GROWTH STATUS AND ACADEMIC PERFORMANCE IN BRAZILIAN SCHOOL AGE CHILDREN

Growth retardation impairs mathematical, but not reading and spelling abilities

Gilberto N.O. Brito[1], Mercedes de Onis[2]

ABSTRACT - *Aim:* To assess the effect of child growth status on academic achievement and the association between child growth and academic standing. *Method:* The heights of 722 middle-school children were measured using standard procedures and height-for-age z (HAZ) scores were calculated based on an international reference. Academic performance was assessed by an adaptation of the Wide Range Achievement Test (WRAT3) composed of Reading, Arithmetic and Spelling. *Results:* Children in the group with higher HAZ scores performed better than children in the group with lower HAZ scores only on the Arithmetic subtest. This finding was confirmed by a multiple regression model analysis of the data. In addition, only performance on the Arithmetic subtest was positively associated with HAZ. *Conclusion:* These results indicate that growth retardation impacts specifically on the development of arithmetic (numeracy) skills and are consistent with a three-fold model of life course influences on health including latency, cumulative and pathway effects.

KEY WORDS: child growth, achievement, academic standing, mathematical ability, cognitive development, neurobehavior.

Crescimento e desempenho acadêmico em escolares brasileiros: retardo no crescimento interfere com a matemática mas não com a leitura e a escrita

RESUMO - *Objetivo:* Examinar o efeito do crescimento no desempenho acadêmico e a associação entre crescimento e competência acadêmica. *Método:* A estatura de 722 escolares da rede pública de Niterói foi medida através de procedimentos padronizados e escores padronizados da estatura para a idade (HAZ) foram calculados com base em referência internacional. O desempenho acadêmico foi avaliado através de uma adaptação do Wide Range Achievement Test (WRAT3) composto de leitura, aritmética e ditado. *Resultados:* Crianças com HAZs mais elevados apresentaram um desempenho melhor do que crianças com HAZs mais baixos somente na aritmética. Este achado foi confirmado por uma análise de modelo de regressão múltipla dos dados. Ademais, somente o rendimento em aritmética mostrou uma associação positiva com HAZ. *Conclusão:* Os resultados indicam que o retardo no crescimento impacta especificamente no desenvolvimento de competência em matemática e são consistentes com um modelo de influências durante o curso da vida que inclui efeitos de latência, cumulativos e de trajetória.

PALAVRAS-CHAVE: crescimento, desempenho acadêmico, competência em matemática, desenvolvimento cognitivo, neurocomportamento.

The deleterious effects of growth retardation as evaluated by low height-for-age during infancy and early childhood on behavior and cognitive functions in late childhood are well-known[1-4]. Along this line, Brito and deOnis[5] demonstrated a significant association between growth status and hyperactive/ conduct problem and inattentive behaviors and also between growth status and a qualitative rating of academic performance by the teachers of school children in the greater metropolitan area of Rio de Janeiro, Brasil.

However, this report could not determine whether

the association between growth status and academic performance is of a general nature or specific to reading, spelling or arithmetic. In addition, the qualitative rating of academic performance in the report of Brito and deOnis[5] impedes a more precise quantitative evaluation of the effects of growth status on academic achievement.

The objective of the present study was to determine the effect of growth status on the academic standing of school children in the greater metropolitan area of Rio de Janeiro as assessed by an achievement test composed of Spelling, Arithmetic and Reading subtests. On the basis of the findings that growth status is associated with hyperactive/conduct problem and inattentive behaviors[5] and that poor attentional control can disrupt mathematical procedures[6,7], it was hypothetized that growth impairment more likely interferes with arithmetic (numeracy) abilities in comparison with reading and spelling (literacy).

