

Major depression and cigarette smoking: results of a 21-year longitudinal study

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ABSTRACT

Background. The aim of this paper was to examine the association between major depression and cigarette smoking among young adults in a birth cohort before and after adjusting for confounding factors.

Method. Data were gathered over the course of the Christchurch Health and Development Study (CHDS). The CHDS is a longitudinal study of a birth cohort of 1265 New Zealand children studied to age 21. Data were gathered by interview on: (a) major depression over the period 16–21 years; (b) daily smoking and nicotine dependence over the period from 16–21 years. In addition, the study included extensive information on social, family, and behavioural factors in childhood and adolescence.

Results. Young people meeting DSM-IV criteria for major depression had elevated rates of daily smoking and nicotine dependence. These associations were reduced substantially by control for potential confounding child and adolescent factors. Nonetheless, even after such control, major depression was associated with increased rates of daily smoking (IRR = 1.19; 95% CI = 1.03, 1.39) and elevated rates of nicotine dependence (OR = 1.75; 95% CI = 1.13, 2.70).

Conclusions. The results suggest that much of the association between smoking and depression reflects common confounding factors that are associated with both outcomes. Nonetheless, even after control for these factors there is evidence of a possible causal linkage between smoking and depression. The direction of causality between smoking and depression remains unknown.

INTRODUCTION

It has been well documented that individuals who experience major depression tend to have higher rates of cigarette smoking and nicotine dependence when compared with those without depression (Kaplan *et al.* 1984; Kandel & Davies, 1986; Anca *et al.* 1990; Breslau *et al.* 1990, 1993, 1998; Covey & Tam, 1990; Glassman *et al.* 1990; Glassman, 1993; Kendler *et al.* 1993, 1999; Breslau, 1995; Brown *et al.* 1996; Fergusson *et al.* 1996; Patton *et al.* 1996, 1998; Rohde *et al.* 1996;

Choi *et al.* 1997; Kandel *et al.* 1997; Killen *et al.* 1997; Cicchetti & Toth, 1998; Escobedo *et al.* 1998; Lerman *et al.* 1998; Black *et al.* 1999; Jorm *et al.* 1999; Albers & Biener, 2002; Dierker *et al.* 2002; Ludman *et al.* 2002; Martini *et al.* 2002). For example, in a study of a community sample of young adults, Breslau *et al.* (1993) found a higher rate of first-incidence major depression among young adults with a history of nicotine dependence (OR = 2.45 (1.17–5.15)) compared to those without such history. A number of population-based studies have found similar associations in samples of both adults (Covey & Tam, 1990; Glassman *et al.* 1990; Breslau *et al.* 1991, 1993, 1998; Patton *et al.* 1998; Black *et al.* 1999; Jorm *et al.* 1999;

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Kendler *et al.* 1999) and youth (Breslau *et al.* 1990; Fergusson *et al.* 1996; Patton *et al.* 1996, 1998; Kandel *et al.* 1997). Several studies have also found evidence of dose-response relationships between the extent of smoking and rates of depression (e.g. Kendler *et al.* 1993; Jorm *et al.* 1999), in addition to evidence that depression increases the likelihood of progression from nicotine use to heavier levels of nicotine dependence (Breslau *et al.* 1991, 1993, 1998; Patton *et al.* 1998).

Although the co-morbidities between cigarette smoking and depression have been well documented, the mechanisms leading to these associations remain controversial. There are two general explanations of the association: confounding and selection; and causation.

First, confounding and selection: it may be suggested that the association between smoking and depression arises from common confounding factors that are associated with both increased risks of depression and increased risks of smoking. These confounding factors may include both genetic and environmental factors (Breslau *et al.* 1993; Kendler *et al.* 1993, 1999; Brown *et al.* 1996; Fergusson *et al.* 1996; Kandel *et al.* 1997; Albers & Biener, 2002). This issue has been addressed in a series of studies that have examined the associations between smoking and depression after adjustment for confounding factors. Although all studies have found that adjustment for confounding reduces the association substantially, some studies (Kendler *et al.* 1993; Albers & Biener, 2002) have found that control for confounding is adequate to explain the association whereas others (Breslau *et al.* 1991, 1993; Martini *et al.* 2002) have not found this.

