31)	5.09 ± 0.24	93.25 ± 5.73	–	79.41 ± 10.38	98.70 ± 3.05	58.54 ± 6.42	82.48 ± 4.20
(mean ±)	EG (*n* = 37)	5.03 ± 0.25	91.08 ± 5.83	–	79.54 ± 9.35	99.29 ± 2.15	58.64 ± 5.14	82.13 ± 3.47
	P value	0.06	0.09	–	0.57	0.34	0.94*	0.70*
	CI 95 %	−0.02 to 0.21	−4.99 to 0.63	–	−4.66 to 4.90	−0.67 to 1.85	−2.70 to 2.90	−2.20 to 1.50
4th	CG (*n* = 30)	6.15 ± 0.22	95.96 ± 4.27	–	89.60 ± 10.68	100.00	68.06 ± 7.39	88.40 ± 4.14
(mean ±)	EG (*n* = 32)	6.10 ± 0.28	91.68 ± 6.39	–	83.87 ± 10.80	100.00	64.96 ± 5.73	85.06 ± 3.26
	P value	0.47	**0.02**	–	**0.03**	**	0.06*	**<0.01***
	CI 95 %	−0.07 to 0.18	−7.06 to −1.49	–	−11.18 to −0.26	**	−6.44 to −0.25	−5.22 to −1.45
5th (mean ±)	CG (13)	7.02 ± 0.20	93.76 ± 4.32	78.92 ± 7.11	97.46 ± 7.10	99.59 ± 1.10	75.15 ± 7.38	89.00 ± 3.08
	EG (16)	7.03 ± 0.25	92.75 ± 6.75	73.50 ± 8.44	89.62 ± 11.98	99.75 ± 1.00	71.43 ± 8.79	85.37 ± 5.13
	P value	0.30*	0.64*	0.05	**0.04**	0.88	0.23*	0.07
	CI 95 %	−0.08 to 0.27	−5.46 to 3.42	−11.35 to 0.50	−15.22 to −0.44	−0.75 to 0.87	−9.99 to 2.56	−6.80 to −0.44
6th (mean ±)	CG (12)	8.02 ± 0.24	96.75 ± 3.59	82.91 ± 8.54	99.00 ± 3.46	99.66 ± 1.15	84.66 ± 6.48	92.66 ± 3.36
	EG (16)	8.08 ± 0.28	97.50 ± 3.22	82.56 ± 9.06	95.06 ± 9.28	100.00 ± 0.00	80.68 ± 8.10	91.12 ± 3.82
	P value	0.98	0.59	0.91*	0.22	0.24	0.22	0.27*
	CI 95 %	−0.15 to 0.26	−1.90 to 3.40	−7.29 to 6.59	−9.74 to 1.87	−0.25 to 0.92	−9.83 to 1.87	−4.39 to 1.31

Notes: Bold, significant difference between groups; *, T-test independent samples; **, the symmetry variable was constant in both groups; n, absolute frequency; CG, comparison group; EG, exposed group to poverty; CI, 95 % confidence interval; Var, variation; Adapt, adaptability; Flu, fluency; Sim, symmetry; Perf, performance; Total IMP esc, Total Infant Motor Profile score; –, not applicable, the Infant Motor Profile does not allow assessment of adaptability before 6 months of age.

Higher maternal education and the availability of gross motor toys were also associated with better motor scores, as shown in linear regression, consistent with findings from other middle-income settings (Miquelote et al., 2012; Vernon-Feagans & Cox, 2013). These factors likely reflect both greater access to developmental information and more opportunities for practice. Importantly, very low total IMP scores and atypical variation are recognized risk markers: atypical variation is associated with CNS impairments and later cognitive deficits (Hadders-Algra, 2018a; Hair et al., 2022; Heineman et al., 2010), while very low total scores predict risk for cerebral palsy and lower intelligence quotient in later childhood (Hadders-Algra & Heineman, 2021; Wu et al., 2020). These findings underscore the importance of early detection and intervention.

4.4. Strengths and limitations

This study assessed motor development using the IMP, focusing on qualitative domains rather than milestones alone, during a period of rapid change in infancy within in a population exposed to poverty in Brazil. The longitudinal design and the use of GEE enabled the inclusion of repeated assessments while accounting for within-infant correlations. However, notable dropout rates at seven and eight months may have influenced the results for those ages. Additionally, the final sample size did not meet the ideal number planned a priori, five to ten times the number of independent variables (Chen & Kang, 2014). Conducting research in communities facing poverty presents challenges such as residential mobility and unstable contact information, but remains crucial for advancing equity in early child development.

