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GROWTH STATUS, BEHAVIOR AND NEUROPSYCHOLOGICAL PERFORMANCE

A study of Brazilian school age children

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ABSTRACT - *Aim:* To assess the association between child growth and teacher-reported behavior and academic standing, and neuropsychological performance. *Method:* The heights of 344 public-school children were measured using standard procedures. Teachers were requested to complete two behavioral and one academic performance rating scales. Neuropsychological assessment consisted of the Edinburgh Handedness Inventory, the Steadiness Test and the Purdue Pegboard. Height-for-age z (HAZ) scores were calculated based on an international reference. Standard (z) scores for each factor of the first two behavioral rating scales and for each neuropsychological variable were computed for each child based on locally-derived norms. *Results:* HAZ scores were negatively correlated with factors related to hyperactivity, conduct problem, impulsivity and inattention of the behavioral rating scales. In addition, the lower the HAZ score the worse the academic performance. *Conclusion:* These results add to the existing evidence indicating a strong association between growth status and child behavior and academic performance.

KEY WORDS: child growth, hyperactivity, inattention, conduct problem, neurobehavior.

Crescimento, comportamento e desempenho neuropsicológico: estudo de escolares brasileiros

RESUMO - *Objetivo*: Examinar a associação entre crescimento, comportamento na sala de aula, rendimento acadêmico e desempenho neuropsicológico em escolares. *Método*: A estatura de 344 escolares da rede pública de Niterói foi medida através de procedimentos padronizados. Os professores preencheram duas escalas de avaliação comportamental e uma escala de avaliação do rendimento acadêmico. O exame neuropsicológico incluiu o Inventário da Preferência Manual de Edimburgo, o Teste do Equilíbrio da Haste e a Prancha de Purdue. Escores padronizados da estatura para a idade (HAZ) foram calculados com base em referência internacional. Escores padronizados (z) dos fatores das duas escalas de avaliação comportamental e das variáveis neuropsicológicas foram computados para cada criança com base em normas derivadas localmente. *Resultados*: Escores HAZ apresentaram correlação negativa com fatores relacionados à hiperatividade, problemas de conduta, impulsividade e inatenção das escalas de avaliação comportamental. Ademais, quanto mais baixo o escore HAZ, pior se mostrou o rendimento acadêmico. *Conclusão*: Os resultados acrescentam à evidência de associação entre crescimento, comportamento na sala de aula e rendimento acadêmico.

PALAVRAS-CHAVE: crescimento, estado nutricional, hiperatividade, inatenção, conduta, neurocomportamento.

Growth retardation - as measured by low height-for-age - during infancy and early childhood has been found to have a strong adverse effect on cognitive function in late childhood[1-3]. However, less is known about relationships between growth impairment and behavior and neuropsychological performance. In Brazil, to a large extent, research in child neuropsychology has been hindered by the lack of normative data for neurobehavioral assessment in children[4]. Earlier research of the first author has focused on the development of normative data for neuropsychological instruments used in the assessment of children in Brazil such as the Conners Abbreviated Teacher Rating Scale[5], the Teacher Rating Scale-Brazil (TRS-B)[6], the Edinburgh Handedness Inventory[7-8], the Attention Deficit/Hyperactivity Disorder Teacher Rating Scale-Brazil (ADHD-DSM-IIIR-B)[9], the Steadiness Test and the Purdue Pegboard[10]. The

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clinical applications and relevance of these instruments for research in child neuropsychology in Brazil are described elsewhere[11].

The aim of our study is to build up on the earlier research described above and explore the association between child growth (i.e., height-for-age) and neurobehavioral performance in a sample of Brazilian school age children as assessed by the TRS-B, the ADHD-DSM-IIIR-B, the Academic Performance Teacher Rating Scale (AcPTRS-B), the Edinburgh Handedness Inventory, the Steadiness Test and the Purdue Pegboard.

