Early puberty maturation in the prediction of early adult substance use: a prospective study

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ABSTRACT

Aims: To examine whether self-reporting a later stage of pubertal development in early adolescence predicts young adults’ use of illicit drugs.


Participants: Cohort of 2710 young adults who completed a self-report questionnaire about their use of cannabis and amphetamines at the 21-year follow-up.

Measurements: Young adults’ use of cannabis and amphetamines were measured at the 21-year follow-up. Stage of pubertal development was assessed at the 14-year follow-up. Potential confounding and mediating variables were assessed between birth and when the child was 14 years.

Findings: Of 2710 young adults, 49.9% (47.3 females and 52.7% males) reported that they had used cannabis and 21.0% (18.9% females and 23.3% males) reported that they had used amphetamines and cannabis by 21 years. In multivariate analyses, adolescents with a later stage of puberty were more likely to use cannabis or amphetamines in young adulthood. This association was not confounded by mother's education or child's gender and age. Part of the relationship was explained by the higher frequency of child externalizing behaviour at 14 years.

Conclusions: The findings warrant further attention to puberty as a sensitive period in an individual's development. With regard to prevention, there is a need to understand more about the pathways between pubertal development, child behaviour problems and substance use.

Keywords: Adolescent, puberty, substance use, young adult.

INTRODUCTION

Early adolescence has been identified as an important stage of development [1]. There is strong evidence that the use of substances, including illicit drugs, begins in early adolescence and peaks in late adolescence to early adulthood [2,3]. Early experimentation with substances has been shown to be a risk factor for more advanced drug use, drug dependence and psychological problems related to drugs [4,5]. There is a need to identify and understand the characteristics of subgroups of individuals who are more liable to use illicit substances during adolescence and early adulthood. Puberty has been documented as a sensitive period that is associated with the onset of mental health and behaviour problems, e.g. substance use [6–8]. Despite evidence suggesting a relationship between the
timing of puberty and initiation of smoking and drinking in adolescence, there is a paucity of evidence regarding whether stage of pubertal maturation as measured in early adolescence predicts the intensity of illicit drug use by young adults, and whether this association is affected by gender.

**Pubertal maturation and substance use**
Pubertal maturation can be described in terms of progression and timing. Marshall & Tanner [9,10] defined the five stages of normal pubertal development in children and adolescents. There is growing evidence that those with an early onset of puberty or early pubertal maturation are more likely to engage in problem behaviours and substance use [11–19]. For example, data from the National Longitudinal Survey of Adolescent Health have shown that early maturing boys [19] and girls [20] are more likely to engage in delinquent behaviour and to use licit and illicit drugs. These effects are particularly strong for girls [16].

Although a substantial amount of research has examined the importance of pubertal timing or status in the development of substance use, relatively little is known about the continuing impact of pubertal maturation beyond mid-adolescence into early adulthood. The Finnish twins [12] and the Swedish longitudinal project [21] investigated the relationship between pubertal timing and substance use in older adolescents and young adults. These two studies found that early menarche was associated with early initiation into and greater frequency of smoking and alcohol consumption. These associations persisted into late adolescence and early adulthood.

**Possible mechanisms for the link between early pubertal maturation and substance use**
Despite evidence of a relationship between pubertal maturation and substance use, there remains some uncertainty about the pathways through which puberty influences substance use; however, several mechanisms have been proposed. First, it is suggested that early maturing adolescents face new responsibilities with which they are not able to cope [22]. In this regard, behaviour problems and drug use represent forms of adaptation to their new roles as an adolescent [21]. In addition, it is possible that children with externalizing behaviour inflate their self-reported pubertal stage. Given that childhood externalizing (aggressive/delinquent behaviour) is associated with subsequent substance use [23], it may moderate the association between pubertal development and substance use.

A second explanation focuses on the role of parent–child relationships. Existing evidence suggests that changes during pubertal development may weaken the parent–adolescent bonds so that the adolescent is more prone to deviant behaviours [20]. Paikoff & Brooks-Gunn [24] have shown that pubertal changes in adolescence are associated with increased conflict and reduced trust between adolescents and their parents. This may lead to affiliation of young individuals with deviant peers and greater engagement in the use of substances.

