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Cognition and environment are predictors of infants' motor development over time

Cognição e ambiente são preditores do desenvolvimento motor de bebês ao longo do tempo

Cognición y ambiente son predictores del desarrollo motor de bebés a lo largo del tiempo

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ABSTRACT | We conducted a longitudinal investigation on the relationships among motor and cognitive development, biological aspects, maternal practices, parental knowledge, and family environments of infants. Forty-nine infants aged between 3 and 16 months participated in the study. They were evaluated through the Alberta Infant Motor Scale and the Cognitive Scale of the Bayley Scales of Infant Development. Their parents answered a questionnaire about biological factors, the Daily Activities of Infant Scale, affordances for motor development (Baby Scale) in the home environment, and the Brazilian version of the Knowledge of Infant Development Inventory. We conducted evaluations in schools for 4 months. Generalized estimating equations, Bonferroni correction, and Spearman's rank correlation coefficient were used. Significant associations were found in the (1) univariate analysis between motor and cognitive development and environmental factors (education level, income, toy availability, physical space, parental practices and knowledge, breastfeeding duration, and school frequency); (2) multivariate analyses between motor development and income, and between father's age and physical space at home. Motor and cognitive developments were concluded to depend on each other, and environmental factors were shown to be more significant in the associations rather than the biological ones, stressing the importance of home, of parental care, and of the experiences children go through along the first years of their lives.

Keywords | Motor Skills, Cognition, Environment, Child development.

RESUMO | Investigou-se longitudinalmente relações entre desenvolvimento motor e cognitivo, aspectos biológicos, práticas maternas, conhecimento parental e ambiente familiar de bebês. Participaram do estudo 49 bebês (3-16 meses) avaliados com a Alberta Infant Motor Scale e a Escala Mental da Bayley Scale of Infant Development. Os pais responderam o questionário sobre fatores biológicos, Daily Activities of Infant Scale, o Affordances no Ambiente Domiciliar para o Desenvolvimento Motor – Escala Bebê, e o Inventário sobre Conhecimento do Desenvolvimento Infantil. Avaliações foram conduzidas nas escolas ao longo de 4 meses. Foram utilizadas Equações de Estimativa Generalizada, teste de Bonferroni e coeficiente de correlação de Spearman. Observaram-se associações significativas na (1) análise univariada entre desenvolvimento motor e cognitivo e fatores ambientais (escolaridade, renda, disponibilidade de brinquedos, espaço físico, práticas e conhecimento parental, tempo de aleitamento e frequência na escola); (2) multivariada entre o desenvolvimento motor e renda, idade do pai e espaço físico da residência. Concluiu-se que os desenvolvimentos motores e cognitivos se mostraram interdependentes e fatores ambientais se mostraram mais significativos nas associações em detrimento dos biológicos, reforçando-se a importância do lar, do cuidado dos pais e das

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experiências que a criança vivencia ao longo dos primeiros anos de vida.

Descritores | Destreza Motora; Cognição; Ambiente; Desenvolvimento Infantil.

RESUMEN | Se investigó longitudinalmente relaciones entre desarrollo motor y cognitivo, aspectos biológicos, prácticas maternas, conocimiento parental y ambiente familiar de bebés. Participaron del estudio 49 bebés (3-16 meses) evaluados con la Alberta Infant Motor Scale y la Escala Mental da Bayley Scale of Infant Development. Los padres respondieron al cuestionario sobre factores biológicos Daily Activities of Infant Scale, el Affordance en el Ambiente Domiciliario para el Desarrollo Motor – Escala Bebé, y el Inventario sobre Conocimiento del Desarrollo Infantil. Se condujeron evaluaciones en las escuelas a lo largo de 4 meses. Se utilizaron Ecuaciones de Estimativa Generalizada, prueba de Bonferroni y coeficiente de correlación de Spearman. Se observó asociaciones significativas en la (1) análisis univariada entre desarrollo motor y cognitivo y factores ambientales (escolaridad, renta, disponibilidad de juguetes, espacio físico, prácticas y conocimiento parental, tiempo de amamantamiento y frecuencia en la escuela); (2) multivariada entre el desarrollo motor y renta, edad del padre y espacio físico de la residencia. Se concluye que los desarrollos motores y cognitivos se mostraron interdependientes y factores ambientales se mostraron más significativos en las asociaciones debido a los factores biológicos, se reforzando la idea de la importancia del hogar, del cuidado de los padres y de las experiencias que el niño vive a lo largo de sus primeros años de vida.

