

Childhood Neurodevelopmental Disorders and Violent Criminality: A Sibling Control Study

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Abstract The longitudinal relationship between attention deficit hyperactivity disorder (ADHD) and violent criminality has been extensively documented, while long-term effects of autism spectrum disorders (ASDs), tic disorders (TDs), and obsessive compulsive disorder (OCD) on criminality have been scarcely studied. Using population-based registers of all child and adolescent mental health services in Stockholm, we identified 3,391 children, born 1984–1994, with neurodevelopmental disorders, and compared their risk for subsequent violent criminality with matched controls. Individuals with ADHD or TDs were at elevated risk of committing violent crimes, no such association could be seen for ASDs or OCD. ADHD and TDs are risk factors for subsequent violent criminality, while ASDs and OCD are not associated with violent criminality.

Keywords Autism spectrum disorders · Attention deficit hyperactivity disorder · Neurodevelopmental disorders · Criminality · Familial confounding

Introduction

Childhood neurodevelopmental disorders [i.e., attention deficit hyperactivity disorder (ADHD), autism spectrum disorders (ASDs), tic disorders (TDs), and obsessive compulsive disorder (OCD)] affect about 5–10 % of the population (Gillberg 1995; Wichstrom et al. 2012) and are either lifelong disorders or often persist into adult life (Biederman et al. 2006; Gillberg 1995). They are, by definition, associated with functional and psychosocial impairments (APA 1994). Although OCD has not traditionally been defined as a neurodevelopmental disorder it shows an overlap with ASD, ADHD and TDs, is under genetic influence and has an early age of onset (Anckarsäter et al. 2011), which is why it is referred to as a neurodevelopmental disorder in this article.

For ADHD, a clear link to adult violent criminality has been established (Satterfield et al. 2007). However, for other neurodevelopmental disorders it remains uncertain if they are associated with increased risk for antisocial behavior later in life.

The relationship between ADHD and criminality has been well documented in longitudinal studies (Mannuzza et al. 2008; Satterfield et al. 2007). Twin and family studies suggest common etiological antecedents (Biederman et al. 1995; Nadder et al. 2002) between ADHD and juvenile delinquency, and that the inter-generational transmission of ADHD and youth criminality is influenced by a highly heritable general liability (Bornovalova et al. 2010).

For ASDs, cross-sectional studies from forensic psychiatry (Siponmaa et al. 2001) and in juvenile correctional

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institutions (Ståhlberg et al. 2010) have indicated a small overrepresentation of criminality. ASDs have also been linked to symptom clusters described within the construct of psychopathy (Soderstrom et al. 2005). The few existing longitudinal studies have not been designed to capture criminality (Billstedt et al. 2005), or have had few participants (Hippler et al. 2010). However, research suggests that subclinical autistic-like traits are associated with delinquency and substance abuse (Geluk et al. 2012; Lundström et al. 2011).

The relationship between TDs and OCD and criminality is even more uncertain. TDs seem overrepresented among clients in juvenile correctional institutions (Ståhlberg et al. 2010) compared to general population controls, and OCD is overrepresented in forensic psychiatry (Soderström and Nilsson 2003). Additionally, men with OCD are more likely to exhibit antisocial personality disorder (Torres et al. 2006). In clinical and epidemiological studies, both CD and oppositional defiant disorder (ODD) are found to coexist with TDs (Ghanizadeh and Mosallaei 2009). No longitudinal studies, however, have focused on the possible link between TDs and criminality, whereas a small ($n = 48$) follow-up study of individuals with OCD found no overrepresentation of criminality (Thomsen 1995).

