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Anabolic androgenic steroids and violent offending: confounding by polysubstance abuse among 10 365 general population men

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ABSTRACT

Background and Aims Anabolic androgenic steroid (AAS) use is associated with aggressive and violent behaviour, but it remains uncertain if this relationship is causal in humans. We examined the link between AAS use and violent crime while controlling for polysubstance abuse and additional suggested risk factors for violence. **Design** Cross-sectional study of a population-based sample. **Setting** In 2005, all Swedish-born male twins aged 20–47 years were invited to participate in the Swedish Twin Adults: Genes and Environment (STAGE) survey of the Swedish Twin Register (response rate = 60%). **Participants** A total of 10 365 male survey participants with information on AAS use. **Measurement** Data on self-reported use of AAS, alcohol and other substances, attention deficit hyperactivity disorder (ADHD) and personality disorder symptoms were linked to nation-wide, longitudinal register information on criminal convictions, IQ, psychological functioning and childhood socio-economic status (SES) covariates. **Findings** Any life-time use of AAS was associated strongly with conviction for a violent crime [2.7 versus 0.6% in convicted and non-convicted men, respectively; odds ratio (OR) = 5.0, 95% confidence interval (CI) = 2.7–9.3]. However, this link was substantially reduced and no longer significant when controlling for other substance abuse (OR = 1.6, 95% CI = 0.8–3.3). Controlling for IQ, psychological functioning, ADHD, personality disorder symptoms and childhood SES did not reduce the risk further. **Conclusion** In the general population, co-occurring polysubstance abuse, but not IQ, other neuropsychological risks or socio-economic status, explains most of the relatively strong association between any anabolic androgenic steroid use and conviction for a violent crime.

Keywords Anabolic androgenic steroids, general population, polysubstance abuse, psychiatry, survey, violent crime.

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INTRODUCTION

Illicit use of anabolic androgenic steroids (AAS) has aimed primarily at enhancing athletic performance and body appearance. AAS use spread among the general population during the 1980s and is currently seen as a major health problem [1]. Beyond the desired anabolic muscle-building effects, AAS use has been associated with various somatic (e.g. cardiovascular and reproductive) complications and psychiatric side effects (e.g. depression, irritability, mania) [1–3]. AAS are indeed psychoactive substances and affect several neurotransmitters across different brain regions, including the reward system and aggression-related pathways [4], possibly expressed as improved self-esteem but impaired impulse control, extreme mood swings and aggression [5,6].

A divergent literature has tested the association of AAS with aggression and violent behaviour in humans. For example, Pope *et al*. [7] studied possible psychiatric effects of supraphysiological doses of testosterone in normal men. Their randomized controlled trial revealed testosterone-induced mania and verbal hostility responses. However, effects varied considerably across individuals and only a few subjects contributed to the overall weak but significant effect. Klötz *et al*. [8] examined registered criminality in a selected clinical cohort of individuals tested for AAS use in Sweden. AAS-positive individuals were significantly more often convicted of fraud and weapons offences, but not for violent or property crime. Further, Swedish remand prisoners with known substance abuse reported AAS use more often when suspected of a violent crime compared to other offence categories. However, no temporal relation to the suspected offence was identified [9]. Very few population surveys have addressed a possible AAS–violence link. One nationally representative survey of US adolescents found a small but significant risk for self-reported serious violent behaviour among those also reporting AAS use, even after controlling for polysubstance abuse and previous violent behaviour [10]. Another US population survey suggested that AAS use was associated strongly with self-reported aggressiveness (physical fights, hurting somebody, robbery) [11]. To summarize, besides observed aggression and hostility side effects in humans [6,12] and increased aggressive behaviour in male rodents upon chronic AAS exposure [13,14], results are less consistent among humans and, specifically, the possible causal impact of AAS on interpersonal violence remains unproven.

