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Sleep problems in children with autism spectrum disorders, developmental delays, and typical development: a population-based study

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SUMMARY

This study compared parent-reported sleep characteristics in 2 to 5 year-old children with autism spectrum disorders (ASD) to children with other developmental delays (DD) and typical development (TD). We included 529 children (303 ASD [167 males], 63 DD [46 males], and 163 TD [134 males]) enrolled in the CHARGE study, an ongoing population-based case-control study. The mean age of participants was 3.6 years (standard deviation 0.8 years). ASD diagnosis was confirmed with Autism Diagnostic Interview-Revised (ADI-R) and Autism Diagnostic Observation Schedules (ADOS). Cognitive and adaptive functioning was assessed using Mullen Scales of Early Learning (MSEL) and Vineland Adaptive Behavior Scales (VABS), respectively. Demographic, medical and sleep history information were ascertained from California birth records, telephone interview, medical assessments at clinic visit, and parent-administered questionnaires. Fifty-three percent of children with ASDs had at least one frequent sleep problem, followed by 46% of children with DDs, and 32% of the TD group ($P < 0.0001$). Exploratory factor analyses of sleep history data yielded two factors: sleep onset problems and night waking. Children with ASD had marginally higher sleep onset factor scores and significantly higher night waking factor scores compared to the TD group. Factor scores for children with DD were intermediate between the ASD and TD groups. Cognitive or adaptive development did not predict severity of sleep problems in the ASD group.

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Keywords

autism; autistic spectrum disorder; sleep problems; developmental delay

INTRODUCTION

Sleep problems are commonly reported by parents of young children. Approximately 25% of typically developing preschool-aged children have sleep problems pertaining to bedtime resistance, sleep onset delays, and night awakenings (Scher *et al.*, 1995; Armstrong *et al.*, 1994; Johnson, 1991; Jenkins *et al.*, 1984). Other less common sleep disturbances that concern parents include night terrors or nightmares and repetitive rhythmic behaviors, which manifest during the toddler-preschool period in some children (Anders *et al.*, 2000). Finally, 1–3% of children experience sleep-disordered breathing (Gislason & Benediktsdottir, 1995; Ali *et al.*, 1993), a medical condition that also contributes to a reduced quality of sleep. Sleep problems have been broadly classified into three major categories (American Psychiatric Association, 1994; American Academy of Sleep Medicine, 2001): (1) dyssomnias include sleep onset delays and night awakenings, (2) parasomnias include behaviors involving motor and autonomic activation which intrude on sleep (e.g. night terrors, nightmares, repetitive rhythmic behaviors), and (3) sleep disorders secondary to a physical illness or another psychological disorder. The extant literature has focused primarily on the presence of dyssomnias in both typically developing children as well as clinical samples (Sadeh *et al.*, 2002; Wiggs & Stores, 2001; Malow, 2004).

Autism spectrum disorders (ASD) are pervasive developmental disorders characterized by deficits in social interaction, language development and communication, as well as restricted and stereotyped behavior patterns or interests. Children with ASD experience similar sleep problem types to those observed in typically developing children, although the existing literature suggests that the prevalence of sleep problems in autism is markedly higher than expected, occurring in 44–83% of school-age children (Richdale, 2001). Richdale and Prior (1995) compared preschool- and school-aged children with ASD to a normative sample and found significantly higher levels of current general sleep difficulties according to parent report (44% versus 27%). Parents of autistic children commonly express that their children resist going to bed at an appropriate time (Couturier *et al.*, 2005; Wiggs & Stores, 2004), have difficulties in initiating sleep (Richdale & Prior, 1995; Couturier *et al.*, 2005; Wiggs & Stores, 2004; Allik *et al.*, 2006b; Gail Williams *et al.*, 2004; Honomichl *et al.*, 2002; Patzold *et al.*, 1998), and exhibit nighttime (Richdale & Prior, 1995; Wiggs & Stores, 2004; Allik *et al.*, 2006b; Gail Williams *et al.*, 2004; Honomichl *et al.*, 2002; Patzold *et al.*, 1998; Schreck & Mulick, 2000), and early morning waking (Richdale & Prior, 1995; Patzold *et al.*, 1998; Polimeni *et al.*, 2005; Hering *et al.*, 1999).

There is a bidirectional impact between sleep problems and child development. Sleep disturbances increase the parenting burden and family stress (Sadeh *et al.*, 2002; Polimeni *et al.*, 2005; Doo & Wing, 2006; Wiggs & Stores, 1998; Mindell & Durand, 1993). Recently, in a large population-based study, mothers of typically developing preschoolers with a parent-reported sleep problem also endorsed poor general health (Martin *et al.*, 2007).

Family stress was associated with poorer sleep quality in school-aged children with typical development and in children with developmental disabilities (Wiggs & Stores, 1998; El-Sheikh *et al.*, 2006).