Secondly, causation: the alternative explanation is that the association between smoking and depression, after adjustment for confounding, reflects a cause and effect association between smoking and depression. There are potentially two ways in which such an association may occur. First it may be proposed that the association arises as a result of self-medication in which those experiencing depression tend to increase their intake of cigarettes to reduce symptoms of depression (Kaplan *et al.* 1984; Kandel & Davies, 1986; Breslau *et al.* 1991, 1993; Killen *et al.* 1997; Cicchetti & Toth, 1998; Escobedo *et al.* 1998; Lerman *et al.* 1998; Ludman

et al. 2002). In turn the consequence of this would be to increase both daily cigarette intake and risks of nicotine dependence. An alternative explanation is that by various routes the development of cigarette smoking and nicotine dependence may increase individual susceptibility to depression (Brown *et al.* 1996; Choi *et al.* 1997; Wu & Anthony, 1999; Goodman & Capitman, 2000). For example, it has been suggested that both the social stigma attached to smoking (Martini *et al.* 2002) and the fact that smoking may alter brain chemistry (Breese *et al.* 1997) may be factors that could lead to smoking increasing individual susceptibility to depression.

Against this background, research into smoking and depression faces two major methodological challenges. The first is to control this association for a wide range of confounding and selection factors that may be associated with the development of both cigarette smoking and depression. The second challenge is to develop modelling methods to explore the likely direction of any causal influence between smoking and depression. Clearly, one of the best ways of addressing both of these issues is through the use of a longitudinal study that examines the development of both cigarette smoking and depression from childhood into adulthood with information being collected regularly on the onset and offset of both smoking and depression and upon a wide range of confounding factors.

In this paper we present the results of a study of the linkages between the development of cigarette smoking and the development of major depression in a birth cohort of New Zealand children studied to the age of 21. The aims of this study were: (1) to document the extent of the association between daily cigarette intake, nicotine dependence and major depression over the period from 16 to 21; (2) to adjust the associations between depression and smoking for a wide range of confounding factors including: childhood factors, family factors, life events, peer affiliations and co-morbid mental disorders; and (3) to examine the likely direction of causal influence by controlling the associations between smoking and depression for antecedent depression and smoking to examine the ways in which changes in depression were associated with changes in smoking.

METHOD

Participants

The data described in this report were gathered during the course of the Christchurch Health and Development Study (CHDS). The CHDS is a longitudinal study of an unselected birth cohort of 1265 children (635 males, 630 females) born in the Christchurch, New Zealand, urban region in mid-1977. This cohort has now been studied at birth, 4 months, 1 year and at annual intervals to age 16 years, and again at ages 18 and 21 years, using information obtained from a combination of sources including: parental interview; teacher report; self-report; psychometric assessment; medical and police records. A detailed overview of the study design and summary of study findings has been given previously (Fergusson *et al.* 1989; Fergusson & Horwood, 2001). The following measures were used in the present analysis.

Measures

Smoking

At ages 16, 18 and 21 years, sample members were questioned about their frequency of cigarette smoking over the past month. Young people who reported smoking were also asked a series of custom written survey items designed to assess symptom criteria for nicotine dependence. This information was used to classify participants on two measures of smoking behaviour at age 16, 18 and 21 years: (a) frequency of smoking: young people's reports of smoking frequency were used to provide an estimate of the number of cigarettes smoked per day at each age; and (b) nicotine dependence: the symptom report data were used to classify sample members according to DSM criteria for nicotine dependence. At age 16, this classification was based on DSM-III-R (APA, 1987) criteria, whereas at ages 18, 21 years the classification was based on DSM-IV (APA, 1994) criteria. Questions relating to both smoking and nicotine dependence referred to the respondent's situation at the time of interview.

To examine the adequacy of the prevalence estimates of smoking and nicotine dependence found in the CHDS, comparisons were made with independently obtained estimates from the Dunedin Multidisciplinary Health and Development Study (DMHDS). These comparisons

showed good agreement between study estimates. For example, at age 21, 36% of the CHDS cohort were daily smokers compared with 35% of the DMHDS cohort. Similarly, at age 21, 25% of the CHDS cohort met criteria for nicotine dependence compared with 18% of the DMHDS cohort.