Recently, AAS use has been identified as one component of polysubstance abuse [1,15]. AAS might be a gateway to other illicit drug use [16] and, conversely, the use of illicit drugs might precede that of AAS use [17]. A recent Swedish study based on toxicological testing of police suspects found additional licit (e.g. benzodiazepines) or illicit substances in 60% of AAS-positive suspects, with cannabis and amphetamine being the most common [18]. Kanayama & Pope concluded that AAS users often engage in experimentation, both with additional performance- or appearance-enhancing drugs (e.g. human growth hormone) and classical drugs of abuse [1]. Interviews with patients primarily seeking treatment for AAS use indicated polysubstance abuse, including amphetamine and ephedrine, as attempts to improve endurance and fat-burning, cannabis abuse to relax and opioids to reduce pain after a heavy work-out [15]. Interviews with substance abusers suggest that most use AAS to improve work-out results and become stronger. The few who have other reasons might attempt to conceal concomitant drug use, alleviate self-esteem or prepare for a crime [19].

The life-time prevalence of AAS use is much higher in prisoners than in general population controls [9,20], and there are common risk factors for AAS use, criminality and substance abuse in general. Childhood conduct disorder is a major risk factor for AAS use among weight-lifters [21] and also substantially increases adult risk for antisocial personality disorder, criminality and overall substance misuse [22,23].

To conclude, there is indeed an observed association between AAS use and violent behaviour, and AAS use often co-occurs with use of other illicit drugs. However, previous research mainly used small, selected samples that may provide biased estimates of possible causal effects, including weight-lifters [24], substance abusers [19] and remand prisoners [9]. Further, the few population-based studies did not focus upon the association with violent crime [11,25] or were limited to adolescents and young adults' self-reported violence [10].

We aimed to expand upon previous research by examining the link between AAS use and officially registered violent offending while controlling for polysubstance abuse and additional suggested violence risk factors in one of the largest studies to date, a general population cohort of 20–47-year-old men. Self-reported data on AAS, other drug and alcohol use, attention deficit hyperactive disorder (ADHD) and personality disorder symptoms were linked to national longitudinal register information on established literature-based violence correlates: general cognitive ability (IQ), psychological functioning and childhood socio-economic status.

METHODS

The Swedish Twin Register and STAGE

The Swedish Twin Register encompasses all twins born in Sweden since 1886 [26]. In the Study of Twin Adults: Genes and Environments (STAGE), all twins in the Swedish twin register born 1959–85 (20–47 years at data collection in 2005–06) and where both siblings were alive and living in the country ($n = 42\ 224$; 21 174 men, 21 050 women) were invited to participate in a web-based survey. The self-report questionnaire addressed socio-demographic conditions, stressful and traumatic life events, physical and mental health, substance misuse and sexual behaviour. Participants could also choose a telephone interview supplemented with a self-administered paper questionnaire for sensitive topics. Non-responders were reminded up to three times and the overall response rate for the survey was 60.1%. Prior linkage with Swedish national registries [27] found that STAGE non-responders do not differ from responders regarding age, birth weight or in-patient treatment for neurological disorders. Nevertheless, non-responders were more often male, criminally convicted and treated for psychiatric conditions. They were also less educated, and had somewhat lower general cognitive ability (IQ) at mandatory conscription (males only) at age 18 years (all P-values <0.001) [27].

Participants

We included all male STAGE participants who responded to questions on the use of anabolic androgenic steroids (AAS) ($n = 10\ 365$). Women were excluded due to the rarity of both violent crime (life-time conviction rate less than 1%) [28] and AAS use [29]; of the four women reporting AAS use, none was convicted for a violent crime.

Exposure and outcome

Any life-time use of AAS was examined with the question: 'Have you ever used anabolic androgenic steroids?'. Violent offending was defined as any conviction of a violent offence in the Swedish lower court from 1973 to 2009. The National Criminal Conviction Register includes all people with custodial or non-custodial sentences, even when a prosecutor decided to caution or fine without a formal trial or a defendant was judged to suffer from medico-legal insanity at the time of perpetration. Because criminal responsibility in Sweden starts at age 15, no offences committed before this age are recorded in the Conviction Register. In line with previous research, we used a broad definition of violent crime [28,30] capturing offending with the intention or consequence of causing physical or psychological harm or coercing another individual. We included: homicide, assault, robbery, threats and violence against an officer, gross violation of a person's/woman's integrity, unlawful coercion, unlawful threats, kidnapping, illegal confinement, arson, intimidation and sexual violence, including rape, sexual coercion and child molestation. Attempted and aggravated forms of these offences were included when applicable.