It has also been suggested that early maturing adolescents have greater levels of school behaviour problems and lower academic performance [25,26]. However, these findings are contradicted by other studies of adolescent boys [19]. Given that adolescent academic
performance in high school predicts subsequent use of illicit drugs [27], there is a need to
examine the mediating effect of school performance on the link between pubertal
development and substance use in late adolescence/early adulthood.

Another explanation proposed by Stattin & Magnusson [21] and Patton et al.[28] suggests
that those who mature earlier are more likely to engage with older peers and to begin a
more mature (drug-using) life-style at a younger age. This explanation has not been tested
adequately.

In summary, most of the evidence describing the association between pubertal maturation
and substance use is based on investigations carried out in early or mid-adolescence. Only
limited research has examined the impact of puberty on young adults’ use of illicit drugs and
the severity of such use. In addition, most of the information is obtained from female-only
studies. There is a need to determine whether the association between pubertal maturation
and substance use holds through to early adulthood and whether the association differs
according to gender. As age can be associated with both pubertal maturation and substance
use, its potential confounding effect must also be taken into account. Further, longitudinal
studies that measure potential mediating factors in adolescence are needed to identify a
possible causal pathway.

Using data from a pre-birth cohort we examine whether stage of pubertal maturation
assessed in early adolescence predicts use of illicit drugs in young adults (measured at 21
years). As cannabis and amphetamines are the two most commonly used and abused illicit
drugs in Australia, the outcomes of interest in this study are use of cannabis and/or
amphetamines by young adults. We examine whether there is a link between pubertal
status and substance use independent of a selected group of confounding and mediating
factors.

**METHODS AND MATERIALS**

**Participants**
Data for this paper are derived from the Mater-University of Queensland Study of
Pregnancy (MUSP) and its outcomes. Briefly, commencing in 1981, 8556 consecutive women
in early pregnancy were invited to participate in the study; 8458 agreed to participate and
7223 gave birth to a live singleton baby at the study hospital [29,30]. Mothers and children
were subsequently followed-up at 3–5 days, 6 months and 5, 14 and 21 years after the
child’s birth. Due to resource constraints, a subsample of 3748 adolescent were
administered a physical assessment questionnaire including questions about stage of
puberty at the 14-year follow-up. Of these individuals, 2710 young adults completed a self-
report questionnaire about their use of cannabis and amphetamines at 21 years. Informed
consent was obtained from all participants. Ethical approval for all phases of the study was
obtained from ethics committees at the University of Queensland and the Mater Hospital.
Measures

Pubertal status
We obtained self-report data on pubertal development using Tanner drawings of the five stages of pubertal development, which for males include the development of genitalia and pubic hair and for females, breasts and pubic hair [31,32]. Validation of the drawings was conducted on a sample of males and females who completed the questionnaire and were examined by physicians blind to their questionnaire responses. There were moderate to strong correlations between self-reports and physician assessments [31]. More recent validations have confirmed that child/youth self-reports of pubertal development have good agreement with independent ratings [33,34].

Young adults’ use of illicit drugs
Cannabis use by the participants was assessed at the 21-year follow-up via a self-report questionnaire in which they were asked: 'In the last month how often did you use cannabis, marijuana, pot, etc.?'. Amphetamine use was assessed by asking: 'In the last 12 months how often did you use amphetamines like speed, uppers, or pep pills?'. For each of these drugs, young adults were divided into two groups: those who had never used these drugs and those who had used them. For the purpose of this study, we created a composite variable with three categories: never used illicit drugs (cannabis or amphetamines); used cannabis but not amphetamines; and used amphetamines with or without cannabis.

Other covariates
Socio-demographic information, including child’s gender, mother’s age and education, was collected when the child was born. Child externalizing behaviour was assessed when the child was 5 years of age using the Child Behavior Check List (CBCL) [35]. Adolescent age was measured at the 14-year follow-up at the same time as the assessment of pubertal status. In this study, these variables are considered as possible confounding factors. Adolescent externalizing behaviour and anxiety/depression were assessed at 14 years using the Youth Self Report (YSR) [36] version of the CBCL. Adolescent academic performance in high school was assessed at the 14-year follow-up via a self-report questionnaire and the participants were divided into three groups: high, medium and low school performance. The Parent–Adolescent Communication Scale [37] was used to assess mother–adolescent communication at the 14-year follow-up. For the purpose of this study, these variables are included as potential mediating factors.