Major depression

At age 16, 18 and 21 years, in the context of a comprehensive mental health interview, sample members were assessed on standardized diagnostic criteria for major depression in the previous 12 months. At age 16, this questioning was based on the Diagnostic Interview Schedule for Children (DISC) (Costello *et al.* 1982) supplemented by additional custom written items to assess DSM-III-R symptom criteria that were not covered in the original version of this instrument. At ages 18 and 21 years, items from the Composite International Diagnostic Interview (CIDI) (WHO, 1993) were used to assess DSM-IV symptom criteria for major depression. At each age, sample members were classified as having major depression if they met DSM diagnostic criteria for a major depressive episode in the previous 12 months.

Again, comparisons with the DMHDS showed good agreement between studies. For example, at age 21, 18.2% of the CHDS cohort met criteria for major depression in the previous 12 months compared with 17.3% of the DMHDS cohort.

Fixed covariates

To control for possible confounding of the associations between depression and cigarette smoking by pre-existing social, family and individual factors, a range of measures were selected from the database of the study. These measures (see below) were selected on the basis that they were known to be associated with either smoking or depression.

Gender

Race

Sample members were classified as either New Zealand Maori (11.3% of the sample) or non-Maori on the basis of self-definition of ethnicity obtained at age 21.

Childhood adversity (0–16 years)

This measure provided an overall index of the young person's exposure to social and family disadvantage during childhood up to age 16 years. The adversity score combined information from 11 indicators that spanned the following areas of disadvantage: (i) measures of socio-economic disadvantage including family socio-economic status, parental education levels and family living standards; (ii) measures of family instability including parental separation/divorce, multiple changes of parents and inter-parental violence; (iii) measures of childhood physical and sexual abuse; (iv) measures of parental adjustment including parental history of alcohol problems, criminality and illicit drug use. This scale has been shown to be strongly associated with measures of mental health and substance use in adolescence (Fergusson & Horwood, 2003).

Novelty seeking (16 years)

When sample members were aged 16, the extent of novelty-seeking behaviour was assessed using the novelty-seeking scale of the Tridimensional Personality Inventory (Cloninger, 1987). The reliability of this scale, assessed using coefficient α , was 0.76.

Neuroticism (14 years)

Neuroticism in adolescence was assessed using a short-form version of the neuroticism scale of the Eysenck Personality Inventory (Eysenck & Eysenck, 1964), administered when sample members were aged 14 years. The reliability of this scale, assessed using coefficient α , was 0.80.

Childhood conduct problems (12 years)

When sample members were aged 12 years, information on child behaviour problems was obtained from parental and teacher report. Parents were interviewed using a behaviour questionnaire that combined items from the Rutter *et al.* (1970) and Conners (1970) parental questionnaires, whereas teachers were asked to complete a combined version of the Rutter *et al.* (1970) and Conners (1969) teacher questionnaires. Using this information, a series of items was selected from the report data describing the child's tendencies to conduct disordered and oppositional behaviour as reported by parents

and teachers (Fergusson *et al.* 1991). Factor analysis of these data showed that these items could be combined into unidimensional scales reflecting the extent of conduct problems as reported by parents and teachers (Fergusson *et al.* 1991). For the purposes of the present analysis, parent and teacher reports were combined into a single scale to provide an overall measure of the extent of the child's tendencies to conduct disordered behaviour at age 12. The reliability of this scale, assessed using coefficient α , was 0.93.

Parental smoking (0–16 years)

Parents of study participants were interviewed at each year from birth to age 16. As part of this assessment, information was obtained on the extent of parental cigarette smoking at each age. For the purposes of the present analysis, a measure of the extent of exposure to parental smoking during childhood was constructed from a count of the number of years the young person had lived in a home in which one or both parents smoked up to age 16.

Parental attachment (15 years)

When sample members were aged 15 years, young people were questioned about the quality of their parental attachments using the parental attachment scale from the Inventory of Parent and Peer Attachment (Armsden & Greenberg, 1987). The scale assesses components of attachment relating to the quality of communication with parents, the extent of trust between parents and offspring, and the extent of alienation from parents. The full scale score was used in the present analysis. This scale had high internal consistency ($\alpha=0.92$).

Time dynamic covariates

A range of time dynamic covariates were included in the analysis to control for changing aspects of the young person's life experience during the period from 16–21 years. These measures were assessed concurrently with depression at age 16, 18 and 21 years, and included the following.