Potential confounders

Substance abuse

The STAGE self-report provided data on life-time DSM-IV alcohol abuse/dependence [31] and (life-time) use of amphetamine, cocaine, cannabis, benzodiazepines or zolpidem and Rohypnol. Rohypnol use was asked for separately, as its active substance flunitrazepam probably confers a higher risk of dependence, and has been claimed to trigger violent behaviour [32].

Seven other substances were asked for in the survey and initially tested for their effect on the association between AAS and violence: methylphenidate, codeine, other opioids, ecstasy, lysergic acid diethylamide (LSD), gammahydroxybutyrate (GHB) and psilocybin ('mushrooms'), but not included in our analyses as described in the Statistics section.

For each endorsed substance including AAS, additional questions addressed age at first use, age at most frequent use and intensity during that period, and age at last use. However, substantial non-response rates for these follow-up items would have compromised the analyses and were not used.

General intelligence

General intelligence (IQ) was measured within the Swedish Enlistment Battery, used as part of compulsory conscription and mandatory for more than 95% of young Swedish men up to 2009. The test consists of four subscales capturing different aspects of cognitive ability (verbal, spatial, inductive and technological), measured on the stanine (standard nine) scale (a normal distribution divided into nine categories, with mean = 5 and standard deviation = 2). The scale was standardized for each conscription year, so there was no change in the distribution over time. A subset of all men enlisting in 1965 were retested 1–4 years later, yielding high test–retest correlations (1 and 2 years, respectively = 0.89; 3 years = 0.80, 4 years = 0.84) [33].

Psychological functioning

Psychological functioning was also measured at compulsory conscription. Based on a semistructured interview by a clinical psychologist, psychological functioning was judged on a 1–9 stanine scale supposedly reflecting stress coping during war or similar extreme stress situations [34].

ADHD

Current ADHD was assessed with the 18 symptom criteria from DSM-IV [31], some slightly rephrased to suit adults more appropriately. Respondents self-reported symptoms persisting for at least 6 months on a three-point scale (0 = no, 1 = yes, to some extent or 2 = yes). We constructed a dichotomous measure of possible adult ADHD according to DSM-IV diagnostic cut-offs of six or more of nine items endorsed with yes or yes, to some extent, in the attention deficit and/or the hyperactivity/impulsivity criteria subsets. Age of symptom onset, pervasiveness across settings and distress or impairment criteria were not considered.

Personality disorder

A screen-positive result for self-reported personality disorder was defined as ≥4 points on the 11-item Iowa Personality Disorder Screen [35]. With a ≥ 4 cut-off, the instrument has a sensitivity of 0.77 and a specificity of 0.71 [36].

Socio-economic status (SES)

From the National Censuses of 1970, 1975, 1980 and 1985, we obtained socio-economic characteristics of the early childhood household (childhood family income). For each individual, we used information from the census closest in time to the year after his birth, meaning that age at census ranged from less than 1 to 10 (the latter only for individuals born 1959). Income was based on the taxed income of the 'head of household' assigned in the census (in married couples at the time, always the man). To manage skewness and inflation, income was rank-coded in deciles (1–10) in each census year. Living with a single mother was coded 1, otherwise 0. We used Statistics Sweden's coding of Household SEI (socio-economic index) constructed from both parents' occupation and divided into categories reflecting the education needed for the job, associated status and payment. As SEI coding has changed somewhat over time, we collapsed the coding into four categories: low (skilled and unskilled workers across all fields), medium (low and intermediate position white-collar workers), high (high-position white-collar workers) and self-employed professionals and entrepreneurs. The latter included all owners of private enterprises (except agricultural), regardless of size [37,38].