Other results indicate that parental hassle intensity is associated with sleep problems in children with autism (Richdale *et al.*, 2000). Additionally, there is accumulating evidence for a relationship between sleep and developmental functioning in children (Sadeh *et al.*, 2002; Wolfson *et al.*, 1998). Disturbed sleep in children has been associated with cognitive, verbal and attention impairments (Fallone *et al.*, 2005; Randazzo *et al.*, 1998; Gozal, 1998; Quine, 1991), self-help and daytime behavior problems (Quine, 1991; Allik *et al.*, 2006a) including injury-prone behavior (Owens *et al.*, 2005). Daytime dysfunction due to disturbed sleep patterns may be especially taxing for children with neurodevelopmental disorders such as ASD, who already have difficulties in social interaction and communication.

Most research on sleep problems in children has used subjective measures such as sleep diaries and parent-reported questionnaires. Although biases are introduced when utilizing this method, parent reports remain an established measure of sleep behavior in children. Honomichl *et al.* (2002) found that children whose parents reported a sleep problem, in contrast to those who did not, consistently displayed more delayed sleep onsets and greater sleep fragmentation, which was reflected in subscale scores of the Children's Sleep Habits Questionnaire (CSHQ; Owens *et al.*, 2000), a validated measure of sleep problems and sleep diaries. Parents may be unaware of certain sleep behaviors, and thus, underreport them if their child does not alert them in any way. Several studies have demonstrated parental underreporting of sleep problems using objective measures (e.g. actigraphy, videosomnography) (Allik *et al.*, 2006b; Sadeh, 1996; Minde *et al.*, 1993; Sadeh *et al.*, 1991), although Hering *et al.* (1999) found that parental reports of sleep problems were overstated when compared to actigraphic recordings. In general, parent reports of their children's sleep problems appear to be a conservative but reliable measure (Minde *et al.*, 1993).

The underlying cause of poor sleep may include behavioral factors, medical factors or an interaction of both factors. Medical conditions that can impact sleep patterns in children include the presence of seizures, cerebral palsy, sleep disordered breathing, and pharmacologic side effects (Owens *et al.*, 1998; Newman *et al.*, 2006). A recent report indicated a significant association between the presence of insomnia and parasomnias with gastrointestinal symptoms as reported by parents (Liu *et al.*, 2006). Children with ASD in particular may be prescribed medications, e.g. respiridone, that may have a disruptive impact on sleep (Mindell & Owens, 2003).

Research investigating sleep patterns in children with ASD has documented parental concerns, although shortcomings in the existing literature include small sample sizes, inconsistent diagnostic definitions, and convenience samples of controls. None of the studies to date have used a population-based sample for comparison, thus limiting both the validity and the generalizability of their findings. The aim of this report was to compare parent-reported sleep characteristics in young children with ASD between 2 and 5 years of age to

typically developing children of the same age as well as children with other developmental delays using a large, well-characterized population-based study sample.

METHOD

Participants

Participants (*n*= 529) were enrolled in the CHARGE (Childhood Autism Risks from Genetics and the Environment) Study. Eligible children were those who: a) were between the ages of 24 and 60 months, b) were living with at least one biologic parent, c) had a parent who spoke English or Spanish, d) were born in California, and e) were residing in the catchment areas of a specified list of Regional Centers in California. The CHARGE Study is an ongoing population-based case-control study with subjects sampled from three strata: children with autism, children with developmental delay but not autism, and children selected from the general population (Hertz-Picciotto *et al.*, 2006). Children with autism as well as children with other developmental delays were identified through Regional Centers, which are funded by the State of California to provide case management services to children with eligible developmental disorders, regardless of socioeconomic level and racial/ethnic group. Children from the general population were identified from state birth files, and a stratified random sample was generated by frequency-matching to a projected distribution of cases on age, sex, and Regional Center catchment area. Parents were contacted by letter and/or phone to describe the study. Recruitment began in April 2003, and children in this paper include those enrolled from April 2003 through December 2006. During this period of recruitment, clinical assessment and other relevant data were available on 677 children who were examined by the CHARGE study at a clinic site in Sacramento or Los Angeles. From this pool of children, 592 sleep histories were obtained (87.4%). Fifteen children did not complete all developmental assessments to satisfy group definitions in this paper and 48 did not meet the group definition criteria; thus, these 63 children were excluded from all analyses. No further exclusions were made based on genetics, family phenotype, or other characteristics, with the exception of children who had visual, hearing or motor impairments that precluded standardized developmental assessment. This study was approved by institutional review boards of the University of California in Davis and Los Angeles and the State of California Department of Developmental Services. Informed consent was obtained prior to participation. The final sample of 529 participants included 303 children with ASD, 63 with developmental delays, and 163 with typical development.

