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Associations of adverse childhood experiences with smoking initiation in adolescence and persistence in adulthood, and the role of the childhood environment: Findings from the 1958 British birth cohort.

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Abstract

Adverse childhood experiences (ACEs) have been identified as a strong determinant of smoking. We aimed to examine the association between ACEs and early smoking initiation and subsequent persistence and the contribution of five pathways including family factors, parental involvement, material living conditions, social activities and conscientiousness.

Data are from 7 414 individuals born in 1958 in Great Britain included in the National Child Development Study. ACEs were measured at ages 7, 11, and 16. Smoking initiation was derived from smoking variables from ages 16 to 42 and persistent smoking was derived from smoking variables from ages 23 to 42. We modelled the relationship between ACEs and smoking, and further assessed the contribution of each pathway using multinomial logistic regressions.

During childhood, 20.9% of respondents experienced one ACE and 6.4% two or more. Those who experienced ACEs had a higher risk of initiating smoking by age 16 and of persistent smoking ($RRR_{\text{initiation by 16y}} = 1.89 [1.62; 2.20]$ for one ACE; $RRR_{\text{initiation by 16y}} = 2.36 [1.81; 3.08]$ for two or more ACEs, and $RRR_{\text{persistent smoking}} = 2.07 [1.73; 2.47]$ for one ACE, $RRR_{\text{persistent smoking}} = 2.59 [1.92; 3.49]$ for two or more ACEs). The factors that contributed most to explaining these associations were parental smoking, sibling order and conscientiousness. ACEs remained associated with persistent smoking after further adjusting for young adulthood variables.

Smoking prevention measures may need to be tailored when considering adolescents from communities where ACEs are more prevalent to curtail initiation, intensity and persistence.

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Keywords

Smoking; Social environment; Chronic stress exposure; Health behaviour; Cohort study; Social inequalities in health; Life course

1 Introduction

2 Tobacco smoking represents one of the most important and preventable causes of premature
3 mortality worldwide (1). On average, smokers die 10 years earlier than non-smokers from
4 tobacco related causes (2). Smoking is one of the most popular addictive behaviours initiated
5 and established during adolescence, with to date a substantial prevalence among adolescents
6 worldwide (3). Early initiation of smoking is associated with the development of more severe
7 levels of nicotine addiction with persistent smoking thereafter (4). Understanding the factors
8 that contribute to the initiation and continuation of smoking is critical for public health and
9 policy to develop more tailored smoking prevention interventions that will be effective in
10 reducing the prevalence of smoking.

11 Smoking is not only a consequence of an individual's intrinsic tendency towards addiction to
12 nicotine or cigarette smoking. Factors related to the social influences with which individuals
13 evolve and interact, play an important part in determining smoking (5). Adverse childhood
14 experiences (ACEs) described as a set of psychological trauma, abuse, living conditions, out of
15 the child's control, that can generate chronic stress responses in the child's immediate
16 environment (6), have been associated with poor health outcomes across the life course,
17 including chronic lung diseases (7) and lung cancer (8), partly through the adoption and
18 persistence of unhealthy behaviours (9), with a strong relationship with smoking (10).

19 In 1999, Anda et al. showed that individuals who had experienced more adverse childhood
20 experiences were more likely to start smoking at younger ages and continue to do so over time
21 (11). Since then, several studies have reported that ACEs are associated with an increased
22 likelihood of smoking behaviours along the life course in adulthood (12–14,10,15–23) and more
23 recently in adolescence (24,25) after various adjustments. Most of these studies controlled for
24 age, sex and/or ethnicity, socioeconomic indicators and had additionally adjusted for other
25 factors such as ethnicity, family factors, alcohol consumption, mood disorder, and marital

26 status, showing a robust association between childhood adversity and smoking. The
27 intermediate processes linking adversity and smoking are not well understood.

28 In previous research, several factors were found to partially mediate the relationship between
29 ACEs and smoking including family factors (26,27), parenting practices (28,29), material living
30 conditions (30,31), social activities (32–34), and conscientiousness (35,36). One of the
31 limitations of previous studies is the lack of simultaneous consideration of potential
32 intermediate or mediating factors identified in the risk of early initiation and subsequent
33 persistence of smoking. It remains unclear whether these intermediate factors mediate the
34 association between ACEs and the risk of smoking initiation in adolescence and its maintenance
35 in adulthood, and which ones are the main drivers of the association.

36 In this study, we aimed (i) to assess the relationship between ACEs and early smoking initiation
37 and persistence controlling for prior confounders and (ii) to comprehensively identify the
38 contribution of all the above potential mediators in the association between ACEs and smoking
39 initiation and continuation over the life course.

40

41 **Method**

42 **Study design and participants**

43 We analysed data from the 1958 National Child Development Study (NCDS), a national birth
44 cohort study of 17 415 people born in 1958 in Great Britain. A full description of the study
45 design and methods has been detailed elsewhere (37). There have been 12 waves of data
46 collection so far, at birth, ages 7, 11, 16, 23, 33, 42, 44/45, 46, 50, 55, and 62. Information on
47 multiple aspects of participants' lives was collected from a number of sources (i.e. parents,
48 teachers, cohort members, medical personnel, health visitor). Detailed information on ethics
49 approval and informed consent across the different data collection waves is available from the
50 study website (38). We used information on participants up to age 42 when more detailed

51 information on smoking was collected. A total of 7 414 had complete exposure and outcome
52 data of whom 4 587 (38%) also had complete for all other covariates. The sample selection
53 strategy is described in Appendices Figure A.1.