Anxiety disorder

As part of the mental health interview at age 16, 18 and 21 years, sample members were also assessed on DSM criteria for a range of anxiety

disorders in the previous 12 months. At age 16 questioning was based on the DISC using DSM-III-R criteria. At age 18, 21 years questioning was based on items from the CIDI and DSM-IV diagnostic criteria. Anxiety disorders assessed included generalized anxiety disorder, specific phobia, social phobia, panic disorder and agoraphobia.

Alcohol abuse/dependence

At each interview from 16–21 years, sample members were questioned concerning their use of alcohol and problems associated with alcohol use. At age 16, alcohol related problems were assessed using the Rutgers Alcohol Problem Index (White & Labouvie, 1989). This information was then used to classify sample members according to DSM-III-R criteria for alcohol abuse in the previous 12 months. At age 18 and 21 years, items from the CIDI were used to classify sample members according to DSM-IV symptom criteria for alcohol abuse and alcohol dependence in the previous 12 months.

Deviant peer affiliations

At 16, 18 and 21, sample members were questioned concerning the extent to which their friends used tobacco, alcohol or illicit drugs, had problems associated with substance use, were involved in crime or in trouble with the police. These items were combined to produce an overall measure of the extent to which the young person affiliated with substance using or delinquent peers at each age (Fergusson & Horwood, 1999). These scales were of moderate reliability ($\alpha = 0.74$ at age 16; $\alpha = 0.85$ at age 18; $\alpha = 0.85$ at age 21).

Adverse life events

At each age, the extent to which the young person was exposed to stressful or adverse life events during the previous 12 months was assessed using a life events checklist based on the Feeling Bad Scale (Lewis *et al.* 1984). This scale spanned items relating to relationship problems and difficulties, health problems and accidents, victimization, pregnancy and parenthood, employment and related problems. The extent of exposure to adverse life events in each year was assessed on the basis of a count of the total number of life events reported by the respondent for that year.

Statistical methods

The associations between major depression and measures of cigarette smoking (daily intake; nicotine dependence) were estimated using rate ratios and 95% confidence intervals (Table 1). The rate ratio estimate for the measure of daily cigarette intake was the incidence rate ratio (IRR) whereas the rate ratio for nicotine dependence was the odds ratio (OR).

Associations between major depression and the outcome measures were adjusted for confounding by fitting generalized estimating equation (GEE) models (Liang & Zeger, 1986). In these models, daily cigarette smoking and nicotine dependence were dependent variables; major depression, the fixed covariates and time dynamic covariates were predictors. For daily smoking, a negative binomial regression model was fitted whereas for nicotine dependence, a logistic regression model was fitted. Models were fitted to give population averaged estimates of model parameters over the period 16–21 years. All models included an age factor to allow for time dynamic changes in the rate of each outcome with age. To take account of possible reverse causal effects all models included lagged measures of daily smoking and nicotine dependence observed at the preceding point of observation. In fitting both models, all covariates were included but only significant covariates are shown in Table 3. From the fitted models the estimates of the adjusted risk ratios were obtained by exponentiating the model parameters for major depression (Table 3).

Sample size and sample bias

The present analysis is based on the sample of 1061 young people for whom information was available on cigarette smoking and depression at age 16, 18 or 21 years. This sample represented 84% of the initial cohort of 1265 children who entered the study at birth. However, since not all participants were assessed at all ages, the numbers of respondents with non-missing observations varies with the age of assessment (see Table 1). This variability in the numbers of individuals available for analysis raises the issue of the extent to which the results may have been influenced by sample selection bias. To address this issue, the techniques described by Carlin *et al.* (1999) were used. These methods involved

Table 1. Associations between major depression (past 12-months) and cigarette smoking at ages 16, 18, and 21 years

Smoking	Major depression		Risk ratio* (95% CI)
	No	Yes	
16 years (<i>N</i>)	(897)	(56)	
Cigarettes smoked/day, mean	1.09	2.39	2.19 (1.34–3.58)
Nicotine dependent, %	5.6%	23.2%	5.12 (2.59–10.14)
18 years (<i>N</i>)	(838)	(187)	
Cigarettes smoked/day, mean	2.59	5.05	1.95 (1.33–2.85)
Nicotine dependent, %	11.5%	24.6%	2.52 (1.70–3.74)
21 years (<i>N</i>)	(827)	(184)	
Cigarettes smoked/day, mean	3.50	5.96	1.70 (1.16–2.50)
Nicotine dependent, %	21.0%	40.2%	2.52 (1.80–3.54)

* The risk ratio for mean number of cigarettes per day is the incidence rate ratio; the risk ratio for nicotine dependence is the odds ratio. All *P* values were <0.001.

a two-stage analysis process. In the first stage a sample selection model was constructed by using data gathered at birth to predict inclusion in the sample for analysis at each age. In the second stage, the data were reanalysed by fitting regression models in which the observations for each individual were weighted by the inverse of the probability of sample inclusion at each age. This analysis produced essentially identical conclusions to those reported here, suggesting that the effects of missing data and possible sample selection bias on the results were likely to be minimal.