In this context, greater investment is needed in educational programs that promote effective parenting practices, improved housing conditions, reduced household crowding, quality maternal education, and the availability of age-appropriate gross and fine motor toys. These factors contribute to creating an environment that supports healthy child development.

4.5. Clinical implications

- At six months of age, infants exposed to poverty showed lower scores in variation, fluency, and the total IMP score; at seven months, lower scores were observed only in the fluency domain. Six months thus appears to be a gold window in early childhood.
- Male sex and single-parent were identified as risk factors for atypical motor development. In contrast, having access to fine motor toys in the home was a protective factor against atypical variation, which is associated with risk for neuromotor and CNS-related disorders.
- When studying motor development in infants exposed to poverty, it is important to consider not only socioeconomic status but also living conditions, civil status, parental education, and the availability of age-appropriate toys in the home environment.

5. Conclusion

Infants exposed to poverty showed lower IMP scores at six months (variation, fluency, and total) and lower fluency at seven months, indicating six months as a sensitive window for intervention. Across models, male sex and household crowding were associated with poorer motor outcomes, whereas cohabiting caregivers, higher maternal education, and access to age-appropriate toys were protective factors. Additionally, older infants had better scores in comparison with youngers. These findings underscore the importance of early monitoring and pragmatic, family-centered strategies that enhance caregiving practices and motor affordances in low-income settings. Larger longitudinal cohorts are needed to confirm these associations and to evaluate multicomponent interventions aimed at improving early motor development.

CRediT authorship contribution statement

Carolina Fioroni Ribeiro da Silva: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ana Luiza Righetto Greco:** Writing – review & editing, Writing – original draft, Visualization, Validation,

Table 4
Multiple linear regression model adjusted for the variables referring to the Infant Motor Profile domains.

The domain of the IMP	Variable	β	*p*-value	CI 95 %
Variation	PIR	0.01	<0.01	−0.02 to −0.05
	Sex (Male)	−2.07	<0.01	−3.37 to −0.77
	Infant age at time of assessment (months)	2.18	<0.01	1.64 to 2.73
	Maternal education	0.42	0.01	0.07 to 0.77
	QIC = 12,170.13; pseudo-R^2 = 0.26			
Adaptability	Infant age at time of assessment (months)	5.73	<0.01	2.85 to 8.62
	Maternal age (years)	0.30	0.02	−0.11 to −0.72
	Number of children	1.76	0.03	0.11 to 3.41
	QIC = 1927.13; pseudo-R^2 = 0.48			
Symmetry	Infant age at time of assessment (months)	0.30	<0.01	0.14 to 0.45
	Maternal age (years)	−0.04	0.07	−0.08 to −0.01
	Civil status (cohabitating caregivers)	0.91	0.03	0.05 to 1.78
	NA			
Fluency	Sex (Male)	−2.93	<0.01	−4.79 to −1.06
	Infant age at time of assessment (months)	4.37	<0.01	3.53 to 5.21
	Type of residence (house)	3.76	<0.01	1.43 to 6.09
	Number of adults in the residence	−0.73	<0.01	−1.14 to −0.32
	Gross motor toys	0.41	0.02	0.04 to 0.79
	NA			
Performance	Sex (Male)	−3.10	0.01	−5.47 to −0.74
	Infant age at time of assessment (months)	6.81	<0.01	6.28 to 7.34
	Number of adults in the residence	−0.79	<0.01	−1.34 to −0.24
	QIC = 11,199.68; pseudo-R^2 = 0.76			
Total score	Sex (Male)	−2.02	<0.01	−0.03 to −0.88
	Infant age at time of assessment (months)	2.97	<0.01	0.02 to 3.39
	Number of adults in the residence	−0.42	<0.01	−0.07 to −0.13
	QIC = 3026.22; pseudo-R^2 = 0.72			

Notes: The table includes only the IMP domains and variables that remained in the final model after backward stepwise selection ($p < 0.05$). PIR, poverty income ratio; β, standardized regression coefficient; 95 % CI, 95 % confidence interval; QIC, quasi-likelihood under the independence model criterion; NA, not available because the model fit indices (QIC and pseudo-R^2) are reported only for models where estimation was successful. For some domains (e.g., Symmetry), convergence issues or data separation prevented calculation.