Palabras clave | Destreza Motora; Cognición; Ambiente; Desarrollo Infantil.

INTRODUCTION

Development challenges in the first years of live foretell future disorders[1]. In this phase, the quick brain development[2] guides behavioral acquisitions[2,3]. Biological factors[1,2,5,6], environments[4-6]; socioeconomic family status[6], parental practices, and home structure conditions[4] may influence development paths[4,6-9]. Associations have been reported between child development and environmental factors, and these sometimes play a stronger role than the very biological vulnerability of children, which suggests the environment is capable of modulating the risks children are exposed to[7].

Environmental factors lead to behavioral differences, and challenging environments have been shown to be positive in the acquisitions[4,6,10]. Factors posing risks or providing protection – other than economic aspects, physical housing aspects, and toy availability – need to be identified. Specifically, parental practices and knowledge have received little attention from Brazilian researchers[9-11], due to their limited tools[9] and difficulty getting parents to follow their children's routines. The related literature is observed to predominantly have studies focusing on risk factors, rather than investigating protection factors[12], which play roles to improve the quality of life of children. A prevalence of investigations focusing on just one aspect or constraint is also observed to exist, in which researchers fail to investigate how different factors, whether biological or environmental, are combined to interfere in an individual's development path[13].

Moreover, although cross-sectional designs help understand posture acquisition by infants[11,14], longitudinal studies are limited. Brazil has few cross-sectional studies focusing on infants' posture acquisition and its influencing factors[1,8]. Thus, the objective of this study was to conduct a longitudinal investigation on the associations among motor and cognitive development, biological aspects, maternal practices, parental knowledge, and family environments of infants. In this study, we introduce the assumption that, throughout time, the strength of biological and environmental factors is modified in a way that provides a different way to foretell infants' motor and cognitive development.

METHODOLOGY

Design and subjects

This is a cross-sectional, descriptive, observational study. The research has been approved by the ethics committees of two universities (numbers 0596081 2.6.0000.5341 and 2008018). All parents signed consent forms.

Forty-nine infants participated in the study, of which 55.1% were boys and 24.5% were preterm. The corrected ages of the babies ranged from 3 to 16 months

at the three evaluation times (T), whose averages were 8 (T1), 10 (T2), and 12 (T3) months. The inclusion criteria were: being an infant attending a children's school and being aged between 0 and 18 months. The exclusion criteria comprised: having bone, muscle, and joint alterations, having neurological diseases, having acute diseases, and having underwent interventions.

Tools

A questionnaire was used, containing biological factors of infants (Apgar score at minute 5); prematurity; weight; length, and head circumference at birth; commitment to neonatal ICUs, age of parents, cohabiting, caregiver's duties, and time of exclusive breastfeeding.

Motor development was evaluated using the Alberta Infant Motor Scale (AIMS)[15], an instrument that has been validated[16] and regulated[17] in Brazil. Individual evaluations with minimum handling, in prone (21 items), supine (9), sitting (12) and standing (16) positions being performed for 20 minutes each. We analyzed assumed postures, anti-gravity motion, and weight bearing. A percentile was used, which describes motor development in three categories: delayed (below 5), suspected (between 5 and 25), and normal (above 25)[15].

Cognitive development was evaluated through the Mental Scale of Bayley Scale of Infant Development – second edition[18], which was individually applied through different tasks, each of which specific to a certain development stage. Gross scores are linked to corrected ages and converted into the Mental Development Index (MDI) – a variable used in the study and presented as Bayley MDI – it describes cognitive performance in four categories: expedited (above 119), within normal limits (below 85 and 114), slightly delayed (between 70 and 84), and significantly delayed (below 69)[18].

The Brazilian version[19] of Affordances in the Home Environment for Motor Development – Infant Scale (AHEMD–IS) was used to investigate opportunities for learning at home[4]. AHEMD is organized in dimensions of characteristics regarding socioeconomic status, family, home physical space, toys, and daily activities[4,19].

Maternal practices were investigated using and adapted version of Daily Activities of Infant Scale (DAIS), which evaluates opportunities for posture control and exploration of movements made available by the caregiver during different tasks in an infant's routine. The responses are arranged in an ordered scale with various opportunities for development[20]. The sum of the scores make up the total score of DAIS.

