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Role of parental occupation in autism spectrum disorder diagnosis and severity

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INTRODUCTION

Autism Spectrum Disorder

Autism spectrum disorder (ASD) is characterized by deficits in social interaction and communication, as well as restricted interests and repetitive behaviors which first manifest in early childhood (American Psychiatric Association [APA], 2013; Holzer et al., 2006; Volkmar et al., 2014). This complex neurodevelopmental disorder affects between 1–3% of

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children globally (Autism and Developmental Disabilities Monitoring Network [ADDM] Surveillance Year 2010 Principal Investigators, 2014; Kim et al., 2011; Baron-Cohen et al., 2009). According to recent estimates, approximately 1 in 68 children in the United States has an ASD diagnosis (ADDM Surveillance Year 2010 Principal Investigators, 2014), with presence in all racial and ethnic groups and higher prevalence observed in boys (ADDM Surveillance Year 2010 Principal Investigators, 2014). Additionally, according to a recent study of parent reports, prevalence of ASD in the US could be as high as 1 in 50 (Blumberg et al., 2013).

ASD Etiology

Despite this growing literature on prevalence and incidence of ASD, less is known about the etiology of this disorder. Genetic studies have suggested that ASD might be at least partially due to genes expressed when exposed to environmental factors (Blake, Hoyme, & Crotwell, 2013; Herbert et al., 2006; LaSalle, 2013). Recent studies of environment factors have focused on heavy metals (Rahbar et al., 2012; Rahbar et al., 2013), pesticides (Roberts et al., 2007), and particulate matter (Volk, Hertz-Picciotto, Delwiche, Lurmann, & McConnell, 2011). Previous studies have also shown an increased risk as high as 19% in siblings of children with ASD (Ozonoff et al., 2011; Rutter, 2005). It also has been hypothesized that exposure to environmental factors may trigger or enhance genetic risks (Volk et al., 2014).

Broader ASD Phenotype

Though specific genotypic aspects of ASD have yet to be identified, some investigators have suggested that parents of children with ASD may present with less recognizable autistic-like phenotypic characteristics, sometimes referred to as a “broader phenotype” (Bishop et al., 2004; Bolte, Knecht, & Poustka, 2007; Briskman, Happe, & Frith, 2001; Constantino & Todd, 2005; Dawson et al., 2007; Hoekstra, Bartels, Verweij, & Boomsma, 2007; Piven, Palmer, Jacobi, Childress, & Arndt, 1997; Sasson, Lam, Parlier, Daniels, & Piven, 2013; Scheeren & Stauder, 2008; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). These traits may include obsessive-compulsive symptoms (Kano, Ohta, Nagai, Pauls, & Leckman, 2004), decreased ideational and word fluency (Wong, Maybery, Bishop, Maley, & Hallmayer, 2006), impairments in phonological processing (Schmidt et al., 2008), facial emotion processing deficits (Adolphs, Spezio, Parlier, & Piven, 2008), social impairment (Constantino & Todd, 2005; Sasson et al., 2013), and lack of empathy (Szatmari et al., 2008). Bishop et al. (2004) reported that parents of children with ASD scored higher on the social subscale (P=0.004) and communication subscale (P=0.015) of the Autism Spectrum Quotient (AQ), a screening instrument for severity of autistic symptoms with greater scores indicative of more autism-like symptomology (Bishop et al., 2004). Furthermore, Wheelwright et al. (2010) reported that both mothers and fathers of children with ASD scored higher than parents of typically developing (TD) controls (P<0.05) on all five subscales of the AQ, including social skills, attention switching, attention to detail, communication, and imagination (Wheelwright et al., 2010). The Broad Autism Phenotype Questionnaire is an instrument designed to measure personality and language traits indicative of ASD in non-autistic relatives of people with ASD (Hurley, Losh, Parlier, Reznick, & Piven, 2007). The Broad Autism Phenotype Questionnaire has statements such as “I like to be around other people” and “I am comfortable with unexpected changes in plans" with responses on a Likert scale of 1-Very rarely, 2-Rarely, 3-Occationally, 4-Somewhat often, 5-Often, and 6-Very Often (Hurley et al., 2007). Recently, Sasson et al. (2013) reported that pairs of parents who were "broader phenotype" positive, according to the Broad Autism Phenotype Questionnaire, were more likely to have children with ASD (Sasson et al., 2013). Conversely, in another study, no significant difference was observed between mean AQ scores of parents of children with ASD versus those of TD children (Scheeren & Stauder, 2008).