It should be noted that any relationship between risk factors and outcomes may be affected by familial effects (genetic, environmental, or a combination) that are correlated to both exposure and outcome. For instance, neurodevelopmental disorders and criminality both show substantial heritability (Frisell et al. 2012; Lichtenstein et al. 2010) and are correlated with factors such as low parental education (Chronis et al. 2003; Harper and McLanahan 2004), psychiatric morbidity (Nigg and Hinshaw 1998; Rutter and Quinton 1984), psychological distress (Weiss 2002; Whipple and Webster-Stratton 1991) and poorer family functioning (Cussen et al. 2012; Stouthamer-Loeber et al. 2002). If familial effects are present, siblings that share such characteristics but not the neurodevelopmental disorder will differ less regarding outcome than unrelated individuals without neurodevelopmental disorders.

We used a large population-based Swedish sample to explore the relationship between childhood neurodevelopmental disorders and subsequent violent criminality, and simultaneously account for possible familial effects.

Methods

Registers

This study is based on the linkage of six Swedish population-based, longitudinal registries—the *Multi-Generation*, *Pastill*, *Patient*, *Crime*, *Education*, and *Grade 9*

Registers, and the *Integrated Database for Labor and Market Research*, using the unique personal identification number (PIN) as key. The PIN is assigned to every Swedish citizen upon birth or arrival to the country.

The Pastill Register

Since 1999, the Child and Adolescent Mental Health Services (CAMH) in Stockholm County, Sweden has used a client database (Pastill) with clinical patient information for all individuals attending CAMHS in the greater Stockholm area, which includes the capital of Sweden and surrounding suburban areas. Complete and valid data, including sociodemographic data, referral reason, treatment provided, and diagnostic assessment are available from 2001 to 2010 for 92,000 individuals (Lundh et al. 2012; Magnusson et al. 2012) based on one or more clinical contacts at 19 in- and outpatient clinics. Diagnoses according to the Diagnostic and Statistical Manual of Mental Disorders—fourth edition (APA 1994) and the International Classification of Diseases and Related Health Problems—tenth edition (WHO 1992) are assigned based on clinical contacts with psychiatrists, psychologists, and social workers.

The Patient Register

The Patient Register encompasses data on all psychiatric inpatient care since 1973 and includes best-estimate specialist diagnoses assigned according to ICD versions 8, 9, and 10. Since 2001, the register also comprises information from outpatient consultations with specialist physicians.

The Multi-Generation Register

The Multi-Generation Register contains data on relatedness for all individuals born in Sweden since 1932 or who immigrated to the country before age 18 (index persons) and their parents. Thus, it is possible to identify sibling and half-sibling relationships for these individuals. In 2010, the register contained 10,325,966 index persons (Statistics Sweden 2010).

The National Crime Register

The National Crime Register contains data convictions in Swedish district courts, including cases where the prosecutor decided to caution or fine without court proceedings, were retrieved for all individuals aged 15 and older (15 years is the age of legal responsibility in Sweden) from 1973 and onwards. Conviction data were used because the Swedish Criminal Code determines that individuals are convicted as guilty regardless of medical or mental disorder. Hence, it includes offenders found not guilty by reason

of insanity who would be acquitted in other jurisdictions, as well as those receiving custodial or non-custodial sentences. The Crime Register has excellent coverage; only 0.05 % of crimes had incomplete personal identification numbers from 1988 to 2000 (Fazel and Grann 2006).

The Education Register

The Education Register provided information about highest achieved education and *the Grade 9 Register* included information since 1988 about all grades obtained in the 9th and final year of compulsory school (usually age 15).

The Integrated Database for Labor and Market Research

The Integrated Database for Labor and Market Research included information about income since 1990 for all individuals age 16 years or older (Statistics Sweden 2009).

Subjects

All individuals born 1984–1994 who lived in the greater Stockholm area at any time were identified. Probands were identified as those having a relevant diagnosis in the case register Pastill at any time from 2001 to 2009. We found 1,366 cases diagnosed with ADHD, 954 with ASDs, 214 with TDs, and 857 with OCD (totaling 3,391 cases, Table 1). In addition, we identified 2,301 healthy (defined as having no registered diagnosis in Pastill) full and 594 half-siblings also born 1984–1994. Finally, ten random population controls, matched by age, sex, and residential area (divided into finely grained areas, to account for variation in socioeconomic differences and possible environment-specific effects) were selected separately for patients (33,910 controls), and for full (23,008 controls) and half-siblings (5,758 controls) at the dates when the patients obtained their diagnoses (Table 1).