Diagnostic confirmation

All children with autism were evaluated with the Autism Diagnostic Interview-Revised (ADI-R; Le Couteur *et al.*, 2003) and the Autism Diagnostic Observation Schedules (ADOS; Lord *et al.*, 2000) to confirm their diagnosis. Final autism case status was defined as meeting criteria on the communication, social interaction, and repetitive behavior domains of the ADI-R with onset prior to 36 months and scoring at or above the social + communication cutoff for autism on the ADOS module 1 or 2. Children classified with autism spectrum disorders were those who did not meet full criteria for autism on either or both the ADI-R and ADOS, but did meet criteria on either the communication or the social interaction domain of the ADI-R prior to 36 months, were within 2 points of the cut-off on

the other domain, and were above the social + communication cutoff for ASD on the ADOS module 1 or 2. Children with autism and autism spectrum disorders were combined into one group (ASD group). Additionally, cases were also administered the Mullen Scales of Early Learning (MSEL; Mullen, 1995) and the Vineland Adaptive Behavior Scales (VABS; Sparrow *et al.*, 1984) to determine cognitive and adaptive status.

Parents of children with other developmental delays and those from the general population completed the Social Communication Questionnaire (SCQ; Rutter *et al.*, 2003) to screen for autism spectrum disorders; children with scores above the screening cut-off of 15 were assessed with the ADI-R and ADOS, and removed from the comparison groups. All children were assessed using MSEL and VABS, and comparison groups were defined using composite scores on both assessments. The delayed development group (DD group) was defined as having a score of 70 or less on MSEL and/or a score of 69 or less on VABS. The typically developing group (TD group) only included children from the general population who had a score of 71 or above on MSEL and a score of 70 or above on VABS.

All CHARGE study clinical assessment personnel have attained research reliability on all developmental assessments (ADI-R, ADOS, MSEL, and VABS); the team includes Spanish bilingual and bicultural staff.

Sleep problems and covariates

Information on current sleep behavior, habits, and patterns was ascertained with the CHARGE Sleep History, a parent-administered questionnaire that includes 39 Likert scale items (0 = never; 1 = rarely; 2 = sometimes; 3 = frequently; 4 = always) describing sleep behavior, habits, and patterns (Table 1). Other information included sleep duration and parental evaluation of their child's sleep problems on the child and family's daily functioning. This study only focused on the 30 items that were similar to the items found in the Children's Sleep Habits Questionnaire (CSHQ; Owens *et al.*, 2000).

Demographic (child race/ethnicity, maternal age, paternal age, parental education) and reproductive information (birth weight, gestational age, birth order) was obtained from the CHARGE Environmental Exposure Questionnaire and from California birth records. The Environmental Exposure Questionnaire (EEQ) is a telephone-administered interview with the mother and the primary caregiver designed by the CHARGE study, and includes questions about demographics, maternal medical history, and various environmental exposures such as diet, household product use, residence, and occupational history. Children's histories of seizures and current use of medications and supplements were obtained from the Child Medical History, a structured questionnaire administered by physicians. Information on current gastrointestinal symptoms was collected using the CHARGE GI History, a parent-administered questionnaire that includes 10 Likert scale items (0 = never; 1 = rarely; 2 = sometimes; 3 = frequently; 4 = always) describing current gastrointestinal symptoms as well as questions related to food allergies and diet restrictions. (All CHARGE study forms available from authors on request.)

Covariates of interest were selected *a priori* and included child's age in years, sex, mother's level of education (college degree versus no degree), history of non-febrile seizures, current

use of medications for chronic or recurrent conditions (e.g. ADHD, allergies, anxiety, asthma, constipation, hyperacidity, insomnia, mood disorders, seizures, thyroid abnormalities), current use of dietary supplements (excluding multivitamins and fluoride), current gastrointestinal symptoms (frequent gaseousness/bloating, diarrhea, or constipation), and birth order (first born versus later born).

Statistical Analyses

All analyses were carried out using SAS version 9.1 (SAS Institute Inc., Cary, NC).

Descriptive statistics—Comparisons of categorical variables were statistically evaluated using a Likelihood Ratio Chi-square test, and continuous variables were assessed using one-way analysis of variance (ANOVA) or Kruskal-Wallis test.