Some researchers have suggested that many professionals in highly systemized occupations, especially those involving mathematical proficiency (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Fitzgerald, 2002; James, 2003) and musical talent (Pring, Ryder, Crane, & Hermelin, 2012), function with undiagnosed Asperger's Disorder while exceling in their chosen fields. Baron-Cohen, et al. (2001) even demonstrated that a group of undergraduate students with majors in science and mathematics, including physical sciences, biological sciences, mathematics, computer science, and engineering, scored significantly higher on all areas of the AQ in comparison to classmates with majors in humanities and social sciences (Baron-Cohen et al., 2001). Given the "broader phenotype" symptoms of ASD seen in some parents of children with ASD, some have proposed that these parents may have highly technical and structured occupations in fields such as science, engineering, and accounting (Baron-Cohen, Wheelwright, Scott, Bolton, & Goodyear, 1997; Baron-Cohen, 2006; Buchen, 2011; Jarrold & Routh, 1998; Wheelwright & Baron-Cohen, 2001). For example, Baron-Cohen et al. (1997) reported that a community sample of fathers of children with ASD were more likely to be engineers. Further, Jarrold and Routh (1998) analyzed the same data and reported that occupations in accounting, science, and medicine were also more frequent in fathers of children with ASD. Notably, Windham et al. (2009) most recently demonstrated in a population based study in San Francisco, CA that risk of having a child with ASD was almost two times greater for mothers in highly technical occupations (AOR=1.7; 95% CI:1.1–2.8).

Environmental Exposures

Considering growing recognition of the effects of environmental exposures on brain development and function (Landrigan, 2010), and the increase in susceptibility during *in utero* development(Miodovnik, 2011; Miodovnik et al., 2011), some have suggested that environmental factors may contribute to *de novo* mutations, increasing risk of ASD (Kinney, Barch, Chayka, Napoleon, & Munir, 2010). These environmental factors could be mediated through pesticides (Roberts, Karr, & Council on Environmental Health, 2012), lead (Kim et al., 2013; Parajuli, Fujiwara, Umezaki, & Watanabe, 2013; Rahbar, White, Agboatwalla, Hozhabri, & Luby, 2002), arsenic (Parajuli et al., 2013; Rahbar et al., 2012), mercury (Marques, Dorea, Bernardi, Bastos, & Malm, 2009; Rahbar et al., 2013), or combustion pollutants (Tang et al., 2008). Given that environmental exposures include occupation-related exposures, it is also important to consider the possibility of parental occupational exposures as a risk factor for ASD (Williams & Ross, 2007).

To investigate these factors, we conducted a study in Houston, TX, the fourth largest city in the US which houses the world's largest medical center, corporate headquarters for numerous oil companies, and the National Aeronautics and Space Administration (NASA), yielding a population with various education levels, occupational possibilities, and risks of environmental exposures. Though Baron-Cohen et al. (1997) proposed that fathers of children with ASD were more likely to be employed in positions requiring superior organizational and analytical skills, Jarrold and Roth (1998) suggested that the sample used may have been biased towards professionals due to a greater desire of these parents to pursue a diagnosis and better proficiency navigating the medical system. For this study, we tested the association of a broader ASD phenotype in parents, as indicated by occupational characteristics, and risk of occupational teratogen exposures with ASD diagnosis in offspring. Furthermore, in a subsample containing only children with an ASD diagnosis, we evaluated the possible relationship between broader phenotype and risk of teratogen exposure with ASD severity of offspring.

METHODS

Study Population

This is a secondary exploratory analysis of data from two previous studies conducted at the University of Texas Health Science Center at Houston (UTHealth) in a sample of 273 children ages 7 to 18 years. The first study was an NICHD-funded case-control study of developmental impairment of the orbitofrontal-limbic circuit of the brain as a possible biomarker for children ages 7–18 with ASD from 1999 to 2004 (herein referred to as Study 1). The second study was an NIMH-funded project designed to assess the behavioral and cognitive aspects of ADHD in children with ASD ages 7–12 years from 2006 to 2011 (herein referred to as Study 2). Children for both of these studies were recruited through local Houston school districts, parent groups (e.g., The Arc of Greater Houston, The Autism Society), several clinics associated with the Department of Psychiatry (e.g., the Child, Adolescent, and Family Clinic, the Developmental Neuropsychology Clinic), and other local agencies. Case ascertainment for both studies was the same, with suspected ASD cases being determined first by clinical interview and observation by two licensed clinical psychologists, both with more than 20 years of experience. Those who met criteria for ASD according to the DSM-IV-TR (APA, 2000) were administered both the Autism Diagnostic Interview-Revised (ADIR) (Lord, Rutter, & Couteur, 1994) and the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 2002). The ADI-R is a structured interview that assesses a subject’s developmental history and is administered to the parents of children at least 18 months old (Rutter, Le, & Lord, 2003), while the ADOS uses structured and semi-structured tasks to evaluate a subject’s social interaction and communication with the examiner (Lord et al., 2002).

