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ORIGINAL PAPER

Learning disabilities and allergies among children and adolescents: are they linked?

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ABSTRACT

Introduction: The main purpose of this work is to study the incidence of learning disabilities among children and adolescents during the period 2009–2018 in the United States and to find not only statistically significant predictors but also a possible association between learning disabilities and allergies.

Material and methods: The statistical methods used to derive the results of this work were the χ^2 test and one-way analysis of variance (ANOVA), in order to check the statistical significance of learning disabilities in relation to socio-economic factors of children and adolescents. In addition, a multivariate logistic regression analysis was used with the odds ratio (OR) to find statistically significant prognostic factors for learning disabilities. The Pearson correlation coefficient was used to find the relationship between learning disabilities and allergies.

Results: According to multiple logistic regression analysis, children and adolescents whose families are in a poor financial situation, family income less than $35,000, and health insurance coverage "Medicaid" have two times higher risk of the occurrence of learning disabilities. In addition, children who have neither mother nor father also have higher risk for the occurrence of learning disabilities. Finally, a statistically significant relationship was found between the number of cases of learning disabilities and food allergies.

Conclusions: The results of this study describe for the first time the importance of deprivation (of family and financial comfort) as a primary prognostic risk factor for learning disabilities in children. It has also been found that not only deprivation but also death of the parents play a key role in the increased risk of developing these disorders. Moreover, a link has been found between learning disabilities and food allergies.

KEY WORDS:

prognostic factors, socioeconomic factors, learning disabilities, allergies.

INTRODUCTION

Learning disabilities (LD) are disorders in childhood, characterised by significant impairments in reading (dyslexia), writing (dysgraphia), and mathematics (dyscalculia) [1]. Difficulties in word recognition, reading comprehension, and inattention are some of the symptoms that the child is faced with [2, 3]. The school grades of children with LD are observed to be low in spite of their normal intelligence (IQ greater than or equal to 90) and sensory abilities [4, 5]. The prevalence of LD is approximately 14% among children and adolescents in the US [6]. Preterm birth, neonatal complications, language delay, and epilepsy are important risk factors for learning disabilities in children [7–9]. Moreover, home environment and family stresses, health risks, as well as socioeconomic status have also been reported [10].

Low socioeconomic status (SES) has been linked not only with poor physical health but also with mental health in childhood [11–19]. In particular, children from

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low socioeconomic backgrounds are 1.18–3.34 times more likely to have mental health problems than their peers [19]. The association between LD and SES appears to be complex because symptoms are associated with interactions between genes and the environment during development [20]. Other factors that have been suggested as being responsible include maternal mental health [21], substance abuse [22], and the parent's involvement (or lack thereof) in raising their child [23].

Prior studies have found a positive association of allergies with learning disabilities [24, 25], but no clinical evidence of causation. Allergy is an adverse reaction caused by inhalants such as pollens and animal dandruff. Allergies, however, are caused not only by inhalation but also by food and chemicals present in the environment. Allergies affecting the brain can cause the child to have difficulty concentrating, easily detaching and eventually exhibiting unstable learning patterns. Allergies can be a major cause of a child's learning difficulties at school as they suffer from nasal impurity, watery eyes, fatigue, and headaches. For this purpose, this work studies learning disabilities and allergies in the United States in the period 2009–2018 in order to find statistically significant predictors for LD and a possible link between LD and allergies.