54 [Smoking initiation and long-term smoking](#)

55 The outcomes assessed in this analysis were smoking initiation and long-term smoking, derived
56 from information on smoking behaviour reported in questionnaires from ages 16 to 42. At each
57 age, “non-smokers” were defined as those who reported not smoking and “current smokers”
58 were defined as follows: at 16y as those who reported smoking at least one cigarette per week,
59 at 23y as those who reported currently smoking cigarettes and those who reported smoking
60 cigars or pipes, at 33y as those who reported currently smoking cigarettes and as those who
61 reported smoking at least one cigarette per month, at 42y as those who reported smoking
62 cigarettes every day. At 16 years, weekly cigarette consumption was also defined for
63 subsequent analyses in five categories: non-smoker, 1–19, 20–39, 40–59 and ≥ 60
64 cigarettes/week. From 23y to 42y, “former smokers” were defined as those who reported not
65 currently smoking but had previously smoked cigarettes. If the “never smokers” at any point in
66 the follow-up reported having smoked cigarettes regularly at an earlier age, we coded them as
67 “former smokers”.

68 From this set of smoking variables from 16 to 42 years we derived the smoking initiation
69 variable as follows: “never smokers” were defined as those who had never smoked at ages 16
70 to 42; individuals who had “started smoking by age 16” were defined as those who reported
71 smoking at 16y; and “smoking initiation after age 16” were defined as those who reported not
72 having smoked in a previous sweep but who reported having smoked or being a former smoker
73 at 23 or 33, or 42 years of age.

74 Similarly, long-term smoking was derived from smoking variables from ages 23 to 42 whereby
75 “non-smokers” were defined as those who never smoked from ages 23 to 42; “persistent

76 smokers” were defined as those who smoked from ages 23 to 42; and the last group of
77 individuals was classified as those with a heterogeneous smoking consumption. A detailed
78 description of the construction of the smoking variables is given in Appendices File A.1.

79 ACEs

80 The exposure of interest was adverse childhood experiences (ACEs) and was constructed
81 according to previous work carried out in the NCDS dataset (39). The NCDS has a wealth of
82 prospectively collected ACEs data collected from the child’s parent, the health visitor or their
83 teacher. ACEs were measured by counting the number of positive responses across all three
84 surveys at ages 7, 11, and 16 of the following categories: child in care, physical neglect,
85 offenders, parental separation, mental illness, and alcohol abuse (6,39). Based on the
86 distribution of the cumulative ACEs score (1.69 % of participants were defined as having three
87 or more ACEs), a three-category variable was constructed (0 adversity/1 adversity/more than
88 one adversity). A full description of the six categories together with detailed information on
89 ACEs score construction is given in Appendices File A.1.

90 Covariates

91 Baseline variables, previously identified in the literature as confounders in the associations
92 between ACEs and the two main smoking outcomes (initiation by age 16 and long-term
93 smoking) and tested in bivariate analysis, were mother’s age at birth, respondent’s sex and birth
94 weight. Socioeconomic background was also included since early childhood adversity is more
95 frequent among children growing up in disadvantaged socioeconomic conditions (30) and
96 individuals from disadvantaged socioeconomic groups are more likely to smoke, to be heavy
97 smokers and to be more heavily dependent on smoking (4). Socioeconomic background was
98 measured using parental socioeconomic classification of occupations (SEC), based on a
99 questionnaire completed at birth by the parents (I-professional occupations & II-intermediate
100 occupations/III-skilled occupations (non-manual)/III-partly skilled occupations (manual)/IV-
101 partly skilled occupations & V-unskilled occupations).

102 We considered five blocks of potential mediating variables in this study: family factors, parental
103 involvement, material living conditions, social activities, and conscientiousness. Family factors
104 comprised sibling order at 7y (Single child/Elder/2nd place or more) and parental smoking at
105 16y (Smoker/Non-smoker). Parental involvement was derived from variables measured at age
106 7 including reading to the child, outdoor activities (Frequent/Occasionally, Hardly ever), and
107 father's role in the management of the child (Equal parental investment/Father less invested/
108 Father not invested). Material living conditions at ages 7, 11, and 16
109 (Advantaged/Disadvantaged). Social activities at age 16 ranked from 0 to 4, where 4 indicates
110 a high participation in parties with friends. We also considered conscientiousness at age 16
111 measured with a score in which higher values indicated higher conscientiousness.

112 Other potential subsequent mediators during early adulthood were included in an additional
113 analysis of long-term smoking, namely: education level at 23y (A level -12 years of education/O
114 levels-10 years of education/ No qualifications), age of first child before 23y (No child/Child
115 [18-23y]/Child <18y), Employment at 23y (With employment/Unemployed). See Appendices
116 File A.1 for more a detailed description of the covariates.

117 [Statistical analysis](#)

118 We first carried-out either χ^2 test or the Wilcoxon signed-rank test to estimate bivariate
119 associations between the covariates and each outcome (smoking initiation or long-term
120 smoking). Second, we used multinomial logistic regression models to estimate relative risk
121 ratios (RRR) of smoking initiation or long-term smoking comparing participants who reported
122 one, or two or more ACEs to those who did not. We defined an adjusted model controlling for
123 baseline confounders and parental SEC (Model 1). Then we further adjusted for each block of
124 covariates to assess the contribution of each respective pathway and identify potential mediators
125 for future analyses. We defined a final model including all of the intermediate variables to
126 assess the residual effect of ACEs on smoking (Model 2) (40).