The combination of these assessments, along with records review by the two licensed psychologists, both of whom are highly experienced in the assessment and diagnosis of ASD and who are certified as meeting research reliability on both the ADI- and/ADOS, were used to confirm if suspected cases met full criteria for an ASD diagnosis. Controls were recruited using the same sources used to recruited cases, from Houston school districts, parent groups, and local agencies. Controls were determined not to have possible signs indicative of ASD based on interviews and clinical observation. Those who did not meet full criteria for a formal diagnosis of ASD based on records review, ADOS, and ADI-R scores were categorized as controls. Exclusion criteria for Study 1 (Loveland, Bachevalier, Pearson, & Lane, 2008) and Study 2 (Pearson et al., 2012) have been previously published.

Exposure Assessment

Parental occupations were gathered through demographic questionnaires during assessment of children. Using the Standard Occupational Classification (SOC) system, a data source system maintained by the Bureau of Labor Statistics which can be used to classify workers into occupational categories based on job duties, skills, education, and training (Bureau of Labor and Statistics (BLS), 2013), listed parental occupations were classified as technical (not people-oriented) versus non-technical and white-collar (work done in an office or professional environment) versus blue-collar (work involving manual labor). For example, those working in engineering, scientific research, and accounting were considered having technical, white-collar occupations while those in healthcare professions were consider having non-technical, white-collar positions. However, it should be noted that some healthcare professions, such as surgical or nursing assistants, were categorized as blue-collar positions. To determine high risk of occupational exposures to hazardous teratogens, a thorough review of literature and reports from the National Institute of Occupational Safety and Health (NIOSH) was utilized. Each occupation listed for parents of study participants was searched to determine which teratogens, if any, individuals with such occupations would potentially be exposed to. If the reviewer of this literature was unable to determine potential for exposure, this data point was left incomplete.

Data Analysis

To explore differences in white-collar occupations, including engineering, information technology, science, healthcare, and accounting/financial analysis, we used logistic regression models. Each occupation was entered into the model as a dummy variable with all other white-collar occupations serving as a referent group. These models were then adjusted for demographic factors, including child's sex, race, and age, in multivariate analyses. Logistic regression was also used to evaluate associations between parental occupational characteristics, such as technical nature, white-collar, high risk of teratogen exposure, and ≥16 years of education, and ASD diagnosis of children. Adjustment for these models included all demographic variables as well as any occupational characteristic determined to be a potential confounder by having a p-value of less than 0.20 and changing the point estimate for technical classification by at least 10%.

Next, we assessed differences in mean ADOS and ADI-R domain scores as well as ADOS and ADI-R total scores using Generalized Linear Models (GLM) for univariate analyses. GLM has been indicated as a more appropriate analysis process than ANOVA (Young, Brewer, & Williamson, 2003). For the investigation of ASD symptomatology, as assessed by the ADOS (Lord et al., 2000) and the ADI-R (Lord et al., 1994) scores, and its possible association with characteristics of paternal and maternal occupations, including technical or non-technical, white-collar or blue-collar, and high-risk or low-risk of occupational exposure to hazardous teratogens, we also used GLM. Furthermore, we adjusted for effects of potential confounding demographic variables (e.g. child's age, sex, and race), along with parental occupational characteristics that were determined to be potential confounders by having a *p*-value of less than 0.20. Occupational characteristic variables that changed the measure of effect for association with technical classification by greater than 10% when included in the original model were included in a final multivariable model.

RESULTS

Demographic characteristics of cases and controls were similar. The proportion of male ASD cases was comparable to that of controls (78.7% and 78.2%, respectively). Minor differences in race and age distributions were not statistically significant. There were also no significant differences in employment status between mothers of cases and controls; however the percentage of controls with unemployed fathers was greater than that of cases (10.8% and 3.5%, P=0.02). Details on demographic information for cases and controls can be found in Table 1.

To explore differences in white-collar occupations, we also used logistic regression models. For paternal occupations, odds of having a child with ASD were twice as high for fathers who were engineers as compared to all other white-collar occupations (OR=2.57, 95% CI: 1.01, 6.54). Additionally, fathers of cases were seven times more likely to work in healthcare (OR=7.10, 95% CI: 2.03, 24.76) and five times more likely to work in accounting/financial analysis (OR=5.07, 95% CI: 1.34, 19.36). After adjustment for demographic variables, age, sex, and race, the association for engineering occupations was no longer significant; however, the associations between paternal occupations in healthcare and accounting/financial analysis with ASD case status of offspring were still significant (AOR=6.38, 95% CI: 1.72, 23.68 and AOR=4.60, 95% CI:1.19, 17.72, respectively). Though there were no statistically significant differences in maternal occupations for unadjusted or adjusted models, preliminary analyses did yield marginally significant results for the association of maternal occupations in healthcare with odds being twice as high in mothers of cases than controls (OR=2.41, 95% CI: 0.98, 5.95). Results of these analyses are displayed in Table 2.