Principal Factor Analysis—To identify clusters of sleep problems on the CHARGE Sleep History, an exploratory factor analysis was performed on all participants (n=529). To be included in the factor analysis, responses to all 30 items must be present. Missing data on item responses on the CHARGE Sleep History questionnaire occurred rarely. Eighty-three of 529 Sleep History surveys (15.7%) had one or more missing responses. Specifically, 49 out of 529 surveys were missing 1 item response (9%), 16 were missing 2 responses (3%), and 18 were missing 3 or more responses (3%). The maximum number of missing responses was 7 out of 30. To avoid excluding subjects from the entire factor analysis because of one or a few missing items, values were imputed using median values of the entire sample of children. Kaiser's measure of sampling adequacy (MSA; Cerny & Kaiser, 1977) was used to quantify the goodness-of-fit of the principal factor model; squared multiple correlations (SMCs) were used as the prior communality estimates. Items with factor loadings greater than 0.40 were included and orthogonal (varimax) rotations were performed. Factor-scoring coefficients were generated to be used in regression models.

Based on the SMC ranges (0.22 – 0.65), we used the exploratory factor analysis instead of the principal components analysis, which assumes all SMCs to be near 1.0. Kaiser's MSA was 0.82, suggesting an adequate goodness-of-fit of the factor analysis model. (MSA ranges between 1.0 and 0, with values less than 0.50 considered a poor fit.) Varied factor-loading thresholds were examined with the optimal threshold yielding correlations greater than 0.40. The most favorable number of factors was two, based on statistical criteria and factor interpretability. These two factors accounted for 95% of the variance present in the sleep characteristics retained in the model.

Multivariate Linear Regression Analyses—All covariates were assessed for potential confounding by examining associations of each covariate with the primary predictor of interest (group) and with each response variable (factor scores, total amount of sleep); covariates broadly associated ($p < 0.20$) with both the predictor and the response variable were initially included in the multivariate models. Tolerance was calculated to assess collinearity among variables fitted in each model; a tolerance value of <0.10 was considered as an indicator for collinearity. Child's sex and age were included in all models to adjust for the study design. Final multivariate linear regression models were fitted to determine

whether sleep factors derived from the exploratory factor analysis and total amount of sleep by parent report were associated with the three main diagnostic groups: ASD, developmental delay, and typical development. A secondary set of regression analyses of the ASD group alone was performed to determine whether sleep factors and total amount of sleep were associated with delay in cognitive or adaptive development. Three sets of models were constructed to determine differences comparing: ASD children with delayed versus ASD children with typical cognitive development; ASD children with delayed versus ASD children with typical adaptive development; and ASD children with delayed cognitive and adaptive development versus ASD children with typical development on one or both measures.

RESULTS

The mean age of children included in the analyses (n = 529) was 3.6 years (SD 0.8); TD children were significantly younger compared to the DD (3.3 years versus 3.6 years, P = 0.04) or the ASD (3.3 years versus 3.7 years, $P < 0.0001$) groups. Males represented 88% (n = 167) in the ASD group, 73 % (n = 46) in the DD group, and 82% (n = 134) in the TD group (P = 0.01). Overall, close to half the children were White, one-third Hispanic, and the remainder of other race/ethnicity (Table 2). Mothers of DD children had the lowest level of education: 27% with college degree, as compared to mothers of ASD (45%, P = 0.01) or of TD (52%, P = 0.001) children (Table 2).

About one-fifth of children with DD had a history of non-febrile seizures compared to children with ASD (6.6%, P = 0.002) or children with typical development (0%, $P < 0.0001$); although the proportion of children with ASD and history of non-febrile seizures was also significantly higher than that of children in the TD group ($P < 0.0001$, Table 3). Current use of medications and/or dietary supplements was significantly higher in children with ASD (34%) and DD (48%) compared to TD controls (17%; $P < 0.0001$, $P < 0.0001$, respectively). Similarly, frequent gastrointestinal symptoms such as gaseousness/bloating, diarrhea and/or constipation were reported more frequently in the ASD (30%) and DD (21%) groups compared to the TD group (5.1%; $P < 0.0001$, P = 0.0008, respectively, Table 3).

Overall, 53% of children with ASD and 46% of DD children had at least one sleep problem that was reported as occurring “frequently” or “always” compared to 32% of TD children ($P < 0.0001$, $P < 0.05$, respectively, Table 4). In the ASD group, 21% of parents perceived that their child’s sleep problem affected the child’s daily functioning and 23% of parents reported that their child’s sleep problem affected the family’s daily functioning. Similarly, 20% of children in the DD group had a sleep problem that affected their daily functioning and 21% of children in this group had a sleep problem that affected their family’s daily functioning. In contrast, 1.2% of children in the TD group had a sleep problem that affected their daily functioning and 2.5% had sleep problems that affected their family’s daily functioning (AU versus TD, $P < 0.0001$; DD versus TD, $P < 0.0001$, Table 4). The majority of children slept between 10 and 12 hours in a 24 hour period, but TD children tended to get one additional hour of sleep compared to children with ASD (median: 11 versus 12 hours, $P < 0.0001$).