Table 5
Adjusted multiple logistic regression to identify risk factors for presenting atypical categories or low scores on the Infant Motor Profile.

Domain	Variable	Category	95 % CI (RRR) 95 % CI	P - value (ANOVA)
Variation	Sex	Female	1.00	<0.01
		Male	1.28 (2.57) 5.17	
	Infant age at time of assessment (months)	–	0.24 (0.34) 0.49	<0.01
	Civil status	Cohabitating	1.00	<0.01
		Single-parent	1.08 (1.23) 1.75	
	Fine motor toys	–	0.74 (0.84) 0.97	0.01
	NA			
Fluency	Infant age at time of assessment (months)	–	0.31 (0.43) 0.60	<0.01
	QIC = 166.35; pseudo-R^2 = 0.13			
Performance*	Type of residence	Apartment	1.00	<0.01
		House	0.04 (0.15) 0.64	
	QIC = 85.98; pseudo-R^2 = 0.07			

Notes: The table includes only the IMP domains and variables that remained in the final model after backward stepwise selection ($p < 0.05$). RRR, Relative Risk Ratio; *, the result corresponds to a binomial generalized linear model with logistic linkage. Independence between performance observations was assumed because the frequency was rare; CI, 95 % confidence interval; QIC, quasi-likelihood under the independence model criterion; NA, not available because the model fit indices (QIC and pseudo-R^2) are reported only for models where estimation was successful.

Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Afrânio Márcio Corrêa Vieira:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Methodology, Formal analysis. **Luiza Ribeiro Machado:** Writing – review & editing, Writing – original draft. **Giuseppina Sgandurra:** Writing – review & editing, Visualization, Supervision. **Eloisa Tudella:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Conceptualization.

Funding

The São Paulo Research Foundation (FAPESP) (process number 2018/24930-0; 2020/11267-1), and the Coordination of Superior Level Staff Improvement (CAPES, finance code 001). This work has been partially supported by Italian Ministry of Health Grant RC2023 to G.S, and Heinrich Heine University.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgements

The authors thank the families for availability and participation in the research, the collaborators Stefani Raquel Sales Fritsch, Joyce Nogueira, Liz Araújo Rohr, and Murilo Mageste de Moraes, the São Paulo Research Foundation (FAPESP) (process number 2018/24930-0; 2020/11267-1), the Coordination of Superior Level Staff Improvement (CAPES, finance code 001), Italian Ministry of Health Grant RC2023, and Heinrich Heine University.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.106054.

Data availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

References

Ackerman, B. P., & Brown, E. D. (2010). Physical and psychosocial turmoil in the home and cognitive development. In *American Psychological Association* (pp. 35–47). https://doi.org/10.1037/12057-003

Adolph, K. E., & Franchak, J. M. (2017). The development of motor behavior. *WIREs Cognitive Science, 8*(1–2), Article e1430. https://doi.org/10.1002/wcs.1430

Araújo Rohr, L., Cabral, T. I., & ц., Moraes, M. M. D., & Tudella, E.. (2021). Reaching skills in six-month-old infants at environmental and biological risk. *PLoS One, 16*(7), Article e0254106. https://doi.org/10.1371/journal.pone.0254106

Bishwokarma, A., Shrestha, D., Bhujel, K., Chand, N., Adhikari, L., Kaphle, M., … Karmacharya, I. (2022). Developmental delay and its associated factors among children under five years in urban slums of Nepal. *PLoS One, 17*(2), Article e0263105. https://doi.org/10.1371/journal.pone.0263105

Black, M. M., Walker, S. P., Fernald, L. C. H., Andersen, C. T., Digirolamo, A. M., Lu, C., … Grantham-Mcgregor, S. (2017). Early childhood development coming of age: science through the life course. *The Lancet, 389*(10064), 77–90. https://doi.org/10.1016/s0140-6736(16)31389-7

Blair, C., & Raver, C. C. (2016). Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics, 16*(3), S30–S36. https://doi.org/10.1016/j.acap.2016.01.010

Bland, J. M., & Altman, D. G. (1997). CronbachБ—≥s alpha. *BMJ, 314*(7080), 572. https://doi.org/10.1136/bmj.314.7080.572

Brandes-Aitken, A., Braren, S., Vogel, S. C., Perry, R. E., Brito, N. H., & Blair, C. (2022). Within-person changes in basal cortisol and caregiving modulate executive attention across infancy. *Development and Psychopathology, 34*(4), 1386–1399. https://doi.org/10.1017/s0954579421000262

Brasil. (2018). Decreto Nб╟ 9.396, de 30 de maio de 2018. https://www.gov.br/cidadania/pt-br/acesso-a-informacao/legislacao/decreto-no-9-396-de-30-de-maio-de-2018-senarc.

