2015-06-01

Examining the Relationship Between Anemia, Cognitive Function, and Socioeconomic Status in School-Aged Ecuadorian Children

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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June 2015

ABSTRACT

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Background and Objectives: It is estimated that over 40% of children in Ecuador are anemic. Anemia in children can influence physical and cognitive development and have lasting effects on adulthood productivity and quality of life. The objectives of this study were to: (1) evaluate the relationship of anemia and cognitive function, and (2) determine the influence of demographic factors on cognitive function.

Population and Setting: The sample consisted of 175 school-aged children between 5 to 11 years old attending a school in a poverty stricken area of Guayaquil, Ecuador.

Methods: A descriptive correlational cross sectional design was used to study the relationship between the level of anemia and the level of cognitive function. Other demographic factors were evaluated to determine their influence on cognitive function. Data were collected at the school using the Raven's Coloured Progressive Matrices to measure cognitive function and the STAT-Site® MHgb Meter to measure hemoglobin levels.

Results: No significant correlation was found between the level of anemia and cognitive function. Multiple regression analysis of demographic variables and cognitive function found age (Beta = 0.56, $t = 8.6$, $p = 0.000$) and income (Beta = 0.16, $t = 2.5$, $p = 0.01$) to be significant predictors of cognitive function.

Interpretation and Conclusion: Many factors influence cognitive function and development. Additional research is needed to determine the effect of income level and related factors, such as parental time spent with the child doing homework, value placed on education in the home, education level of the parents, and quality of nutrition. Interventions to improve socioeconomic level, enhance parenting styles that foster cognitive development, and improve nutrition should be implemented.

Keywords: anemia; iron deficiency anemia; cognitive function; cognitive development; socioeconomic status; income

ACKNOWLEDGEMENTS

I would first like to thank my thesis committee for your support through this entire process. Heartfelt thanks goes to Mary Williams, PhD, for your constant encouragement, direction, and guidance. Although words cannot express my gratitude for your personal investment in me and this project, suffice it to say that this work would not be what it is without your contribution. Sheri Palmer, DNP, thank you for allowing me to be part of your research and for providing the opportunity to do more. Jane Lassetter, PhD, thank you for keeping me on the writing straight and narrow. You have each strengthened my determination to keep pressing forward. Thank you for always being there to help along the way.

I would also like to thank the Brigham Young University College of Nursing faculty for providing a stellar education. Thanks to the Brigham Young University's Graduate Research fellowship program and to the College of Nursing Scholarship fund for the financial support necessary to complete this work. Additional thanks to Sondra Heaston, Stacie Hunsaker, and the undergraduate nursing students who made it possible to complete this study. Special thanks to the Hogar de Cristo foundation in Ecuador and all of the students who participated in this study. A big thanks goes to my dear family for always believing in me and helping to make my dreams come true!

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Introduction

Despite iron being one of the most common elements in the earth, iron deficiency anemia (IDA) is one of the most prevalent nutritional disorders in the world (Sanou & Ngnie-Teta, 2012). Anemia is a decrease in the number of red blood cells or hemoglobin (Hgb), which leads to a reduced capacity of blood to carry oxygen (National Heart, Lung and Blood Institute, 2012). Approximately 25% of the world's population has anemia, and iron deficiency causes about 50% of the cases (Benoist, McLean, Egli, & Cogswell, 2008). Factors that contribute to the development of IDA include insufficient dietary intake of iron, vitamin deficiencies (folate, Vitamin A, B^{12}, C, and D), parasitic infections, (Milman, 2011), inflammation, genetic factors, and reduced bioavailability of micronutrients (Righetti, Koua, Adiossan, Glinz, Hurrell, N'Goran, … & Utzinger, 2012).

The reduced oxygen carrying capacity associated with anemia can have adverse physiological effects, resulting in particularly worrisome symptoms in the developing brains of children. Symptoms of an anemic brain include weakness, fatigue, and the inability to concentrate, all of which lead to a decline in cognitive function (Khedr, Hamed, Elbeih, El-Shereef, Ahmad, & Ahmed, 2008). Long-term effects of anemia can result in learning disabilities, often yielding less promising work opportunities in the future and diminished overall well-being in adulthood (Paxson & Schady, 2007; Righetti et al., 2012).