METHOD

Participants – All 920 children registered in the 5th through 8th grades (middle school) of Instituto de Educação Prof. Ismael Coutinho (IEPIC), a large public school in the metropolitan area of Rio de Janeiro (Niterói), participated in this study. As reported previously[5,8-14], we selected this school not only because of its large enrollment but also because it attracts children from all ethnic and socioeconomic groups, although mostly from lower social classes, and with place of residence in communities distributed throughout Niteroi, a city located across the Guanabara Bay from Rio de Janeiro, and adjacent localities (São Gonçalo, Maricá e Itaboraí). A total of 198 participants who requested school transfer or otherwise dropped out of IEPIC were excluded from the study because their data could not be completed. Therefore, the final number of participants was 722 children (281 boys and 441 girls) with a mean age of 13.5 years (SD=1.4). Two hundred and ninety three children (40.6%) were Caucasian, 275 (38.1%) were of African ancestry and 154 (21.3%) were of a multiple-race group. The distribution of the occupation of the fathers of the participants, according to Hollingshead and Redlich[15], was: 1 (N=28, 3.9%), 2 (N=21, 2.9%), 3 (N=83, 11.5%), 4 (N=90, 12.5%), 5 (N=43, 6.0%), 6 (N=197, 27.3%), 7 (N=225, 31.2%); information could not be obtained for the occupation of the fathers of 35 (4.8%) children. The distribution of the occupation of the mothers of the participants, also according to Hollingshead and Redlich (1958), was: 1 (N=22, 3.1%), 2 (N=27, 3.7%), 3 (N=26, 3.6%), 4 (N=38, 5.3%), 5 (N=8, 1.1%), 6 (N=84, 11.6%), 7 (N=409, 56.6%); information could not be obtained for the occupation of the mothers of 108 (15.0%) children. Occupational levels 1 and 2 include university-educated executives, business managers in large concerns, and major and lesser professionals; occupational levels 3 and 4 comprise administrative personnel, own-

ers of small independent businesses and minor professionals; and occupational levels 5, 6 and 7 include skilled, semi-skilled and unskilled laborers with lower educational levels. In addition, 243 (33.7%) children had failed at least one grade in school at the time they participated in the study. Seventy two (9.97%) participants were left-handed for writing, a frequency distribution consistent with data reported elsewhere[13,16]. The children had their auditory and visual function screened and the presence of auditory or visual dysfunction was treated as a variable in data analysis; 37 (5.1%) and 150 (20.8%) participants were deemed to have auditory and visual dysfunction, respectively.

The study was approved by the Board of Directors of 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 – Procedures for anthropometric measurements have been described in a previous article[5]. Briefly, height was measured following standard procedures and three measurements were taken for each participant with the mean value used for data analysis. Age was ascertained through the child's birth certificate included in his/her school records. Height-for-age (HAZ) scores were calculated based on the National Center for Health Statistics/World Health Organization (NCHS/WHO) reference using the age-specific regression equations[17] and implemented in the ANTHRO software[18]. HAZ was then treated as a continuous variable in data analysis and also as a categorical variable, i.e., children with HAZ equal or below –1.5 were arbitrarily considered to have an abnormally low height-for-age.

Academic assessment – The academic performance of the participants was assessed by an adaptation of the Wide Range Achievement Test-3[19] developed by the author for use in Brazilian school children. In brief, the WRAT3 is composed of three subtests: (i) Reading - the recognition and naming of letters and the pronunciation of words out of context; (ii) Spelling - writing of name, letters and words to dictation; (iii) Arithmetic - counting, reading number symbols, solving oral problems and performing written computations. There are two alternate forms (Blue and Tan) which allow for the initial measure and reassessment of academic skills.

The procedures for the adaptation of the WRAT3 for public middle-school children in the metropolitan area of Rio de Janeiro are described in Brito (text in preparation). The contents of the Arithmetic subtest were unaltered. However, the subtests Reading and Spelling were constructed in Portuguese and were not directly translated from the English version. Two alternate forms of the Reading (pronunciation of words) and Spelling (words to dictation) subtests were developed such that the selection of the items for one of the forms took into account mirror like items on the alternate form. Each form was constructed to have an adequate range of item difficulty. Several item compositions were constructed and screened by professionals in the areas of linguistics, speech therapy and psychology.

