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Abstract

Background: The present study examined the associations between cannabis use in adolescence and young adulthood and self-reported adult attention deficit/hyperactivity disorder (ADHD) symptoms in adulthood.

Methods: A 25-year prospective longitudinal study of the health, development, and adjustment of a birth cohort of 1,265 New Zealand children. Measures included assessments of adolescent and young adult cannabis use and at age 25, measures of childhood socioeconomic disadvantage, family adversity, childhood and early adolescent behavioural adjustment and cognitive ability, and adolescent and young adult other drug use.

Results: Cannabis use by age 25 was significantly ($p < .0001$) associated with increasing self-reported adult ADHD symptoms at age 25. Adjustment of the association for potentially confounding factors from childhood and early adolescence reduced the magnitude of the association, but it remained statistically significant ($p < .0001$). However, control for the mediating effects of other drug use in adolescence and early adulthood reduced the association between cannabis use and adult ADHD symptoms to statistical non-significance ($p > .20$).

Conclusions: The current study suggested that the association between cannabis use and adult ADHD symptoms was mediated by other substance use that was associated with cannabis use. The results suggest that cannabis use leads to other drug use, which in turn leads to increased ADHD symptoms. However, it should be noted that the potential influence of such factors as genetic predispositions may still be unaccounted for.

Keywords: cannabis use, adult ADHD, substance use, mental health, longitudinal study

1. Introduction

In recent years, there have been growing concerns and debates about the effects of cannabis use on the health and well-being of young people. These concerns have been motivated by evidence of growing cannabis use in young people (Rey et al., 2002; von Sydow et al., 2001), changes in the nature and strength of cannabis (ElSohly et al., 2000; Licata et al., 2005), and by growing evidence linking cannabis to mental health and other problems (Fergusson et al., 2006a; Fergusson et al., 2002; Fergusson et al., 2006b; Hayatbakhsh et al., 2007; Looby and Earleywine, 2007; Rey et al., 2002). While the role of cannabis in encouraging psychosocial problems in young people remains controversial, there is growing evidence from both epidemiology and neuroscience that cannabis may be more harmful than previously believed (Hall and Pacula, 2003; Hall, 2006).

One particular concern that requires further attention is the extent to which the use, and in particular heavy use of cannabis, may be related to problems in attention and cognitive processing among users of the drug. Specifically, there have been frequent references in the literature on cannabis that suggest that cannabis use may be associated with impairment of attention, even when the individual is not intoxicated (for reviews see: Kalant, 2004; Lundqvist, 2005; Pope et al., 2001). For example, Harvey and colleagues (Harvey et al., 2007) found that adolescents who used cannabis at least once a week had significantly poorer performances on cognitive tasks requiring attention and spatial working memory. Messinis et al (Messinis et al., 2006) found that long-term cannabis users showed impairments to attention and processing speed using a battery of neuropsychological tests. Also, Solowij et al (Solowij et al., 2002) reported that heavy cannabis users showed impaired attention and executive functioning across several neuropsychological tests, and that the degree of impairment of attention was associated with increasing years of heavy cannabis use. A study by Ehrenreich and colleagues (Ehrenreich et al., 1999) found that impairments to attention were more acute for those individuals who began using cannabis prior to age 16 years. In addition, Gruber et al (Gruber et al., 2003) found that heavy cannabis users reported that their cannabis use had impaired their cognitive abilities in general.

Although several studies have found an association between cannabis use and attention problems, even after controlling for potentially confounding factors, it may be argued that these persistent associations may be due to the effects of residual confounding that is associated with both cannabis use and attention problems. Also, a number of the studies reporting associations between cannabis use and attention problems were cross-sectional or retrospective in nature. A more advantageous design for examining the associations between cannabis use and later attention problems would be a longitudinal design in which measures of cannabis use, cognitive functioning, and potentially confounding factors obtained prospectively.