Exploratory Factor Analysis

The exploratory factor analysis produced two factors involving 11 sleep history items which were retained for further analysis. The factors were: Sleep Onset Problems [7 items] and Night Waking [4 items] (Table 4). Internal consistency (i.e., Cronbach α, an index of reliability for a set of items that indicates the extent to which items measure the same characteristic) was calculated for each factor and was within conventional levels (Sleep Onset Problems α = 0.79 and Night Waking α = 0.81). "Has trouble falling asleep" was the most common item in factor 1, sleep onset problems, reported as occurring frequently in 24% of children with ASD, 19% of DDs, and 9% of TDs ($P < 0.0001$, Table 4). In factor 2, night waking, parents of 7% of ASDs, 2% of DDs, and 1% of TDs indicated the item "Wakes up screaming during the night" as occurring frequently ($P = 0.0014$, Table 4).

The item scores were evaluated for a possible cut-off total associated with significantly elevated, or "high", factor scores (defined as a factor score one standard deviation or higher above the mean). The sum of item scores that corresponded to "high" factor scores in *all* children were selected as cut-offs. On factor 1, sleep onset problems, the maximum sum of items was 28 points, and 15 or more item score points corresponded to a "high" factor score. Overall, 53 (10%) participants met this cut-off of 15 or more points on sleep onset items. The largest proportion of elevated sleep onset problems was in those with ASD ($n = 41$, 13%) followed by participants with DD ($n = 6$, 9.5%) and TD ($n = 6$, 3.7%). On factor 2, night waking, a sum of items equal to 7 or more points (out of 16 points total) corresponded to a "high" factor score, and 8.5% of participants ($n = 45$) met this point cut-off. The ASD group had the highest proportion of participants with elevated item scores ($n = 34$, 11%), followed by 6.3% participants with DD ($n = 4$), and 4.3% with TD ($n = 7$).

Multivariate Linear Regression Analyses

The primary set of regression analyses focused on comparing children with ASD, DD and TD on (1) sleep onset factor scores, (2) night waking factor scores, and (3) hours of sleep in a 24-hour period with adjustment for covariates. In a model adjusted for child's sex, age, current use of allergy, CNS and respiratory medications, and frequent gastrointestinal symptoms, children with ASD had higher sleep onset factor scores compared with TD children, although the difference was of borderline statistical significance (β [coefficient] = 0.177, SE [standard error] = 0.091, $P = 0.05$). Higher sleep onset scores, indicating more sleep onset problems, were associated with CNS medication use (β = 0.366, SE = 0.153, $P = 0.02$) and frequent gastrointestinal symptoms (β = 0.385, SE = 0.099, $P = 0.0001$) in all groups whereas respiratory medication use was significantly associated with lower sleep onset factor scores (β = −0.370, SE = 0.152, $P = 0.01$). Children with DD did not differ significantly from the ASD or TD groups on sleep onset factor scores. Night waking factor scores were significantly elevated in the ASD group compared to TD children (β = 0.294, SE = 0.090, $P = 0.001$) after adjusting for child's sex, age, allergy and respiratory medications, and birth order. Factor scores significantly decreased by 0.16 for each year increase in a child's age (β = −0.164, SE = 0.050, $P = 0.001$). Use of respiratory medications was also significantly associated with lower night waking factor scores (β = −0.347, SE = 0.159, $P = 0.03$). For parent report of average sleep duration in a 24 hour period, a model adjusted for child's age, sex, mother's education level, and use of respiratory medications

suggested that children with ASD tended to sleep about half an hour less than TD children (β = −0.473, SE = 0.156, *P* = 0.003). Mother's education and child's use of respiratory medications were also strong predictors of increased sleep duration (β = 0.431, SE = 0.140, *P* = 0.002; β = 0.607, SE = 0.265, *P* = 0.02, respectively) in all children.

Since cognitive and adaptive development appeared to play a role in the frequency of sleep problems, we examined the entire study sample for associations between cognitive and adaptive scores and sleep onset and night waking factor scores as well as total amount of sleep, adjusted for child's age and sex. Overall, participants' higher cognitive and adaptive scores were significantly associated with (1) lower sleep onset factor scores (cognitive: β = −0.049, SE = 0.021, *P* = 0.02; adaptive: β = −0.080, SE = 0.024, *P* = 0.0009); (2) lower night waking factor scores (cognitive: β = −0.055, SE = 0.022, *P* = 0.01; adaptive: β = −0.081, SE = 0.024, *P* = 0.001); and (3) increase in amount of sleep (cognitive: β = 0.121, SE = 0.036, *P* = 0.001; adaptive: β = 0.115, SE = 0.042, *P* = 0.006). However, in secondary analyses of the ASD group alone, sleep disturbances were not associated with cognitive and/or adaptive delays.