Diagnoses (Potential Risk Factors)

The diagnoses in the Pastill registry are assigned by specialist child and adolescent psychiatrists, licensed psychologists, and social workers. To validate Pastill diagnoses, we compared diagnoses in Pastill to those obtained through parental telephone interviews in a study addressing all 9- and 12-year-old twins born in Sweden (CATSS, Anckarsäter et al. 2011) using the Autism—Tics, AD/HD and other Comorbidities Inventory (A-TAC). A-TAC is a well-validated instrument with excellent psychometric properties for ASDs and ADHD and good psychometric properties for TDs and OCD (Hansson et al. 2005; Larson et al. 2010). Fifty-nine twins in the CATSS study were registered in the Pastill

registry. The accuracy, expressed as percent agreement from Pastill to the A-TAC, was 60 % for ASDs (based on 6/10 individuals), 77 % for ADHD (14/18), 100 % for TDs (3/3) and 44 % for OCD (4/9). In another study, examining individuals with a documented ASD in Pastill found that 92 % (CIs 82–97) of Pastill ASD diagnoses could be confirmed by hospital records (Idring et al. 2012).

Outcome

Consistent with other work, *violent crime* was defined as homicide, assault, robbery, arson, any sexual offense (rape, sexual coercion, child molestation, indecent exposure, and sexual harassment), illegal threats, and intimidation recorded up to 2009 in the National Crime Register (Fazel et al. 2009). Attempted and aggravated forms of these offenses were also included whenever applicable according to the Swedish Penal Code.

Covariates

Confounders

Parental incomes were derived from the *Integrated Database for Labor and Market Research*. Both maternal and paternal income for the year the child was diagnosed according to Pastill were divided into quartiles, based on income profiles of all parents in Sweden with one or more children born 1984–1994. Both paternal and maternal education were included and given as highest level attained: completed compulsory school or lower, completed high school, less than 3 years of higher education, 3 or more years of higher education.

Mediators

It is unclear if ADHD without concomitant CD or ODD increases the risk for criminality (Mannuzza et al. 2008; Mordre et al. 2011). This could also apply to other neurodevelopmental disorders. Further, adult psychiatric morbidity and substance misuse may mediate the relationship with criminality (Fazel et al. 2009). Thus CD, ODD, adult psychiatric disorders, and substance misuse were included in the analyses.

CD and ODD were identified in Pastill. From the Patient Register, we identified schizophrenia (ICD-9 code: 295; ICD-10 code: F20), non-organic psychosis (ICD-9: 291–292, 296B, 296X, 297, 298; ICD-10: F21–F25, F28–F29, F32.3, x.5 in F10–F19), bipolar disorder (ICD-9: 296A, 296C–296E, 296W; ICD-10: F30–F31), substance abuse/dependence (ICD-9: 304, 305X; ICD-10: F11–F19 except x.5) and alcohol abuse/dependence (ICD-9: 303, 305A, ICD-10: F10 except

Table 1 Number of probands, siblings, and matched controls^a in a Swedish prospective study of four childhood neurodevelopmental disorders and risk of violent criminality

	Probands	Controls ^a	Full siblings of probands	Controls ^a	Half-siblings of probands	Controls ^a
ASD	954	9,540	661	6,609	153	1,461
ADHD	1,366	13,660	898	8,979	304	2,962
TD	214	2,140	146	1,460	41	405
OCD	857	8,570	596	5,960	96	930
Total	3,391	33,910	2,301	23,008	594	5,758