METHOD

Subjects

A computer-generated unbiased sample of 346 children was the subject of this study. The children had a mean age of 9.4 years and were drawn from a large public school in the greater Rio de Janeiro area (Niteroi) with over 2000 registered children in preschool, elementary and junior high school classes. We selected this school not only due to its large number of children but also because it attracts children from all ethnic groups and social strata, albeit mostly from lower social classes, with place of residence in communities distributed throughout Niteroi, a city located across the Guanabara Bay from Rio de Janeiro. Children were screened for the presence of minor physical disabilities, motor and vocal tics, speech disorders, and other behavioral deviances (e.g., nail biting, streotypies) by the use of a physical handicap and behavior checklist described elsewhere[11] and those with impairment deemed capable to interfere with performance of the Steadiness Test and the Purdue Pegboard (e.g., visuomotor impairment or severe motor tics) were excluded from the study. Only two boys, one who refused to be tested and another boy who presented with a severe form of strabismus, were removed from the study. The final sample comprised 344 children (173 boys and 171 girls). The social class distribution of children in the present sample, according to Hollingshead and Redlich[12], was: I (N=2, 0.6%), II (N=9, 2.6%), III (N=34, 9.9%), IV (N=119, 34.6%) and V (N=176, 51.2%). Social classes I and II include university-educated executives, business managers in large concerns, and major and lesser professionals; social class III includes administrative personnel, owners of small independent businesses and minor professionals; and social classes IV and V include skilled, semi-skilled and unskilled laborers with lower educational levels. One hundred and forty eight children (43.0%) were Caucasian, 129 (37.5%) were of African ancestry and 67 (19.5%) were of a multiple-race group.

The study was approved by the Board of Directors of the Instituto de Educação Prof. Ismael Coutinho (IEPIC) and performed under the auspices of the agreement celebrated between IEPIC and the Instituto Fernandes Figueira of the Fundação Oswaldo Cruz (FIOCRUZ).

Anthropometric measurements

Height was measured following standard procedures[13]. Two trained individuals (the first author and a research associate) collected the data on height under the supervision of a nutritionist acquainted with anthropometric measurement procedures. Three measurements of height, each of which required to be within 0.5 cm of the others, were taken for each child and the mean height was used for data analysis. Age was determined through the child's birth certificate included in his/her school records. Height-for-age z scores (HAZ) were calculated based on the National Center for Health Statistics/World Health Organization (NCHS/WHO) reference using the age-specific regression equations[14] and implemented in the ANTHRO software[15]. HAZ was then used as a continuous variable in data analysis.

Behavioral assessment

The teachers of the children were requested to complete the TRS-B[6] and the ADHD-DSM-IIIR-B[9]. Both rating scales were scored from not at all (0) and just a little (1) to pretty much (2) and very much (3).

The TRS-B is comprised of 62 items distributed among five factorial dimensions (Hyperactivity-Conduct Problem; Independent Functioning-Positive Socialization; Inattention; Neuroticism/Anxiety; Negative Socialization). Standard (z) scores for each of these factors were computed for each child based on locally-derived norms[6] and used as indices of behavioral functioning. Standard (z) scores were then entered as continuous variables in the statistical analysis of the data. Except for the behavioral dimension Independent Functioning-Positive Socialization, higher (and more positive) standard z scores signify that the child is having more difficulties along the behavioral dimensions derived from the TRS-B.

The ADHD-DSMIIIR-B includes the entirety of the diagnostic criteria for Attention Deficit/Hyperactivity Disorder (ADHD) according to DSM-IIIR[16]. Standard (z) scores for each of the factors extracted from this scale, Hyperactivity-Impulsivity and Inattention, were computed for each child based on locally-derived norms[9] and also used as indices of behavioral functioning. Standard (z) scores were then used as continuous variables in the analysis. Higher (and more positive) standard z scores signify that the child is having more difficulties along the two behavioral dimensions derived from the ADHD-DSMIIIR-B.