- 127 - Model 1: Model 1 + baseline confounders (mother's age, birthweight, sex) + parental SEC
- 128 - Model 1A: Model 1 + family factors (sibling order, parental smoking)
- 129 - Model 1B: Model 1 + parental involvement (reading to the child, outdoor activities,
- 130 father's role in the management of the child)
- 131 - Model 1C: Model 1 + material living conditions
- 132 - Model 1D: Model 1 + social activities
- 133 - Model 1E: Model 1 + conscientiousness
- 134 - Model 2: fully adjusted model

135 For long-term smoking outcome, we further controlled for educational level, age at first child
136 and employment.

- 137 - Model 3: fully adjusted model + educational level + age of first child + employment

138

139 We imputed data for covariates with missing data using the multiple imputation by chained
140 equations method in the population with non-missing data for ACEs and smoking (n=7 414).
141 Forty-two imputations were conducted, using the two-step process recommended by von
142 Hippel to ensure replicable estimates of the standard errors (41,42), taking the missing at
143 random assumption for the covariates. Comparisons were made between complete-case
144 analyses and those run on estimates obtained by imputation to ensure that our results were not
145 biased by missing values (Appendices Table A.1 and Appendices Table B.1). Statistical
146 analyses were performed using STATA v17

147

148 [Data sharing](#)

149 Anonymised data from the 1958 NCDS are freely available and can be obtained by registering
150 on the UK data service (<https://ukdataservice.ac.uk/>).

151 **Results**

152 A total of 7 414 participants were included for whom 37.91% had initiated smoking by 16y and
 153 23.28% were smoking more than 20 cigarettes per week at 16 years. From ages 23 to 42, 17.16%
 154 were persistent smokers. In addition, during childhood, 20.88% of the individuals experienced
 155 one ACE and 6.41% two or more.

156 A higher proportion of individuals who experienced adversity, compared to those who did not,
 157 had parents from a disadvantaged SEC, had older siblings, had a smoking parent, had fathers
 158 who were absent in their family investment, had occasionally or rarely reading activities or
 159 outdoor activities, lived in poor material conditions during childhood, attended a lot of parties,
 160 and had a lower conscientiousness score (Table 1).

161 **Table 1. Descriptive statistics of variable of interest by ACEs in 7414 participants from**
 162 **the 1958 National Child Development Study.**

| Variable | Level | ACEs | | | Total n=7414 (100%) |
|---------------------------------|---------------------------|----------------------------------|---------------------------------|--|------------------------|
| | | None n=5391 (72.71%) n (%) | One n=1548 (20.88%) n (%) | Two or more n= 475 (6.41%) n (%) | |
| Smoking initiation | Never smoked | 1452 (26.93%) | 300 (19.38%) | 79 (16.63%) | 1831 (24.70%) |
| | Initiation by 16y | 1831 (33.96%) | 730 (47.16%) | 250 (52.63%) | 2811 (37.91%) |
| | Initiation > 16y | 2108 (39.10%) | 518 (33.46%) | 146 (30.74%) | 2772 (37.39%) |
| Amount of smoking at 16y | Non-smoker | 3560 (66.04%) | 818 (52.84%) | 225 (47.37%) | 4603 (62.09%) |
| | 1 to 19 cig./week | 780 (14.47%) | 234 (15.12%) | 71 (14.95%) | 1085 (14.63%) |
| | 20 to 39 cig./week | 492 (9.13%) | 203 (13.11%) | 71 (14.95%) | 766 (10.33%) |
| | 40 to 59 cig./week | 324 (6.01%) | 157 (10.14%) | 61 (12.84%) | 542 (7.31%) |
| | More than 60 cig./week | 235 (4.36%) | 136 (8.79%) | 47 (9.89%) | 418 (5.64%) |
| Long-term smoking | Never smoked | 1452 (26.93%) | 300 (19.38%) | 79 (16.63%) | 1831 (24.7%) |
| | Persistent smoking | 794 (14.73%) | 353 (22.8%) | 125 (26.32%) | 1272 (17.16%) |
| | Heterogeneous consumption | 3145 (58.34%) | 895 (57.82%) | 271 (57.05%) | 4311 (58.15%) |
| Sex | Men | 2580 (47.86%) | 766 (49.48%) | 247 (52%) | 3593 (48.46%) |
| | Women | 2811 (52.14%) | 782 (50.52%) | 228 (48%) | 3821 (51.54%) |
| Mother's age | ≤ 23 y | 1320 (24.49%) | 439 (28.36%) | 151 (31.79%) | 1910 (25.76%) |
| | 24-27 y | 1500 (27.82%) | 365 (23.58%) | 119 (25.05%) | 1984 (26.76%) |
| | 27-31y | 1207 (22.39%) | 285 (18.41%) | 76 (16%) | 1568 (21.15%) |
| | > 31y | 1222 (22.67%) | 399 (25.78%) | 107 (22.53%) | 1728 (23.31%) |
| | Missing | 142 (2.63%) | 60 (3.88%) | 22 (4.63%) | 224 (3.02%) |