Number of subjects diagnosed with *ASD* autism spectrum disorder, *ADHD* attention deficit hyperactivity disorder, *TD* tic disorder, *OCD* obsessive compulsive disorder. Whereas 2,847 probands were diagnosed with just one of the four disorders, 8.9 % (see Appendix Table 4) had also been diagnosed with one or more concurrent neurodevelopmental disorder (cf. Table 4 in Appendix). Hence $3109 - 2847 = 262$, of these were included in more than one analysis by disorder

^a Controls were matched separately for each proband, sibling, and half-sibling by birth year, sex, and residential area (divided into finely grained areas to account for socioeconomic differences and possible neighbourhood-specific effects)

x.5). Diagnostic validity is continuously evaluated and high for major psychiatric disorders such as schizophrenia and bipolar disorder (Ekholm et al. 2005; Sellgren et al. 2011). We also included missing grades as a potential mediator, defined as at least 15, out of 16, missing grades, to indicate excessive absence and truancy at the end of 9-year mandatory school.

Statistical Analyses

Association Between Neurodevelopmental Disorders and Violent Criminality

Associations between each neurodevelopmental disorder and violent criminality were investigated using conditional logistic regression, comparing patients and matched controls. *Importantly*, time-at-risk for the studied outcomes was equal for patients and their matched controls. If an individual was ascribed several diagnoses, it was included in the conditional logistic regressions pertaining to the different neurodevelopmental disorder, e.g., both the regression for ADHD and the regression for ASD. In the analyses, comorbidity between the neuropsychiatric diagnoses was not taken into account because less than 10 % had comorbid diagnoses (“Appendix”), although it is well-known that comorbidity is a prominent feature of neurodevelopmental disorders (Gillberg 1995).

Healthy (no neurodevelopmental diagnosis in Pastill) siblings and half-siblings of the probands were analyzed in separate logistic regression models comparing risk for violent criminality in these siblings to separately matched sibling controls from the population.

When only familial confounding may affect the findings, results from this method will be comparable to those from ordinary within-sibling analyses. In addition, we can more easily adjust for non-familial confounding, for example, (1)

by ensuring equal time at risk between the compared groups to avoid bias due to left truncation or right censoring, and (2) by using simple matching to control for birth cohort or period effects.

All statistical analyses were conducted with SAS 9.3 software.

Results

Descriptive Statistics

Potential confounders like parental income and education differed minimally between the 3,391 probands and 33,910 matched controls. The same relation was observed between the 2,301 full siblings and 594 half-siblings compared to the 28,586 separately matched controls (Table 2). All potential mediators, however, were more common among probands than controls; bipolar disorder was 2.5 times as prevalent, and substance abuse 3 times. Violent crime occurred 2.5 times more often among cases than controls. For full siblings of probands with any of the four neurodevelopmental disorders, a similar but less pronounced pattern emerged. For example, bipolar disorder was 4 times as common compared to controls but violent offending only marginally more frequent (2.4 vs. 2.0 %).

Neurodevelopmental Disorders and Violent Offending

Children diagnosed with ADHD had a substantially increased risk for violent criminality (OR 4.6, 3.7–5.7) (Table 3). However, controlling for confounders attenuated the risk and accounting for measured confounders and mediators resulted in further attenuation but a moderately strong effect remained (OR 2.7, 2.0–3.8). By contrast, no

Table 2 Descriptive statistics for confounders, mediators, and outcomes for probands, siblings, and matched controls^a in a Swedish prospective study of four childhood neurodevelopmental disorders and risk of violent criminality