Caçola, P., Gabbard, C., Santos, D. C. C., & Batistela, A. C. T. (2011). Development of the affordances in the home environment for motor development-infant scale. *Pediatrics International, 53*(6), 820–825. https://doi.org/10.1111/j.1442-200X.2011.03386.x

Caçola, P. M., Gabbard, C., Montebelo, M. I. L., & Santos, D. C. C. (2015). Further development and validation of the Affordances in the Home Environment for Motor Development-Infant Scale (AHEMD-IS). *Physical Therapy, 95*(6), 901–923. https://doi.org/10.2522/ptj.20140011

Chancel, L., Piketty, T., Saez, E., & Zucman, G. (2022). World inequality report 2022. https://wir2022.wid.world/www-site/uploads/2023/03/D_FINAL_WIL_RIM_RAPPORT_2303.pdf.

Chen, B., & Kang, D. (2014). *Clinical epidemiology* (4th ed.). Shanghai Scientific and Technical Publishers.

Coxon, M. L., Hoyt, C. R., Smith, A. E., & Hadders-Algra, M. (2023). Going beyond conventional assessment of developmental motor disorders: Exploring video methods for early identification among children 0 to 3Б—┴Years. *Advances in Rehabilitation Science and Practice, 12*. https://doi.org/10.1177/27536351231207740

Da Rocha Neves, K., De Souza Morais, R. L., Teixeira, R. A., & Pinto, P. A. F. (2016). Growth and development and their environmental and biological determinants. *Jornal de Pediatria (Versцёo em Portuguц╙s), 92*(3), 241–250. https://doi.org/10.1016/j.jpedp.2015.08.009

Davis, J. T. M., & Hines, M. (2020). How large are gender differences in toy preferences? a systematic review and meta-analysis of toy preference research. *Archives of Sexual Behavior, 49*(2), 373–394. https://doi.org/10.1007/s10508-019-01624-7

Dinkel, D., & Snyder, K. (2020). Exploring gender differences in infant motor development related to parentБ—≥s promotion of play. *Infant Behavior and Development, 59*, Article 101440. https://doi.org/10.1016/j.infbeh.2020.101440

Domagalska-Szopa, M.g., Szopa, A., Serrano-GцЁmez, M.a. E., Hagner-Derengowska, M., & Behrendt, J. (2022). Identification of risk factors in pre-term infants with abnormal general movements. *Frontiers in Neurology, 13*. https://doi.org/10.3389/fneur.2022.850877

Dumas, J. E., Nissley, J., Nordstrom, A., Smith, E. P., Prinz, R. J., & Levine, D. W. (2005). Home chaos: sociodemographic, parenting, interactional, and child correlates. *Journal of Clinical Child & Adolescent Psychology, 34*(1), 93–104. https://doi.org/10.1207/s15374424jccp3401_9

Fernald, L. C. H., & Gunnar, M. R. (2009). Poverty-alleviation program participation and salivary cortisol in very low-income children. *Social Science & Medicine, 68*(12), 2180–2189. https://doi.org/10.1016/j.socscimed.2009.03.032

Fioroni Ribeiro Da Silva, C., Greco, A. L. R., Castilho Cabrera Santos, D., Sgandurra, G., & Tudella, E. (2023). Association between contextual factors and affordances in the home environment of infants exposed to poverty. *Children, 10*(12), 1932. https://doi.org/10.3390/children10121932

Fioroni Ribeiro Da Silva, C., Menici, V., Tudella, E., Beani, E., Barzacchi, V., Battini, R., Orsini, A., Cioni, G., & Sgandurra, G. (2022). Parental practices and environmental differences among infants living in upper-middle and high-income countries: A cross-sectional study. *International Journal of Environmental Research and Public Health, 19*(17), Article 10833. https://doi.org/10.3390/ijerph191710833

Freitas, T. C. B., Gabbard, C., Caçola, P., Montebelo, M. I. L., & Santos, D. C. C. (2013). Family socioeconomic status and the provision of motor affordances in the home. *Brazilian Journal of Physical Therapy, 17*(4), 319–327. https://doi.org/10.1590/s1413-35552013005000096

Fundação Maria Cecilia Souto, V. (2020). Sцёo Carlos Б—⌠ SP. Primeira infц┌ncia primeiro, no municц╜pio. https://primeirainfanciaprimeiro.fmcsv.org.br/municipios/sao-carlos-sp/.