MATERIAL AND METHODS

The data used in this work come from the National Health Interview Survey (NHIS) dataset [26] and cover the period 2009–2018. The target population for NHIS is the civilian noninstitutionalised population of the United States. NHIS data are collected through personal household interviews. The main objective of NHIS is to monitor the health of the U.S. population through the collection and analysis of data on a broad range of health topics. Each year, a representative sample of households across the country is selected for NHIS using a multistage cluster sample design. Trained interviewers from the U.S. Census Bureau visits each selected household and administers the NHIS in person. To identify the children with learning difficulties, each household was asked to answer the following question: "Has a representative from a school or a health professional ever told you that [child's name] had a learning disability?". The total number of children examined was 617,012, while the number of children and adolescents with LD was 47,548. Moreover, in the geographic classification of the U.S. population, states are grouped into four regions used by the U.S. Census Bureau:

- Northeast: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania,
- Midwest: Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska,
- South: Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky,
- Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas,
- West: Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

The statistical methods used to extract the results of this work are the χ^2 test for categorical and one-way analysis of variance (ANOVA) for continuous variables, in order to check the zero hypothesis that the average of children and adolescents in the United States with LD did not differ according to their socio-economic characteristics such as gender, age, race, origin, parent's education, family income, poverty status, health insurance coverage, current health status, family structure, place of residence, and region. Factors that determine the prevalence of LD were assessed by using multiple logistic regression analysis. To assess the predictors of LD, data were used regarding children with a new diagnosis of LD compared to a matched cohort of children without LD. In particular, the control group was the group of children without LD with the same socioeconomic characteristics as the group of children with LD. Predictors were represented using the OR and 95% confidence intervals, and $p < 0.05$ was considered statistically significant. More specifically, the odds ratio was used to determine whether a particular characteristic was a risk factor for learning disabilities, and to compare the magnitude of various risk factors for that outcome. An OR > 1 means that the characteristic was associated with higher odds of outcome, and an OR < 1 means that the characteristic was associated with lower odds of outcome. Pearson correlation coefficient was used for the relationship between LD and allergies for the period 2009–2018. The study was carried out using IBMSPSS 25 software package for Windows.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

RESULTS

As shown in Table 1, there is a statistically significant difference in the number of LD children in relation both to gender and age, occurring mainly in males (63.2%) in the age group 12–17 years (50.4%), while the most common origin and race are White (79.1%) and not Hispanic or Latino (42.1%). Most children with learning disabilities have parents with more than a high school diploma (62.1%) and excellent or very good current health status (63%). Moreover, most families whose children have LD are not poor (43.6%), with a family income of $35,000 or more (36.2%) and Medicaid health insurance coverage

TABLE 1. Results of χ^2 and one-way ANOVA test

Characteristics	Number of children with LD	Percentages	*p*-value
Gender			< 0.001
Male	30,061	63.2	
Female	17,487	36.8	
Age			< 0.001
3–4	2,420	5.1	
5–11	21,177	44.5	
12–17	23,952	50.4	
Race			< 0.001
White	35,111	79.1	
Black or African American	8,267	18.6	
Asian	983	2.2	
Origin			< 0.001
Hispanic or Latino	10,570	12	
Mexican or Mexican American	6,607	7.5	
Not Hispanic or Latino	36,980	42.1	
White, single race	25,984	29.6	
Black or African American, single race	7,676	8.7	
Parents' education			< 0.001
Less than a high school diploma	6,940	15.4	
High school diploma	10,157	22.5	
More than a high school diploma	27,965	62.1	
Family income			< 0.001
Less than $35,000	19,318	27.6	
$35,000 or more	25,353	36.2	
$35,000–$49,999	5,531	7.9	
$50,000–$74,999	6,975	10.0	
$75,000–$99,999	4,388	6.3	
$100,000 or more	8,460	12.1	
Poverty status			< 0.001
Poor	13,435	29.5	
Near poor	12,209	26.8	
Not poor	19,864	43.6	
Health insurance coverage			< 0.001
Private	19,597	41.5	
Medicaid	23,999	50.8	
Other coverage	1,154	2.4	
Uninsured	2,526	5.3	
Current health status			< 0.001
Excellent or very good	29,937	63.0	
Good	13,196	27.8	
Fair or poor	4,401	9.3	

TABLE 1. Cont.