Academic assessment

The teachers were also requested to complete the AcPTRS-B[11] for each child and instructed to rate his/her academic performance as much above average, above average, average, below average and much below average in comparison to their classmates. This measure of academic performance was included in the statistical analysis of the data as dummy-coded variables.

Neuropsychological assessment

The procedures for neuropsychological testing are described in detail elsewhere[10]. Briefly, the neuropsychological battery used in the present report was administered over two sessions (one session a day) by the first author and a research associate. Children were tested individually in a quiet and acclimatized room of the school.

The first session included the following tests:

Edinburgh Handedness Inventory. This instrument was used to assess the manual preference of the participants. The procedures for the administration of the Edinburgh Handedness Inventory in children were as described before[8]. Each child was requested to perform the ten tasks included in the inventory and the hand used to perform each activity was recorded. Laterality quotients (LQs) could range from -100 (consistent left-handedness) to +100 (consistent right-handedness)[8].

Steadiness Test. This test was used to assess motor persistence, motor coordination and attention[17]. The procedures for this test were as reported by Brito and Santos-Morales[10] and Gardner[17]. Three trials of 60 sec were administered with the hand the child preferred to use in the test as well as with the non-preferred hand. Trials for each hand were administered alternately. Standard (z) scores for total number of contacts and total touch time across the three trials were derived for each child based on Brazilian norms[10].

The second session consisted of the following test:

Purdue Pegboard. This instrument provides an excellent test of fine motor coordination in children with neurodevelopmental disabilities[17]. Procedures for this test were as described in Brito and Santos-Morales[10] and Tiffin[18]. Standard (z) scores for number of pegs placed with the

Table 1. Mean (and SD) z scores, and minimum and maximum z scores for height-for-age, and the behavioral and neuropsychological variables. N=344 children.

	Mean	SD	Minimum	Maximum
Height-for-age	0.28	1.10	-2.92	4.61
Behavior				
TRS-B				
Hyperactivity/Conduct Problem	-0.21	0.99	-1.56	4.07
Independent Functioning/Positive Socialization	0.16	0.54	-1.21	1.69
Inattention	-0.77	0.34	-1.56	0.22
Neuroticism/Anxiety	-0.81	0.32	-1.56	0.15
Negative Socialization	-0.91	0.28	-1.56	-0.15
ADHD-DSM-IIIR-B				
Hyperactivity/Impulsivity	-0.76	0.36	-1.56	0.42
Inattention	-0.98	0.28	-1.71	-0.28
Neuropsychological Performance				
Edinburgh Handedness Inventory				
Laterality quotient	75.40	53.13	-100.00	100.00
Steadiness Test				
Total number of contacts				
Preferred hand	0.0	0.95	-1.88	2.74
Non-preferred hand	0.0	0.95	-2.19	2.80
Total touch time (s)				
Preferred hand	0.0	0.95	-1.42	2.85
Non-preferred hand	0.0	0.95	-1.61	2.86
Purdue Pegboard				
Number of pegs placed				
Preferred hand	0.0	0.95	-2.42	2.06
Non-preferred hand	0.0	0.95	-2.42	2.31
Total time to place 10 pegs (s)				
Preferred hand	0.0	0.95	-1.94	2.38
Non-preferred hand	0.0	0.95	-2.24	2.60
Total time to transfer 10 pegs (s)				
Preferred hand	0.0	0.95	-2.17	2.54
Non-preferred hand	0.0	0.95	-1.91	2.50
Both hands	0.0	0.95	-2.62	2.21
Assembly	0.0	0.95	-2.29	2.56

TRS-B, Teacher Rating Scale-Brazil; ADHD-DSM-IIIR-B, Attention Deficit/Hyperactivity Disorder Teacher Rating Scale-Brazil.

Table 2. Spearman's rank-order correlation coefficients between height-for-age z-scores and z-scores for the behavioral, academic and neuropsychological variables. N=344 children.