Statistics

The association of life-time AAS use and violent offending was analysed with logistic regression and 95% confidence intervals (CIs) were calculated with robust standard errors (SAS version 9.3), taking into account the relatedness of twin siblings. We adjusted analyses for birth year as a categorical variable and continued with four additional steps. First, birth year-adjusted bivariate associations were calculated separately for AAS, different illicit and licit drugs and alcohol abuse/dependence with a violent crime conviction as outcome. Secondly, we tested if including each specific substance individually influenced the association of AAS with violent crime (data not shown). After removing those that did not yield any change in the association of AAS and violent crime (methylphenidate and codeine), we entered all remaining substances (alcohol, amphetamine, cannabis, benzodiazepines, Rohypnol, other opioids, ecstasy, LSD, GHB and psilocybin) into the model, and proceeded to iteratively remove the substance with the weakest association to violent crime from the model. If removing the substance affected the association (β-value) of AAS with violent crime by more than 10% it was re-entered into the model, followed by removing the substance with the next weakest association. This variable selection procedure revealed that including any substance in addition to amphetamine and Rohypnol did not further attenuate the association of AAS with violent crime, although several other substances were associated substantially with violent crime (Table 2, third column from the left). However, based on previous research and judging potential loss of power to be minor, we chose to keep four other common drugs of abuse (alcohol, cannabis, other benzodiazepines and cocaine) in the statistical analyses. Thirdly, we performed birth year-adjusted multivariate analyses where use of AAS, Rohypnol, other benzodiazepines, amphetamine, cocaine, cannabis and alcohol abuse/dependence were entered simultaneously into the model (Table 2, right-most column). Fourthly, and finally, we tested the association between AAS and violent crime controlling for the literature-based potential confounders described above (Table 3).

Missing values for specific covariates were replaced using multiple imputation in fully conditional specification (FCS) [39] models with the SAS command Proc MI. Each covariate was modelled as a function of all other covariates, AAS use and violent crime. Covariates were modelled with ordinal logistic regression, except IQ and psychological functioning, which were imputed as linear, bounded by 1 and 9 and rounded to the nearest integer. To ensure that the imputation did not unduly influence the results, we present distributions of covariates before and after imputation, and results from complete-case analysis in the Appendix (Supporting information, Tables S1 and S2).

RESULTS

A total of 4.9% of 10 365 male participants ($n = 511$) had been convicted for a violent crime and 0.7% ($n = 76$) reported AAS use. There was no difference in age at first conviction between AAS users and non-users ($P > 0.80$). Table 1 presents distribution and association of self-reported AAS use with other substance use, psychiatric/psychological characteristics and socio-economic background factors.

As suggested from Table 2, those convicted of a violent crime reported AAS use more often [2.7 versus 0.6%, odds ratio (OR) = 5.0, 95% CI = 2.7–9.3]. This association was substantially attenuated and lost statistical significance after adjusting for other life-time substance abuse. Similarly, associations also decreased considerably for the five non-AAS life-time drug abuse practices (Table 2), but less so for DSM-IV alcohol abuse/dependence when adjusting for co-occurring substance use. However, these links remained significant for any life-time use of Rohypnol, amphetamine and cannabis and for DSM-IV alcohol abuse/dependence. Adjusting only for life-time use of Rohypnol and amphetamine was sufficient to attenuate the association of AAS with violent crime to a non-significant OR = 1.7, 95% CI = 0.9–3.3 (data not shown).

Table 3 shows the influence of potential confounders beyond co-occurring substance abuse on the association of AAS use and violent offending. Overall, the association between AAS use and violent offending declined (from OR = 5.0 to 3.6–4.2) when we adjusted for intelligence, psychological functioning or possible ADHD, respectively. Only marginal changes (to 4.5–4.9) were found for the

Table 1 Association of self-reported anabolic androgenic steroid (AAS) use with other substance use, psychiatric/psychological and socio-economic characteristics among 10 365 20–47-year old Swedish general population men.