	Probands %	Controls %	Full siblings %	Controls %	Half-siblings %	Controls %
Male sex	63.7	63.7	51.6	51.6	55.7	53.8
<i>Confounders</i>						
Father's income ^a	10/13/21/56	11/11/18/59	9/11/19/61	11/11/18/60	19/21/26/33	19/19/25/38
Mother's income ^a	7/12/32/48	9/12/31/48	7/11/28/54	9/13/30/48	7/15/37/41	8/13/33/46
Father's education ^b	18/45/14/22	17/45/15/23	16/45/15/24	18/44/15/23	32/53/7/9	28/53/10/9
Mother's education ^b	13/48/16/22	13/46/17/23	12/48/17/23	16/44/17/23	22/58/10/9	22/55/11/12
<i>Mediators</i>						
ODD	4.0	c	c	c	c	c
CD	3.9	c	c	c	c	c
Schizophrenia	0.1	0.02	0.1	0.01	0	0.01
Nonorganic psychosis	1.0	0.2	0.3	0.2	0.4	0.4
Bipolar disorder	0.3	0.1	0.4	0.1	0.2	0.1
Drug abuse	3.2	1.1	1.3	0.9	3.7	2.7
Alcohol abuse	5.5	2.8	3.8	2.4	6.2	4.7
Missing grades ^d	2.7	0.1	0.9	0.6	2.5	1.5
<i>Outcome</i>						
Violent crime	4.9	2.0	2.4	2.0	7.0	4.6

^a Quartiles: based on income profiles of all parents in Sweden with one or more children born 1984–1994

^b Quartiles: completed compulsory school, high school, <3 years of higher education, ≥3 years of higher education

^c Data not available

^d 15, out of 16, missing grades in mandatory school

increased risk was identified for ASDs and later violent criminality (ORs 1.1–1.3). Childhood TDs increased the risk for violent crime (OR 2.2, 1.1–3.4). When adjusting for additional measured confounding and mediators, the risk relating to TDs increased (OR 3.2, 1.4–7.5). Finally, no risk effect of childhood OCD on later violent criminality could be identified in any of the analyses (ORs 0.7–1.3).

Post-hoc Analysis

Since both ADHD and TDs had consistent moderate-to-strong associations with violent crime, we tested if the combination of ADHD and TDs would have a substantial effect on the primary outcome compared to matched controls, but no effect could be discerned in the analyses (ORs 0.6, 0.2–2.2, *p* = .41).

Siblings and Violent Offending

Compared to their matched controls, full siblings of individuals diagnosed with ADHD had a small but significantly increased risk for violent crime (OR 1.5, 1.0–2.3) (Fig. 1). Half-siblings of ADHD probands were also at increased risk (OR 1.8, 1.2–2.8) when including all tested mediators and confounders. Neither full nor half-siblings of individuals

with ASDs had any noticeable risk increase (ORs 0.6–1.4, all nonsignificant). Full and half-siblings of individuals diagnosed with TDs showed no significantly increased risk (ORs 0.5–1.5). Full siblings of children diagnosed with OCD showed no risk increase for violent offending, whereas for half-siblings, we identified a nonsignificant risk increase (ORs 2.1 in the unadjusted and 2.5 in the adjusted analyses).

Discussion

Our data, using almost 3,400 patients with diagnoses of ADHD, ASDs, TDs, or OCD, strongly suggests that these disorders differ regarding risk for future violent criminality when compared to matched population controls. First, similar to other studies (Mannuzza et al. 2008; Satterfield et al. 2007), childhood ADHD was clearly associated with violent criminality. Second, consistent with a previous study on TDs (Ghanizadeh and Mosallaei 2009), we found that TDs were associated with an increased risk for violent crime, an association that does not seem to be mediated by adult mental health problems. Third, even though previous studies have suggested that ASDs and OCD are related to criminality (Siponmaa et al. 2001; Soderström and Nilsson

Table 3 Odds ratios with 95 % confidence intervals, for violent offending in different neurodevelopmental disorders in a Swedish prospective study of four childhood neurodevelopmental disorders and risk of violent criminality