Characteristics	Number of children with LD	Percentages	*p*-value
Family structure			< 0.001
Mother and father	26,828	56.4	
Mother, no father	16,317	34.3	
Father, no mother	2,006	4.2	
Neither mother nor father	2,396	5.0	
Place of residence			< 0.001
Large MSA (population size 1 million or more)	24,738	52.0	
Small MSA (less than 1 million)	15,130	31.8	
Not in MSA	7,681	16.2	
Region			< 0.001
Northeast	8,895	18.7	
Midwest	10,835	22.8	
South	17,719	37.3	
West	10,102	21.2	

LD – learning disabilities, MSA – metropolitan statistical area

(50.8%). In addition, most children with LD have both mother and father as a family structure (56.4%). Finally, the region with the most frequent occurrence of LD was the south (37.3%), with a population size of one million or more (52.0%).

Table 2 shows the multiple logistic regression analysis and odds ratios in order to find the predictors of the occurrence of LD. As shown in Table 2, all prognostic factors are statistically significant ($p < 0.05$). According to multiple logistic regression, the risk of LD is significantly higher with male gender (odds ratio [OR 1.71], age 12–17 years old [OR 1.0], Black or African American race [OR 3.0], and "Less than a high school diploma" parents' education status [OR 1.5]). In addition, the risk of LD is significantly higher with family income less than $35,000 (OR 2.3), poverty status "poor" (OR 2.0), health insurance coverage "Medicaid" (OR 1.8), and current health status "Fair or poor" (OR 1.0). Children who have neither mother nor father have almost two times higher risk for the occurrence of LD (OR 1.5). Finally, the risk of LD is significantly higher in the region "Northeast" (OR 1.3) and place of residence "not in a metropolitan statistical area" (OR 1.0). Figure 1 shows the trend in both LD and allergies during the period 2009–2018 in the United States. There is an increasing trend in the appearance of LD, and food and skin allergies but a decreasing trend in the appearance of respiratory allergies.

Table 3 shows the Pearson correlation coefficient among the total number of LD and allergic patients for the years 2009 to 2018. The type of allergies that have been examined were food, respiratory, and skin allergies. As can be seen in Table 3, the incidence of learning disabilities is statistically significantly associated only with food allergies ($p < 0.05$). The Pearson correlation coefficient between the total number of LD and allergic patients is 0.58, which indicates that there is a correlation between LD and food allergies.

In order to confirm the link between LD and food allergies, a multivariate logistic regression analysis was also used for children with food allergies. As can be seen in Table 4, family structure plays a crucial role in the incidence of food allergies. In particular, children who have neither mother nor father have the highest risk for the occurrence of this type of allergy (OR 1.29). Moreover, the risk of food allergies is significantly higher with male gender (OR 1.03), age 12–17 years (OR 1.0), Black or African American race (OR 1.03), and fair or poor current health status (OR 1.0). Children whose families have more than a high school education status (OR 1.0), who are not poor (OR 1.0), and whose health insurance coverage neither was private or Medicaid (OR 1.42) also have an increased risk of having food allergies. Finally, the risk of food allergies is significantly higher in the region "Northeast" (OR 1.08) and place of residence "Small MSA" (OR 1.18).

Figure 2 represents the prognostic risk factors with the odds ratios for LD in children. As can be seen, race, family income, and family structure play a crucial role in LD, while these children are two-fold more likely to be males.

DISCUSSION

Increasing attention should be given to the prognostic factors that have the highest odds ratio. It is noteworthy that children whose families are in a poor financial situation are twice as likely to have learning disabilities. Moreover, family structure plays a crucial role in the incidence of LD. Children who have neither mother nor fa-

TABLE 2. Statistically significant predictors of learning disabilities in children using multivariate logistic regression