After each review of the materials, a field-test study with a sample of 5th through 8th grade IEPIC children was conducted and content changes were introduced depending on their response profiles on the two alternate forms (Blue and Tan) of the Brazilian-version of the WRAT3 (Teste do Desempenho Acadêmico3-TDA3). Three such field-test studies were performed in the academic years of 1996 (N=40), 1997 (N=26) and 1998 (N=147) until the two forms were deemed appropriate by the panel of experts. In the present study, only one of the two forms of the TDA3 was administered to each participant. Half the classes within each grade (5th through 8th) were administered the Blue form whereas the other half filled the Tan form. The form administered was determined randomly by the use of a table of random numbers, but with the restriction that the distribution of the forms for the classes was balanced. In addition, only the written computations section of the Arithmetic subtest was administered since the other sections of this subtest (counting, reading number symbols and solving oral problems) do not apply to middle-school children.

Statistical analysis – The data were analysed using PC-SAS[20]. We used Proc GLM to perform multi- and univariate analyses of variance and Proc REG to perform a stepwise linear multiple regression of the data. Proc CORR was used to determine whether growth status correlated with reading, spelling and arithmetic scores of the TDA3 and the individual correlation was used as the conceptual unit of error rate since this study purported to test the a priori hypothesis of an association between growth status and arithmetic ability.

RESULTS

Table shows mean (and SD) correct and error scores on the Spelling and Reading subtests and mean (and SD) correct score on the Arithmetic subtest of the TDA3 for children with HAZ scores above –1.5 and children with HAZ scores equal or below this value. Analyses of the data to be reported elsewhere revealed significant effects of sex, age and form of the test. For the present report, a multivariate analysis of variance (MANOVA) of the data demonstrated a significant effect of HAZ group membership (F=2.32, df=5, 670, P=0.04), independent of the effects of sex, age and form of the test. Univariate analyses of variances (ANOVAs) showed a significant effect of HAZ group membership on the performance of the Arithmetic subtest of the TDA3 (F=5.97, df=1, 674, P=0.01), but not on the performance of the Spelling and Reading subtests. Children in the group of HAZ scores above –1.5 performed significantly better than children in the group with lower HAZ scores on the Arithmetic subtest.

A linear stepwise multiple regression model analysis of the data confirmed the specificity of the effect of HAZ scores on the performance of the Arithmetic subtest of the TDA3 (F=4.11, P=0.04). HAZ scores had no effect on performance of the Spelling and Reading subtests.

In addition, only performance on the Arithmetic subtest was significantly and positively associated with HAZ scores as revealed by a correlation analysis of the data (r=0.07, p=0.03) such that the higher the HAZ score the better the performance of the child.

Table. Mean (and SD) correct and error scores on the Spelling and Reading subtests and mean (and SD) correct score on the Arithmetic subtest of the TDA3 for children with HAZ scores above –1.5 and children with HAZ scores equal or below this value.

TDA 3	HAZ					
	Above −1.5 z			Equal or below −1.5 z		
	N	Mean	SD	N	Mean	SD
Spelling						
Correct score	679**	25.7	5.7	42	24.7	5.8
Error score	679**	14.2	5.7	42	15.2	5.7
Arithmetic	680	16.9	2.8	42	15.8	5.6
Reading						
Correct score	675*	36.3	3.9	42	36.2	3.8
Error score	675*	5.6	3.9	42	5.6	3.8

*Five children with severe auditory deficiency were not included; **One child refused to complete the Spelling subtest.

DISCUSSION

The results show that growth impairment has a specific effect on the performance of arithmetic (numeracy), but not on the performance of reading and spelling (literacy), in 5th through 8th grade (middle) school children. In addition, the data demonstrate that growth status is positively and specifically correlated with competency in arithmetic.