Anemia in childhood can mark the beginning of a trajectory toward cognitive deficits in adulthood, but how IDA creates those alterations in cognitive development is not completely understood. Animal studies have found that neurotransmitter metabolism might be affected. For example, studies using rats found that iron deficiency resulted in reduced myelination of neurons (Beard, 2003), which slowed neuron signal transfer. Other rodent research found IDA might affect the dopaminergic system and certain enzymes needed for the development of brain areas used for cognitive function, such as the hippocampus (Lozoff & Georgieff, 2006). These findings suggest it is important to recognize and seek treatment for IDA before periods of rapid brain growth and development (Bryan et al., 2004) to prevent these cognitive deficits.

Studies have shown that by treating IDA, especially early on in life, cognitive function might be improved (Congdon, Westerlund, Algarin, Peirans, Gregas, Lozoff & Nelson, 2012; Falkingham, Abdelhamid, Curtis, Fairweather-Tait, Dye, & Hooper, 2010; Kapil, Sachdev, Dwivedi, Pandey, Upadhyay, & Sareen, 2013). The majority of these studies have been done with infants, with few studies focusing on school-aged children (Beard, 2003).

Anemia in Ecuador

A charity organization in Ecuador previously identified problems in the growth and development of Ecuadorian school-age children. This organization asked the nursing college at a private university in the western United States to assess school-aged children in Guayaquil, Ecuador for anemia. Anemia defined by the World Health Organization (WHO) is a hemoglobin level less than 11.5 g/dL in children 5 to 12 years old (Benoist et al., 2008). Using this criterion, researchers found anemia rates over 40% among school-aged children in Guayaquil (S. Palmer, personal communication November 2013), indicating a much higher rate than the 25% global anemia prevalence reported by WHO (Benoist et al., 2008). As a next step, researchers wanted to determine what might contribute to the diminished growth rate and cognitive development in these children. Because anemia has been identified as a significant problem among Ecuadorian children, it is important to determine the relationship between anemia levels and cognitive function.

The purpose of this study was to evaluate the relationship between anemia levels, cognitive function, and demographic characteristics in school-aged Ecuadorian children from 5 to 11 years old.

Methods

Design

A descriptive correlational, cross sectional design was used to study the relationship between the level of anemia, level of cognitive function, and demographic data among Ecuadorian school-aged children (from 5 to 11 years old).

Setting

The study was conducted in a poverty stricken area in Guayaquil, Ecuador. The 570 students who attend this school are between 5 and 11 years old.

Sample

All students attending the school were eligible, except those with known mental disabilities. To obtain a power of .80, a correlation of .30, and an alpha of .05, it was estimated that a sample size of 88 was needed.

The sample size obtained was 175 children from the following grade levels; 20 (11.4%) second grade students, 46 (26.3%) third grade students, 39 (22.3%) fourth grade students, 29 (16.6%) fifth grade students, and 41 (23.4%) sixth grade students. The average age of participants was 8 years old with a standard deviation of 1.6. Seventy-two (41.1%) were male, and 103 (58.9%) were female.

Monthly household incomes were reported by category with the majority of student households (66.3%) reporting income between \$200 to \$400 dollars per month. Descriptive statistics for demographic characteristics and study variables are reported in Table 1.

Procedures

Approval to complete this study was obtained from the University's Institutional Review Board (IRB) and the sponsoring charity agency in Ecuador. A liaison from the sponsoring charity explained the purpose of the study and potential risks and benefits to the parents and children and answered their questions before obtaining parents' signed consent and the children's verbal assent. Data collection began in spring 2014 by research assistants who administered the cognitive function and anemia tests in a vacant class room.

Prior to administering the tests, research assistants were trained during an orientation meeting on instrument standardization procedures to maximize reliability. The Spanish speaking research assistants were instructed on proper administration techniques for the Raven's Coloured Progressive Matrices (CPM) test to measure cognitive function, such as maintaining the correct order of questions and minimizing distraction during the test. The research assistants used a dialogue script in both English and Spanish, taken directly from the CPM instruction manual, to ensure test questions were asked in an identical manner for each participant. Two research assistants rotated around the room during administration to clarify questions about the test.

