Left-Handedness in Children with Neurodevelopmental Disorders

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Abstract

Objective

This cross-sectional study investigated handedness in patients followed in a university-based child development clinic. The goal was to expand on previous research that identified left- and mixed-handedness in children and adolescents as being a risk factor for language problems, scholastic difficulties, and attention-deficit hyperactivity disorder (ADHD).

Methods

Young adult patients and parents of patients < 18 years completed a 13-item survey approved by the university's institutional review board. The items documented primary and comorbid diagnoses; age, gender, race and ethnicity of patients; age at first diagnosis; type of health care provider who diagnosed child; birth month; and hand preference for common activities of daily living (i.e., writing, eating, throwing ball, bathing, brushing teeth).

Results

996 surveys were completed from February 2016 through August 2016. Males comprised 73.3% (n = 731) of the study sample. The average age was 9.26 years ($\bar{x}$ males = 9.26, $\bar{x}$ females = 9.47, range 2 to 22 years). ADHD as a single diagnosis was the most common category (40.9%, n = 408), followed by ADHD with comorbidities (not including autism) (36%, n = 359). Autism coexisting with ADHD and other comorbid conditions comprised 10.3% (n = 103) of the sample. 82.1% (n = 813) of the total study sample preferred the right hand for writing, which is less than the 90% reported for the general population. Left-handedness was reported by 15.6% (n = 155) and mixed-handedness was reported by 2.2% (n = 22) of the sample.

Conclusions

Our findings support the possible interconnection among left-handedness/mixed-handedness, right hemisphere neurotransmitter dysfunction, and neurodevelopmental disorders such as ADHD, autism, and learning problem.

Keywords: neurodevelopmental disorders, hand preference, ADHD, autism, left-handedness

Introduction

Attention-deficit hyperactivity disorder (ADHD) affects approximately 11% of the pediatric population.[1] The prevalence of ADHD has remained fairly stable, compared to the increasing prevalence of autism, which was estimated to be 6.7 per 1,000 in 2000 and 14.7 per 1,000 in 2010.[2,3]

ADHD and autism share symptoms of impaired executive brain function. Executive brain function includes selection and perception of important information; manipulation of information in working memory, planning and organization; behavioral control; adaptation to changes; and decision making.[4] Children and adolescents with impaired executive function frequently experience challenges at developing goal-oriented behavior. They also have difficulty exhibiting feelings of empathy, changing current behavior based on insight, and planning further behavior according to the current environmental situation. They experience difficulty in formulating concepts, thinking abstractly, and recalling information through the use of memory aids.

The symptoms of executive function impairment are thought to be related to abnormalities in the frontal striatal circuits in individuals with ADHD, obsessive-compulsive disorder, depression and schizophrenia.[5,6] Right hemispheric dysfunction also has been implicated in executive function impairment,[7]suggesting differences in brain lateralization in individuals who have ADHD and executive function problems.[8] We were interested in learning if our patients with ADHD and histories of language problems and scholastic difficulties had significant mixed- or left-handedness, which could reflect differences in brain lateralization.

Patients and Methods

After obtaining IRB approval, we distributed a 13-question survey to parents of patients presenting to an ADHD/Child Development Clinic at an academic medical center in the Southeastern United States. Patients 18 years and older completed their own surveys, while parents completed surveys for those under the age of 18 years. Respondents consented to and completed the survey in 3 to 5 minutes while waiting to see a clinician. The survey questions asked respondents to select a primary diagnosis and any comorbid diagnoses, age and gender of patient, race and ethnicity of patient, age when the first diagnosis was made, provider who diagnosed child with the first diagnosis, month of birth, and hand preference for common activities (i.e., writing, eating, throwing ball, bathing, brushing teeth). Respondents deposited the completed surveys in a locked box at the clinic checkout station.

DSM-5 diagnostic classifications were used to stratify the study participants into groups: autism spectrum disorder (F84.0), ADHD (F90.0-F90.2), depression (F34.81)/anxiety (F93.0), and learning disabilities (F79.0). We also combined some diagnostic groups (e.g., ADHD plus autism and comorbid conditions such as sleep disorders, anxiety disorders) for analysis. Data were abstracted from survey responses and analyzed using descriptive, parametric and non-parametric procedures using SAS JMP Pro v.13.0.