Grunau, R. E., Whitfield, M. F., Petrie-Thomas, J., Synnes, A. R., Cepeda, I. L., Keidar, A., … Johannesen, D. (2009). Neonatal pain, parenting stress and interaction, in relation to cognitive and motor development at 8 and 18 months in preterm infants. *Pain, 143*(1), 138–146. https://doi.org/10.1016/j.pain.2009.02.014

Hadders-Algra, M. (2004). General movements: A window for early identification of children at high risk for developmental disorders. *The Journal of Pediatrics, 145*(2), S12–S18. https://doi.org/10.1016/j.jpeds.2004.05.017

Hadders-Algra, M. (2018a). Early human motor development: From variation to the ability to vary and adapt. *Neuroscience & Biobehavioral Reviews, 90*, 411–427. https://doi.org/10.1016/j.neubiorev.2018.05.009

Hadders-Algra, M., & Heineman, K. R. (2021). *The infant motor profile*. Routledge/Taylor & Francis Group. https://doi.org/10.4324/9780429341915

Hair, N. L., Hanson, J. L., Wolfe, B. L., & Pollak, S. D. (2022). Low household income and neurodevelopment from infancy through adolescence. *PLoS One, 17*(1), Article e0262607. https://doi.org/10.1371/journal.pone.0262607

Hardin, J. W., & Hilbe, J. M. (2002). *Generalized estimating equations*. Chapman and Hall/CRC. https://doi.org/10.1201/9781420035285

Heineman, K. R., Bos, A. F., & Hadders-Algra, M. (2008). The Infant Motor Profile: A standardized and qualitative method to assess motor behaviour in infancy. *Developmental Medicine & Child Neurology, 50*(4), 275–282. https://doi.org/10.1111/j.1469-8749.2008.02035.x

Heineman, K. R., Bos, A. F., & Hadders-Algra, M. (2011). Infant Motor Profile and cerebral palsy: promising associations. *Developmental Medicine & Child Neurology, 53* (s4), 40–45. https://doi.org/10.1111/j.1469-8749.2011.04063.x

Heineman, K. R., La Bastide-Van Gemert, S., Fidler, V., Middelburg, K. J., Bos, A. F., & Hadders-Algra, M. (2010). Construct validity of the Infant Motor Profile: Relation with prenatal, perinatal, and neonatal risk factors. *Developmental Medicine & Child Neurology, 52*(9), e209–e215. https://doi.org/10.1111/j.1469-8749.2010.03667.x

Karlamangla, A. S., Merkin, S. S., Crimmins, E. M., & Seeman, T. E. (2010). Socioeconomic and ethnic disparities in cardiovascular risk in the United States, 2001Б—⌠2006. *Annals of Epidemiology, 20*(8), 617–628. https://doi.org/10.1016/j.annepidem.2010.05.003

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Koutra, K., Chatzi, L., Roumeliotaki, T., Vassilaki, M., Giannakopoulou, E., Batsos, C., Koutis, A., & Kogevinas, M. (2012). Socio-demographic determinants of infant neurodevelopment at 18 months of age: MotherБ—⌠Child Cohort (Rhea Study) in Crete, Greece. *Infant Behavior and Development, 35*(1), 48–59. https://doi.org/10.1016/j.infbeh.2011.09.005

Liang, K.-Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika, 73*(1), 13–22. https://doi.org/10.1093/biomet/73.1.13

Lima, M., Eickmann, S., Lima, A., Guerra, M., Lira, P., Huttly, S., & Ashworth, A. (2004). Determinants of mental and motor development at 12 months in a low income population: A cohort study in northeast Brazil. *Acta Paediatrica, 93*(7), 969–975. https://doi.org/10.1111/j.1651-2227.2004.tb18257.x

McPherson, S., Barbosa-Leiker, C., McDonell, M., Howell, D., & Roll, J. (2013). Longitudinal missing data strategies for substance use clinical trials using generalized estimating equations: an example with a buprenorphine trial. *Human Psychopharmacology: Clinical and Experimental, 28*(5), 506–515. https://doi.org/10.1002/hup.2339