Research assistants were also oriented on how to use the STAT-Site® MHgb Meter to ensure consistency of Hgb measurement in the children. Quality controls were run before testing each morning, according to STAT-Site® protocol. Each participant's finger was cleansed with an alcohol wipe and air dried before the blood sample was obtained. A lancet was used to draw the blood, and the blood sample was placed on the test strip. A Band-Aid was then placed on the participant's finger, and the test strip was placed into the STAT-Site® Meter to obtain the Hgb reading.

At the school, two Spanish-speaking research assistants administered the CPM during class time. In order minimize the effect of fear on the children's performance during the cognitive function test, the Hgb testing was done on a separate day from CPM administration. Ten students at a time were administered the CPM. Students were placed at adequate distance apart so they could not share any information. The two Spanish-speaking research assistants oversaw both the administration of the CPM and the hemoglobin testing to ensure similarity in application of both tests. Immediately before administration of the Hgb test, the child was asked whether he or she had eaten breakfast that morning and whether he or she had been sick or had diarrhea in the last three days.

Participants were identified by a code number, and only the researchers had access to their names. Study results were presented in aggregate form to ensure participants' confidentiality.

Instruments

Raven's Coloured Progressive Matrices. The Raven's Coloured Progressive Matrices test measures cognitive function and nonverbal intelligence and was selected because it is language independent. It is designed for children ages 5 to 11 years (Raven, Raven, & Court, 1998). It is comprised of 36 multiple choice questions listed in order of progressive difficulty. Each question involves identifying patterns, and participants are asked to choose the missing elements that complete the pattern. The test was not time limited and students were given as much time as needed to complete the test. Internal consistency reliability ranges from .85 to .93, and concurrent validity has been established with correlations of nonverbal and general intelligence tests ranging from .5 to .8 (Campbell, Brown, Cavanagh, Vess, & Segall, 2008). Internal reliability estimates for our study were .895.

Hemoglobin. Hemoglobin levels were measured using participants' capillary blood samples from a finger prick utilizing the STAT-Site® MHgb Meter. Venous blood is considered a more valid method to obtain hemoglobin levels, yet the use of venous blood is not always feasible in such settings because it requires a venous access rather than a finger prick. Capillary blood appears to be a valid option as a correlation between venous blood Hgb level and capillary blood hemoglobin level (r^2 = .646). In addition, no significant differences in Hgb levels (p = 0.372) have been found whether using venous blood levels or capillary levels (Gomez-Simon et al., 2007).

Demographic questionnaire. Each student's parent completed a demographic questionnaire prior to test administrations. Questions included information about the student, including age, gender, height, weight, grade level, whether the child had been to a doctor in the last three months, and whether the child had been given medication to treat intestinal parasites in the last three months. There were also questions about the family, including monthly household income, number of people in the household, and type of drinking water in the home.

Data Analysis

Data were entered into Microsoft Excel, cleaned, double checked for accuracy, and then analyzed with the Statistical Package for the Social Sciences (SPSS) program, version 22. Descriptive statistics were also used to describe the sample's demographics. Correlational statistics were used to determine significance and magnitude of the relationship between (1) the level of anemia, (2) the level of cognitive function, and (3) demographic data. Pearson product moment correlation coefficients between outcome variables and demographic characteristics were calculated. Relationships between demographic characteristics and outcome variables were also assessed using multiple regression. Both parametric and nonparametric correlational statistics were used, based on the level of data.

Results

Hemoglobin and CPM scores

Mean and *SD* Hgb levels were 12.3 and (1.5) g/dL respectively. Mean and *SD* CPM scores were 21.9 and (6.8) respectively. Pearson product moment correlations between Hgb levels, CPM scores and demographic variables of age, height, and weight were calculated. Correlations are reported in Table 2.

Hemoglobin levels were not significantly correlated with any of the other variables. Cognitive function had significant positive correlations with age, height, and weight, with older students scoring higher in cognitive function. Age, height, and weight were also significantly positively correlated with each other, with older students being taller and weighing more.