Results

We collected 996 surveys over a six-month period. Males represented 73.3% (n = 731) of the study sample. The average reported age was 9.26 years ($\bar{x}$ males = 9.26, $\bar{x}$ females = 9.47, range 2 to 22 years). The racial breakdown among respondents was 63.8% (n = 633) white, 29.8% (n = 296) black, 0.4% (n = 4) Asian, and 5.9% (n =

135) identified as Hispanic. Diagnostic categories associated with the population are provided in Table 1.

Among respondents, the average age of first diagnosis was 5.1 years (SD = 2.3). Yet, there were significant differences with the sample based on diagnosis. For example, those patients who had a diagnosis of autism alone were more often diagnosed at a younger age, whereas those with depression/anxiety (DA) were more often diagnosed later. There was no significant variation in the age of diagnosis in the other diagnostic categories.

We also explored the type of health care providers who made the initial diagnoses, as research indicates that 75% to 85% of initial ADHD diagnoses are made in primary care settings.[9] Of the 996 surveys, 933 respondents answered this question (Table 2). Within our sample, pediatricians (49.5%, n = 461) were listed most commonly as making an initial non-specific diagnosis. They were followed by developmental pediatricians (14.6%, n = 136) and some combination (18.1%, n = 168) of providers (e.g., pediatrician and psychologist). The paucity of child psychiatrists in the clinic's referral area was reflected in the responses, with only 11.1% (n=103) of the patients being initially diagnosed by psychiatrists.

The proportion of our study population that preferred their right hand for various activities of daily living varied from 82.2% (n = 808) for writing to 76.7% (n = 750) for bathing (Table 3). This was less than expected, based on prior research establishing that 90% of the general population is right-handed. Thus, the relative risk (RR) in this study group of being "non right-handed" (i.e., left- or mixed-handed) was 1.62 (95% confidence interval), which demonstrates some difference between the study group and what has been reported within the general population.

Discussion

Individuals' brains typically have a dominant hemisphere, which is reflected in their hand dominance. Handedness, the individual preference for use of a hand (i.e., the dominant hand), is a continuous variable ranging from strong left to strong right.[10] There are four types of handedness: left-handedness, right-handedness, mixed-handedness, and ambidexterity.

Approximately 90% of the world population is right-handed.[11,12] Left-handedness occurs in 9% to 10% of individuals and is somewhat more common in men than women.[13] Cross-dominance or mixed-handedness is the change of hand preferences between tasks. This occurs in an estimated 1% of the world population.[10(25)] Ambidexterity is rare, but it can be learned. Truly ambidextrous individuals can perform any task equally well with either hand. People who learn this skill still tend to favor their originally dominant hand. Finally, the terms *ambilevous* and *ambisinister* are used to describe people who demonstrate awkwardness with both hands.

Handedness is thought to be polygenic, with at least 40 loci contributing to determining this trait. The heritability of handedness is approximately 24%. If both parents of a child are left-handed, there is a 26% change of that child's being left-handed.[14] We did not ascertain hand preference in the parents of our study respondents.

Prenatal development has been linked to handedness, with in utero thumb sucking being related to postnatal handedness. Research has posited that asymmetric prenatal positioning may create asymmetric stimulation of the vestibular system, which plays a role in the development of handedness.[15] A Swedish research team examined the relationship between prenatal ultrasound scans and maternal distress during pregnancy with subsequent child handedness. The study demonstrated that prenatal exposure to maternal depressive symptoms and critical life events was associated with increased risk for child non-right-handedness and mixed handedness, after adjustment for parity, maternal age, birth outcomes, infant sex, and parental handedness. In this Swedish study, non-right- and mixed-handedness, rather than left-handedness, were associated with increased risk of language difficulties and ADHD symptoms at five years of age, after adjustment for smoking during pregnancy, depressive symptoms, and critical life events. The researchers suggested that mixed-handedness, which reflected atypical brain laterality, could be a marker of both the severity of prenatal exposure to maternal distress and of increased risk for childhood ADHD symptoms.[16]

The human brain is structurally and functionally asymmetric. Brain asymmetry, language, and handedness are believed to be closely linked.[17] Language processing is a function of the left hemisphere, which is typically dominant in right-handers. Left-handed people may exhibit a right-dominant or distributed pattern in the brain, a cross-wiring that may make them more prone to impaired learning or functioning and possibly at increased risk for brain disorders.[18] Atypical laterality (i.e., less asymmetry or atypical brain lateralization and non-righthandedness) is associated with language impairment and some neuropathologies related to mental illness in adults.[19,20]