While there has been substantial research into cannabis use and attention problems, there has been no examination of the extent to which cannabis use is a risk factor for symptoms of adult attention deficit/hyperactivity disorder (ADHD). Barkley and Murphy (Barkley and Murphy, 1998) described the symptoms of adult ADHD as including, in part, distractibility, the inability to control attention, and the lack of ability to focus and sustain attention for extended periods of time, and argue that these symptoms may be related to functional impairments in daily life. It may be argued that the impairments of attention observed in cannabis users may mirror those in individuals with symptoms of adult ADHD, and that it may be possible to link adult ADHD symptoms with earlier cannabis use.

A further issue that requires consideration is the extent to which the linkages between cannabis use and impairment of attention may be mediated by other substance use. In particular, there is considerable evidence to suggest that those using cannabis have higher rates of other forms of drug use (Fergusson et al., 2006a; Kandel et al., 1992). It may be suggested that it is the increased use of other drugs which accounts for the increased rates of attention problems amongst cannabis users (Bolla et al., 2003; Ersche et al., 2006; Ornstein et al., 2000; Quednow et al., 2007; Verdejo-Garcia and Perez-Garcia, 2007; Verdejo-Garcia et al., 2007), with cannabis use being only indirectly related to attention and cognition.

Against this background, the present study uses data gathered from a 25-year longitudinal study to examine the linkages between cannabis use up to age 25, and self-reported ADHD symptoms at age 25. The aims of these analyses were:

1. To examine the linkages between the extent of cannabis use prior to age 25 and self-reported adult ADHD symptoms at age 25;
2. To adjust the associations between cannabis use and adult ADHD symptoms for confounding factors including family socioeconomic background, family functioning, childhood behavioural adjustment, and childhood cognitive ability; and;
3. To examine the role of co-occurring use of drugs other than cannabis as a mediating factor between the use of cannabis and later ADHD symptoms.

2. Methods

2.1 *Participants and sample size*

The data were gathered during the course of the Christchurch Health and Development Study (CHDS). In this study a birth cohort of 1265 children (635 males, 630 females) born in the Christchurch (New Zealand) urban region in mid-1977 has been studied at birth, 4 months, 1 year and annually to age 16 years, and again at ages 18, 21 and 25 years (Fergusson and Horwood, 2001; Fergusson et al., 1989). The analyses were based on the 1003 study participants for whom information was available for outcomes at age 25 years (79% of the original sample). All study information was collected on the basis of signed and informed consent from study participants.

2.2 Measures

2.2.1 *Estimated cannabis use, ages 15-25*

At the age 15, 16, 18, 21, and 25 year assessments, participants were questioned as to the number of occasions on which they had used cannabis during each year. For the purposes of the present study, these estimates were summed for the period 15 to 25 years to arrive at an estimate of the total

number of times participants had used cannabis during the period 15-25 years (M = 228.1, SD = 473.9). The estimate of the total number of times participants had used cannabis during the period 15-25 years was then used to classify participants using a categorical measure of total cannabis use, ranging from 1 (never used cannabis) to 6 (used cannabis 400+ times).

In addition, a further measure of frequency of cannabis use was created. First, the annual data on the amount of cannabis use were classified into a series of class intervals as follows: did not use cannabis during the year; used less than monthly on average (1-11 times); used at least monthly on average (12-50 times); used at least weekly on average (more than 50 times). These were then averaged over the period 15-25 years to arrive at an estimate of the average annual frequency of cannabis use during the period 15-25 years.

Finally, a measure of cannabis dependence during the period 18-25 years was obtained using questions based on the generic DSM-IV (American Psychiatric Association, 1994) criteria for substance dependence derived from the Composite International Diagnostic Interview (CIDI) (World Health Organization, 1993). Participants were classified as being cannabis dependent during the period 18-25 years if they met the DSM-IV criteria for cannabis dependence at any point during that period.