Statistical analysis
We first conducted a series of correlation tests to examine the relationship between pubertal stage and substance use, and other covariates included in the study (Table 1). We then used \( \chi^2 \) tests and univariate logistic regression analysis to estimate the unadjusted risk [odds ratio (OR) and 95% confidence intervals (95% CI)] of having used cannabis or amphetamines by age 21 for each category of adolescent pubertal status (with the reference category being pubertal status 1 or 2). As the outcome comprises three values (never used illicit drugs, only used cannabis and used cannabis and amphetamines), we analysed the data using multinomial logistic regression analysis. In order to determine whether gender differences moderated the effect of pubertal status, we computed an interaction term between pubertal status and gender. Using the likelihood ratio test, we
found no statistically significant gender interaction effect. The findings are presented for the whole sample and for males and females, separately.

**Table 1: Correlations between variables included in the study.**

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th>Gender use</th>
<th>Mother’s education</th>
<th>Externalizing at 5</th>
<th>Externalizing at 14</th>
<th>Anxiety/depression at 14</th>
<th>School performance at 14</th>
<th>Mother–adolescent communication at 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pubertal stage</td>
<td>0.16*</td>
<td>0.18**  0.08*  0.01^  0.01^  0.13**  0.01^  0.03^  0.02^</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>–</td>
<td>0.002^  0.04***  0.02^  0.02^  0.04^  0.01^  0.04***  0.04^</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>–</td>
<td>0.05****  0.01^  0.09**  0.02^  0.21**  0.01^  0.07***  0.07***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substance use</td>
<td>–</td>
<td>0.01^  0.06***  0.27**  0.02^  0.12**  0.09**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother’s education</td>
<td>–</td>
<td>0.07**  0.06***  0.02^  0.06***  0.01^</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing at 5</td>
<td>–</td>
<td>0.18^  0.09**  0.08**  0.21**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Externalizing at 14</td>
<td>–</td>
<td>0.45**  0.22**  0.22**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anxiety/depression</td>
<td>–</td>
<td>0.14**  0.09**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School performance</td>
<td>–</td>
<td>0.11**</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Mother–adolescent</td>
<td>–</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>communication</td>
<td>–</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Spearman’s correlation coefficient where at least one of the variables is non-parametric; b Pearson’s correlation coefficient where two variables are continuous; rho: correlation is significant at * P < 0.0001; ** P < 0.01; *** P < 0.05.

For testing the impact of a selected group of possible confounding and mediating factors, we performed four separate multivariate analyses (Table 2). In the multivariate analyses we controlled first for child’s gender and age, mother’s education and child externalizing at 5 years (model 1). We controlled subsequently for adolescent externalizing (model 2), adolescent anxiety/depression (model 3), mother–adolescent communication and adolescent school performance (model 4). In order to explore the gender comparison for associations and impact of confounding and mediating factors, we repeated the univariate and multivariate logistic regressions stratified by gender (Table 4). Analyses were conducted using STATA version 10.

**Table 2: Percentage and risk of young adults’ ever use of cannabis and amphetamines by pubertal status.**

<table>
<thead>
<tr>
<th>Stage of puberty</th>
<th>None</th>
<th>Used only cannabis</th>
<th>Used amphetamines and cannabis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>(95% CI)</td>
<td>%</td>
</tr>
<tr>
<td>One or two (n = 218)</td>
<td>57.3</td>
<td>29.4 Ref</td>
<td>13.3 Ref</td>
</tr>
<tr>
<td>Three (n = 1092)</td>
<td>50.3</td>
<td>29.9 1.2 (0.8–1.6)</td>
<td>19.9 1.7 (1.1–2.6)</td>
</tr>
<tr>
<td>Four (n = 1186)</td>
<td>46.9</td>
<td>31.1 1.3 (0.9–1.8)</td>
<td>22.0 2.0 (1.3–3.1)</td>
</tr>
<tr>
<td>Five (n = 214)</td>
<td>38.3</td>
<td>32.2 1.6 (1.1–2.6)</td>
<td>29.4 3.3 (2.0–5.6)</td>
</tr>
</tbody>
</table>

CI: confidence interval; OR: odds ratio.
Table 4: Association between stage of pubertal development and young adults’ ever use of cannabis and amphetamines by gender.