DISCUSSION

In this population-based study of parent reported sleep problems in preschool children with ASD, developmental delay without ASD and typical development, parents in all three groups reported very high rates of sleep concerns. Approximately half of the parents of children with ASD and children with developmental delay reported at least one sleep difficulty, while one-third of the parents of children with typical development had similar concerns. These prevalence rates of at least one sleep problem are similar to those reported previously (Richdale & Prior, 1995; Couturier *et al.*, 2005; Wiggs & Stores, 2004; Gail Williams *et al.*, 2004; Polimeni *et al.*, 2005; Hering *et al.*, 1999; Liu *et al.*, 2006; Cotton & Richdale, 2006; Owens *et al.*, 1998). Given that this is the first large sample of children with ASD to be assessed for sleep problems and to be compared with a population-based comparison sample, it is interesting to observe comparable rates.

An exploratory factor analysis of the CHARGE sleep questionnaire yielded two factors indicating two types of sleep problems predominant in this group of young children: problems with sleep onset and with night awakenings. Regression models that adjusted for age, sex and medical factors suggested that children with ASD have a trend towards more problems with sleep onset and have significantly more night awakenings compared to their peers with typical development. Children with developmental delay fell between these two groups, with fewer problems reported in both areas than for children with ASD, but more than for typically developing children. Medical factors, such as use of psychoactive medications and gastrointestinal problems, were also associated with reported sleep problems in all children, although in different ways. Psychoactive medications were associated with increased sleep onset difficulties but not night waking. Likewise, frequent gastrointestinal symptoms were related to more problems with sleep onset but not night waking.

The CHARGE Sleep History factor scores were subsequently dichotomized for two groups of participants: one with “high” sleep problems scores meaning that scores were one standard deviation or more above the mean sleep factor score and another group with “low” scores, meaning less than one standard deviation above the mean. Hence, while all of the children that met the item score cut-off had significantly high factor scores, children with elevated factor scores but item scores below the set cut-offs were not considered as having a “high” or severe sleep problem in this set of analyses. Using this conservative definition, our results suggest that while children with ASD are more likely to have high sleep disturbances (13%) compared to children with other developmental delays (9%) or typical development (5%), all three groups have a lower incidence of more severe sleep disturbance than previously reported (Couturier *et al.*, 2005; Polimeni *et al.*, 2005; Cotton & Richdale, 2006).

In contrast, when we compared a parent report of at least *one* frequent sleep problem, 52% of children with ASD, 46% of children with other developmental delays, and 32% of typically developing children had a current sleep problem. These findings are in the middle of a range of reported rates of sleep problems in children with ASD (44–86%) (Richdale & Prior, 1995; Couturier *et al.*, 2005; Wiggs & Stores, 2004; Gail Williams *et al.*, 2004; Polimeni *et al.*, 2005; Hering *et al.*, 1999; Liu *et al.*, 2006; Cotton & Richdale, 2006). Likewise, our results in children with other developmental disabilities corresponded to those of Cotton and Richdale (2006) who found a prevalence of 44% for current sleep problems in a group of 43 children with intellectual disabilities. The previously reported prevalence of sleep problems in a typically developing sample of children ranged between 11% and 50% (Couturier *et al.*, 2005; Polimeni *et al.*, 2005; Owens *et al.*, 1998; Cotton & Richdale, 2006); our findings were consistent with the mid-range of the reported rates. Direct comparison of the frequency of sleep problems across studies is difficult because of variations in instruments used to ascertain the data on sleep problems or in the definition of sleep problems. Nevertheless, our results approximated previously reported prevalence of sleep problems as reported by parents.

The relationships between cognitive and adaptive development and sleep patterns in young children with autism spectrum disorders have not been previously investigated with such a large sample. In our combined analyses with all diagnostic groups together, lower cognitive and adaptive function was associated with increased difficulties with sleep onset and night awakening, as well as shorter duration of sleep. In studies of children with mild to severe intellectual disabilities of mixed etiologies, more severe levels of intellectual disability were associated with more parent-reported sleep problems, both in terms of sleep onset latency and night waking duration (Richdale *et al.*, 2000; Didden *et al.*, 2002). However, in the ASD group alone, cognitive level and adaptive function did not predict the severity of either type of sleep problem or the duration of sleep. Similar results have been reported previously in a smaller sample (Richdale & Prior, 1995).

The impact of parent-reported sleep problems also differed across the diagnostic groups. Very rarely did parents of children with typical development report that their children’s sleep problems affected child or family function, whereas a high percentage of parents from the other groups so reported. These results are consistent with a previous report (Richdale *et al.*, 2000) of the impact of a child’s sleep problem on the family. We found one in five

families of children with ASD and with developmental delay reported sleep problems affecting both child and family function.