2.2.2 *Adult ADHD symptoms, age 25*

At age 25, participants were questioned as to their experience of a range of cognitive and behavioural problems related to attention, executive function, and impulse control. The questions were drawn from an 18-item scale of adult attention deficit disorder symptoms developed by Barkley and Murphy (Barkley and Murphy, 1998), using a four-point Likert response scale. The scale consists of items pertaining to symptoms of both hyperactivity and attention deficit that have been experienced by the individual in the previous six months. Principal components analysis revealed that the factor structure of the scale was best described as a single factor that accounted for 86% of the variance in the scale. Therefore, responses were summed across the 18 items to arrive at

a measure of adult ADHD symptoms experienced during the six months prior to the interview at age 25 (α = .87). These scores were then standardized to a mean of 100 and standard deviation of 10 for the purposes of the present investigation.

2.2.3 *Covariate factors*

A range of covariate factors were chosen for the analyses, based on: (a) their correlation with cannabis use at ages 15-25; and (b) previous research on the present cohort suggesting that the factors were related to cannabis use. The following covariate factors were chosen for inclusion in the analyses:

2.2.3.1 S*ocioeconomic status of family of origin.*

Family socio-economic status at birth. This was assessed at the time of the survey child's birth using the Elley-Irving (Elley and Irving, 1976) scale of socio-economic status for New Zealand. This scale classifies SES into 6 levels on the basis of paternal occupation, ranging from 1 = professional occupations to 6 = unskilled occupations.

2.2.3.2 *Family functioning*

Family adversity. A measure of family problems was calculated using a count measure of 38 different measures of family disadvantage during the period 0-15 years, including measures of disadvantaged parental background, poor pre-natal health practices and perinatal outcomes, and disadvantageous child-rearing practices (Fergusson et al., 1994).

Parental alcoholism/alcohol problems, criminal offending, and drug use. When sample members were aged 11, their parents were questioned about parental use of drugs. At the 15-year assessment parents were further questioned concerning their history of alcoholism or alcohol problems and criminal offending.

2.2.3.3 C*hildhood and adolescent behavioural adjustment.*

Child conduct and attention problems (ages 7-13). Parent and teacher reports on child conduct and attention problems were obtained from an interviews with the child's mother using a behavior questionnaire that combined items from the Rutter, Tizard, and Whitmore (1970) and Conners (1970) parental questionnaires. These reports were summed and the resulting scores averaged over the seven year period to produce a scale score measure reflecting the extent of the child's tendencies to conduct and attention problems at ages 7-13.

2.2.3.4 *Early adolescent scholastic ability.*

Scholastic ability. At age 13 cohort members were administered the Test of Scholastic Abilities (TOSCA: Reid et al., 1981). This test is designed to assess the extent to which the child exhibits the skills and competencies necessary for academic work in high school. The test was scored as recommended in the test manual to give a total scholastic ability score.

2.2.3.5 *Individual factors.*

Gender. Recorded at birth.

2.2.4 *Co-occurring other drug use.*

Other drug use (ages 15-25). At each assessment at ages 16, 18, 21, and 25, cohort members were questioned as to their use of drugs other than cannabis during each year of each assessment period. These questions were used to create a measure of other drug use that represented the number of different other drugs a participant used in any given year. For the purposes of this analysis, participants were classified as having used a particular class of substance in a given year if they reported using any drug within the substance class on at least one occasion. These responses were then summed to generate continuous drug diversity scores for each year from age 15-16 to age 24-25. The diversity scores for each year were then summed to arrive at a measure

of the overall consumption of other drugs during the period 15-25 years. It should be noted that, a previous study of the present cohort reported that in 98% of cases, cannabis had been used either in the same year or prior to the first use of other drugs. In 86% of cases the individual reported the use of cannabis at least one year prior to the year in which other drugs were first reported to have been used (Fergusson et al., 2006a).

2.3 *Statistical analyses*

The association between cannabis use during the period 15-25 years and adult ADHD symptoms at age 25 were tested for linear trend by using one-way analysis of variance for means. Then, to adjust the association for potentially confounding factors related to childhood and early adolescence, multiple regression models were fitted to the data, in which all potentially confounding factors were entered simultaneously. Following this, in order to examine the possible mediating effect of other drug use, these models were extended to include measures of other drug use during ages 15-25. Tests of statistical significance for the adjusted associations were given by t-tests.