<table>
<thead>
<tr>
<th>Stage of puberty</th>
<th>Females</th>
<th></th>
<th></th>
<th></th>
<th>Males</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only cannabis</td>
<td>Amphetamine and cannabis</td>
<td>Only cannabis</td>
<td>Amphetamine and cannabis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
<td>Unadjusted</td>
<td>Adjusted</td>
</tr>
<tr>
<td>One or Two</td>
<td>Ref</td>
<td>0.9 (0.5–1.8)</td>
<td>0.9 (0.4–1.8)</td>
<td>1.7 (0.6–4.5)</td>
<td>2.6 (0.7–9.1)</td>
<td>1.4 (0.9–2.3)</td>
<td>1.4 (0.8–2.2)</td>
<td>1.9 (1.1–3.3)</td>
</tr>
<tr>
<td>Three</td>
<td>Ref</td>
<td>1.1 (0.5–2.1)</td>
<td>1.1 (0.5–2.2)</td>
<td>2.0 (0.7–5.2)</td>
<td>2.7 (0.8–9.6)</td>
<td>1.7 (1.1–2.7)</td>
<td>1.4 (0.8–2.3)</td>
<td>2.3 (1.3–4.1)</td>
</tr>
<tr>
<td>Four</td>
<td>Ref</td>
<td>1.2 (0.6–2.7)</td>
<td>1.0 (0.4–2.4)</td>
<td>3.1 (1.4–9.1)</td>
<td>3.5 (0.9–13.4)</td>
<td>2.4 (1.2–4.7)</td>
<td>1.9 (0.9–4.0)</td>
<td>3.5 (1.7–7.3)</td>
</tr>
</tbody>
</table>

* Never use of substance and stages 1 or 2 puberty considered reference category; adjusted for participant’s age, gender and externalizing behaviour at 5 years and mother’s education, adolescent externalizing behaviour and anxiety/depression, mother–adolescent communication and adolescent school performance. CI: confidence interval; OR: odds ratio.

RESULTS

Overall, 2710 participants (1410 females and 1300 males) provided information about their stage of puberty and their use of cannabis and amphetamines. The mean and median age was 13.9 years [standard deviation (SD) = 0.31 years] at the time the puberty data were collected. Of the participants, 15.7% were born to mothers who did not complete high school. In the current study, the majority of the sample (84.1%) reported being at Tanner stages 3 or 4, with females more likely to be in stage 4 and males more likely to be in stage 3. At the 21-year follow-up 48.4% of young adults (50.4% females and 46.2% males) reported that they had never used illicit drugs. Some 49.9% of the participants (47.3% females and 52.7% males) reported that they had used cannabis while 21.0% (18.9% females and 23.3% males) had ever used amphetamines. The vast majority (92.0%) of the 798 young adults who reported use of amphetamines had also used cannabis; hence, this subgroup is referred to as amphetamine and cannabis users.

Further information about the variables included in this study is given in Table 1. There is a significant association between pubertal stage and young adults' substance use. Of the covariates included in the study, gender, age and YSR externalizing are associated significantly with both puberty and substance use. Male participants and those who were older or those who manifested higher levels of externalizing behaviour at 14 years were more likely to report the use of illicit drugs at 21 years, and to be in later stages of pubertal development at the 14-year follow-up. Hence, the possible confounding or mediating effects of these factors need to be examined. Mother's education, by contrast, is associated with neither pubertal status nor young adults' substance use. However, child externalizing at 5 years, mother–adolescent communication and adolescent school performance are associated with substance use but not pubertal status.
Participants categorized as stages 1 or 2 of puberty were least likely to report having used either cannabis (41.3%) or amphetamines (13.3%) by young adulthood (see Table 2). There was an increasing rate of substance use across each stage of puberty, with the stage 5 group being most likely to report use of cannabis (OR = 2.0; 95% CI: 1.4, 3.0) or amphetamines (OR = 2.7; 95% CI: 1.7, 4.4). The association between pubertal status and young adults' substance use appears to be stronger for the use of both amphetamines and cannabis. Adolescents who reported that they were at stage 5 of puberty were 3.3 times more likely to use amphetamines and cannabis but had only a modest increased risk of using only cannabis by 21 years (OR = 1.6; 95% CI: 1.1, 2.6) compared to those in stages 1 or 2 of puberty.