| | | | | | |
|-----------------------------|--------------------------|---------------|---------------|--------------|---------------|
| Birth weight | Q1: Low weight | 1082 (20.07%) | 329 (21.25%) | 118 (24.84%) | 1529 (20.62%) |
| | Q2 | 1394 (25.86%) | 405 (26.16%) | 117 (24.63%) | 1916 (25.84%) |
| | Q3 | 1327 (24.62%) | 357 (23.06%) | 110 (23.16%) | 1794 (24.2%) |
| | Q4: High weight | 1291 (23.95%) | 351 (22.67%) | 91 (19.16%) | 1733 (23.37%) |
| | Missing | 297 (5.51%) | 106 (6.85%) | 39 (8.21%) | 442 (5.96%) |
| Parental SEC | I & II | 1131 (20.98%) | 195 (12.6%) | 19 (4%) | 1345 (18.14%) |
| | IIINM | 536 (9.94%) | 139 (8.98%) | 35 (7.37%) | 710 (9.58%) |
| | IIIM | 2630 (48.79%) | 748 (48.32%) | 218 (45.89%) | 3596 (48.5%) |
| | IV&V | 914 (16.95%) | 379 (24.48%) | 171 (36%) | 1464 (19.75%) |
| | Missing | 180 (3.34%) | 87 (5.62%) | 32 (6.74%) | 299 (4.03%) |
| Sibling order | Single child | 478 (8.87%) | 110 (7.11%) | 22 (4.63%) | 610 (8.23%) |
| | Elder | 1703 (31.59%) | 367 (23.71%) | 81 (17.05%) | 2151 (29.01%) |
| | ≥ 2 | 3022 (56.06%) | 911 (58.85%) | 312 (65.68%) | 4245 (57.26%) |
| | Missing | 188 (3.49%) | 160 (10.34%) | 60 (12.63%) | 408 (5.5%) |
| Parental smoking | Non smoker | 1345 (24.95%) | 223 (14.41%) | 40 (8.42%) | 1608 (21.69%) |
| | Smoker | 3060 (56.76%) | 977 (63.11%) | 325 (68.42%) | 4362 (58.83%) |
| | Missing | 986 (18.29%) | 348 (22.48%) | 110 (23.16%) | 1444 (19.48%) |
| Parental involvement | Mother = Father | 3224 (59.8%) | 709 (45.8%) | 166 (34.95%) | 4099 (55.29%) |
| | Mother > Father | 1569 (29.1%) | 407 (26.29%) | 103 (21.68%) | 2079 (28.04%) |
| | Father not | 376 (6.97%) | 173 (11.18%) | 88 (18.53%) | 637 (8.59%) |
| | Missing | 222 (4.12%) | 259 (16.73%) | 118 (24.84%) | 599 (8.08%) |
| Outdoor activities | Most weeks | 4683 (86.87%) | 1157 (74.74%) | 310 (65.26%) | 6150 (82.95%) |
| | Occasionally/hardly ever | 506 (9.39%) | 229 (14.79%) | 110 (23.16%) | 845 (11.4%) |
| | Missing | 202 (3.75%) | 162 (10.47%) | 55 (11.58%) | 419 (5.65%) |
| Reading activities | Most weeks | 3126 (57.99%) | 732 (47.29%) | 160 (33.68%) | 4018 (54.19%) |
| | Occasionally/hardly ever | 2051 (38.04%) | 651 (42.05%) | 261 (54.95%) | 2963 (39.96%) |
| | Missing | 214 (3.97%) | 165 (10.66%) | 54 (11.37%) | 433 (5.84%) |
| Housing deprivation | Advantaged | 3714 (68.89%) | 882 (56.98%) | 200 (42.11%) | 4796 (64.69%) |
| | Disadvantaged | 1650 (30.61%) | 664 (42.89%) | 273 (57.47%) | 2587 (34.89%) |
| | Missing | 27 (0.5%) | 2 (0.13%) | 2 (0.42%) | 31 (0.42%) |
| Leisure: parties | 0: No parties | 897 (16.64%) | 214 (13.82%) | 66 (13.89%) | 1177 (15.88%) |
| | 1 | 978 (18.14%) | 244 (15.76%) | 75 (15.79%) | 1297 (17.49%) |
| | 2 | 1333 (24.73%) | 385 (24.87%) | 114 (24%) | 1832 (24.71%) |
| | 3 | 1213 (22.5%) | 350 (22.61%) | 102 (21.47%) | 1665 (22.46%) |
| | 4: Lots of parties | 642 (11.91%) | 241 (15.57%) | 73 (15.37%) | 956 (12.89%) |
| | Missing | 328 (6.08%) | 114 (7.36%) | 45 (9.47%) | 487 (6.57%) |
| Conscientiousness | Score: med [p25-p75] | 8 [6-10] | 7 [5-9] | 7 [5-9] | 8 [6-10] |
| | Missing | 275 (5.1%) | 107 (6.91%) | 24 (5.05%) | 406 (5.48%) |
| Education level | A level | 1450 (26.9%) | 212 (13.7%) | 30 (6.32%) | 1692 (22.82%) |
| | O level | 2292 (42.52%) | 612 (39.53%) | 151 (31.79%) | 3055 (41.21%) |
| | No level | 1591 (29.51%) | 701 (45.28%) | 288 (60.63%) | 2580 (34.8%) |
| | Missing | 58 (1.08%) | 23 (1.49%) | 6 (1.26%) | 87 (1.17%) |

| | | | | | |
|----------------------|-----------------|---------------|---------------|--------------|---------------|
| Employment | With employment | 4174 (77.43%) | 1075 (69.44%) | 303 (63.79%) | 5552 (74.89%) |
| | Unemployed | 1163 (21.57%) | 450 (29.07%) | 166 (34.95%) | 1779 (24%) |
| | Missing | 54 (1%) | 23 (1.49%) | 6 (1.26%) | 83 (1.12%) |
| Age 1st child | No child | 4228 (78.43%) | 1031 (66.6%) | 276 (58.11%) | 5535 (74.66%) |
| | Child [18-23y] | 1039 (19.27%) | 452 (29.2%) | 174 (36.63%) | 1665 (22.46%) |
| | Child < 18y | 70 (1.3%) | 42 (2.71%) | 19 (4%) | 131 (1.77%) |
| | Missing | 54 (1%) | 23 (1.49%) | 6 (1.26%) | 83 (1.12%) |

163

164 Individuals who had started smoking by age 16 or individuals with persistent smoking from 23
165 to 42 years were more likely to have experienced adversities during childhood, to have had
166 parents from a disadvantaged SEC (IIIM, IV&V), to have been younger siblings, to have had a
167 smoking parent, to have engaged occasionally or rarely in outdoor activities to have had fathers
168 who were less involved in parenting than their mothers or even absent from family investment,
169 to have had occasionally or rarely reading activities, to have lived in poor material conditions
170 during childhood, to have attended a lot of parties and to have had a lower conscientiousness
171 score, compared to those who had never smoked. In addition, individuals with persistent
172 smoking from 23 to 42 years, compared to those who never smoked, generally had no level of
173 education, were unemployed at 23y, and had a child born before 23y (Table 2A and Table 2B).