One limitation of our study is the reliance on parent report. In studies that have compared both parent report of sleep problems and objective actigraphy of sleep patterns in school age children with ASD, parents were accurate reporters of sleep patterns if their child made them aware of their difficulty (e.g. child disturbs the parent when they are awake at night) (Wiggs & Stores, 2004). The results of the current study are similar to other studies of children with ASD that utilized parent report only using the CSHQ (Couturier *et al.*, 2005; Honomichl *et al.*, 2002), although the CHARGE study is the first to examine sleep in a large, well-defined, population-based sample with confirmed ASD cases and population-based controls; thus, we are confident that these findings are less confounded by recruitment bias or diagnostic uncertainty than previously published reports.

Another potential limitation of this study includes the short response format used to describe the type of sleep problems, a 5-point Likert scale. Other questionnaires, such as the CSHQ (Owens *et al.*, 2000), include a number of statements that parents respond to for clarification of the sleep problems noted. However, the rapidity in which the CHARGE Sleep History Questionnaire can be completed (5 minutes) and the similarity to outcomes using longer questionnaires such as the CSHQ suggest that accurately probing about sleep problems is not time-consuming and the use of a briefer questionnaire is valid and useful.

In summary, this study supports previous research indicating that children with ASD have greater difficulty with sleep onset and night waking than children with developmental delay and typical development. This confirmation is notable, given that the study sample was well-defined, population-based, and that we controlled for medical and other factors affecting sleep. Sleep onset and night awakenings are the predominant problem areas, and these problems affect daily functioning of both the child and the families of one in five children with either ASD or developmental delay. Further research related to both etiology of these sleep disturbances as well as effective interventions is warranted.

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Table 1

CHARGE Sleep History

Sleep History items (0 = Never 1=Rarely 2=Sometimes 3=Frequently 4=Always)	
• Wakes up screaming during the night	• Would stay in bed until gotten up
• Screams during the second half of the night	• Is sleepy during the day
• Throws tantrums at bedtime	• Goes to bed at different times
• Sleeps better in places other than his/her bed	• Walks in sleep
• Gets less than 6 hours sleep in a 24 hour period	• Rocks body, bangs head, or rocks head in sleep
• Talks in sleep without knowing it	• Snores
• Sleeps more than other children his/her age	• Resists going to bed at night
• Is sluggish or irritable when awakened	• Sleeps less than children his/her age
• Has trouble falling asleep	• Has frequent let movements while asleep
• Takes frequent naps during the day	• Sleeps in a family bed
• Stops breathing during sleep	• Has nightmares
• Complains of the room or bed being uncomfortable	• Wakes up screaming approximately 2 hours after going to sleep
• Sleeps longer or shorter periods on the weekends versus the weekdays	• Needs a stuffed animal, toy, blanket, pacifier, night light to fall asleep
• Engages in violent behavior while asleep (hits, kicks, punches)	• Expresses fear about going to sleep or is afraid to fall asleep
• Complains of jaw pain during the day or grinds teeth at night	• Takes naps without being told or at an age when naps are not normal
How many hours does your child sleep per night?	
How many hours does your child nap during the day?	
How many hours does you child sleep in 24 hours?	

Do you think your child has a sleeping problem that affects his/her daily functioning?	Yes	No
Do you think your child has a sleeping problem that affects your family's daily functioning?	Yes	No

Table 2

Demographic and perinatal characteristics of children with ASD, delayed and typical development*

	ASD (n=303)		DD (n=63)		TD (n=163)		
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	***P* value**
Child's age, yrs							
2	71	23.4	14	22.2	60	36.8	<.0001
3	102	33.7	28	44.5	62	38.1	
4	108	35.6	21	33.3	41	25.1	
5	22	7.3	0	0.0	0	0.0	
Sex, % male	267	88.1	46	73.0	134	82.2	.01
Race/Ethnicity							
White	155	51.2	25	39.7	78	47.9	.32
Hispanic	98	32.3	28	44.4	52	31.9	
Other	50	16.5	10	15.9	33	20.2	
Maternal age at birth of child, y							
<25	36	11.9	13	20.6	31	19.0	.12
25–34	187	61.7	39	61.9	93	57.1	
≥35	80	26.4	11	17.5	39	23.9	
Paternal age at birth of child, y							
<25	24	8.1	9	15.0	22	13.7	.21
25–34	144	48.6	31	51.7	78	48.4	
≥35	128	43.2	20	33.3	61	37.9	
Mother's level of education							
≤High school	38	12.5	20	31.7	33	20.3	<.0001
Some college	130	42.9	26	41.3	46	28.2	
≥College degree	135	44.6	17	27.0	84	51.5	
Highest level of educational attainment in household							
≤High school	24	7.9	14	22.2	20	12.3	.006
Some college	97	32.0	25	39.7	52	31.9	
≥College degree	182	60.1	24	38.1	91	55.8	
Birth weight, g							