Four additional logistic regression models examine the roles of potential psycho-social risk factors as confounders and mediators of the association between stage of puberty and young adults' use of illicit drugs. Multivariate analyses (Table 3) show that adjustment for child's gender and age, child externalizing behaviour and mother's education does not change the relationship between pubertal status and young adults' substance use (model 1). This indicates that the relationship between stage of puberty and substance use is not confounded by these variables. Further adjustment for adolescent externalizing behaviour (model 2) led to a substantial attenuation in the magnitude of association between stage 5 puberty and young adults' illicit drug use (OR = 1.6; 95% CI: 1.0, 2.7 for use of cannabis only and OR = 2.7; 95% CI: 1.4, 5.2 for use of cannabis and amphetamines). The association did not change when adolescent anxiety/depression was added into the analysis (model 3). Inclusion of mother–adolescent communication and adolescent school performance (model 4) produced no further impact on the association between pubertal status and substance use.

**Table 3: Multivariate association between pubertal status and young adults' ever use of cannabis and amphetamines.**

<table>
<thead>
<tr>
<th>Stage of puberty</th>
<th>Young adults' cannabis and amphetamines ever use (OR (95% CI)) 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only cannabis</td>
</tr>
<tr>
<td></td>
<td>Model 1</td>
</tr>
<tr>
<td>One or two</td>
<td>Ref</td>
</tr>
<tr>
<td>Three</td>
<td>1.2 (0.8–1.8)</td>
</tr>
<tr>
<td>Four</td>
<td>1.5 (1.0–2.2)</td>
</tr>
<tr>
<td>Five</td>
<td>2.0 (1.2–3.3)</td>
</tr>
</tbody>
</table>

2 Never use of substance and stages 1 or 2 puberty considered reference category; model 1 adjusted for participant's age, gender and externalizing behaviour at 5 years and mother's education; model 2 adjusted for previous model plus adolescent externalizing behaviour; model 3 adjusted for previous model plus adolescent anxiety/depression; model 4 adjusted for previous model plus mother–adolescent communication and adolescent school performance. CI: confidence interval; OR: odds ratio.

An examination of gender differences (Table 4) shows that, in females, there is no significant association between stage of puberty and use of cannabis. However, females who were at the most advanced stage of puberty at the 14-year follow-up were at least three times more likely to have ever used both amphetamine and cannabis by 21 years, although this association became non-significant when controlled for other covariates (mainly
externalizing behaviour at 14 years). For male participants, a more advanced stage of puberty (stages 4 and 5) predicted an increased rate of illicit drug use by 21 years, with the stronger relationship being for use of amphetamines and cannabis. Adjustment for selected confounding and mediating factors reduced significantly the effect of pubertal stage on use of substances in early adulthood.

**DISCUSSION**

Using data from a pre-birth longitudinal study we examined the impact of pubertal stage reported by adolescents at the 14-year follow-up of the study on subsequent use of cannabis and amphetamines measured when the participants were 21 years old. For both females and males, progression through the stages of puberty was associated with substantial increases in the rate of illicit drug use by age 21. This association was independent of participant's age, indicating that faster progression through pubertal process predicts independently an increased risk of illicit drug use.

Our study also suggests that a significant proportion of the association between pubertal status and young adults' substance use is mediated by adolescent externalizing behaviour. Individuals with more advanced pubertal status (stages 4 and 5) are more likely to manifest extreme levels of aggressive and delinquent behaviours and to be involved in the subsequent use of illicit drugs compared to other children. Although there was no gender–puberty interaction for the association with use of illicit drugs, adolescent externalizing behaviour had a stronger impact on the association for females than for males.