174

Table 2. Characteristics of study participants by (A) smoking initiation and (B) long-term smoking (n=7414).

175

| Variable | Level | A. Smoking initiation | | | B. Long term smoking | | |
|--------------|----------------|-----------------------|----------------------------|---------------------------|-----------------------|-----------------------------|------------------------|
| | | Never smoked n (%) | Initiation by 16y n (%) | Initiation > 16y n (%) | Never smoked n (%) | Persistent smoking n (%) | Heterogeneous n (%) |
| ACEs | None | 1452 (79.3%) | 1831 (65.14%) | 2108 (76.05%) | 1452 (79.3%) | 794 (62.42%) | 3145 (72.95%) |
| | One | 300 (16.38%) | 730 (25.97%) | 518 (18.69%) | 300 (16.38%) | 353 (27.75%) | 895 (20.76%) |
| | Two or more | 79 (4.31%) | 250 (8.89%) | 146 (5.27%) | 79 (4.31%) | 125 (9.83%) | 271 (6.29%) |
| Sex | Men | 801 (43.75%) | 1409 (50.12%) | 1383 (49.89%) | 801 (43.75%) | 581 (45.68%) | 2211 (51.29%) |
| | Women | 1 030 (56.25%) | 1402 (49.88%) | 1389 (50.11%) | 1 030 (56.25%) | 691 (54.32%) | 2 100 (48.71%) |
| Mother's age | ≤ 23 y | 443 (24.19%) | 786 (27.96%) | 681 (24.57%) | 443 (24.19%) | 382 (30.03%) | 1085 (25.17%) |
| | 24-27 y | 496 (27.09%) | 751 (26.72%) | 737 (26.59%) | 496 (27.09%) | 347 (27.28%) | 1141 (26.47%) |
| | 27-31y | 406 (22.17%) | 555 (19.74%) | 607 (21.9%) | 406 (22.17%) | 249 (19.58%) | 913 (21.18%) |
| | > 31y | 441 (24.09%) | 628 (22.34%) | 659 (23.77%) | 441 (24.09%) | 257 (20.2%) | 1030 (23.89%) |
| | Missing | 45 (2.46%) | 91 (3.24%) | 88 (3.17%) | 45 (2.46%) | 37 (2.91%) | 142 (3.29%) |
| Birth weight | Q1: Low weight | 408 (22.28%) | 589 (20.95%) | 532 (19.19%) | 408 (22.28%) | 298 (23.43%) | 823 (19.09%) |
| | Q2 | 507 (27.69%) | 672 (23.91%) | 737 (26.59%) | 507 (27.69%) | 323 (25.39%) | 1086 (25.19%) |
| | Q3 | 414 (22.61%) | 670 (23.83%) | 710 (25.61%) | 414 (22.61%) | 304 (23.9%) | 1076 (24.96%) |

| | | | | | | | |
|----------------------|-----------------|---------------|---------------|---------------|---------------|--------------|---------------|
| | Q4: High weight | 406 (22.17%) | 702 (24.97%) | 625 (22.55%) | 406 (22.17%) | 272 (21.38%) | 1055 (24.47%) |
| | Missing | 96 (5.24%) | 178 (6.33%) | 168 (6.06%) | 96 (5.24%) | 75 (5.9%) | 271 (6.29%) |
| Parental SEC | I & II | 362 (19.77%) | 432 (15.37%) | 551 (19.88%) | 362 (19.77%) | 162 (12.74%) | 821 (19.04%) |
| | IIINM | 178 (9.72%) | 241 (8.57%) | 291 (10.5%) | 178 (9.72%) | 98 (7.7%) | 434 (10.07%) |
| | IIIM | 882 (48.17%) | 1368 (48.67%) | 1346 (48.56%) | 882 (48.17%) | 624 (49.06%) | 2090 (48.48%) |
| | IV&V | 353 (19.28%) | 648 (23.05%) | 463 (16.7%) | 353 (19.28%) | 332 (26.1%) | 779 (18.07%) |
| | Missing | 56 (3.06%) | 122 (4.34%) | 121 (4.37%) | 56 (3.06%) | 56 (4.4%) | 187 (4.34%) |
| Sibling order | Single child | 197 (10.76%) | 188 (6.69%) | 225 (8.12%) | 197 (10.76%) | 93 (7.31%) | 320 (7.42%) |
| | Elder | 608 (33.21%) | 677 (24.08%) | 866 (31.24%) | 608 (33.21%) | 320 (25.16%) | 1223 (28.37%) |
| | ≥ 2 | 928 (50.68%) | 1796 (63.89%) | 1521 (54.87%) | 928 (50.68%) | 789 (62.03%) | 2528 (58.64%) |
| | Missing | 98 (5.35%) | 150 (5.34%) | 160 (5.77%) | 98 (5.35%) | 70 (5.5%) | 240 (5.57%) |
| Parental smoking | Non smoker | 466 (25.45%) | 437 (15.55%) | 705 (25.43%) | 466 (25.45%) | 164 (12.89%) | 978 (22.69%) |
| | Smoker | 1044 (57.02%) | 1766 (62.82%) | 1552 (55.99%) | 1044 (57.02%) | 842 (66.19%) | 2476 (57.43%) |
| | Missing | 321 (17.53%) | 608 (21.63%) | 515 (18.58%) | 321 (17.53%) | 266 (20.91%) | 857 (19.88%) |
| Parental involvement | Mother = Father | 1052 (57.45%) | 1496 (53.22%) | 1551 (55.95%) | 1052 (57.45%) | 646 (50.79%) | 2401 (55.69%) |
| | Mother > Father | 500 (27.31%) | 802 (28.53%) | 777 (28.03%) | 500 (27.31%) | 383 (30.11%) | 1196 (27.74%) |
| | Father not | 147 (8.03%) | 274 (9.75%) | 216 (7.79%) | 147 (8.03%) | 123 (9.67%) | 367 (8.51%) |
| | Missing | 132 (7.21%) | 239 (8.5%) | 228 (8.23%) | 132 (7.21%) | 120 (9.43%) | 347 (8.05%) |