RESULTS

Associations between depression and smoking (16–21)

Table 1 shows the associations between major depression and measures of cigarette smoking at ages 16, 18 and 21. At each age, the table reports mean daily cigarette intake and percentages of those meeting DSM-IV criteria for nicotine dependence for those with and without major depression in the preceding year. The associations between major depression and daily cigarette intake are described by the incidence rate ratio (IRR) whereas the associations between nicotine dependence and major depression are described by the odds ratio (OR).

Table 1 shows that, at all ages, those with major depression had significantly ($P < 0.001$) elevated rates of both daily cigarette intake and

nicotine dependence. The IRR values for daily cigarette intake range from 1.70 to 2.19 whereas the values of the OR for nicotine dependence range from 2.52 to 5.12.

Associations between major depression, cigarette smoking and confounding factors

Table 2 shows the associations between major depression at ages 15–16, 17–18 and 20–21 years and a series of fixed and time dynamic factors. The table shows that depression at various ages was related to a wide range of factors that included: gender; ethnicity; childhood adversity; novelty-seeking; neuroticism; early conduct problems; parental attachment; anxiety disorders; alcohol abuse/dependence; adverse life events; peer affiliations; previous cigarette smoking and nicotine dependence.

A parallel analysis conducted on patterns of cigarette smoking and/or nicotine dependence showed that many of the factors associated with major depression were also associated with cigarette smoking and nicotine dependence. Factors associated with both outcomes included: ethnicity; childhood adversity; novelty-seeking; neuroticism; early conduct problems; parental attachment; anxiety disorders; alcohol abuse/dependence; adverse life events; peer affiliations; previous cigarette smoking and nicotine dependence.

These findings clearly suggest the presence of a series of overlapping and correlated factors that could potentially confound the association between smoking and major depression.

Table 2. Associations between major depression (15–16, 17–18, 20–21 years) and measures of fixed and time dynamic covariates

Measure	Major depression								
	(15–16 years)			(17–18 years)			(20–21 years)		
	No	Yes	<i>P</i>	No	Yes	<i>P</i>	No	Yes	<i>P</i>
Fixed covariates									
Female, %	48.6	76.8	***	45.6	73.8	***	47.8	65.2	***
New Zealand Māori, %	10.2	20.0	*	10.1	15.9	*	10.8	13.6	NS
In highest quartile of childhood diversity (0–16 years), %	20.4	42.9	***	18.1	43.5	***	19.9	34.1	***
In highest quartile of novelty-seeking (16 years), %	26.5	32.1	NS	25.2	33.8	*	24.5	34.7	**
In highest quartile of neuroticism (14 years), %	21.4	46.3	***	19.6	39.1	***	20.6	36.1	***
In highest quartile of childhood conduct problems (12 years), %	24.1	37.7	*	23.4	32.9	*	23.6	28.7	NS
In lowest quartile of parental attachment (15 years), %	23.5	48.2	***	21.8	38.3	***	21.4	36.8	***
Time dynamic covariates									
Anxiety disorder in interval, %	18.7	53.6	***	11.2	43.3	***	8.2	33.7	***
Alcohol abuse/dependence in interval, %	4.6	19.6	***	17.0	30.5	***	26.6	40.8	***
In >5 adverse life events in interval, %	7.1	23.2	***	18.0	37.1	***	12.9	33.2	***
In highest quartile of deviant peer affiliations in interval, %	23.1	44.6	***	22.9	39.0	***	20.7	32.1	***
Cigarettes smoked per day at previous interval†, mean	0.3	0.5	NS	1.0	2.1	***	2.6	4.6	***
Nicotine dependent at previous interval†, %	—	—	—	5.0	15.0	***	10.8	23.5	***

† For the interval from age 15–16, smoking at the previous interval was assessed on the basis of reported rates of smoking at age 14. However, nicotine dependence was not assessed at this age.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Adjustments for confounding factors

Table 3 shows the associations between major depression and cigarette smoking adjusted for a series of fixed and time dynamic covariates. The fixed factors spanned measures of gender, race, childhood adversity, novelty-seeking, child neuroticism, childhood conduct problems and parental smoking. The time dynamic factors included: anxiety disorder; alcohol dependence; adverse life events; and deviant peer affiliations. In addition, all associations were adjusted for daily cigarette intake and nicotine dependence at the previous interval.