3. Results

3.1 *ADHD symptom scores*

Raw scores on measure of ADHD symptoms were calculated by summing the responses to each of the 18 items (see Method). The mean raw score for the cohort was 5.13 (SD = 5.48). As suggested by Barkley and Murphy, the scores were compared to a cut-off point of 1.5 standard deviations above the mean to determine the number of individuals with "clinically significant" levels of ADHD symptoms. These analyses suggested that 9.3% of the sample (n = 93) had clinically significant levels of ADHD symptoms.

3.2 *Associations between cannabis use to age 25 and adult ADHD symptoms at age 25.*

Table 1 shows the cohort classified into six groups based on the estimated amount of cannabis used by age 25. These groups range from non-users, to those who had used cannabis on more than 400 occasions prior to age 25. For each group, the Table reports on standardized measure of adult ADHD symptoms (see Methods). The Table shows that the increasing use of cannabis prior to the age of 25 was associated with increasing levels of ADHD symptoms reported at age 25 ($p < .0001$; $r = 0.17$). Those using cannabis more than 400 times by age 25 had rates of adult ADHD symptoms that were 0.5 standard deviations higher than those who reported no cannabis use by age 25.

INSERT TABLE 1 HERE

Examination of those cohort members with clinically significant ADHD symptom scores (> 1.5 standard deviations above the mean) found that increasing use of cannabis was associated with increasing rates of clinically significant ADHD symptomatology (Mantel-Haenszel χ^2 (1) = 12.9, $p < .001$). Those using cannabis more than 400 times by age 25 had rates of clinically significant ADHD symptomatology that were 2.97 times those who had not used cannabis.

3.3 *Associations between cannabis use to age 25 and covariate factors*

Table 2 shows the correlations between the extent of cannabis use by age 25, ADHD symptom scores at age 25, and a range of factors related to family socioeconomic background, family functioning, and childhood and adolescent behavioural adjustment and cognitive ability. The Table shows:

1. Cumulative cannabis use by age 25 was significantly correlated with family socioeconomic status at birth ($p < .01$). Lower levels of socioeconomic status were associated with greater levels of cannabis use in adolescence and young adulthood.

2. Cannabis use by age 25 was also significantly correlated with measures of family functioning, including: overall family adversity ($p < .0001$); parental drug use ($p < .0001$); parental offending ($p < .0001$); and parental alcoholism ($p < .0001$). Increasing levels of family dysfunction were associated with greater levels of cannabis use in adolescence and young adulthood.
3. Cannabis use by age 25 was also significantly associated with two measures of childhood and adolescent behavioural adjustment: conduct problems during ages 7-13 ($p < .0001$) and attention problems during ages 7-13 ($p < .0001$). Conduct and attention problems in childhood were associated with increased levels of cannabis use in adolescence and young adulthood.
4. Cannabis use by age 25 was significantly correlated with a measure of scholastic ability at age 13 ($p < .001$). Lower scholastic ability scores were associated with increased levels of cannabis use in later life.
5. Cannabis use by age 25 was also significantly correlated with gender ($p < .0001$). Males reported higher levels of cannabis use than females.
6. In addition, ADHD symptoms at age 25 were significantly correlated with family adversity ($p < .0001$), parental criminal offending ($p < .05$), and both conduct and attention problems at ages 7-13 ($p < .0001$).

In addition, there was a strong correlation ($r = .63$, $p < .0001$) between the measure of cannabis use by age 25 and the measure of the use of other drugs during the period 15-25 years.

INSERT TABLE 2 HERE

3.4 *Associations between cannabis use by age 25 and adult ADHD symptoms at age 25, adjusted for confounding factors and co-occurring drug use.*

One explanation for the pattern of associations shown in Table 1 is that these reflect the presence selection and confounding processes relating to both cannabis use and adult ADHD symptoms in

adulthood. Two models were fitted to the data in order to adjust for confounding and possible mediation pathways. In Model 1, the associations between cannabis use and symptoms of ADHD were adjusted for the potentially confounding factors shown in Table 2. In this model, the family background, childhood, and early adolescent covariate factors were added to the model simultaneously. Model 2 was an extension of Model 1, and included other drug use during ages 15-25 years as a variable that mediated the linkage between cannabis use and symptoms of adult ADHD. Table 3 shows the the standardized regression coefficients for the bivariate associations between the factors and ADHD symptoms at age 25, and for the fitted models after adjustment for: (a) confounding factors in childhood and adolescence (Model 1); and (b) after adjustment for both confounding factors and co-occurring other drug use (Model 2). The Table shows:

1. After adjustment for covariate factors related to family background and functioning, and childhood and early adolescent behavioural adjustment and cognitive ability, the association between cannabis use by age 25 and adult ADHD symptoms at age 25 was reduced in magnitude, but remained statistically significant ($\beta = .13$, $p < .0001$). Statistically significant covariate factors in the final model included conduct problems at ages 7-13 ($p < .01$), and attention problems at ages 7-13 ($p < .05$).
2. Adjustment for co-occurring other drug use substantially reduced the magnitude of the association between cannabis use by age 25 and adult ADHD symptoms at age 25, to the point of statistical non-significance ($\beta = .05$, $p > .20$).

INSERT TABLE 3 HERE

3.5 *Supplementary analyses*

3.5.1 *Alternative classifications of cannabis consumption, ages 15-25.* In order to examine the robustness of the above findings to alternative classifications of cannabis consumption, the analyses above were repeated using two alternative measures: (1) a measure of the estimated cannabis

consumption during each year, averaged over the period 15-25 years; and (2) a measure of DSM-IV cannabis dependence during ages 18-25. These analyses revealed a pattern of results similar to those reported previously. In each case, adjustment for confounding factors reduced the magnitude of: (a) the association between the averaged class measure of cannabis use and ADHD symptoms at age 25; and (b) cannabis dependence during ages 18-25 and ADHD symptoms at age 25. In each case the association remained statistically significant. However, controlling for co-occurring other drug use reduced the associations between cannabis use or dependence and ADHD symptoms to statistical non-significance ($p > .30$).

3.5.2 *Lagged measures of drug consumption.* It could also be argued that the results above may have been influenced by a reverse causal relationship in which the associations between ADHD symptoms at age 25 and cannabis and other drug consumption during ages 15-25 could reflect the effects of current ADHD symptoms leading to increases in cannabis and other drug consumption. In order to account for this possibility, the analyses described above were repeated using lagged measures of cannabis and other drug use, in which the measures of cannabis and other drug consumption were restricted to the period 15-24 years, with the ADHD symptoms measured at age 25 years. The results of these analyses were congruent with those presented above, suggesting that the findings reported above were not influenced by potential reverse causal pathways in which the occurrence of ADHD symptoms increased the rate of cannabis and other drug use.

4. Discussion

This study has used data gathered over the course of a 25-year longitudinal study to examine the linkages between the extent of cannabis use up to the age of 25 and symptoms of adult ADHD at age 25. This analysis led to the following conclusions.

First, in confirmation of previous research linking cannabis use and attention (Ehrenreich et al., 1999; Gruber et al., 2003; Harvey et al., 2007; Kalant, 2004; Lundqvist, 2005; Messinis et al.,

2006; Pope et al., 2001; Solowij et al., 2002), there were clear linkages between the extent of adult ADHD symptoms at age 25 and the extent of cannabis use up to age 25. Young people who had used cannabis over 400 times by age 25 had mean scores on the ADHD symptom measure that were 0.5 standard deviations higher than those who had not used cannabis up to age 25. In addition, there was also an association between cannabis use and clinically significant levels of ADHD symptoms as defined by Barkley and Murphy (Barkley and Murphy, 1998). Furthermore, there was evidence of a linearly increasing dose-response relationship between the extent of cannabis use and ADHD symptoms at age 25 years.

One explanation of the association between cannabis use and ADHD symptom scores is that this may be due to common confounding processes that influence both cannabis use and attention processes in adulthood (Macleod et al., 2004). A strength of the present study was the assessment of a wide range of prospectively-measured confounding factors relating to social, family, behavioural, and cognitive measures prior to the use of cannabis. The inclusion of confounding factors reduced the magnitude of the of the association between cannabis use and ADHD symptoms, but the association remained statistically significant. This result is consistent with previous studies that have reported that the link between cannabis and attention cannot be explained by common confounding factors (Gruber et al., 2003; Harvey et al., 2007; Messinis et al., 2006).