A previous report[5] demonstrated a significant and specific association between growth status and the behavioral domains Hyperactivity/Conduct Problem and Inattention such that the lower the HAZ of the child the higher the degree of neuropsychopathology along those two behavioral domains. In addition, that report[5] also showed a significant association between HAZ and teacher's ratings of academic performance; the lower the HAZ the worse the rating of academic performance. However, the instruments used in that study[5] could not determine whether the association between growth status and academic performance was of a general nature or specific to reading, spelling or arithmetic. Moreover, the qualitative rating of academic performance used in Brito and deOnis[5] impeded a more precise quantitative evaluation of the association of growth status and academic achievement. The data presented here indicate that this association is specific to arithmetic and, additionally, show that children with HAZs lower than –1.5 perform significantly worse than children with HAZs higher than –1.5 on the arithmetic but not on the reading and spelling subtests of TDA3. The specificity of the effect of growth status on the performance of the arithmetic subtest was confirmed by multiple regression analysis of the data. The evidence herein presented taken in conjunction with the data of Brito and deOnis[5] suggests that the specific effect of growth impairment on competency in arithmetic is mediated by the behavioral domains Hyperactivity/Conduct Problem and Inattention. Such a suggestion would be in line with the evidence that poor attentional control is disruptive to mathematical procedures[6,7].

The pathway linking physical growth and neurocognitive development is probably an extremely complex and multifaceted process involving biological and psychosocial factors. As emphasized by Hertzman and Power[21], "it is well known that exposure to both beneficial and adverse circumstances over the life course will vary for each individual and will constitute a unique life exposure trajectory, which will manifest as different expressions of health and well-being". Those authors advanced a three-fold model of life-course influences on health including latency, cumulative and pathway effects that are not mutually exclusive. According to this model, a latency effect represents the relationships between an exposure at a certain point in the life course and the future probability of health expressions, irrespective of intervening experience. Cumulative effects refer to multiple exposures over the life course whose effects on health combine. Finally, pathway effects signify that dependent sequences of exposures in which exposure at one stage of the life course influence the probability of other exposures later in the life course as well as associated expressions.

Hertzman and Power[21] envisage the need for surgical treatment of congenital cataracts within the first three months of life for the full recovery of eyesight and the association of maternal nutritional deficiency in pregnancy with an increased risk of antisocial personality disorder and schizophrenia among offspring in their adult life as instances of latency effects in human populations. Duration of exposure to economic hardship shows a cumulative effect on several health outcomes in adulthood and the pathway effects proposed by those authors pose that early events influence the life-course trajectory in such a manner as to lead to particular social destinations which then impact health outcome.

The model put forward by Hertzman and Power[21] seems to be directly applicable to the data of the present report. Chronic nutritional deficiencies pre- and postnatally could have long-term developmental consequences on behavior and academic standing and, therefore, could be considered as an important instance of a latency effect. In addition, the effects of chronic nutritional deficiencies certainly combine with other adverse life circumstances such as socioeconomic hardship and thus constitute cumulative effects on neurobehavioral development. Finally, it is likely that early and chronic nutritional deficiencies lead to a pathway of further socio-cultural deprivation thereby compounding a destination down the ladder of social position which then feeds back in a negative sense on neurobehavioral development. It deserves emphasis that it is the brain that mediates the effects of each one of these variables and so it is the development of the brain that may be altered in an enduring manner by this pernicious pathway. This viewpoint merits consideration in regards to public policy if we are to break the vicious pathway to neuropsychopathology in adulthood and old age.

In conclusion, the present study found significant and specific effects of growth impairment on the performance of arithmetic (numeracy), but not on the performance of reading and spelling (literacy), in a large sample of 5th through 8th grade Brazilian middle-school children. In addition, it was found that growth status is positively and specifically correlated with competency in arithmetic. However, it is still possible that growth status is associated with more fundamental aspects of reading and spelling which could not be addressed by the instruments used in this report as, for example, phonological decoding, phonological awareness and lexical access. Such research is currently underway in my laboratory.