The adjustments reported show estimates of the population averaged rate ratios between major depression and cigarette smoking after adjustment for the covariate factors. These adjustments were obtained by fitting generalized estimating equation (GEE) models to the data on cigarette smoking, major depression and the covariate factors. The adjusted estimate for daily smoking is the incidence rate ratio whereas the adjusted estimate for nicotine dependence is the odds ratio. The adjusted results in Table 3 lead to two general conclusions, as follows.

Table 3. Risk ratios between depression and cigarette smoking ages 16–21 adjusted for: fixed factors; and fixed and time dependent factors

Outcome	Risk ratio†	95% CI	Significant covariates‡
Daily cigarette intake			
Adjusted for fixed factors	1.39	(1.20–1.61)***	1–6
Adjusted for all factors	1.19	(1.03–1.39)*	1–5, 7–10
Nicotine dependence			
Adjusted for fixed factors	2.18	(1.51–3.15)***	1–3, 5
Adjusted for all factors	1.75	(1.13–2.70)*	2, 3, 5, 7–9

† The risk ratio for daily cigarette intake is the incidence rate ratio; the risk ratio for nicotine dependence is the odds ratio.

‡ Covariates were: fixed covariates, 1=childhood adversity; 2=novelty-seeking (16 years); 3=child neuroticism (14 years); 4=childhood conduct problems (12 years); 5=parental smoking; 6=parental attachment (15 years); time dynamic covariates, 7=prior smoking frequency; 8=alcohol abuse/dependence; 9=deviant peer affiliations; 10=adverse life events.

* $P < 0.05$; *** $P < 0.001$.

First, it is clear that control for confounding factors reduced the associations between major depression and cigarette smoking very

substantially. Prior to adjustment, the risk ratios between major depression and daily cigarette smoking ranged from 1.70 to 2.19. After adjustment, the incidence risk ratio reduced to 1.19. Similarly, prior to adjustment the odds ratio between major depression and nicotine dependence ranged from 2.52 to 5.12, whereas the adjusted odds ratio was 1.75. These reductions arose from a series of common and time dynamic factors that were associated with major depression and cigarette smoking. Key covariate factors included: childhood adversity; novelty-seeking; child neuroticism; childhood conduct problems; parental smoking; parental attachment; alcohol dependence; adverse life events; deviant peer affiliations; and frequency of smoking at the previous interval. The implication of these findings is that much of the association between major depression and cigarette smoking arose from common confounding factors that were associated with both major depression and cigarette smoking. These covariates include both fixed and time dynamic factors.

Secondly, even after extensive control for fixed and confounding factors there were still small but detectable tendencies for major depression to be associated with increased risks of cigarette smoking. The adjusted risk ratios show that major depression was associated with a 19% increase in average daily cigarette intake and a 1.75 times increase in the odds of nicotine dependence.

Further tests of causal direction

The preceding analysis explicitly assumed that depression influenced changes in smoking behaviours even after control for confounders. It is, however, possible to propose a counter model in which cigarette smoking explains changes in depression after adjustment for confounders. To explore these issues, the data were subject to a supplementary structural equation model analysis to examine the goodness of fit and consistency of three models of the data. These models were: a reciprocal cause model in which depression and smoking exerted mutual influences on each other at each observation point; a uni-causal model in which depression influenced smoking after adjustment for covariates and previous smoking; and a uni-causal model in which smoking influenced depression after adjustment for covariates and previous depression.

This analysis led to the following conclusions: the model of reciprocal influence proved produced inconsistent results across time, suggesting that this model was not sufficiently stable to estimate the postulated reciprocal pathways; and both of the uni-causal models fitted the data but the fit of the model assuming that depression influenced smoking after control for covariates and previous smoking was somewhat better than the fit of the model that assumed that smoking influenced depression after control for covariates and previous depression.