We also investigated associations between parental occupation characteristics and ASD diagnosis. The main occupational characteristic of interest for these analyses was technical nature of occupations. Secondary characteristics included white-collar, risk of occupational exposure to teratogens, and ≥16 years of education. Occupational teratogen exposures included, but were not limited to, solvents, metals, exhaust, pesticides, and disinfectants. No paternal occupational characteristic was found to have statistically significant associations with ASD diagnosis in unadjusted analyses. Moreover, after adjusting for age and risk of teratogen exposure, technical paternal occupation was still not associated with ASD diagnosis. Technical nature of maternal occupation was also not associated with ASD diagnosis in unadjusted analysis and after adjustment for age and IQ. Lastly, we evaluated the association between shared parental occupation characteristics. These analyses also did not yield statistically significant results for unadjusted models and after adjusting for age and IQ. More information on results of these analyses can be seen in Table 3.

To evaluate associations between technical nature of parental occupations and ASD severity, we used analysis of a subsample including children with ASD diagnosis only. The mean score for the ADI-R communication domain was significantly higher (indicative of worse communicative function) for children of parents with technical occupations compared to those of parents with non-technical occupations (17.9 vs. 13.1, $P<0.01$). In addition, the association of both parents having technical occupations with the mean ADI-R social impairment domain score was higher for children of parents with technical occupations than for children of parents with non-technical occupations (21.9 vs. 17.4, $P=0.04$). Details of these analyses are in Table 4.

Lastly, we examined the associations of multiple parental occupation characteristics on total ADI-R and ADOS scores of offspring. In univariate analyses, mean ADI-R total score of children of fathers with white-collar versus blue-collar occupations was higher (44.1 vs. 37.4, $P=0.02$), suggestive of more severe overall autistic symptomatology. Significance was also seen with higher ADOS scores (indicative of more severe ASD symptomatology) for children of fathers with white-collar occupations (13.2 vs. 11.48, $P<0.05$). ADI-R total scores were also higher for children of fathers with risk of any teratogen exposures versus no exposure (44.5 vs. 39.5, $P=0.04$). Initial analysis of was not suggestive of any significant relationship between paternal technical occupation and ASD severity of offspring according to ADI-R scores. However, multivariate analysis, adjusting for potential confounders including white-collar occupation, risk of teratogen exposure, education ≥ 16 years, and child age, sex, and race, yielded statistically significant results for the association between higher ADI-R scores of children of fathers with technical occupations (40.5 vs. 34.5, $P=0.02$). When joint parental occupation characteristics were evaluated, children of parents who both had technical occupations had a significantly higher mean ADI-R total (50.4 vs. 39.6, $P=0.02$), and this association was maintained after adjusting for child's age, sex, and race (48.6 vs. 38.8, $P=0.03$). Although parental technical occupation was not significantly associated with ADOS scores, the association between white-collar occupations of both parents and ADOS scores was marginal ($P=0.06$). No maternal occupational characteristic was alone found to be significantly related to ASD severity of children. More information is available in Table 5.

DISCUSSION

Previous studies have suggested that ASD may be partially associated with genetic inheritance of mutations after exposure to environmental teratogens occurring prenatally or in early childhood. This genetic susceptibility may be due to mutations in parents or epigenetic changes in earlier generations that become more apparent in offspring. Though researchers have not yet identified specific genotypic aspects of ASD, some have suggested that parents of children with ASD may actually have a "broader autism phenotype" that is less recognizable (Wheelwright et al., 2010). Additionally, others have theorized that this phenotype can be magnified in offspring (Constantino & Todd, 2005).