REFERENCES

1. Berkman DS, Lescano AG, Gilman RH, Lopez SL, Black MM. Effects of stunting, diarrhoeal disease, and parasitic infection during infancy on cognition in late childhood: a follow-up study. Lancet 2002;359:564-571.
2. Chang SM, Walker SP, Grantham-McGregor S, Powell CA. Early childhood stunting and later behaviour and school achievement. J Child Psychol Psychiatry 2002;43:775-783.
3. Grantham-McGregor SM. A review of studies of the effect of severe malnutrition on mental development. J Nutr 1995;125:2233S-2238S.
4. Gorman KS. Malnutrition and cognitive development: evidence from experimental/quasi-experimental studies among the mild-to-moderate malnourished. J Nutr 1995;125:2239S-2244S.
5. Brito GNO, deOnis M. Growth status, behavior and neuropsychological performance: a study of Brazilian school age children. Arq Neuropsiquiatr 2004;62:949-954.
6. Hitch GJ. The role of short-term working memory in mental arithmetic. Cogn Psychol 1978;10:302-323.
7. Geary DC. Mathematics and learning disabilities. J Learn Disabil 2004;37:4-15.
8. Brito GNO, Lins MFC, Pinto RCA. A behavioral assessment scale for Attention Deficit Disorder in Brazilian children based on DSM-III-R criteria. J Abn Child Psychol 1995;23:509-520.
9. Brito GNO, Santos TR. The Bender Gestalt Test in 5- to 15-year-old Brazilian children: Norms and validity. Braz J Med Biol Res 1996;29:1513-1518.
10. Brito GNO, Alfradique GMN, Pereira CCS, Porto CMB, Santos TR. Developmental norms for eight instruments used in the neuropsychological assessment of children: Studies in Brazil. Braz J Med Biol Res 1998;31:399-412.
11. Brito GNO. Escala de Avaliação do Comportamento Infantil para o Professor (EACI-P). Rio de Janeiro: Editora Entreletras, 1999:1-32.
12. Brito GNO, Pereira CCS, Santos-Morales TR. Behavioral and neuropsychological correlates of hyperactivity and inattention in Brazilian school children. Dev Med Child Neurol 1999;41:732-739.
13. Brito GNO, Santos-Morales TR. Lateral preferences in 8- to 15-year-old Brazilian children assessed with the Edinburgh Inventory: Different measures of handedness and comparison with younger children and adults. Dev Neuropsychol 1999;16:433-453.
14. Brito GNO, Santos-Morales TR. Developmental norms for the Gardner Steadiness Test and the Purdue Pegboard: A study with children of a Metropolitan school in Brazil. Braz J Med Biol Res 2002;35:931-949.
15. Hollingshead AB, Redlich FC. Social class and mental illness. New York: Wiley, 1958.
16. Brito GNO, Lins MFC, Paumgartten FJR, Brito LSO. Hand preference in 4- to 7-year-old children: An analysis with the Edinburgh Inventory in Brazil. Dev Neuropsychol 1992;8:59-68.
17. Dibley MJ, Goldsby JB, Staehling NW, Trowbridge FL. Development of normalized curves for the international growth reference: historical and technical considerations. Am J Clin Nutr 1987;46:736-748.
18. World Health Organization and US Centers for Disease Control. ANTHRO software. Version 2000. Geneva: WHO, 2002.
19. Wilkinson GS. WRAT3: Wide Range Achievement Test. Wilmington, Wide Range, 1993:1-188.
20. SAS Institute. SAS/STAT user's guide. Vol. 2. 4th ed. Cary: SAS Institute; 1990.
21. Hertzman C, Power C. Health and human development: understandings from life-course research. Dev Neuropsychol 2003;24:719-744.