	ADHD	ASD	TD	OCD
Unadjusted model	4.6 (3.7–5.7)**	1.3 (0.9–2.0)	2.2 (1.1–4.4)*	0.9 (0.5–1.7)
Adjusted for confounders ^a	4.3 (3.4–3.6)**	1.3 (0.8–2.1)	3.0 (1.5–6.4)**	1.3 (0.7–2.4)
Adjusted for CD and ODD ^b	3.7 (2.9–4.9)**	1.3 (0.8–2.1)	3.1 (1.5–6.7)**	1.2 (0.6–2.2)
Fully adjusted ^c	2.7 (2.0–3.8)**	1.1 (0.6–1.9)	3.2 (1.4–7.5)**	0.7 (0.3–1.5)

* $p < .05$, ** bolded figures are significant $p < .01$

^a Adjusted for parental income and parental education

^b Adjusted for parental income, parental education, ODD, and CD

^c Adjusted for parental income, parental education, ODD, CD, schizophrenia, bipolar disorder, non-organic psychosis, substance abuse/dependence, and missing grades

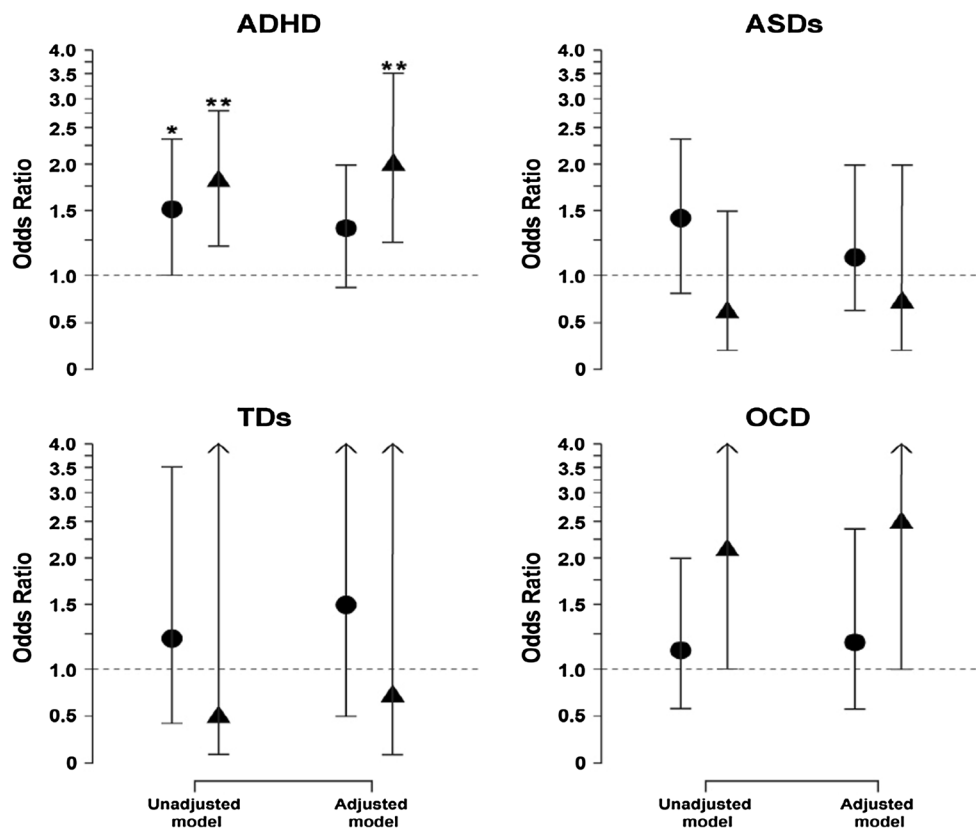


Fig. 1 Relative Risks (Odds Ratios with 95 % Confidence Intervals) for violent offending for full and half-siblings of individuals with neurodevelopmental disorders. Note: *ASD* autism spectrum disorder, *ADHD* attention deficit hyperactivity disorder, *TD* tic disorder, *OCD* obsessive compulsive disorder. *Filled circle* denotes full siblings,

filled triangle denotes half-siblings. “Adjusted” denotes adjusted for parental income and parental education, schizophrenia, bipolar disorder, non-organic psychosis, substance abuse/dependence, and missing grades

2003) we found no such effect. Fourth, in line with family studies (Biederman et al. 1995) and extended twin designs (Bornovalova et al. 2010), familial effects were clearly indicated in the association between ADHD and criminality since unaffected full siblings of individuals with ADHD had a remaining but less pronounced risk for violent criminality.