Characteristics	Children with LD	Controls	Odds ratio (95% CI)	*p*-value
Gender				< 0.001
Male	30,061	285,295	1.71 (1.67–1.74)	
Female	17,487	284,169	1.00	
Age				< 0.001
3–4	2,420	80,824	0.28 (0.26–0.29)	
5–11	21,177	266,059	0.74 (0.72–0.75)	
12–17	23,952	223,745	1.00	
Race				< 0.001
White	35,111	424,057	2.5 (2.3–2.7)	
Black or African American	8,267	82,913	3.0 (2.8–3.2)	
Asian	983	30,201	1.00	
Origin				< 0.001
Hispanic or Latino	10,570	136,434	0.78 (0.75–0.8)	
Mexican or Mexican American	6,607	92,513	0.71 (0.69–0.74)	
Not Hispanic or Latino	36,980	434,196	0.85 (0.83–0.88)	
White, single race	25,984	302,728	0.86 (0.84–0.88)	
Black or African American, single race	7,676	77,259	1.00	
Parents' education				< 0.001
Less than a high school diploma	6,940	63,908	1.5 (1.4–1.5)	
High school diploma	10,157	101,156	1.4 (1.3–1.4)	
More than a high school diploma	27,965	Z385,959	1.00	
Family income				< 0.001
Less than $35.000	19,318	153,275	2.3 (2.2–2.3)	
$35,000 or more	25,353	373,386	1.23 (1.2–1.26)	
$35,000–$49,999	5,531	64,804	1.6 (1.5–1.6)	
$50,000–$74,999	6,975	88,497	1.3 (1.4–1.5)	
$75,000–$99,999	4,388	66,734	1.2 (1.14–1.23)	
$100,000 or more	8,460	153,354	1.00	
Poverty status				< 0.001
Poor	13,435	103,107	2.0 (2.0–2.1)	
Near poor	12,209	120,563	1.6 (1.6–1.7)	
Not poor	19,864	313,776	1.00	
Health insurance coverage				< 0.001
Private	19,597	320,083	0.9 (0.8–0.9)	
Medicaid	23,999	195,893	1.8 (1.7–1.9)	
Other coverage	1,154	15,287	1.1 (1.0–1.2)	
Uninsured	2,526	37,192	1.00	
Current health status				< 0.001
Excellent or very good	29,937	485,316	0.11 (0.10–0.11)	
Good	13,196	77,331	0.30 (0.29–0.31)	
Fair or poor	4,401	7,899	1.00	

TABLE 2. Cont.

Characteristics	Children with LD	Controls	Odds ratio (95% CI)	*p*-value
Family structure				< 0.001
Neither mother nor father	26,828	396,020	1.5 (1.4–1.6)	
Mother, no father	16,317	134,129	0.76 (0.72–0.8)	
Father, no mother	2,006	22,620	1.3 (1.3–1.4)	
Mother and father	2,396	17,866	1.00	
Place of residence				< 0.001
Large MSA (population size 1 million or more)	24,738	313,870	0.75 (0.73–0.77)	
Small MSA (less than 1 million)	15,130	159,785	0.9 (0.8–0.9)	
Not in MSA	7,681	73,310	1.00	
Region				< 0.001
Northeast	8,895	92,041	1.3 (1.3–1.4)	
Midwest	10,835	128,938	1.1 (1.1–1.2)	
South	17,719	211,029	1.1 (1.1–1.2)	
West	10,102	138,623	1.00	

LD – learning disabilities, MSA – metropolitan statistical area

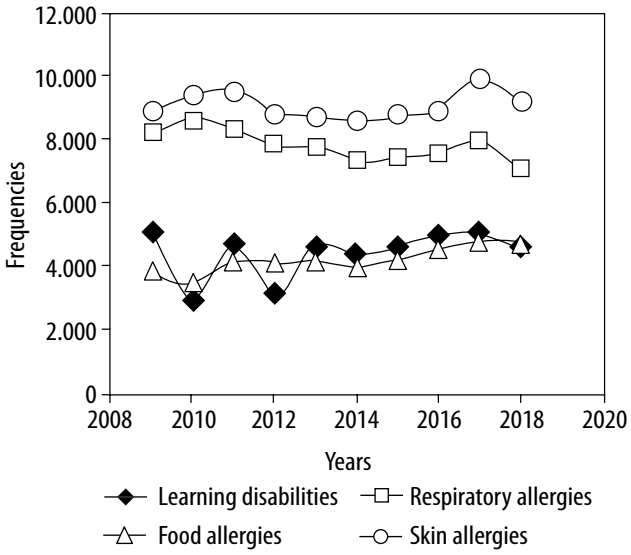

FIGURE 1. The trend in learning disabilities and allergies during the period 2009–2018 in the United States