Broader Phenotype

Individuals with “broader autism phenotype” may choose occupations in highly technical and systemizing fields (Baron-Cohen et al., 1997; Baron-Cohen et al., 2001; Baron-Cohen, 2006; Fitzgerald, 2002; James, 2003; Jarrold & Routh, 1998). Our results indicate that fathers of children with ASD were more than twice as likely to be engineers compared to fathers of TD children. However, past studies of parental occupation and ASD have yielded conflicting results. For example, Baron-Cohen et al. (1997) first reported that both fathers and grandfathers of children with ASD were more likely to be engineers than fathers and grandfathers of TD children, which is consistent with our own findings. However, Jarrold et al. (1998), arguing that the prior analysis did not account for other systemizing occupations, showed that fathers of children in the same sample were also more likely to be accountants, scientists, and physicians. In our own experience, we found that after adjusting for demographic variables, the higher likelihood of having children with ASD for parents who were engineers was no longer statistically significant. However, this increased likelihood of having a child with ASD remained significant for fathers employed in the fields of healthcare and accounting/financial analysis, even when demographic variables were accounted for. This pattern echoes the results of Jarrold and Routh (1998), but is not consistent with the results of Windham et al. (2009) who reported no statistically significant association of paternal occupations in science, engineering, and accounting with ASD diagnosis. To prevent possible biases due to socioeconomic abilities in seeking diagnosis and obtaining treatment for children with ASD, we also assessed the relationship between white-collar versus blue-collar occupations, as well as ≥16 years of education and having a child with ASD and found no associations. We also found no significant relationship between paternal, maternal, or joint technical occupation characteristics and ASD diagnosis. Windham et al. (2009) also considered the possibility that results from precious studies may be biased due to socioeconomic status of parents. Taking into account this and other potential confounders, they used surveillance data of children in San Francisco and reported results similar to our own of no significant association with paternal technical occupation and ASD diagnosis of offspring (Windham, Fessel, & Grether, 2009). Conversely, they did find significant results for the association between maternal occupations in highly technical fields and having offspring with ASD, with sustained significance in mothers in computer programming (Windham et al., 2009). Differences in our results may be due to the fact that parental occupations from our study were obtained at the time of assessment while those of the San Francisco study were obtained from birth records. It is interesting to note that 33% of mothers of cases in our study reported being unemployed or homemakers while only 32% of controls reported the same. This distribution similar to that of the sample in the Windham et al (2009) study, which reported an equal percentage of 36% for both case and control mothers reporting being homemakers.

In addition to testing for higher likelihood of systemizing mothers or fathers of children with ASD, we evaluated joint effects of having both parents in systemizing occupations in accordance with the theory of “assortative mating,” which is the tendency of people with similar characteristics, such as education, field of work, and social interests, to date and marry each other. We also found no association with having both parents with technical occupations and ASD status. However, when we examined the association between joint technical occupation and ASD severity, we found a significantly higher mean total ADI-R score in children with both parents in technical fields, higher mean social impairment ADI-R domain score, and higher mean communication ADI-R domain score for offspring with two parents with technical occupations compared to those with one or no parents in these occupations. These results are consistent with the theories of Baron-Cohen (2006), who has also suggested that the combination of two highly systemizing parents may contribute to the likelihood of producing a child with ASD (Baron-Cohen, 2006; Buchen, 2011), or in this case, a child with more recognizable symptomatology. Additionally, others demonstrated that “assortative mating” may occur in these parents, with social impairment scores of married couples, according to the Social Responsiveness Scale (SRS), a parent-completed questionnaire used to screen for presence and severity of social impairment (Hus, Bishop, Gotham, Huerta, & Lord, 2013), being highly correlated with each other, as well as with their children (Constantino & Todd, 2005). When Windham et al. (2009) assessed this possibility, they found no association between joint technical parental occupations and ASD diagnosis. However, it should be mentioned that prior research only investigated ASD status, but not severity. Therefore, our results imply that the combination of milder autism-like behaviors in two parents could have an additive effect on apparent symptomatology and subsequent ASD severity compared to that of one parent’s symptomatology alone. This would support the findings of another study using the Social Communication Questionnaire (SCQ), a brief screening tool administered to parents or subjects for identification of potential social and communication impairments (Rutter, Bailey, & Lord, 2003), which reported higher scores in children of two parents with positive results on the Broad Autism Phenotype Questionnaire in comparison to those of parents that were not “broader phenotype” positive (P=0.05); however, this study also showed no difference in SCQ scores of children with one versus both parents with positive scores (Sasson et al., 2013).

Exposure to Teratogens

As individuals in certain occupations are at greater risk for exposures to certain hazardous teratogens, it is also important to examine the possible effects of parental occupational exposures on ASD outcomes of offspring. Our study found no significant association between high risk of parental occupational exposures to teratogens and ASD diagnosis of offspring. However, some studies assert that occupational exposures to teratogens may be related to ASD (McCanlies et al., 2012; Windham et al., 2013). One study of children from the Childhood Autism Risk from Genetics and Environment (CHARGE) study reported significantly increased odds of having a child with ASD versus a child with no other developmental disorder for parents with exposures to solvents or asphalt (McCanlies et al., 2012). Windham el at. (2013) most recently reported in a sample from San Francisco that odds of having a child with ASD were greater in mothers with any occupational exposures including exhaust, solvents, pesticides, metals, and disinfectants, but no association was seen with fathers’ exposures. Differences in our results may again be attributed to parental occupations in our study being determined at the time of assessment while those from the CHARGE study were obtained from questionnaires and those from the San Francisco study were obtained from birth records. Additionally, risk of occupational exposure in our study was determined by rigorous review of reports from NIOSH; however, risk from the CHARGE study was ascertained through self-report and additional review by three experienced industrial hygienists and risk in the San Francisco study was determined by the professional judgment of an occupational medicine-certified physician. Moreover the CHARGE analysis excluded children with other developmental disabilities while our analysis control group consisted of all children not formally diagnosed with ASD, including those who may have had other developmental disabilities not defined in the study exclusion criteria.