The version adapted to Brazil of the Knowledge of Infant Development Inventory (KIDI), *Inventário de Conhecimento sobre o Desenvolvimento Infantil*[21], was used to evaluate the caregivers' knowledge of child development; 20 questions regard to specific periods when skills are acquired. The score was obtained by dividing the number of correctly answered questions by the total number of answered questions, and it ranged from 0 (little) to 1 (much knowledge).

Procedures

The motor and cognitive evaluations of infants were conducted at the schools whose representatives signed consent forms. Consent forms were sent to all parents. The remaining instruments were sent to the families; the measurements were performed at three moments in a 4-month period, with a 2-month interval between each evaluation.

Analysis of data

The statistical analysis was conducted through SPSS software (version 20.0). Measures of central tendency and variability were described. Generalized estimating equations were used with Bonferroni correction for motor and cognitive development throughout time; Spearman's rank correlation coefficient was used for the relationship between cognitive and motor scores (values of $r<0.30$ = weak; $0.30 <$ values < 0.60 = moderate; > 0.60 = strong). To associate independents variables with the motor percentiles, simple linear regression was used (for each factor of a subject and their environment at each time). To enable the investigation of a higher number of factors accounting for development and how they behave together, the variables that had $p \leq 0.25$ were used in the multivariate linear regression[22]. The ones that had statistical significance were the only ones kept in the model. Significance level: $p \leq 0.05$.

RESULTS

The subjects' characteristics are shown in Table 1, with the distribution of frequencies by age and in the categories of motor and cognitive development

at each evaluation time. This sample is observed to comprise infants from children's schools whose ages ranged between 2 and 16 months, most of whom were categorized as having normal motor and cognitive development at the three evaluation moments. A higher prevalence of delays and suspected delays was observed in motor development.

Table 1. Distribution of frequencies by age and in the categories of motor and cognitive development at the three evaluation moments

Subject Characteristics	Evaluation moments n (%)		
	M1	M2	M3
Age			
2 months	1 (2%)	-	-
3 months	2 (4.1%)	-	-
4 months	2 (4.1%)	1 (2%)	-
5 months	5 (10.2%)	2 (4.1%)	-
6 months	5 (10.2%)	2 (4.1%)	1 (2%)
7 months	5 (10.2%)	5 (10.2%)	2 (4.1%)
8 months	4 (8.2%)	5 (10.2%)	2 (4.1%)
9 months	7 (14.3%)	5 (10.2%)	5 (10.2%)
10 months	9 (18.4%)	4 (8.2%)	5 (10.2%)
11 months	6 (12.2%)	7 (14.3%)	5 (10.2%)
12 months	3 (6.1%)	9 (18.4%)	4 (8.2%)
13 months	-	6 (12.2%)	7 (14.3%)
14 months	-	3 (6.1%)	9 (18.4%)
15 months	-	-	6 (12.2%)
16 months	-	-	3 (6.1%)
Motor and Cognitive Development Categorization			
AIMS			
Delay	1 (2%)	-	3 (6.1%)
Suspected	11 (22.4%)	12 (24.5%)	11 (22.4%)
Normal	37 (75.5%)	37 (75.5%)	35 (71.4%)
Bayley MDI			
Significant delay	-	-	-
Mild delay	3 (6.1%)	3 (6.1%)	6 (12.2%)
Normal limits	45 (91.8%)	45 (91.8%)	42 (85.7%)
Expedited	1 (2%)	1 (2%)	1 (2%)

Family income of the evaluated infants ranged from R$ 400.00 to R$ 8000.00 per month (M ± SD = R$ 2,267.55 ± 1735.48). Regarding the education level of their parents, high school was the most prevalent one (44.9% females; 46.9% males). The detailed description of the biological variables of study subjects with averages and dispersion is shown in Table 2.

The motor percentile was found to increase (p=0.033) and a significant difference was found between M1 and M2 (p_{1-2}=0.035; p_{2-3}=1.00; p_{1-3}=0.347), which characterizes variability and development plateau (Figure 1).