Although the results of this analysis did not produce strong evidence of the likely causal linkages between smoking and depression, the results led to the conclusion that a model that assumed that depression influenced smoking had the best fit to the observed data and produced the most consistent parameter estimates across time.

DISCUSSION

This analysis has used data gathered over the course of a 21-year longitudinal study to examine possible linkages between cigarette smoking and depression. The major conclusions and implications of this study are summarized below.

First, the study confirmed the findings of previous research (see Introduction) that has examined the linkages between major depression and cigarette smoking: young people who met criteria for major depression had rates of daily cigarette intake that were between 1.70 to 2.19 times higher than young people who did not meet criteria and odds of nicotine dependence that were between 2.52 to 5.12 times higher. These associations were robust and were replicated throughout adolescence and into young adulthood. There seems to be little doubt on the basis of the accumulated evidence that major depression is co-morbid with both daily smoking and nicotine dependence.

In the second stage of the analysis, the associations between smoking and depression were adjusted for a wide range of confounding factors that spanned gender, race, childhood adversity, personality factors, co-morbid anxiety and alcohol use disorders, parental smoking, quality of parental attachment, affiliations with deviant peers and exposure to adverse life events. Adjustment for these factors reduced the associations

between smoking and depression substantially. These findings suggest that a substantial component of the association between smoking and depression is non-causal and arises because the risk factors and life processes associated with the development of both outcomes were correlated and tended to overlap. Nonetheless, smoking and depression remained associated even after extensive control for confounding and selection processes suggesting possible causal associations between these factors.

As outlined previously there have been two explanations of the associations between smoking and depression. First, it may be suggested that the association reflects a process of self-medication in which those who become depressed tend to smoke more to ameliorate symptoms of depression with this behaviour having the effect of increasing longer term daily cigarette intake and risks of nicotine dependence (e.g. Kaplan *et al.* 1984; Kandel & Davies, 1986; Breslau *et al.* 1991, 1993; Killen *et al.* 1991; Cicchetti & Toth, 1998; Escobedo *et al.* 1998; Lerman *et al.* 1998; Ludman *et al.* 2002). The data gathered in this study are consistent with this explanation to the extent that current smoking was found to be related to depression in the past year even when covariate factors and previous smoking was taken into account: those reporting depression in a given year had a higher rate of daily smoking and nicotine dependence than would have been expected on the basis of their past history of smoking and psychosocial background.

However, it is possible to pose a counter model in which smoking increases individual susceptibility to depression (e.g. Brown *et al.* 1996; Choi *et al.* 1997; Wu & Anthony, 1999; Goodman & Capitman, 2000). In this study we conducted a supplementary structural equation model analysis to examine the plausibility of the alternative explanations of the linkages between smoking and depression. This analysis proved to be inconclusive but suggested that the best-fitting and most consistent model was one in which depression influenced smoking behaviours. Thus, although the weight of the evidence suggests the presence of a causal relationship between smoking and depression, the direction of this causal relationship remains unclear. Although prior theory and the present analysis would tend to support a self-medication

model, the data gathered in this study are also consistent with the view that smoking may influence individual susceptibility to depression. This conclusion highlights the limitations of passive longitudinal research for establishing causal directions. Specifically, while such research may provide evidence of a possible causal relationship between variables, determining the direction of causality solely on the basis of longitudinal data will often prove difficult. These considerations suggest the need for findings from longitudinal studies to be both extended and tested using planned experiments wherever possible. For example, if smoking were to lead to depression then one might expect to see that the successful treatment of depression would also be accompanied by a reduction in smoking. Conversely, if smoking were to influence susceptibility to depression then smoking cessation might be accompanied by a reduction in depression. Thus, by examining changes in depression and smoking in the context of programmes designed to treat these conditions it may be possible to gain further insight into the direction of causal influence.

The public health significance of this study rests with the fact that the measures of interest – cigarette smoking and depression – have been listed as being among the top five major causes of mortality and morbidity in the WHO global burden of disease assessment (Murray & Lopez, 1997). In many societies, health priorities focus on programmes designed to address depression or cigarette smoking. An intriguing feature of the present study is that it suggests the presence of causal linkages between smoking and depression. These considerations suggest that public health programmes aimed at reducing major depression may also have indirect effects in reducing cigarette smoking and nicotine dependence within the population or conversely that public health programmes that encourage smoking cessation may have indirect effects in reducing rates of depression.

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