| | | | | | | | |
|---------------------|--------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Outdoor activities | Most weeks | 1536 (83.89%) | 2272 (80.83%) | 2342 (84.49%) | 1536 (83.89%) | 1027 (80.74%) | 3587 (83.21%) |
| | Occasionally/hardly ever | 194 (10.6%) | 386 (13.73%) | 265 (9.56%) | 194 (10.6%) | 173 (13.6%) | 478 (11.09%) |
| | Missing | 101 (5.52%) | 153 (5.44%) | 165 (5.95%) | 101 (5.52%) | 72 (5.66%) | 246 (5.71%) |
| Reading activities | Most weeks | 1061 (57.95%) | 1421 (50.55%) | 1536 (55.41%) | 1061 (57.95%) | 626 (49.21%) | 2331 (54.07%) |
| | Occasionally/hardly ever | 664 (36.26%) | 1230 (43.76%) | 1069 (38.56%) | 664 (36.26%) | 572 (44.97%) | 1727 (40.06%) |
| | Missing | 106 (5.79%) | 160 (5.69%) | 167 (6.02%) | 106 (5.79%) | 74 (5.82%) | 253 (5.87%) |
| Housing deprivation | Advantaged | 1233 (67.34%) | 1685 (59.94%) | 1878 (67.75%) | 1233 (67.34%) | 719 (56.53%) | 2844 (65.97%) |
| | Disadvantaged | 590 (32.22%) | 1117 (39.74%) | 880 (31.75%) | 590 (32.22%) | 550 (43.24%) | 1447 (33.57%) |
| | Missing | 8 (0.44%) | 9 (0.32%) | 14 (0.51%) | 8 (0.44%) | 3 (0.24%) | 20 (0.46%) |
| Leisure: parties | 0: No parties | 424 (23.16%) | 236 (8.4%) | 517 (18.65%) | 424 (23.16%) | 128 (10.06%) | 625 (14.5%) |
| | 1 | 382 (20.86%) | 367 (13.06%) | 548 (19.77%) | 382 (20.86%) | 168 (13.21%) | 747 (17.33%) |
| | 2 | 479 (26.16%) | 661 (23.51%) | 692 (24.96%) | 479 (26.16%) | 306 (24.06%) | 1047 (24.29%) |
| | 3 | 316 (17.26%) | 806 (28.67%) | 543 (19.59%) | 316 (17.26%) | 340 (26.73%) | 1009 (23.41%) |
| | 4: Lots of parties | 128 (6.99%) | 541 (19.25%) | 287 (10.35%) | 128 (6.99%) | 234 (18.4%) | 594 (13.78%) |
| | Missing | 102 (5.57%) | 200 (7.11%) | 185 (6.67%) | 102 (5.57%) | 96 (7.55%) | 289 (6.7%) |
| Conscientiousness | Score: med [p25-p75] | 9 [8-11] | 7 [5-8] | 9 [7-10] | 9 [8-11] | 7 [5-9] | 8 [6-10] |
| | Missing | 89 (4.86%) | 165 (5.87%) | 152 (5.48%) | 89 (4.86%) | 69 (5.42%) | 248 (5.75%) |
| Education level | A level | 588 (32.11%) | 323 (11.49%) | 781 (28.17%) | 588 (32.11%) | 138 (10.85%) | 966 (22.41%) |

| | | | | | | | |
|---------------|-----------------|---------------|---------------|---------------|---------------|--------------|---------------|
| | O level | 788 (43.04%) | 1040 (37%) | 1227 (44.26%) | 788 (43.04%) | 463 (36.4%) | 1804 (41.85%) |
| | No level | 453 (24.74%) | 1365 (48.56%) | 762 (27.49%) | 453 (24.74%) | 670 (52.67%) | 1457 (33.8%) |
| | Missing | 2 (0.11%) | 83 (2.95%) | 2 (0.07%) | 2 (0.11%) | 1 (0.08%) | 84 (1.95%) |
| Employment | With employment | 1469 (80.23%) | 1910 (67.95%) | 2173 (78.39%) | 1469 (80.23%) | 865 (68%) | 3218 (74.65%) |
| | Unemployed | 362 (19.77%) | 818 (29.1%) | 599 (21.61%) | 362 (19.77%) | 407 (32%) | 1010 (23.43%) |
| | Missing | 0 (0%) | 83 (2.95%) | 0 (0%) | 0 (0%) | 0 (0%) | 83 (1.93%) |
| Age 1st child | No child | 1492 (81.49%) | 1819 (64.71%) | 2224 (80.23%) | 1492 (81.49%) | 796 (62.58%) | 3247 (75.32%) |
| | Child [18-23y] | 320 (17.48%) | 830 (29.53%) | 515 (18.58%) | 320 (17.48%) | 438 (34.43%) | 907 (21.04%) |
| | Child < 18y | 19 (1.04%) | 79 (2.81%) | 33 (1.19%) | 19 (1.04%) | 38 (2.99%) | 74 (1.72%) |
| | Missing | 0 (0%) | 83 (2.95%) | 0 (0%) | 0 (0%) | 0 (0%) | 83 (1.93%) |

177 Multivariate multinomial logistic regression results between ACEs and smoking initiation and
178 long-term smoking on the imputed data are presented in Figure 1. In all settings, individuals
179 who had experienced one, or two or more ACEs had gradually a higher risk to initiate smoking
180 in adolescence and to have a persistent consumption in adulthood. The associations between
181 ACEs and smoking outcomes were maintained after adjustment for socioeconomic background
182 and confounding factors: participants who reported one, or two or more ACEs had consistently
183 higher risk to initiate smoking by age 16 (RRR= 1.89 [1.62; 2.2] for one ACE; RRR= 2.36
184 [1.81; 3.08] for two or more ACEs, Model 1) compared to those who have not experienced any
185 adversity. Similarly, participants who had experienced one ACE, or two or more had
186 consistently higher risk to be persistent smokers between 23 and 42 years old (RRR= 2.07 [1.73;
187 2.47] for one ACE, RRR= 2.59 [1.92; 3.49] for two or more ACEs, Model 1), compared to
188 those who had not experienced any adversity.