Multiple regression was conducted to assess relationships between demographic variables and cognitive function. Backward stepwise regression was used to remove non-significant predictor variables from the equation. Because age, height, and weight were significantly positively correlated, only age was included to avoid issues with multi-collinearity. Predictors included in the analysis were age, gender, Hgb, household monthly income, number of people in household, whether student ate breakfast that morning, whether s/he had seen doctor in the last three month, and whether s/he had experienced diarrhea, or taken anti-parasite medication within the last 3 months. Regression coefficients for the final regression equation are reported in Table 3. Only household monthly income and age were significant predictors of cognitive function. The older the student, the higher the cognitive function scores. The greater the household monthly income, the higher the cognitive function scores.

Discussion

Despite having an adequately powered sample, no relationship between Hgb levels and cognitive function was found. Several factors might have influenced this finding. Because some of the CPM tests were given just prior to the students recess break, some students might have rushed through the test to ensure more play time, resulting in them performing less well on the test. It is also possible that some students may have enjoyed the intellectual challenge and spent more time trying to solve the problem, resulting in a higher score. Both situations could have impacted the measurement error, resulting in the inability to measure the true score. Another explanation may be that the cognitive function test used was unable to detect the cognitive function changes most sensitive to low or high Hgb levels. Some researchers have suggested the need to standardize the measurement of cognition as some tests may measure only specific aspects of cognitive function (Petranovic, Batinac, Petranovic, & Ruzic 2008).

Like our study, another cross-sectional study that also used the CPM failed to demonstrate a significant relationship between anemia levels and cognitive function (Dissanyake, 2009). However, other studies using the CPM have shown a direct relationship between lower Hgb levels and lower cognitive function scores (Bandhu et al., 2003; Bandhu et al., 2011; Pollitt et al., 1989).

One explanation for variance in findings is that anemia is likely not the only cause of poor cognitive function. It is possible that cognitive function exists as a variable commonly found in combination with many other factors including deficiencies in macro and micronutrients, environmental factors, and falling behind socially (Bandhu,et al., 2011; Grantham-McGregor & Ani, 2001). One meaningful finding of our study was that household monthly income and age were significant predictors of cognitive function. These results support cognitive function being a result of multiple interrelated factors. It was not surprising that age predicted cognitive function. Older children are further along in cognitive development and typically have more education, life experience, and developmental skills. However, the effect of higher household income on cognitive function requires additional exploration of interrelated factors. For example, higher household income might be due to more educated parents, who create a home environment that encourages cognitive development. Another possibility is that financial stability might allow for additional enriching extracurricular activities or more time for parents to assist students with academic studies. Another consideration is that students from families with higher income have long term access to well-balanced diets, which are generally more expensive (Jones, N. R. V., Conklin, A. I., Suhrcke, M., Monsivais, P., 2014). Students with healthier diets are more likely to have nutritional sources of iron and the micro and macronutrients vital for cognitive development.

Similar to our study, Paxson and Schady (2007) also found a relationship between socioeconomic status (SES) and cognitive function. They evaluated the roles of wealth, health, and parenting in 3,000 underprivileged preschool-aged children from Ecuador, and found a robust association between cognitive function and SES. The association was larger with increased age of the child, suggesting that the effect of higher SES on cognitive development is cumulative and that poorer children fall increasingly behind those children from a higher SES. Paxson and Schady also found a positive correlation between wealth and measures of parenting and child health. For example, the correlation between wealth and whether the parent read to the child was 0.39; the correlation between wealth and the child's Hgb level was 0.24 (Paxson & Schady, 2007).

Limitations

This study's findings are limited to a convenience sample in one school, which might limit generalizability to other settings in Ecuador and elsewhere. In addition, the instrument selected to measure cognitive function (CPM) is nonverbal in nature and could lack the sensitivity needed to detect subtle changes in cognitive function and the full spectrum of intellegence. Furthermore, timing of its administration prior to recess for some students might limit the validity of findings. Finally, not all factors that could impact cognitive function were measured. Other factors might include parental education, quality of parenting, and value placed on education in the home.