Miquelote, A. F., Santos, D. C. C., Cacola, P. M., Montebelo, M. I. D. L., & Gabbard, C. (2012). Effect of the home environment on motor and cognitive behavior of infants. *Infant Behavior and Development, 35*(3), 329–334. https://doi.org/10.1016/j.infbeh.2012.02.002

Mondschein, E. R., Adolph, K. E., & Tamis-Lemonda, C. S. (2000). Gender bias in mothers' expectations about infant crawling. *Journal of Experimental Child Psychology, 77*(4), 304–316. https://doi.org/10.1006/jecp.2000.2597

Netto, C. A., Sanches, E., Odorcyk, F. K., Duran-Carabali, L. E., & Weis, S. N. (2017). SexБ—dependent consequences of neonatal brain hypoxiaБ—ischemia in the rat. *Journal of Neuroscience Research, 95*(1–2), 409–421. https://doi.org/10.1002/jnr.23828

Olsson Mägi, C.-A., Wik Despriee, S., Småstuen, M. C., Almqvist, C., Bahram, F., Bakkeheim, E., … Söderhäll, C. (2022). Maternal Stress, Early Life Factors and Infant Salivary Cortisol Levels. *Children, 9*(5), 623. https://doi.org/10.3390/children9050623

Organização Mundial Da, S.d. (2016). Nacimientos prematuros. http://www.who.int/mediacentre/factsheets/fs363/es/.

Pan, W. (2001). Akaike's information criterion in generalized estimating equations. *Biometrics, 57*(1), 120–125. https://doi.org/10.1111/j.0006-341x.2001.00120.x

Pereira, K. R. G., Saccani, R., & Valentini, N. C. (2016). Cogniц╖цёo e ambiente sцёo preditores do desenvolvimento motor de bebц╙s ao longo do tempo. *Fisioterapia e Pesquisa, 23*(1), 59–67. https://doi.org/10.1590/1809-2950/14685223012016

Pridham, K. F., Brown, R., Clark, R., Sondel, S., & Green, C. (2002). Infant and caregiving factors affecting weightБ—forБ—age and motor development of fullБ—term and premature infants at 1 year postБ—term. *Research in Nursing & Health, 25*(5), 394–410. https://doi.org/10.1002/nur.10047

Rocha, N. A. C. F., Dos Santos Silva, F. P., Dos Santos, M. M., & Dusing, S. C. (2020). Impact of motherБ—⌠infant interaction on development during the first year of life: a systematic review. *Journal of Child Health Care, 24*(3), 365–385. https://doi.org/10.1177/1367493519864742

Rouam, S., Moreau, T., & Broët, P. (2011). A pseudo-R2measure for selecting genomic markers with crossing hazards functions. *BMC Medical Research Methodology, 11*(1), 28. https://doi.org/10.1186/1471-2288-11-28

Saccani, R., Valentini, N. C., Pereira, K. R., & Mц╪ller, A. B., & Gabbard, C.. (2013). Associations of biological factors and affordances in the home with infant motor development. *Pediatrics International, 55*(2), 197–203. https://doi.org/10.1111/ped.12042

Salata, A., Mattos, E. J., & Bagolin, I. P. (2022). Pobreza infantil no Brasil: 2012-2021. https://www.pucrs.br/datasocial/wp-content/uploads/sites/300/2022/09/PUCRS_Data_Social_Estudo_pobreza_infantil_25_09_22.pdf.

Saleem, J., Zakar, R., Mushtaq, F., Bukhari, G. M. J., & Fischer, F. (2021). Comparative analysis of developmental profile between normal and severe acute malnourished under-five children in Pakistan: a multicentre cross-sectional study. *BMJ Open, 11*(8), Article e048644. https://doi.org/10.1136/bmjopen-2021-048644

Sania, A., Sudfeld, C. R., Danaei, G., Fink, G.n., McCoy, D. C., Zhu, Z., … Fawzi, W. (2019). Early life risk factors of motor, cognitive and language development: a pooled analysis of studies from low/middle-income countries. *BMJ Open, 9*(10), Article e026449. https://doi.org/10.1136/bmjopen-2018-026449

Schneider, S. (2013). The international standard classification of education 2011. In *Class and Stratification Analysis*. Emerald Group Publishing Limited.