	R	P
Behavior		
TRS-B		
Hyperactivity/Conduct Problem*	-0.139	0.009
Independent Functioning/ Positive Socialization	0.033	0.538
Inattention*	-0.116	0.030
Neuroticism/Anxiety	-0.073	0.172
Negative Socialization	-0.049	0.355
ADHD (DSM-IIIR)-B		
Hyperactivity/Impulsivity*	-0.111	0.039
Inattention*	-0.113	0.035
Academic performance*	-0.146	0.006
Neuropsychological performance		
Edinburgh Handedness Inventory		
Laterality quotient	0.011	0.835
Steadiness Test		
Total number of contacts		
Preferred hand	-0.004	0.940
Non-preferred hand	-0.047	0.375
Total touch time (s)		
Preferred hand	-0.012	0.814
Non-preferred hand	-0.021	0.685
Purdue Pegboard		
Number of pegs placed		
Preferred hand	-0.054	0.314
Non-preferred hand	-0.033	0.532
Total time to place 10 pegs (s)		
Preferred hand	0.037	0.493
Non-preferred hand	-0.015	0.773
Total time to transfer 10 pegs (s)		
Preferred hand	-0.033	0.541
Non-preferred hand	-0.042	0.436
Both hands	0.014	0.785
Assembly	0.024	0.650

*Significant correlation coefficient TRS-B, Teacher Rating Scale-Brazil; ADHD-DSM-IIIR-B, Attention Deficit/Hyperactivity Disorder Teacher Rating Scale-Brazil.

preferred and non-preferred hands, number of pegs placed with both hands, total time to place 10 pegs across three trials with the preferred and non-preferred hands, total time to transfer 10 pegs across three trials with the preferred and non-preferred hands and total number of items assembled in the "assembly" modality were obtained for each child based on normative data gathered in Brazil[10].

Statistical analysis

The data were analyzed using PC-SAS[19]. Proc CORR was used to determine whether growth status correlated with neurobehavioral variables. Additionally, we used the Spearman's rank-order correlations as the assumptions for the use of parametric procedures could not be met by the neurobehavioral data. Furthermore, the individual correlation was used as the conceptual unit of error rate due to the exploratory nature of our study.

RESULTS

Table 1 shows mean (and SD) z scores, and minimum and maximum z scores for height-for-age and the behavioral and neuropsychological variables. Only nine children (2.6%) had HAZ scores equal or below -2.0. The distribution of scores on the AcPTRS-B was the following: (1) much higher than average - N = 9 (2.6%); (2) higher than average - N = 64 (18.6%); (3) average - N = 209 (60.8%); (4) below average - N = 44 (12.8%); (5) much below average - N = 18 (5.2%). Laterality quotients (LQs) were distributed as follows: (1) -100< LQ<-50, N = 30 (8.7%); (2) -50<LQ<0, N = 5 (1.5%); (3) 0<LQ<+50, N = 0; (4) +50<LQ<+100, N = 309 (89.8%).

Table 2 shows the Spearman's rank order correlation coefficients between HAZ and the z-scores for the behavioral and neuropsychological variables. The data presented in the table demonstrate that HAZ is significantly and negatively correlated with two specific behavioral domains derived from the TRS-B: Hyperactivity/Conduct Problem and Inattention. The lower the HAZ of the child the higher his/her z-score in these two behavioral domains.

The significant negative correlation coefficients also found between HAZ and the z-scores of the behavioral domains extracted from the ADHD-DSM-IIIR-B, i.e., Hyperactivity/Impulsivity and Inattention, provide further confirmation of the specificity of the relationship between height-for-age and Hyperactivity and Inattention.

Teacher ratings of academic performance according to the AcPTRS were also found to be significantly and negatively correlated with HAZ, i.e., the lower the latter scores the higher (and worse) the rating of academic performance.