	ASD (n=303)		DD (n=63)		TD (n=163)		
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	***P* value**
<2500	22	7.3	8	12.7	9	5.5	.21
≥2500	281	92.7	55	87.3	154	94.5	
Gestational age, wk							
<37	33	12.3	5	8.5	18	12.2	.68
≥37	236	87.7	54	91.5	130	87.8	
Birth order							
1st born	135	44.6	21	33.3	75	46.0	.19
2nd born or later	168	55.4	42	66.7	88	54.0	

*Data are given as percentage of each group unless otherwise indicated. Numbers may not add up to total due to sporadic missing data. Percentages may not total 100 because of rounding. *P*-values were calculated using likelihood ratio Chi-square test.

Table 3

Clinical and developmental characteristics of children with ASD, delayed or typical development*

	ASD (n=303)		DD (n=63)		TD (n=163)		
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	***P* value**
History of seizures							
Febrile seizure	18	6.6	2	3.4	3	1.9	.06
Non-febrile seizures	18	6.6	12	20.7	0	0.0	<.0001
Any seizures	28	10.3	12	20.7	3	1.9	<.0001
Current use of medications or supplements for:§							
Allergic disorders	24	8.9	3	5.2	10	6.4	.48
Central nervous system	22	8.1	11	19.0	1	0.6	<.0001
Endocrine system	1	0.4	3	5.2	2	1.3	.04
Gastrointestinal tract	11	4.1	5	8.6	2	1.3	.04
Respiratory tract	14	5.2	10	17.2	12	7.7	.01
Dietary supplements	46	17.0	9	15.5	7	4.5	.0002
Any medications/supplements	93	34.3	28	48.3	26	16.7	<.0001
Current gastrointestinal symptoms							
Gaseousness/bloating	29	10.5	3	4.8	3	2.0	.0014
Diarrhea	44	14.8	5	7.9	2	1.3	<.0001
Constipation	42	14.1	10	15.9	5	3.2	.0002
Any gastrointestinal symptoms	91	30.4	13	20.6	8	5.1	<.0001
Cognitive function, ≤70	237	79.8	60	95.2	0	0.0	<.0001
Adaptive function, <70	220	73.1	44	69.8	0	0.0	<.0001
Combined low cognitive/adaptive function	193	65.4	41	65.1	0	0.0	<.0001
Normal IQ†	39	13.2	0	0.0	163	100	<.0001

*Data are given as percentage of each group unless otherwise indicated. Numbers may not add up to total due to sporadic missing data. Percentages may not total 100 because of rounding. *P*-values were calculated using likelihood ratio Chi-square test.

§excluded medications for transient infections/conditions; also excluded multivitamins and fluoride

†Normal intelligence is defined as Mullen Scales of Early Learning composite score >70 and Vineland Adaptive Behavior Scales composite score ≥70

Table 4

Sleep problems of children with ASD, delayed or typical development (cont.)*

	ASD (n=303)		DD (n=63)		TD (n=163)		
	n	%	n	%	n	%	*P* value
Summarized sleep patterns							
Any frequent sleep problems	159	52.5	29	46.0	52	31.9	<.0001
Any frequent sleep onset problems	155	51.2	29	46.0	52	31.9	.0003
Any frequent night waking problems	30	9.9	2	3.2	3	1.8	.0007
Does sleep problem affect child's daily functioning	61	20.7	12	19.7	2	1.2	<.0001
Does sleep problem affect family's daily functioning	69	23.1	13	21.3	4	2.5	<.0001
Factor 1. Sleep onset problems							
Has trouble falling asleep	74	24.4	12	19.0	14	8.6	<.0001
Goes to bed at different times	67	22.1	20	31.7	21	12.9	.0035
Resists going to bed at night	66	21.8	10	15.9	26	15.9	.23
Sleeps better in places other than his/her bed	53	17.5	11	17.5	14	8.6	.02
Sleeps less than children his/her own age	46	15.2	6	9.5	8	4.9	.0018
Throws tantrums at bedtime	30	9.9	6	9.5	5	3.1	.01
Gets less than 6 hours sleep in a 24 hour period	7	2.3	1	1.6	0	0.0	<.05
Factor 2. Night waking							
Wakes up screaming during the night	20	6.6	1	1.6	1	0.6	.0014
Screams during the second half of the night	19	6.3	1	1.6	1	0.6	.0022
Has nightmares	13	4.3	1	1.6	1	0.6	.03
Wakes up screaming approximately 2 hours after going to sleep	8	2.6	1	1.6	3	1.8	.79

*Data are given as percentage of each group unless otherwise indicated. Numbers may not add up to total due to sporadic missing data. Percentages may not total 100 because of rounding. *P*-values were calculated using likelihood ratio Chi-square test.