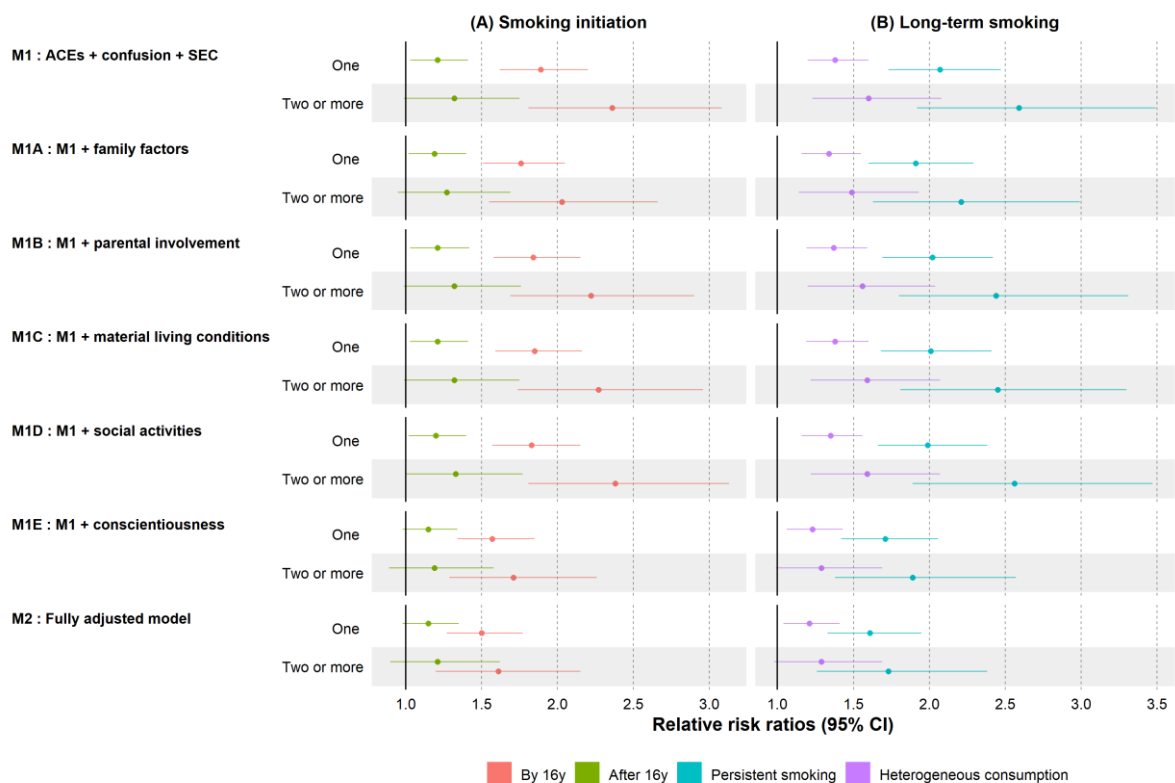
189 For both smoking outcomes, controlling for family factors or conscientiousness had the largest
190 effect while controlling for parenting, material deprivation and social life had little effect on
191 RRRs. Graded associations were observed across ACEs categories, only results for two or more
192 ACEs will be detailed here.

193 The associations between ACEs and risk for smoking by 16y and persistent smoking between
194 ages 23 and 42 were similar in effect size and observed consistently after controlling for
195 intermediate factors of parenting, material deprivation or social life (RRR_{initiation by 16y}=2.22
196 [1.69; 2.9], Model 1 + parental involvement; RRR_{initiation by 16y}=2.27 [1.74; 2.96], Model 1 +
197 material living conditions; RRR_{initiation by 16y}=2.38 [1.81; 3.13], Model 1 + social activities and
198 RRR_{persistent smoking}=2.44 [1.8; 3.31], Model 1 + parental involvement; RRR_{persistent smoking}=2.45
199 [1.81; 3.3], Model 1 + material living conditions; RRR_{persistent smoking}=2.56 [1.89; 3.47], Model
200 1 + social activities).

201 Observed RRRs between ACEs and both smoking outcomes were smaller in size after
 202 controlling for family factors or personality variables ($RRR_{\text{initiation by 16y}}=2.03$ [1.55; 2.66],
 203 Model 1 + family factors; $RRR_{\text{initiation by 16y}}=1.71$ [1.29; 2.26], Model 1 + conscientiousness ;
 204 and $RRR_{\text{persistent smoking}}=2.21$ [1.63; 2.99], Model 1 + family factors ; $RRR_{\text{persistent smoking}}=1.89$
 205 [1.38; 2.57], Model 1 + conscientiousness).

206 When all potential confounders and mediators were controlled for, ACEs remained associated
 207 with smoking initiation by 16y and with persistent smoking (Model 2: $RRR_{\text{initiation by 16y}} = 1.5$
 208 [1.27; 1.77] for one ACE; $RRR_{\text{initiation by 16y}} = 1.61$ [1.2; 2.15] for two or more ACEs; $RRR_{\text{persistent smoking}} = 1.61$ [1.33; 1.95] for one ACE. $RRR_{\text{persistent smoking}} = 1.73$ [1.26; 2.38] for two or
 209
 210 more ACEs).