Table 2. Biological characteristics of subjects

Biological variables	Minimum	Maximum	Average	SD
Gestational age (weeks)	32	42	38.2	2.6
Weight at birth (grams)	2200	3995	3156.3	456.2
Length at birth (cm)	41	53	48.0	2.7
Dead circumference (cm)	29	36	32.2	1.9
APGAR (5th minute)	6	10	8.9	1.2

Caption: cm: centimeters

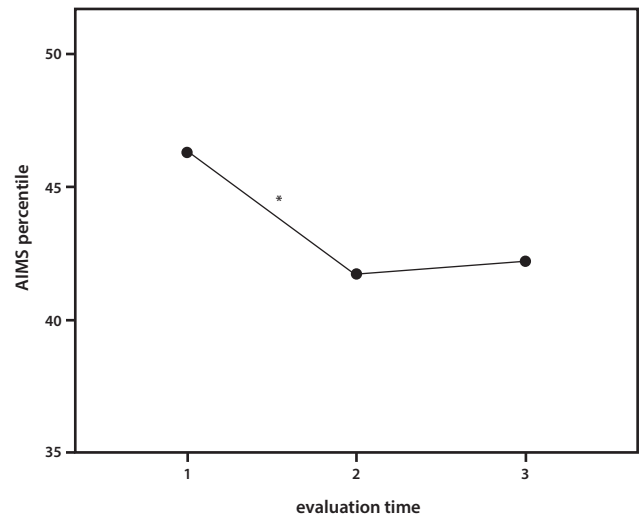

Figure 1. Motor development (AIMS percentile) over the months; *p≤0.05: significant difference between moments

The correlation between motor and cognitive development was significant and moderate at M1 (rho_1=0.496; p_1<0.001) and M2 (rho_2=0.520; p_2<0.001); and strong at M3 (rho_3=0.634; p_3<0.001). Concerning the simple regression, a significant association was observed to exist between motor skills and cognition, with high beta values. In the multivariate one, the association remained in the model at M2 and M3. The increases in the motor repertoire were related to more sophisticated cognitive behavior.

In the regressions, significant associations were observed between motor development and residential factors. In the univariate one, regardless of the moment, the significant association between motor development and cognition, education levels of parents, income, toy availability, physical space at home, maternal practices, parental knowledge, breastfeeding duration, and school frequency time. Table 3 shows the univariate regression

Table 3. Simple linear regression (univariate) at the three evaluation moments with biological and environmental variables having motor development as outcome

Biological and environmental factors	T1		T2		T3	
	Beta	P	Beta	p	Beta	p
Gender (M=1;F=2)	0.252	0.081	0.186	0.202	0.115	0.432
Gestational age	0.167	0.252	0.177	0.225	-0.016	0.913
Weight at birth (grams)	0.084	0.567	0.176	0.227	-0.009	0.948
Head circumference at birth (cm)	-0.033	0.867	0.025	0.900	-0.077	0.695
APGAR (5th minute)	0.288	0.058	0.396	0.008*	0.285	0.061
Admission to neonatal ICU (days)	-0.051	0.741	-0.063	0.687	0.166	0.281
Bayley MDI	0.474	0.001*	0.498	< 0.001*	0.607	< 0.001*
Mother's age	0.145	0.329	0.164	0.269	0.089	0.550
Father's age	0.180	0.225	0.213	0.151	0.151	0.310
Mother's education level	0.447	0.001*	0.546	< 0.001*	0.603	<0.001*
Father's education level	0.511	< 0.001*	0.641	< 0.001*	0.600	<0.001*
Income	0.614	< 0.001*	0.696	< 0.001*	0.570	< 0.001*
Working outside home (1=yes; 2=no)	0.189	0.192	-0.006	0.970	0.052	0.725
Parents together (1=yes;2=no)	-0.106	0.467	-0.172	0.423	0.040	0.783
Number of children in household	-0.138	0.345	-0.091	0.535	-0.147	0.314
Toys (total)	0.187	0.198	0.294	0.040*	0.473	0.001*
Space (total)	0.449	0.001*	0.444	0.001*	0.246	0.088
AHEMD Practices (dichotomous)	0.236	0.102	0.058	0.691	0.192	0.187
AHEMD Practices (lickert)	0.039	0.791	-0.003	0.982	0.227	0.117
DAIS (total)	0.136	0.353	0.133	0.363	0.339	0.017*
KIDI	0.423	0.002*	0.562	< 0.001*	0.474	0.001*
Breastfeeding (months)	0.238	0.107	0.322	0.028*	0.317	0.030*
Time attending school	-0.017	0.907	0.092	0.528	0.319	0.026*

*Variables with p≤0.05; variables whose p values are underlined had p<0.25 and made the initial multivariate regression models

results with the weights of biological and environmental factors having motor development as an outcome variable.