Although we found no association between parental occupational exposures and ASD diagnosis of offspring, in our subanalysis consisting only of children with an ASD diagnosis, we did find that ADI-R scores were higher in children whose fathers had high risk of occupational exposures versus children of other fathers. This observed increase in ASD severity is consistent with other studies that reported an association with levels of teratogen exposures and ASD severity (Adams, Romdalvik, Ramanujam, & Legator, 2007; Adams et al., 2013) adding further question the mechanism and true effect of parental occupational exposures on offspring.

Strengths and Limitations

As an exploratory study of previously collected data, this study has strengths and weaknesses. ASD diagnosis for each child was assessed by two PhD level clinicians, each with over 20 years of experience and who are research-reliable on both the ADOS and the ADI-R. As a result, the quality of ADOS and ADI-R scores and results are considered to be highly reliable. Although parental occupation was ascertained at the time of assessment, it is not possible to ascertain changes in occupation that may have occurred during the pregnancy or during the earlier years of the child's life. While the sample size of the combined studies provided more than enough power to test associations of technical occupations and teratogen exposures with ASD severity, reporting of certain occupations in mothers had small numbers, limiting our analysis. Therefore, the diminished significance observed for the associations of maternal technical occupation with mean ADI-R communication and social impairment domain scores may be contributed to reduced power. Risk of occupational exposures was determined from intensive review of NIOSH reports by an environmental epidemiologist, but it was determined that the sample was too small to further investigate the effects of individual teratogens. Because controls were recruited from the same sources as cases, the similar distribution of males in the case and control group in our sample indicates that this sample is not representative of the community population and may be more of a clinical sample. Also, positive results seen in our study suggest there may be genetic or epigenetic factors influencing ASD severity; however, it is beyond the scope of this investigation to verify this.

Even with these limitations, we were able to show an association between certain paternal occupations, including engineering, healthcare, and accounting/financial analysis, and a higher likelihood of having a child with an ASD diagnosis. Furthermore, we observed more severe autistic symptomology (as indicated with higher ADI-R scores) in children of parents who both had highly technical occupations as well as in those for whom only the father had a highly technical occupation. Our results suggest that there is a joint association between parental occupation and ASD severity, as well as a relationship between paternal occupation and ASD diagnoses. If the broader phenotype theory holds true, identification of parents with these autistic-like characteristics could aid in earlier identification and diagnosis of ASD in their children. This subsequently could result in earlier intervention and better outcomes for these children. Although implications from this study would not directly identify children with ASD by familial characteristics, they could alert clinical service providers to features to be aware of and accelerate evaluations of ASD symptomology in offspring of parents falling into these categories.

Future Directions

To better assess potential for prenatal and post-natal exposures, future studies should obtain parental occupation at the time of the child's birth and at the time of clinical assessment in larger samples to investigate more possible confounders and effect modifiers. Additionally information on professional training, such as college majors and degrees earned, should be gathered to further assess inclination of parents to choose highly structured career paths regardless of eventually entering the workforce. ASD is a very complex disorder, and results of studies on individual parental factors, either as primary or secondary analysis, will continue to build on knowledge and eventually lead to advances in information on the etiology of ASD. Additionally, results from our study allude to the possibility of joint effects of behaviors of individuals with systemizing occupations and risk of more recognizable ASD symptomatology in offspring. This effect could be due to genetic or epigenetic intergenerational transmission which might contribute to having children with greater ASD severity. Therefore, more analysis should be done to determine what factors contribute to desires to work in highly technical fields, and how these factors, if identifiable, can add to the risk of communication or social impairment in the offspring of these individuals.

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Highlights

- We test associations between broader autism phenotype of parents and ASD diagnosis of offspring.
- We examine occupations associated with having offspring with an ASD diagnosis.
- We investigate associations between broader autism phenotype of parents and ASD severity.
- Fathers in healthcare and finance had greater risk of having offspring with ASD.
- Children of parents with technical occupations exhibited greater ASD severity.