Left-handedness and mixed-handedness have been identified as risk factors in populations with mental health conditions, including ADHD. A number of studies conducted prior to ours reported higher than expected rates of non-right-handedness in children with ADHD.[21] Non-right-handedness may explain the presence of comorbid learning and motor difficulties in children with ADHD.[8(315)]

There are many negative connotations (e.g., clumsy, awkward, unlucky, insincere, sinister) with the phrase “left-handed.” Writing in the Latin alphabet may be more difficult may be more difficult with the left hand than the right, because moving one’s hand away from its side toward the other side of the body can cause smudging if the outward side of the hand is allowed to drag across the writing. Writing Chinese characters is more difficult with the left hand due to the importance of stroke order, a challenge that is not encountered by right-handed individuals. Conversely, right-to-left alphabets (e.g., Arabic, Hebrew) are easier to write with the left hand.

A 2014 study by the National Bureau of Economic Research found that left-handed people earn 10% to 12% less over the course of their lives than right-handed people, which was attributed to higher rates of emotional and behavioral problems in left-handed people.[22] Yet, disadvantages are not necessarily uniform. For example, in many athletic activities, being left-handed can be advantageous. Left-handed players often predominate in interactive sports (e.g., table tennis, badminton, cricket, tennis).[23] In one-on-one sports (e.g., tennis, boxing, fencing, judo), left-handed players play 90% of their games against right-handed opponents and are well-practiced at dealing with this asymmetry. Right-handers play 90% of their games against other right-handers and when confronted with left-handers, right-handers are often less practiced. A disproportionately high number of left-handers participate in sports in which direct one-on-one action predominates. Left-handed pitchers are a valued, limited commodity in major league baseball. Teams devote time, energy, and monetary resources to ensure they acquire their share of left-handed pitchers during annual drafts.[24]

Research conducted in the late 1990a examined whether ADHD was uniquely associated with non-right-handedness or associated with anomalous lateralization across domain. Studies documented that ADHD was "associated with anomalous laterality but also indicated that non-right-handedness was not an adequate characterization of this relationship."[8(315)]

More recent research documented that mixed-handedness is associated with atypical cerebral laterality. A longitudinal evaluation of more than 7,000 children and adolescents noted that mixed-handed children, when compared to their right-handed peers, had a twofold increase in odds of having difficulties with language and scholastic performance at the age of eight years. Mixed-handed adolescents experienced a twofold increase in odds of having difficulties in school with language and with ADHD symptoms. Mixed-handed children were also more likely to have scores indicating psychiatric disturbance, including ADHD symptoms (inattention but not hyperactivity).[25]

The relevance of brain laterality for mental health in children is less well studied, particularly in ADHD. Core ADHD symptoms are related to brain function impairment. Right hemispheric dysfunction has been noted in children with ADHD.[26] The right parietal lobe is involved in attentional networks,[27] spatial attention, and working memory[28] tasks in which children with ADHD are frequently deficient.[29]

Our study focused on neuro-developmental and neuropsychiatric disorders. The primary objective of our study was to identify handedness correlating to the studied conditions (e.g., autism, ADHD, learning difficulties). Taken as a whole, our study group consisted of fewer right-hand dominant individuals (82.2% vs 90%) and more non-right-hand dominant individuals (14.3% left-handed, 1.8% mixed-handed) than the 10% reported in the general population. The relative risk (RR) of being left0handed or mixed-handed was 1.62 compared to the general population.

Each of our eight diagnostic subgroups (ADHD only, autism only, learning disabilities only, depression/anxiety only, ADHD plus autism, ADHD plus comorbidities, autism plus comorbidities, and autism/ADHD/comorbidities) reported higher-than-average left-handed and mixed-handed dominance (range 11% in ADHD to 25% in autism). Mixed-handedness was highest in our learning disability group (7%).

Previously published studies found non-right-handedness to be a risk factor for neurobehavioral difficulties and poor scholastic achievement[30] and mixed-handedness to be a higher risk factor for ADHD symptoms. Previous laterality studies in mental health pointed to asymmetry in terms of anatomy and function. Our results confirm previous study findings of non-right-handedness being more common in patients with mental health problems than in the general population.

A limitation of our study was the relatively small sample size (n = 996), a convenience sampling strategy, and the focus on a singular clinic without a control or reference group. However, we believe our sample was representative of the general population in our referral area.