Smith, K. E., Landry, S. H., & Swank, P. R. (2006). The role of early maternal responsiveness in supporting school-aged cognitive development for children who vary in birth status. *Pediatrics, 117*(5), 1608–1617. https://doi.org/10.1542/peds.2005-1284

Straathof, E. J. M., Heineman, K. R., La Bastide-Van Gemert, S., Hamer, E. G., & Hadders-Algra, M. (2022). Infant motor behaviour and functional and cognitive outcome at school-age: a follow-up study in very high-risk children. *Early Human Development, 170*, Article 105597. https://doi.org/10.1016/j.earlhumdev.2022.105597

Suglia, S. F., Saelee, R., Guzman, I. A., Elsenburg, L. K., Clark, C. J., Link, B. G., & Koenen, K. C. (2022). Child socioeconomic status, childhood adversity and adult socioeconomic status in a nationally representative sample of young adults. *SSM - Population Health, 18*, Article 101094. https://doi.org/10.1016/j.ssmph.2022.101094

Team, R. C. (2016). A language and environment for statistical computing. In *R foundation for statistical computing*. https://www.R-project.org.

Tella, P., Piccolo, L. D. R., Rangel, M. L., Rohde, L. A., Polanczyk, G. V., Miguel, E. C., … Ferraro, A. A. (2018). Socioeconomic diversities and infant development at 6 to 9 months in a poverty area of Sцёo Paulo, Brazil. *Trends in Psychiatry and Psychotherapy, 40*(3), 232–240. https://doi.org/10.1590/2237-6089-2017-0008

Tupsila, R., Siritaratiwat, W., Bennett, S., Mato, L., & Keeratisiroj, O. (2022). Intra-individual variability in gross motor development in healthy full-term infants aged 0б—13 months and associated factors during child rearing. *Children, 9*(6), 801. https://doi.org/10.3390/children9060801

Venturella, C. B., & Valentini, N. C. (2013). Desenvolvimento motor de crianц╖as entre 0 e 18 meses de idade: Diferenц╖as entre os sexos. *Motricidade, 9*, 3–12. https://doi.org/10.6063/motricidade.9(2).617

Vernon-Feagans, L., & Cox, M. (2013). I. Poverty, rurality, parenting, and risk: An introduction. *Monographs of the Society for Research in Child Development, 78*(5), 1–23. https://doi.org/10.1111/mono.12047

Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., & Vandenbroucke, J. P. (2008). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Journal of Clinical Epidemiology, 61*(4), 344–349. https://doi.org/10.1016/j.jclinepi.2007.11.008

Wado, Y. D., Austrian, K., Abuya, B. A., Kangwana, B., Maddox, N., & Kabiru, C. W. (2022). Exposure to violence, adverse life events and the mental health of adolescent girls in Nairobi slums. *BMC Women's Health, 22*(1). https://doi.org/10.1186/s12905-022-01735-9

Walker, S. P., Wachs, T. D., Grantham-Mcgregor, S., Black, M. M., Nelson, C. A., Huffman, S. L., … Richter, L. (2011). Inequality in early childhood: risk and protective factors for early child development. *The Lancet, 378*(9799), 1325–1338. https://doi.org/10.1016/s0140-6736(11)60555-2

Wang, T.-N., Howe, T.-H., Hinojosa, J., & Hsu, Y.-W. (2010). Postural control of pre-term infants at 6 and 12months corrected age. *Early Human Development, 86*(7), 433–437. https://doi.org/10.1016/j.earlhumdev.2010.05.022

World Bank, G. (2020). Global estimate of children in monetary poverty. https://openknowledge.worldbank.org/entities/publication/621879d1-0419-5bfb-8ea7-e01fc4981818.

Wu, Y. C., Heineman, K. R., La Bastide-Van Gemert, S., Kuiper, D., Drenth Olivares, M., & Hadders-Algra, M. (2020). Motor behaviour in infancy is associated with neurological, cognitive, and behavioural function of children born to parents with reduced fertility. *Developmental Medicine and Child Neurology, 62*(9), 1089–1095. https://doi.org/10.1111/dmcn.14520

Zare, H., Gilmore, D. R., Meyerson, N. S., & Thorpe, R. J. (2022). Income Inequality, Race/Ethnicity, and Obesity in U.S. Men 20 Years and Older: 1999 to 2016. *American. Journal of Men's Health, 16*(5), Article 155798832211238. https://doi.org/10.1177/15579883221123852

Ziegler, A. (2011). *Generalized estimating equations*. Springer. https://doi.org/10.1007/978-1-4614-0499-6