Neurodevelopmental Disorders and Violent Criminality

The link between childhood ADHD and criminality was not surprising given prior research with smaller clinical samples (Mannuzza et al. 2008; Satterfield et al. 2007). Our analyses suggested that ADHD was indeed a risk factor for criminality when accounting for diagnosed CD

and ODD, thus informing a current clinical controversy (Mannuzza et al. 2008; Mordre et al. 2011) by supporting the notion that ADHD is an independent risk factor for criminality, even though the very likely underreporting of ODD and CD in children with ADHD prohibits a definitive answer. Further, the risk seemed not to be mediated by adult mental ill-health, including substance abuse. Overall, the results highlight that individuals with ADHD are at increased risk for criminality regardless of previous and future comorbid and psychiatric conditions.

The finding that childhood ASDs were unrelated to criminality was in accordance with (a) ASDs being characterized by difficulties in inferring other people's thoughts, but not necessarily their distress (Jones et al. 2010) and (b) psychopathic traits and ASDs not being part of the same construct; rather, that psychopathic traits reflect an additional impairment (Rogers et al. 2006). Nonetheless, when autistic-like traits are associated with delinquency (Geluk et al. 2012), this could reflect the known covariation with ADHD symptoms (Ronald et al. 2008) or other psychopathology (Långstrom et al. 2009), rather than ASDs per se.

TDs were associated with increased risk for violent crime. It might be speculated that this could be related to the comorbidity between TDs and ADHD. The post hoc analyses, however, showed no support for this notion as there was no risk increase for violent criminality in children with ADHD and concomitant TDs, and recent research suggests that TDs comorbid with ADHD might improve adaptation in terms of neuropsychological performance and interpersonal difficulties in school compared to ADHD only (Greimel et al. 2008; Lin et al. 2012). Although, TDs are reported to be associated with increased rates of drug and alcohol abuse (Teive et al. 2001), controlling for substance misuse did not explain the association between TDs and violent crime. A more viable explanation might be the known connection between TDs and explosive outbursts (Budman et al. 2000), which may explain the observed increase in violent crime.

In line with Thomsen (1995), OCD was unrelated to future violent criminality; hence, the noted overrepresentation of OCD in juvenile correctional institutions or forensic psychiatry may stem from selection bias leading to referral primarily of patients with substantial comorbidity with, for example, ADHD, ODD, CD, and substance misuse.

In clinical settings, awareness should be raised about the relationship between ADHD and TDs and criminality, irrespectively of the presence of conduct disorder. Social interventions should be included to reduce the risk for criminality but may be superfluous in the presence of ASD or OCD without concomitant ADHD or TDs,

Familial Factors

Unaffected siblings of individuals with ADHD were also at increased risk for violent crime, suggesting that familial factors shared by siblings without ADHD are also associated with criminality. This is in line with previously reported family studies (Biederman et al. 1995), and the high heritability for antisocial behavior (Frisell et al. 2012) or the elevated levels of distress in families where criminality occurs (Whipple and Webster-Stratton 1991). However, full and half-siblings of ADHD probands had similar criminality risks despite different degrees of genetic similarity (that is, on average sharing 50 and 25 %, respectively, of co-segregating alleles), suggesting that environmental factors such as psychosocial adversity, family conflicts, and severe marital discord (Biederman et al. 1995; Rutter et al. 1975), or the hardships of having a sibling with ADHD (Kendall 1999) might be important.