ther have almost two times higher risk for the occurrence of LD. This can be explained by the fact that the complete lack of parents reflects problems in the psychopathology of the child. However, when combining the higher risk of children in low-income families, the complete lack of parents probably reflects the financial distress faced by these children.

It is also noteworthy that the socio-economic characteristics of children with learning disabilities with the highest odds ratio were the same as those of children with food allergies. Males, 12–17 years old, of Black or African American race are at greater risk for the occurrence of both learning disabilities and food allergies.

TABLE 3. Pearson correlation coefficient for the relationship between learning disabilities and allergies

Factor	Pearson correlation *r*	*p*-value
Learning disabilities	1	
Food allergies	0.58	< 0.05
Respiratory allergies	–0.30	> 0.05
Skin allergies	0.07	> 0.05

Deprivation of family proved to be the primary prognostic risk factor for both LD and food allergies, a fact that implies a possible link between LD and food allergies. One possible explanation is the presence of shared mechanisms among these allergic conditions in relation to learning disabilities. Allergic disease is caused by an acute immunological response that involves mast cells, basophils, and eosinophil activation by allergens cross-linking with immunoglobulin E (IgE) [27]. It then releases histamine and other inflammatory mediators such as cytokines or the eosinophil response [28]. The imbalance between inflammatory mediators and their compensatory molecules may affect central nervous system homeostasis, which may result in neurological disorders or possible LD development in the affected child [29]. Prior studies have been identified allergies as a barrier to learning [30]. It is of the utmost importance to acknowledge the seriousness of learning disabilities in children, which in return reflects the responsibility of underlying diseases such as allergies.

One limitation of the present study is that data were collected through personal household interviews. Non-disclosure such a disability by participants is possible.

TABLE 4. Statistically significant predictors of food allergies in children, using multivariate logistic regression

Characteristics	Children with food allergies	Controls	Odds ratio (95% CI)	*p*-value
Gender				< 0.001
Male	21,708	355,031	1.03 (1.01–1.05)	
Female	20,177	340,653	1.00	
Age				< 0.001
3–4	11,473	191,286	1.01 (0.98–1.03)	
5–11	16,544	270,692	1.00 (1.00–1.05)	
12–17	13,870	233,827	1.00	
Race				< 0.001
White	29,615	517,644	0.90 (0.86–0.94)	
Black or African American	6,683	101,878	1.03 (0.98–1.09)	
Asian	2,184	34,557	1.00	
Origin				< 0.001
Hispanic or Latino	8,035	170,117	0.72 (0.70–0.74)	
Mexican or Mexican American	4,662	114,996	0.62 (0.59–0.64)	
Not Hispanic or Latino	33,850	525,695	0.98 (0.96–1.01)	
White, single race	22,897	366,809	0.95 (0.92–0.98)	
Black or African American, single race	6,167	94,526	1.00	
Parents' education				< 0.001
Less than a high school diploma	7,386	77,344	0.55 (0.53–0.58)	
High school diploma	13,269	121,150	0.69 (0.67–0.71)	
More than a high school diploma	40,674	452,985	1.00	
Family income				< 0.001
Less than $35,000	11,380	199,848	0.81 (0.79–0.83)	
$35,000 or more	27,981	443,721	0.90 (0.88–0.92)	
$35,000–$49,999	4,831	79,451	0.87 (0.84–0.90)	
$50,000–$74,999	5,992	108,535	0.79 (0.76–0.81)	
$75,000–$99,999	4,880	80,030	0.87 (0.84–0.90)	
$100,000 or more	12,276	175,706	1.00	
Poverty status				< 0.001
Poor	7,488	136,426	0.85 (0.83–0.87)	
Near poor	8,776	149,118	0.91 (0.89–0.94)	
Not poor	23,789	370,373	1.00	
Health insurance coverage				< 0.001
Private	24,281	374,446	1.29 (1.23–1.35)	
Medicaid	13,928	257,391	1.08 (1.03–1.13)	
Other coverage	1,337	18,668	1.42 (1.33–1.53)	
Uninsured	2,140	42,694	1.00	
Current health status				< 0.001
Excellent or very good	32,258	587,531	0.29 (0.28–0.31)	
Good	7,451	96,404	0.41 (0.39–0.48)	
Fair or poor	2,178	11,757	1.00	