Table 1

Descriptive characteristics of children and their parents by ASD case status

Variables	Categories	Case (n=211) N (%)	Control (n=78) N (%)	*P*-value
Gender	Male	166 (78.7)	61 (78.2)	0.93
Race	White	156 (74.3)	50 (64.1)	0.10
	Black	23 (10.9)	16 (20.5)	
	Other/Mixed	31 (14.8)	12(15.4)	
Maternal characteristics	Education ≥ 16 years	119 (56.4)	49 (62.8)	0.33
	Unemployed/Retired/Home/Student	70 (33.5)	24 (32.4)	0.87
	Technical	33 (23.4)	8 (16.0)	0.27
	White-collar	126 (89.4)	41 (82.0)	0.18
	Teratogen Exposures	23 (11.2)	7 (9.9)	0.75
Paternal characteristics	Education ≥ 16 years	130 (61.6)	46 (59.0)	0.68
	Unemployed/Retired/Home/Student	7 (3.5)	8 (10.8)	**0.02**
	Technical	107 (56.0)	43 (64.2)	0.24
	White-collar	149 (78.0)	47 (71.2)	0.26
	Teratogen Exposures	75 (39.5)	34 (50.0)	0.13
Age (Years)	7–10	99 (46.9)	43 (55.1)	0.22
	11–15	112 (53.1)	35 (44.9)	

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Table 2

Parental white-collar occupations associated with ASD case status using Logistic Regression

	N (%)		Unadjusted		Adjusted	
	Cases	**Controls**	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
PATERNAL[a]						
Other White-collar	73 (51%)	12 (26%)	Ref	–	Ref	–
Engineering	26 (18%)	11 (23%)	2.57 (1.01, 6.54)	**< 0.05**	2.22 (0.85, 5.81)	0.10
Information Technology	23 (16%)	7 (15%)	1.85 (0.65, 5.26)	0.25	1.60 (0.55, 4.66)	0.39
Science	10 (7%)	4 (9%)	2.43 (0.66, 9.02)	0.18	2.66 (0.70, 10.10)	0.15
Healthcare	6 (4%)	7 (15%)	7.10 (2.03, 24.76)	**< 0.01**	6.38 (1.72, 23.68)	**< 0.01**
Accounting/Financial Analysis	6 (4%)	5 (11%)	5.07 (1.34, 19.26)	**0.02**	4.60 (1.19, 17.72)	**0.03**
MATERNAL[b]						
Other White-collar	79 (63%)	24 (57%)	Ref	–	Ref	–
Engineering	4 (3%)	0 (0%)	NR	–	NR	–
Information Technology	9 (7%)	1 (2%)	0.37 (0.04, 3.04)	0.35	0.30 (0.04, 2.55)	0.27
Science	6 (5%)	4 (10%)	2.19 (0.57, 8.42)	0.25	2.50 (0.58, 10.68)	0.22
Healthcare	15 (12%)	11 (26%)	2.41 (0.98, 5.95)	0.06	1.99 (0.77, 5.12)	0.15
Accounting/Financial Analysis	12 (10%)	2 (5%)	0.55 (0.12, 2.62)	0.45	0.48 (0.10, 2.31)	0.36

[a]Adjusting for age, sex, and race

[b]Adjusting for age, sex, and race

Paternal occupation missing for 48 participants

Maternal occupations missing for 111 participants

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Table 3

Parental characteristics associated with ASD case status using Logistic Regression

	N (%)		Unadjusted		Adjusted	
	Cases	**Controls**	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
PATERNAL[a]						
Technical	107 (51%)	43 (57%)	0.71 (0.40, 1.26)	0.25	0.98 (0.50, 1.94)	0.96
White-collar	149 (71%)	47 (60%)	1.43 (0.76, 2.70)	0.26		
Teratogen Exposure	75 (36%)	34 (44%)	0.65 (0.37, 1.14)	0.13	0.66 (0.34, 1.25)	0.20
Education (≥ 16)	130 (12%)	46 (59%)	1.12 (0.66, 1.90)	0.68		
MATERNAL[b]						
Technical	33 (16%)	8 (10%)	1.60 (0.69, 3.75)	0.28	1.78 (0.73, 4.34)	0.21
White-collar	126 (60%)	41 (53%)	1.85 (0.75, 4.53)	0.18	2.31 (0.89, 6.02)	0.09
Teratogen Exposure	23 (25%)	7 (9%)	1.16 (0.47, 2.82)	0.75		
Education (≥ 16)	119 (56%)	49 (63%)	0.76 (0.45, 1.30)	0.33		
BOTH PARENTS[c]						
Technical	18 (9%)	5 (6%)	1.30 (0.45, 3.75)	0.62	1.74 (0.58, 5.20)	0.33
White-collar	94 (45%)	31 (40%)	1.26 (0.57, 2.75)	0.57		
Teratogen Exposure	10 (5%)	3 (4%)	1.20 (0.32, 4.50)	0.79		
Education (≥ 16)	99 (47%)	41 (53%)	0.80 (0.47, 1.34)	0.39		