Any life-time AAS use	No (n = 10 289)	Yes (n = 76)	Univariate analysis[a] OR (95% CI)
Cocaine	252 (2%)	31 (41%)	25.9 (15.8–42.3)
Amphetamine	425 (4%)	37 (49%)	20.9 (13.2–33.1)
Rohypnol	125 (1%)	19 (25%)	26.0 (14.7–45.9)
Other benzodiazepines	393 (4%)	21 (28%)	10.1 (5.8–17.3)
Cannabis	1979 (19%)	49 (64%)	7.4 (4.5–12.1)
DSM-IV alcohol abuse/dependence	1289 (13%)	25 (34%)	3.3 (2.1–5.4)
Methylphenidate	10 (0%)	2 (3%)	40.1 (8.6–187.2)
Codeine	126 (1%)	6 (8%)	7.5 (3.2–17.8)
Morphine	142 (1%)	9 (12%)	9.5 (4.7–19.3)
Ecstasy	207 (2%)	26 (34%)	23.1 (14.0–38.2)
LSD	92 (1%)	11 (14%)	17.3 (9.0–33.5)
GHB	42 (0%)	11 (14%)	35.1 (17.2–71.8)
Mushrooms	147 (1%)	14 (18%)	14.0 (7.6–25.9)
ADHD screening[b]	893 (13%)	15 (29%)	2.8 (1.5–5.1)
Iowa screening for personality disorder[c]	140 (3%)	2 (5%)	1.8 (0.5–7.3)
IQ, mean (SD)	5.3 (1.9)	4.4 (1.9)	0.8 (0.7–0.9)
Psychological functioning, mean (SD)	5.3 (1.6)	4.6 (2.0)	0.8 (0.6–0.9)
Childhood SES			
Single mother	1792 (17%)	15 (20%)	1.2 (0.6–2.1)
Childhood family income[d]	4.7 (5.0)	4.9 (5.5)	1.0 (0.9–1.2)
Socio-economic index 1 low	3665 (38%)	35 (49%)	1.0 (1.0–1.0)
Socio-economic index 2 medium	3937 (41%)	22 (31%)	0.6 (0.3–1.0)
Socio-economic index 3 high	907 (9%)	9 (13%)	0.9 (0.4–1.9)
Socio-economic index 4 self-employed	1070 (10%)	5 (7%)	0.5 (0.2–1.3)
Missing data on socio-economic index	710 (5%)	5 (75)	–

[a]Birth-year adjusted 95% confidence intervals (CI) based on robust standard errors accounting for relatedness between twin siblings. [b]Proportions based on number of responders with attention deficit hyperactive disorder (ADHD) screening ($n = 6867$). [c]Proportions based on number of responders with personality disorder symptom screening ($n = 5257$). [d]Income was based on the taxed income of the 'head of household' assigned in the census (in married couples at the time, always the man). To manage skewness and inflation, income was rank-coded in deciles (1–10) in each census year. SD = standard deviation; SES = socio-economic status; GHB = gammahydroxybutyrate; LSD = lysergic acid diethylamide; OR = odds ratio.

Table 2 Self-reported life-time substance use and risk of any violent crime conviction among 10 365 20–47-year old men in the Swedish general population.

	Violent offending			
Substance	*Yes (n = 511)*	*No (n = 9854)*	*Bivariate odds ratio[a]*	*Multivariable odds ratio[b]*
AAS	14 (2.7%)	62 (0.6%)	5.0 (2.7–9.3)	1.6 (0.8–3.3)
Rohypnol	40 (7.8%)	104 (1.1%)	9.0 (6.0–13.7)	2.1 (1.2–3.7)
Other benzodiazepines	56 (11.0%)	358 (3.6%)	3.3 (2.4–4.5)	1.1 (0.7–1.6)
Amphetamine	97 (19.0%)	365 (3.7%)	6.9 (5.3–8.9)	2.7 (1.9–4.0)
Cocaine	55 (10.8%)	228 (2.3%)	5.8 (4.2–8.0)	0.9 (0.6–1.5)
Cannabis	208 (40.1%)	1820 (18.5%)	3.2 (3.1–4.6)	1.8 (1.5–2.3)
DSM-IV alcohol abuse/dependence[c]	159 (32.1%)	1155 (12.0%)	3.8 (3.1–4.6)	2.7 (2.2–3.4)