The results of the present analyses also suggest that the linkages between cannabis use and ADHD symptoms may be mediated by the strong linkages between the use of cannabis and the use of other drugs. In a previous study of this cohort, we have reported the presence of strong associations in which the use of cannabis precedes and appears to lead to the use of other drugs (Fergusson et al., 2006a). Control for the effects of other drug use in adolescence and early adulthood reduced the associations between cannabis use and adult ADHD symptoms to statistical non-significance (after controlling for confounding factors). The results of these analyses indicate that other drug use mediated the association between cannabis use and ADHD symptoms.

One interpretation of this pattern of findings is that the observed linkages between cannabis use, other drug use, and ADHD symptoms indicate a causal process in which the use of cannabis leads to increased use of other drugs (Fergusson et al., 2006a), which in turn results in higher rates of adult ADHD symptoms. These results in turn prompt consideration of the aspects of other drug use that may encourage ADHD symptoms. For this cohort, the use of other drugs was dominated by two substances, MDMA (ecstasy) and methamphetamine (Fergusson et al., 2006a). This suggests that the higher rates of adult ADHD symptoms found in cannabis users in this cohort may be due to their higher rates of use of these drugs. That conjecture is consistent with other research suggesting increased rates of cognitive and attention problems amongst methamphetamine and MDMA users (Ersche et al., 2006; Lundqvist, 2005; Ornstein et al., 2000; Quednow et al., 2007).

An alternative explanation for the present findings may be that those using both cannabis and other drugs had greater exposure to all forms of drug use, and that it was the overall burden of exposure to drugs that contributed to increased symptoms of adult ADHD. This explanation would imply that cannabis use may have made a contribution to attention problems, but that this contribution was overlaid by the effects of other drug use.

To our knowledge, this is the first research to suggest that the associations between cannabis use and attention may be mediated by other forms of drug use. For this reason it is important that this result is confirmed by other studies that examine this issue. The present findings also raise the importance of controlling for other drug use in studies of the linkages between cognition/attention outcomes and cannabis use.

These findings are, of course, subject to a number of limitations. First, they report on the experiences of a particular group of individuals born at a specific time and reared in a specific social context. Second, the results are based on self-report data, and thence will be subject to errors of reporting and reminiscence. Third, it could also be argued that there may have been some potentially confounding factors that were unaccounted for (Macleod et al., 2004) including genetic factors that may have influenced both drug use and ADHD symptoms. Fourth, the fact that the

ADHD symptom scale had somewhat weaker associations with childhood history of attention problems than with childhood history of conduct problems would suggest that the adult ADHD scale may be measuring general impulsivity rather than the attention *per se*. This in turn would suggest that cannabis and other drug use may have an effect on impulsive behavior, but the nature of their associations with attention problems in adulthood would be less clear. Finally, although the findings of the study suggested that cannabis use and other drug use were associated with increased risk of ADHD symptoms, it is unclear whether these symptoms could be attributed to acute use of drugs, or the cumulative effect of drug use over time. Future research in this area would benefit from the availability of data on a range of correlated risk influences, such as genetic factors, as well as more detailed examination of the kinds of other drugs that may be related to increases in ADHD symptoms, and more detailed information regarding patterns of drug use in relation to ADHD symptom outcomes.

Notwithstanding these limitations, this study leads to three major conclusions about the linkages between cannabis use and adult ADHD symptoms. First, there was clear evidence to suggest that increasing cannabis use was associated with increasing levels of ADHD symptoms. Second, these associations were not explained by a range of prospectively-measured social, family, cognitive, and behavioural factors. Third, the association between cannabis use and ADHD symptoms appeared to be mediated by other drug use, suggesting the possible existence of a causal chain process in which cannabis use led to increased rates of other forms of drug use, with these being associated with increased symptoms of adult ADHD.

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