The findings of the present study confirm previous investigations, both cross-sectional and longitudinal, which suggest that early pubertal development is associated with increased substance use in adolescents [12,14–16] and young adults [21]. To our knowledge, no previous study has examined prospectively the impact of progression through pubertal status on subsequent use of illicit drugs through to early adulthood independent of gender and age of individuals when pubertal status was measured. The findings of this study indicate that more advanced pubertal status in early adolescence predicts an increased rate of use of cannabis and amphetamines and that this increase is greater for the use of multiple drugs. One possible explanation for the stronger association between stage of puberty and multiple drug use might be that puberty is a period associated with a higher level of risk-taking and sensation-seeking, which are strong predictors for substance use and abuse [38].

Our data vary from Ge et al.[14], who found gender differences in the association between pubertal status and substance use. The results of this study suggest a statistically and independently significant association between pubertal stage and substance use for both males and females. The reason for such a discrepancy may be due to the age at which Ge and colleagues [14] assessed participants for pubertal maturation and substance use—they studied the association between pubertal maturation and substance use in youth aged on average 11.1 years and followed them up 2 years later. Given that pubertal development in males occurs later than females, gender differences in the association found by Ge et al.[14]...
might be due to not having sufficient males who had progressed through the higher stages of puberty when their substance use behaviour was assessed.

Further, the finding that externalizing behaviour at 14 years explains part of the present association is consistent with the proposed hypothesis suggesting that early pubertal development is associated with an increased rate of adolescent psychological problems \[7,13,15,18\]. However, these results did not confirm the hypotheses that poor parent–adolescent communication \[20,24\] or adolescent school performance \[27\] might play an intermediate role between pubertal development and substance use.

This study can be distinguished from earlier investigations in several aspects. First, this study is based on a pre-birth longitudinal cohort that was followed-up to 21 years. This allowed us to examine the prospective impact of pubertal stage on substance use assessed at 21 years. Secondly, we were able to take into account the effect of some potential confounding and mediating factors. Thirdly, this study has measured substance use in both males and females at 21 years, the age at which a high rate of substance use is to be expected.

The findings from this study should be interpreted in the context of several limitations. Because of resource constraints, the Tanner measure was not administered to all respondents. Of the overall cohort, 72.5\% (3748) were asked to complete the questionnaire about puberty, of whom 2710 participated at the 21-year follow-up. Previous MUSP publications have shown that loss to follow-up is associated with disadvantaged socio-economic backgrounds and higher rates of adverse health outcomes \[30\]. Considering that those lost to follow-up have higher levels of adverse health outcomes, our findings are likely to be conservative and may underestimate the extent of the increase in substance use with progression through the stages of puberty.

A second limitation involves the use of self-reports of stage and timing of puberty—the study lacks any biological measures of the pubertal process. While concerns have been expressed about the measurement of progression through the stages of puberty, the Tanner stages are used commonly and have been validated \[31–33\]. However, use of only a single measure of puberty, taken at around age 14, warrants caution when interpreting the results. Thirdly, in MUSP we relied upon self-reports of substance use at the 21-year follow-up. Respondents may under-report their substance use \[39\] and this can affect the effect size of relationship in the present study. Finally, previous studies have shown that affiliation with older peers and deviant groups may contribute to the association between early pubertal development and substance use \[14,21,28\]. A lack of information about this variable in MUSP did not allow us to examine this latter hypothesis. Of course, problem behaviours such as externalizing, reported in early adolescence, might be perceived as an indicator of associating with delinquent peers.

**CONCLUSION**

The present work confirms the importance of pubertal development as a predictor for subsequent use of illicit substances. Our findings suggest that early progression through the stages of puberty increases the likelihood that both males and females will use illicit drugs. This study notes the impact of adolescent psychopathology (externalizing behaviour), in
particular in females, as a possible mediating factor that links advanced pubertal status to use of illicit drugs. Further investigation is required to examine other pathways explaining the association between puberty and substance use, and to evaluate the effectiveness of preventive interventions that address those pathways.

REFERENCES