Numbers in parentheses in the two right-most columns are 95% confidence intervals based on robust standard errors accounting for relatedness between twin siblings. [a]Adjusted only for birth year. [b]Adjusted for birth year and co-occurring life-time use of the other five tested substances or alcohol abuse/dependence. [c]A total of 261 individuals lacked information needed to diagnose alcohol abuse/dependence. AAS = anabolic androgenic steroid.

Table 3 Influence of potential confounders on the association between any life-time anabolic androgenic steroid (AAS) use and a violent crime conviction among 10 365 20–47-year-old men in the Swedish general population.

	Association between AAS use and violent crime, adjusted for	
Covariate	*Birth year and specific covariate*[a]	*Birth year, co-occurring substance abuse and specific covariate*[a]
General intelligence (IQ)	4.0 (2.1–7.5)	1.3 (0.6–2.7)
Psychological functioning	3.6 (1.8–7.0)	1.4 (0.7–3.0)
DSM-IV ADHD	4.2 (2.3–7.8)	1.4 (0.7–2.8)
Possible personality disorder (Iowa)	4.5 (2.4–8.5)	1.5 (0.7–3.1)
Childhood family income	4.9 (2.7–9.0)	1.5 (0.7–3.1)
Childhood socio-economic index	4.6 (2.4–8.6)	1.5 (0.7–3.0)
Single mother family during childhood	4.8 (2.7–8.8)	1.5 (0.7–3.0)
All covariates	3.1 (1.6–6.2)	1.3 (0.6–2.9)

Associations are expressed as odds ratios; figures within parentheses are 95% confidence intervals based on robust standard errors accounting for relatedness between twin siblings. [a]Indicates specific covariate at the beginning of each row, respectively. ADHD = attention deficit hyperactive disorder.

remaining covariates. Adjusting for all covariates decreased the association further. Importantly, none of the measured confounders contributed to additional change following adjustment for co-occurring substance abuse. Further, no significant interactions between these covariates and AAS use on violent crime were found (data not shown).

DISCUSSION

To our knowledge, we have conducted the first large general population study of the relation between AAS use and violent offending that combined self-reports and registry measures of potential confounders. We found a strong association between self-reported life-time AAS use and violent offending in a population-based sample of more than 10 000 men aged 20–47 years. However, the association decreased substantially and lost statistical significance after adjusting for other substance abuse. This supports the notion that AAS use in the general population occurs as a component of polysubstance abuse, but argues against its purported role as a primary risk factor for interpersonal violence. Further, adjusting for potential individual-level confounders initially attenuated the association, but did not contribute to any substantial change after controlling for polysubstance abuse.

Overall, the association between each of the six non-AAS types of substance abuse and violence (Table 2) declined after adjusting for other co-occurring substance abuse. Given the imperfect nature of our measures of substance abuse, it is likely that the associations would have been even more attenuated with better measures. At present, associations remained moderately strong (OR ≥ 2.0) and significant for Rohypnol, amphetamine and DSM-IV alcohol abuse/dependence in multivariable analyses, indicating unique associations of these substances with violence. A causal relation between alcohol and violence is well established [40–42]. Flunitrazepam became a popular drug of abuse in the late 1990s under the brand name Rohypnol, and it was suggested that flunitrazepam induced violent behaviour [43]. Previous case–cross-over research from our group suggests that benzodiazepines in regular doses may have a preventive effect on violence risk, while intake of high doses could trigger violent offending [40,44]. Amphetamine use, in turn, may have irritability and paranoia as serious side effects that could increase violence risk [45].