In the multivariate regression (Table 4), all factors investigated in this study were included in the data analysis process in order to verify how they are associated with motor development over time. Significant associations were observed with cognition (M2 and M3), income (M1, M2, and M3), father's age (M1 and M2), physical space at home (M1 and M2), and maternal practices (M3). Table 4 shows the values of Beta, p, and adjusted R^2. Beta indicated that the weight of each variable in the model, being corrected for the range of variation in the studied factor, was changed at the three evaluation times. The variables that remained in the model accounted for a great deal of variability in motor skills (values of adjusted R^2 close to or above 0.5). The factors with the highest weights in the model (higher Beta values) were income and cognition.

Table 4. Jultivariate linear regression at the three evaluation moments with motor development as the outcome

Time	Beta	p	Adj. R^2
T1			0.472
Father's age	0.234	0.036	
Income	0.541	<0.001	
Space (total)	0.293	0.013	
T2			0.663
Bayley MDI	0.325	0.001	
Father's age	0.229	0.013	
Income	0.530	<0.001	
Space (total)	0.275	0.005	
T3			0.585
Bayley MDI	0.413	<0.001	
Income	0.495	<0.001	
DAIS (total)	0.231	0.027	

DISCUSSION

Motor development

Throughout the three evaluation moments, changes in the values of performance percentiles were observed along the evaluations (M1, M2, and M3). At the second and third evaluation moments, the children were found to have lower motor percentiles, which consequently shows a lower number of acquisitions at this age. The motor and cognitive normality levels were observed to decrease with age, but the delays were found to increase (M3). Studies have described variations in motor percentiles and categorization[5,8]. For example, a recent study reported fluctuations in the motor development categories of 32 Brazilian infants over time: the average or above average category was observed in 68% of the 9-month old infants – six months later, this frequency rose to 94%[8].

Also considering the percentiles, a similar study with Brazilian infants, albeit with a larger sample (n=561) found higher percentile values at the first three months and after 13 months, and these children were found to have less suspected or real motor delays[5]. These results corroborate the ones from this study (higher prevalence of delays at the third evaluation moment) and show that the percentile changes may represent individuality or stability periods in acquisitions[23,24]. The stable periods are not necessarily related to stagnant development. The children were not found to have changed motor patterns, but they may be developing parameters to acquire them. One example is the development of crawling. A child is firstly shown to be capable of standing on all fours, and then of swinging while in the position. This movement will cause their upper and lower limbs to be strengthened in order to be able to move in such way.

Associations and predictors of motor development:

Generally speaking, the factors that were found to be the most associated with the development of studied babies were the environmental ones, rather than individual aspects. Such possibility was already reported in a previous review study[7,13,25]. Biological factors, despite being frequently mentioned as risks to child development[7,11,26,27], were not found to influence the regression models in this study.

The relationship between motor skills and cognition was confirmed in the correlation tests and regressions used, similarly to a previous study[27], which reinforces the interaction of these processes and the predictive ability of cognitive development over the motor one[8,28]. A possible explanation is the coactivation of certain brain areas during these tasks. Cognition mainly activates the prefrontal cortex, which is co-activated in a motor action. In the same direction, a motor action activates the cerebellum, which is also co-activated in a cognitive task[28]. That is, although the nervous system has predetermined primary functional areas, these same areas can be activated in different situations[28].

Factors at home were found to be strong and significant in the associations, remaining in the final multivariate regression models and accounting for a great deal of the development variability. Similar results previously reported with Brazilian infants[9,13], as well as in a literature review[25], reinforce the importance of the environment experienced by a child, and this may minimize biological risk factors.

Income was found to have a significant association in the simple regression, and it was the only factor observed to remain in the multivariate model at the three moments, besides having the highest beta value and being configured as the variable that accounted for the motor percentile the most comprehensively. Associations between motor skills and income were described in a Brazilian study[9]. A higher incidence of delays was observed in families of low socioeconomic statuses[6], as they are more exposed to risk factors and are more prone to being affected by pre-established risks. These families have higher availability of physical space, toys, and time for interaction with their infants[4,6] which are factors that account for these results to a great extent.