None of the other behavioral and neuropsychological variables had a significant correlation with HAZ.

DISCUSSION

The results show that HAZ is negatively and specifically correlated with the behavioral domains of Hyperactivity/Conduct Problem and Inattention derived from the TRS-B. The significant negative correlations also found between HAZ and the two behavioral domains of Hyperactivity/Impulsivity and Inattention extracted from the ADHD-DSM-IIIR-B confirm the specificity of the relationship between growth status and Hyperactivity and Inattention. These significant negative correlations indicate that lower HAZs are associated with higher degrees of neuropsychopathology along those two behavioral domains. The results also show a significant association between HAZ and teacher's ratings of academic performance; the lower the HAZ the worse the rating of academic performance. No associations were found between HAZ and neuropsychological variables derived from the Edinburgh Inventory, the Steadiness Test and the Purdue Pegboard.

The association of HAZ and teacher ratings of children's behavior in the domains Hyperactivity/Impulsivity and Inattention reported in the present study is consistent with the finding that the birth weight of children with generalized hyperkinesis is significantly lower than that of normal children[20]. Furthermore, a study performed in Brazil demonstrated that growth status represents a factor associated with attention deficit-hyperactivity disorder[21]. Moreover, a recent study showed that children stunted in early childhood had more conduct problems at home, regardless of their social backgrounds, and fewer prosocial behaviors at school than non-stunted children[22].

The significant association found in our study between HAZ and teacher's ratings of children's academic performance adds to the evidence from a number of studies demonstrating a relationship between growth status and academic performance and cognitive functioning[22-26]. Although our study could not ascertain the effects of stunting in early childhood on later school achievement due to the small number of children who were stunted in our sample, the direction of the association between height-for-age and academic performance is in agreement with these earlier findings. Furthermore, an association between body-size measures and mental test scores in a population of well-nourished children has also been reported by other investigators[27].

The precise mechanism linking physical growth and poor neurobehavioral development is not known. There has been a long standing interest in whether general or specific nutritional deficiencies at a sensitive or critical period of brain growth or maturation could have a long lasting or permanent "programming" influence on later cognitive performance. One noteworthy example of a nutritional influence on cognitive function is maternal iodine deficiency, which may result in reduced cognitive function or even cretinism[28,29]. Furthermore, prenatal nutritional deprivation changes sleep/wake mechanisms[30] and interferes with benzodiazepine-induced spatial learning deficits[31] in rats as adults. However, it is difficult to extrapolate from such studies in rats to human behavior. In humans, there are at least two commonly suggested explanatory hypotheses. One of these hypotheses is that malnutrition impairs brain growth and neural development and hence future behavior, while the other states that the association between nutritional status and cognitive development is mediated by motor maturation, activity level and exploratory behavior[3]. The association between growth status and cognitive development cannot be regarded as a simple causal relationship because of the complex (proximal and distal) environmental factors that affect both growth and development. It is possible that more than one mechanism act in concert to impair neurobehavioral functioning. It might also be hypothesized that low height-for-age interferes with school achievement by its effect on the behavioral domains related to hyperactivity/impulsivity and inattention as indicated by the present findings.

The fact that we did not find a significant correlation between height-for-age and the neuropsychological variables derived from the Edinburg Handedness Inventory, the Steadiness Test and the Purdue Pegboard is possibly due to the small number of children with severe height-for-age deficits in our sample.

In conclusion, we found significant associations between height-for-age, externalizing behaviors and teacher ratings of academic performance in a large sample of Brazilian school-age children. Externalizing behaviors can interfere with academic performance and are considered to predict future psychosocial adjustment[22]. However, the mechanism of the developmental deficits in academic performance induced by growth retardationdeficits has not yet been elucidated. The use of instruments that assess academic performance directly rather than teacher ratings of academic performance might offer a more precise view of the relationship between growth status and achievement. Such research is now underway in our laboratory.

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