We found no additional effect on the association between AAS use and violent offending from self-reported confounders (ADHD and personality disorder symptoms) or register-based covariates (IQ and psychological functioning from military conscription testing, childhood SESc), although IQ, personality functioning and ADHD initially attenuated the association. Hence, as previous research posits that these confounders covary with substance abuse, it seems that pharmacological, psychological or social effects related to substance abuse *per se* contribute most of the risk for violent offending. This agrees with previous research suggesting a strong relation between substance abuse and violent crime [46]. None of the measured covariates exhibited a significant interaction with the AAS–violent crime link. Further, contrary to expectation, if there was a difference in criminal trajectories between AAS users and non-users we found no difference in age at first conviction.

The life-time prevalence of AAS use reported by 20–47-year-old men was 0.7%, similar to other population studies [11,25]. This stands in stark contrast to the 20% who had ever used AAS in another contemporary, but highly selected, Swedish sample of 194 remand prisoners [44]. Thus, our data are congruent with the idea that although AAS use is considerably more common among violent offenders, the increased risk of interpersonal violence is conferred by co-occurring abuse of substances such as flunitrazepam, amphetamines and alcohol. Animal research has also found an exacerbated risk for aggressive, competitive and dominance behaviours after intake of alcohol or amphetamine in animals pre-treated with AAS [47,48].

Strengths and limitations

We attempted to elucidate the relationship between an unusual exposure (AAS) and a rare outcome (violent crime) in a large, well-characterized adult population cohort. Because the sample consisted of twins, we had the theoretical possibility to strengthen our study further with complementary co-twin control analyses to handle confounding by factors shared by twins. However, such analyses require twin pairs discordant on the exposure, and the rarity of AAS use rendered the statistical power too low for an informative analysis, even in this large sample. Further, unlike previous studies that might have suffered from shared method variance (using self-reported data for both exposure and outcome), we had the opportunity to use an objective outcome measure: conviction of a violent crime.

Some limitations need consideration. First, the STAGE survey had an overall response rate of 60% and, as mentioned above, non-respondents were more often male, criminally convicted, treated for psychiatric conditions, less educated and had lower IQ at conscription [27]. As non-respondents were likely to have a higher prevalence of both exposure and outcome variables, this could lead to some underestimation of the true associations of AAS use and other substance abuse with violent offending. Secondly, self-report data on use of AAS and other substances always involves misclassification risks. If this exposure misclassification was random regarding violent crime, we would underestimate the association of the respective substances and violence. Thirdly, the cross-sectional study design did not allow analysis of the temporal relations of AAS use, other substance use and violent offending. Thus, conclusions regarding the causal pathways among these variables should be avoided.

Self-reports of ADHD and personality disorder symptoms had many missing values (Supporting information, Table S2), primarily because responders who chose a telephone interview (instead of the web questionnaire) sometimes failed to return the separate, self-administered paper questionnaire with mental health questions. As it is likely that choice of response format does not occur completely at random, more well-functioning participants probably provided complete data more often. Hence, although we used multiple imputation of data to compensate for this, we could only reduce bias through appropriate confounder control procedures for factors with available data. In other words, estimates for ADHD and personality disorder may have suffered residual selection bias.

CONCLUSION

Our results suggested that it was not life-time AAS use *per se*, but rather co-occurring polysubstance abuse that most parsimoniously explains the relatively strong association of AAS use and interpersonal violence. Further, substance abuse as such might be a more prominent contributor to violence risk than other individual vulnerability, including poorer cognitive ability or psychological functioning, ADHD or personality disorder or socioeconomic vulnerabilities, although these factors often covary with substance misuse. These findings suggest that professional assessment and treatment of violence risk should consider overall substance use patterns rather than AAS use in isolation.

Declaration of interests

None.

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Supporting information

Additional Supporting information may be found in the online version of this article at the publisher's web-site:

Table S1 Individuals with missing information on each covariate and distribution data before and after multiple imputation.

Table S2 Influence of potential confounders on the association between any life-time anabolic androgenic steroid (AAS) use and a violent crime conviction among 10 365 20–47-year-old men in the Swedish general population. Analyses restricted to responders with valid information on the covariate (complete-case analyses).