Conclusion

Recognition of mixed-handedness could aid in the identification of children who are at risk for language, scholastic, and mental health problems. Identification of early risk factors helps to structure future academic planning and intervention needs and is very useful for clinicians and early intervention services and educators. More neuropsychology studies are needed in conditions such as autism and ADHD. Neuroimaging and neuropsychological evaluation are especially important to help clarify neuro-circuitry in individuals with these conditions.

Conflict of interest: None

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Table 1: Diagnostic categories associated with study respondents

Diagnosis	N	%	$\bar{x}$ Age at Time of Diagnosis (SD)	% Female (N)
ADHD	408	40.9	5.5 (2.1)	24.0 (98)
ADHD+ASD	55	5.5	4.4 (1.8)	18.2 (10)
ADHD+Comorbidity	359	36.0	5.1 (2.2)	32.1 (112)
ASD	25	2.5	3.8 (1.6)	32.0 (8)
ASD+ADHD+Comorbidity	103	10.3	3.1 (2.3)	12.6 (13)
ASD+Comorbidity	19	1.9	5.6 (3.3)	52.6 (10)
DA	14	1.4	8.2 (4.1)	42.9 (6)
LD	13	1.3	4.5 (3.2)	61.5 (8)
All	996		5.1 (2.3)	26.6 (266)

Table 2: Provider type making initial diagnosis

	Diagnostic Categories															
	ADHD		ADHD+ ASD		ADHD+ Comorbidity		ASD		ASD+ADHD+ Comorbidity		ASD+ Comorbidity		DA[a]		LD[b]	
Diagnosing Provider	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Pediatrician	53.7%	203	42.0%	21	51.2%	173	31.8%	7	42.4%	42	26.3%	5	50.0%	6	33.3%	4
Primary Care Provider - Non-Pediatrician	14.3%	54	10.0%	5	10.7%	36	0.0%	0	13.1%	13	10.5%	2	8.3%	1	33.3%	4
Psychiatrist	9.5%	36	10.0%	5	11.2%	38	4.6%	1	14.1%	14	26.3%	5	25.0%	3	8.3%	1
Psychologist	6.4%	24	24.0%	12	8.6%	29	18.2%	4	10.1%	10	15.8%	3	8.3%	1	0.0%	0
Other	16.1%	61	14.0%	7	18.3%	62	45.5%	10	20.2%	20	21.1%	4	8.3%	1	25.0%	3

[a] DA = depression/anxiety; [b]LD = learning difficulties

Table 3: Hand preference for five activities of daily living

Activity	Right	Left	Ambidextrous
Writing	808 (82.2%)	153 (15.6%)	22 (2.2%)
Eating	793 (80.7%)	143 (14.6%)	47 (4.8%)
Bathing	750 (76.7%)	132 (13.5%)	95 (9.7%)
Brushing Teeth	803 (81.7%)	152 (15.5%)	27 (2.7%)
Throwing Ball	763 (78.0%)	134 (13.7%)	81 (8.3%)

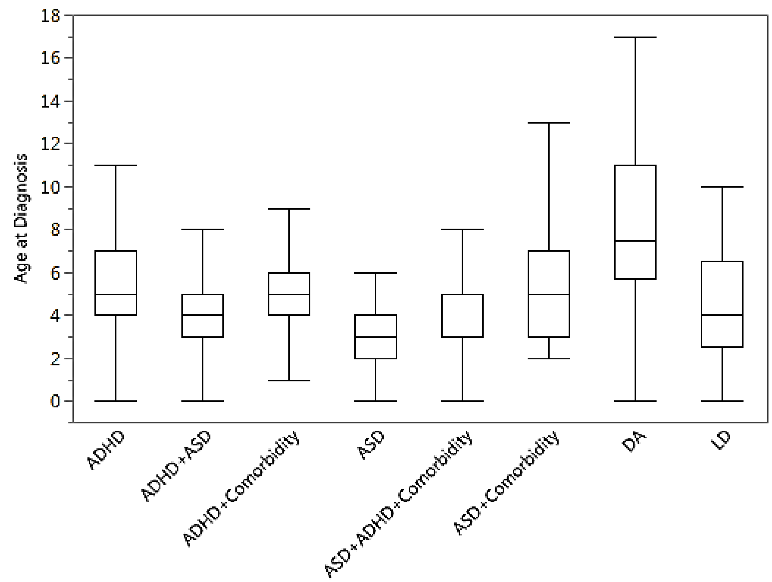

Figure 1: Respondent age at time of initial diagnosis