[a] Adjusting for risk of teratogen exposures and child's age, sex, race

[b] Adjusting for white-collar classification and child's age, sex, race

[c] Adjusting for age, sex, and race

Paternal technical occupation missing for 45 participants

Paternal white-collar information missing for 46 participants

Paternal chemical exposures risk missing for 45 participants

Father's college education missing for 14 participants

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Maternal technical occupation missing for 112 participants

Maternal white-collar information missing for 112 participants

Maternal chemical exposures risk missing for 27 participants

Mother's college education missing for 14 participants

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Table 4

ASD Diagnostic instrument subscale scores by technical occupation in parents of children with ASD

	Paternal			Maternal			Both Parents		
	Technical (n=86)	**Non-Technical (n=107)**	***P***	**Technical (n=33)**	**Non-Technical (n=109)**	***P***	**Technical (n=18)**	**Non-Technical (n=106)**	***P***
	M±SD	**M±SD**		**M±SD**	**M±SD**		**M±SD**	**M±SD**	
ADI-R Domains									
Social Impairment	19.43±7.50	17.77±8.43	0.15	20.42±8.49	8.63±0.83	0.09	21.88±7.09	17.43±8.69	**0.04**
Communication	15.08±6.24	13.73±6.34	0.14	15.60±6.35	13.25±6.84	0.08	17.89±5.39	13.08±6.73	**<0.01**
Repetitive behaviors	6.40±5.88	5.98±3.00	0.30	6.27±2.76	5.94±2.97	0.56	6.83±2.43	6.03±3.02	0.29
ADOS Domains									
Communication	4.66±2.24	4.29±2.23	0.27	4.52±0.36	4.52±0.23	0.38	5.17±1.62	4.39±2.44	0.20
Social Interaction	8.48±3.23	8.26±3.44	0.64	8.48±3.44	8.20±3.64	0.69	8.89±7.34	8.24±3.54	0.46

Table 5

Factors associated with total test instrument scores in children with ASD using General Linear Model

Instruments	Parental Factors	Univariable					Multivariable		
		Yes		No		*P*-value	Yes	No	Adjusted *P*-value
		Mean Score	N	Mean Score	N		Adjusted Mean Score	Adjusted Mean Score	
	PATERNAL								
ADI-R[a]	Technical	44.07	110	40.83	95	0.18	40.52	34.49	**0.02**
	White-collar	44.13	159	37.37	46	**0.02**	38.84	36.17	0.47
	Teratogen Exposure	44.53	124	39.54	80	**0.04**	34.70	40.32	0.08
	Education (≥16)	43.81	138	40.22	87	0.13	39.42	35.59	0.17
ADOS[b]	Technical	13.14	110	12.55	95	0.44	12.03	11.18	0.32
	White-collar	13.28	159	11.48	46	**< 0.05**	12.49	10.72	0.10
	Teratogen Exposure	13.29	124	13.29	80	0.16	11.30	11.90	0.56
	Education (≥16)	13.01	138	12.47	87	0.48			
	MATERNAL								
ADI-R[c]	Technical	45.94	34	39.87	113	0.09	41.80	35.39	0.08
	White-collar	41.37	131	38.16	16	0.87			
	Teratogen Exposure	42.82	196	40.52	23	0.53			
	Education (≥16)	42.79	126	42.15	99	0.79			
ADOS[d]	Technical	13.00	34	12.72	113	0.80	12.35	12.25	0.93
	White-collar	12.82	131	12.47	16	0.81			
	Chemical Exposure	13.63	196	12.86	23	0.52			
	Education (≥16)	12.80	126	12.80	99	0.99			
	BOTH PARENTS								
ADI-R[c]	Technical	50.39	19	39.63	110	**0.02**	48.61	38.76	**0.03**
	White-collar	42.45	99	37.23	30	0.17			

Instruments	Parental Factors	Univariable					Multivariable		
		Yes		No		*P*-value	Yes	No	Adjusted *P*-value
		Mean Score	N	Mean Score	N		Adjusted Mean Score	Adjusted Mean Score	
	Teratogen Exposure	43.10	10	42.45	189	0.91			
	Education (≥1 6)	42.61	106	42.28	119	0.89			
ADOS[d]	Technical	14.06	19	12.63	110	0.31	13.36	11.99	0.34
	White-collar	13.35	99	11.17	30	0.06			
	Teratogen Exposure	14.00	10	12.91	189	0.52			
	Education (≥1 6)	12.86	106	12.74	119	0.87			

[a]Adjusting for white-collar classification, risk of teratogen exposure, education, and child's age, sex, race

[b]Adjusting for white-collar classification, risk of teratogen exposure, and child's age, sex, and race

[c]Adjusting for age, sex, and race

[d]Adjusting for age, sex, and race

Yes=meets occupational characteristic

No=does not meet occupational characteristic