We did not find any remaining, significant risk increase for violent crime in sibling analyses for TDs, ASDs, or OCD.

Strengths and Limitations

Tested predictors, confounders, mediators and outcomes were all derived from nationwide longitudinal registers and not from retrospective self-reports, which minimizes rater and recall biases. Although official statistics usually underreport the true prevalence of mental illness and criminal offending as compared to self-reports, this should only affect absolute rates and does not seem to alter the strength of the association (Arseneault et al. 2000). The cross-validation of diagnoses in Pastill and the A-TAC suggested less than complete agreement). Disagreement between different rater categories does occur for neurodevelopmental disorders (Hartman et al. 2007); however, cross-validation of diagnoses in Pastill (CAMH professionals) and the A-TAC (parent informants) suggested good to excellent agreement. However, since sensitivity and specificity of A-TAC diagnoses are less than perfect, some diagnostic misclassification could be expected; perhaps mostly for TDs where cases were few. Further, we did not differentiate between the different clinical representations of ASDs or TDs. For ASDs, however, the discriminant validity between these conditions is unclear (Lord et al. 2012) and a single autism spectrum disorder category is suggested for fifth edition of the Diagnostic and Statistical Manual of Mental Disorders. Similarly, different types of TDs co-exist frequently in clinical practice. We did not investigate at what age the outcomes or mediators appeared, thus some of the probands may

have committed a violent crime, or been ascribed a diagnosis of bipolar disorder or schizophrenia before entering the Pastill. On the other hand, these types of neurodevelopmental problems are usually diagnosed in childhood, or in connection with admission to school (Anckarsäter et al. 2011) which is why it seems unlikely that the outcome or mediators preceded the diagnosis of the neurodevelopmental disorder. The co-occurrence of one or more of the four studied neurodevelopmental disorders was low (8.4 % of the cases), this is not uncommon in regular clinical practice since one principal diagnosis is usually assigned and clinicians may tend to explain less pronounced symptoms with this principal diagnosis (i.e., the OCD traits are explained by an ASD. The high rate of ASDs compared to ADHD indicates referral bias as population studies find ADHD more prevalent than ASDs, therefore the results may not be representative for the general population. However, although the relative prevalences are not representative for the general population, relative risks could well be representative since the risk for violence conferred by each neurodevelopmental disorder was compared to that of individually matched population controls. Conversely, the results are probably representative for samples derived from large-scale clinical settings.

Conclusions

ADHD and TDs in childhood were associated with violent criminality; and these associations are not mediated by other mental health problems or substance abuse. By contrast, ASDs and OCD are *not* associated with criminality. In addition, the finding that the association between ADHD and criminality is to some extent due to familial effects, suggests that actions aimed at reducing criminality during adolescence should not only target the proband, but should also take the entire familial context into account.

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Appendix

See Table 4.

Table 4 Overlap between diagnoses

ADHD	ASD	TDs	OCD	Frequency	Percent	n with mental retardation
*	*	*	*	34106	91.65	274
1	*	*	*	1179	3.17	40
*	1	*	*	769	2.07	88
*	*	1	*	123	0.33	0
*	*	*	1	776	2.09	12
1	1	*	*	123	0.33	12
*	1	1	*	17	0.05	3
*	*	1	1	25	0.07	0
1	*	*	1	16	0.04	1
1	*	1	*	32	0.09	4
*	1	*	1	29	0.08	0
1	1	1	*	9	0.02	2
1	1	*	1	3	0.01	3
1	*	1	1	4	0.01	0
*	1	1	1	4	0.01	0
1	1	1	1	0	0.00	0

Mental retardation not included in any of the analyses

ASD autism spectrum disorder, ADHD attention deficit hyperactivity disorder, TD tic disorder, OCD obsessive compulsive disorder

1 denotes that diagnosis is present, * denotes that diagnosis is not present

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