Implications

Although nutritional status has been the primary focus in international studies due to the severity of the problem, other factors are important to consider as well. Findings of our study and and Paxson and Schady (2007) suggest that increasing the annual household income would be beneficial and could result in increased cognitive function in children. For example, Paxson and Schady (2007) found that there was a relationship between wealth, health, and parenting quality, to the point of implying that wealth has a causal relationship with children's cognitive function and development. This suggests that finding ways to increase SES might also result in an increase in health, enhanced parenting effectiveness, and optimal cognitive function in children. For example, providing microfinancing has the potential to help poor people grow income-generating projects. Also providing education which supports employment opportunities may help. In addition, studies are needed that evaluate the effect of parenting skills, the value placed on education in the home, and the amount of time spent with children in activities that help develop their cognitive function, such as reading and helping with homework. Findings of these studies can then be used to develop interventions to optimize effective parenting.

It is important to break the poverty cycle because this cycle can perpetuate a lack of cognitive development from generation to generation. Children with lower socioeconomic status may fail to have effective cognitive develop which impacts adulthood and in turn may affect their own children in the future.

Additionally, alternative cognitive function tests or a combination of tests are important to investigate. The CPM test uses picture matrices, which is an ideal choice for an international study where language is an issue. However, cognitive function tests or a combination of tests that have greater sensitivity and can detect small changes are needed. This might include testing reading comprehension, mathematics, science, and verbal versus nonverbal intelligence.

Conclusion

Our study suggests that cognitive function in children is influenced by socioeconomic status. It is important to break the socioeconomic cycle and its influence on cognitive function. A lower household income can create a cycle because children from lower SES in developing countries grow up with poorer cognitive skills, which could lead to lower incomes in adulthood. This in turn might influence cognitive function and development of their own children perpetuating poverty across generations. Since socioeconomic status is modifiable, it is worthwhile to investigate methods to correct SES such as microfinancing to grow income-generating projects, job skill training, and education. Also it is important to investigate factors that may be related to SES and cognitive development such as quality of parenting, parental education, and time spent in the home on cognitive developing activities.

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Appendix A

Table 1

Demographic and Study Information

Characteristic	*N (%)*	*M (SD)*
Age (years)		8.0 (1.6)
Gender		
Male	72 (41.1%)	
Female	103 (58.9%)	
Height (centimeters)		124.2 (10.2)
Weight (kilograms)		27.0 (7.5)
Grade		
2	20 (11.4%)	
3	46 (26.3%)	
4	39 (22.3%)	
5	29 (16.6%)	
6	41 (23.4%)	
Breakfast		
Yes	165 (94.3%)	
No	10 (5.7%)	
Drinking Water (all that apply)		
Water from tank	9 (5.1%)	
Boiled water from tank	46 (26.3%)	
Bottled water	63 (36.0%)	
Other	73 (41.7%)	
Antiparasite pill last 3 months		
Yes	80 (45.7%)	
No	93 (53.1%)	
Diarrhea		
Yes	24 (13.7%)	
No	150 (85.7%)	
Seen doctor last 3 months		
Yes	100 (57.1%)	
No	74 (42.3%)	
Hemoglobin		12.3 (1.5)
CPM Score		21.9 (6.8)

Monthly Household Income		
	$0 - $50	3 (1.7%)
	$51 - $100	8 (4.6%)
	$101 - $200	20 (11.4%)
	$201 - $300	67 (38.3%)
	$301 - $400	49 (28.0%)
	$401 - $500	13 (7.4%)
	$501 - $600	4 (2.3%)
	> $600	1 (0.6%)
	missing	10 (5.7%)
Number in Household		4.9 (1.2)

Appendix B

Table 2

Correlations of Study Variables

Variable	1	2	3	4	5
1 Hemoglobin (units)		0.001	0.146	0.121	0.053
2 CPM Score			0.536**	0.439**	0.362**
3 Age				0.808**	0.641**
4 Height (cm)					0.811**
5 Weight (kg)					

* Significant at $\alpha = .05$ level

** Significant at $\alpha = .01$ level

Appendix C

Table 3

Regression Coefficients for Predictors of Cognitive Function

Variable	B	SE	Beta	t	p	95% CI
Constant	-1.07	2.76		-0.39	.70	-6.5 – 4.4
Monthly Income	0.94	0.38	0.16	2.5	.01*	.2 – 1.7
Age	2.36	0.27	0.56	8.6	.000*	1.8 – 2.9

* Indicates significant result