Despite not remaining in the multivariate model, the education levels of parents were not found to be associated with motor percentiles in the univariate analysis at the three moments. Lower education levels of parents[7,8,9], mainly the mothers[6,29] negatively affect child development. Mother's education level is reported as a variable with a persistent impact on child development, and it influences the child care[9], the organization of the environment[14], and available motor opportunities[9].

In the multivariate model, father's age was found to have significance at the first and second moments. Studies suggest inferior development of teenage mother's children[30], which is similar to this study, with

the poorest performance being the one of children of younger parents. The restricted opportunities of interaction between parents and their children, which negatively impact child development[8,9], may be due to parents' heavy workloads. The age of the infants may have also contributed, as young fathers may demonstrate lack of knowledge and security in caring and stimulating small infants.

Physical space at home was found to be associated with motor percentiles in univariate and multivariate models. Their homes and their surrounding areas are the first environments experienced by children; available space is a factor of protection to motor development[9], it is fundamental in the mediation of walking[3,9], and it influences exploratory behavior[6], mainly in the age range of the infants analyzed in this this study, who are mostly in the period where they acquire the skills of crawling and walking, between 6 and 14 months.

Available toys were found to be associated with motor development in the simple regression, and this relationship had already been reported by previous studies, with association values inferior to the one observed in this study[4,9]. Using appropriate toys stimulates new and varied motor actions and problem-solving[4,9], helps eye-hand coordination[31], thus developing manipulative skills. Toy availability predicts cognitive and motor behavior of infants[3,4], a relationship that was confirmed by this study.

Maternal practices were found to be associated with motor skills in both regression models. At the third moment, the mothers who provided longer exposure to independent positions favored the development of their children; the mothers who carried their infants longer minimized their opportunities for development. Studies suggest that Brazilian mothers carry their infants very often and offer little opportunity for children to sit [32]or lie facing down[33] unsupported on the floor Positions that demand higher muscle strength against the action of gravity[23] should and must be exercised precociously. Caregivers avoid such positions reporting discomfort from the children and fear of death by suffocation, which leads to development delays[5,9,23,34], a factor that may explain these results.

The motor percentile was found to be associated with the knowledge on child development at all moments; parents and caregivers who precisely reported their children's abilities were observed to be capable of adapting the environment in a way to enrich available stimuli, a result that is similar to the one of a previous study[6]. In order to understand the needs from their children, they need to have time to interact with them[8,9]. Infant parents are interested in receiving information that may mediate the development of their children[32]; they do not always have access to it. Parental education programs which instruct parents on activities that are proper to their children's skills[8,9], which moderate the use of equipment[32], and which allow children to be on the floor for longer[32] are currently required.

Breastfeeding was found to be associated with motor development in the univariate model. Higher motor scores are observed in babies who are breastfed for longer[6], which is similar to this study. Higher electroencephalographic activity frequencies[33] and cognitive[11] and motor development[6] superiority are observed in breastfed infants. Nutrition is fundamental for development, and it modulates processes associated with the maturation of brain structure and activity; they interfere in the child development path[35]. Establishing the bond between infants and their mothers and the physical contact between them stimulates motor activity and mediates the remaining abilities of individuals[6]. Before this evidence, a minimum six-month breastfeeding period is suggested in order to prevent undesirable delay conditions[6] and promote development.

School frequency time was found to be associated with the motor percentile in the simple regression at the third moment, with higher scores for babies who have attended school for longer, and that is similar to previous studies[4,6]. This is summed to daycare time – the quality of the context that is offered to infants. A study suggests that infants from schools with contexts that were more appropriate to development were found to have higher development scores[36]. Children's schools may provide experiencing tasks that are more varied than the ones at home, and that stimulates the motor skills[6], as long as the environment is properly organized[36]. In this study, the infants seem to be finding conditions that are proper to development at schools.

Having in mind that this study observed a higher association between environmental factors and child development, a need is suggested, as a practical outcome, to map children who have increased risks of delays and to train their fathers to create opportunities for development. Some actions may potentialize development paths, such as teaching parents how to carry and position infants, making various toys and materials available, and adapting home environments.

CONCLUSION

Environmental factors and cognition accounted for most of the variability in motor development, rather than biological factors, with a special mention to family income, space at home, maternal practices, and father's age. This is a trend that has already been observed in the literature, which suggests that an environment that has plenty of stimuli can minimize the effects from biological vulnerability. Also, environments with restricted opportunities may potentialize risks of development delays.

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