TABLE 4. Cont.

Characteristics	Children with food allergies	Controls	Odds ratio (95% CI)	*p*-value
Family structure				< 0.001
Neither mother nor father	1,069	21,712	1.29 (1.20–1.39)	
Mother, no father	10,498	164,258	1.28 (1.21–1.38)	
Father, no mother	994	25,728	0.78 (0.71–0.85)	
Mother and father	29,327	484,111	1.00	
Place of residence				< 0.001
Large MSA (population size 1 million or more)	23,081	379,924	1.14 (1.11–1.18)	
Small MSA (less than 1 million)	13,539	216,301	1.18 (1.14–1.22)	
Not in MSA	5,267	99,583	1.00	
Region				< 0.001
Northeast	7,431	112,051	1.08 (1.04–1.11)	
Midwest	9,069	157,643	0.93 (0.91–0.96)	
South	15,087	258,348	0.95 (0.92–0.97)	
West	10,298	167,771	1.00	

MSA – metropolitan statistical area

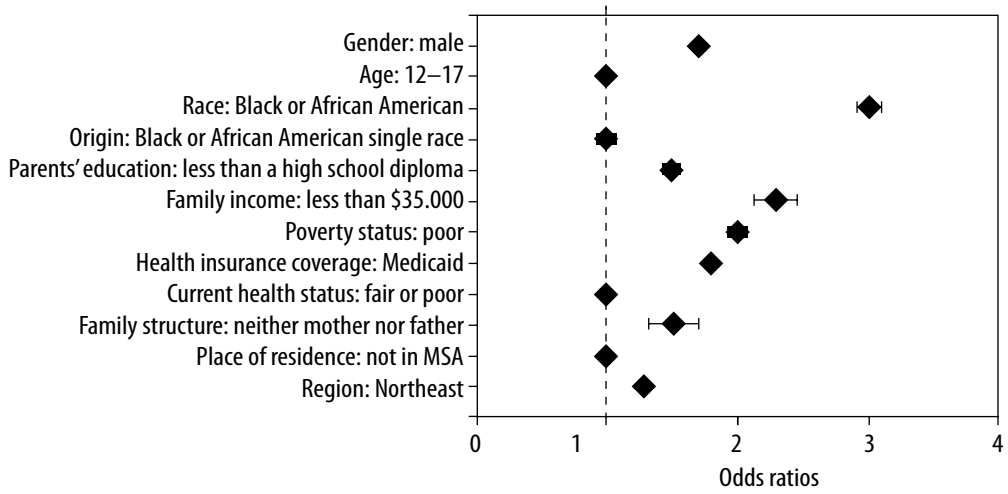

FIGURE 2. Prognostic risk factors with the odds ratios for learning disabilities in children during the period 2009–2018 in the United States

CONCLUSIONS

The importance of this study lies in the association of multiple socio-economic variables with learning disabilities in children 12–17 years old. More specifically, it was found that deprivation of the parents' financial security and education rapidly increases the risk of LD. It was also found that not only deprivation but also the death of parents plays a key role in the increased risk of developing these disorders. Moreover a link was found between learning disabilities and food allergies.

DISCLOSURE

The author declares no conflict of interest.

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