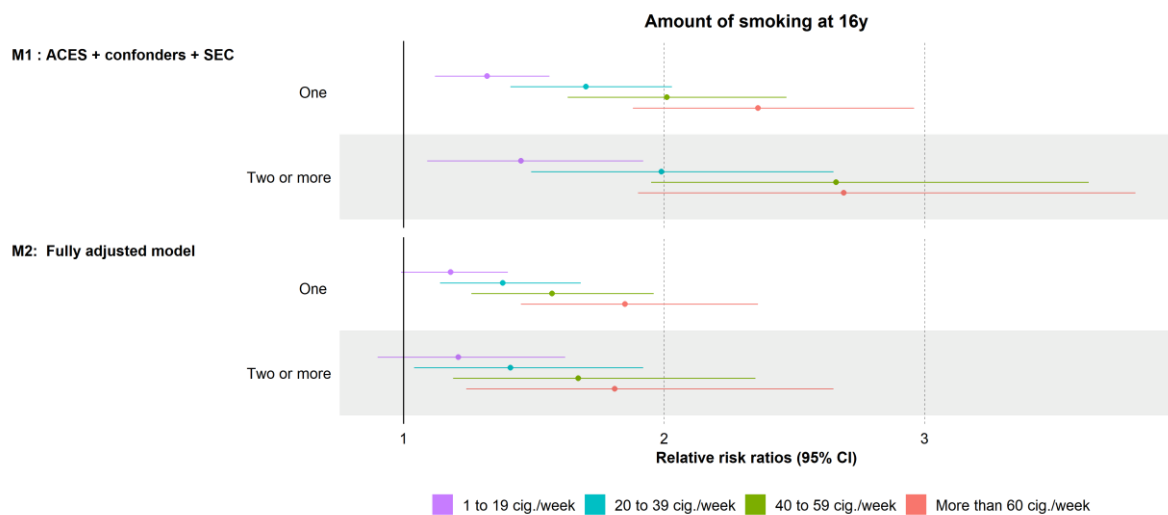
211 **Figure 1: Relative risk ratios for (A) smoking initiation and (B) long-term smoking in 7**
 212 **414 participants from the NCDS 58.** Estimates are from multinomial logistic regression
 213 model where the never smoker group is the reference category. Models are adjusted for sex,
 214 mother's age, birthweight, parental SEC and each block of variables.



215 The additional analysis of the association between ACEs and the amount of smoking at 16y is
 216 presented in Figure 2. Individuals who experienced one, two or more adversities were more

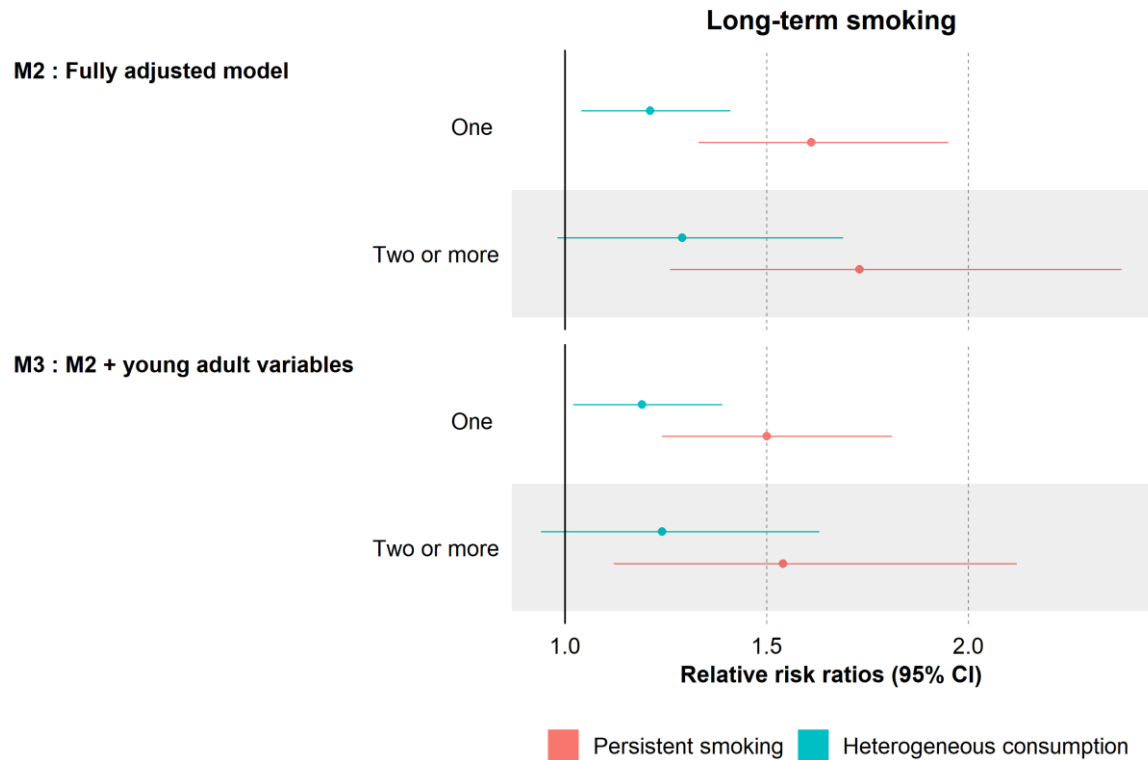
217 likely to smoke a higher number of cigarettes, after adjustment for socioeconomic background
 218 and baseline confounders. ACEs remained associated with smoking consumption ≥ 20
 219 cig./week when all potential confounders and mediators were controlled for.

220 **Figure 2: Relative risk ratios for amount of smoking at 16y in 7 414 participants from the**
 221 **NCDS 58.** Estimates are from multinomial logistic regression model where the never smoker
 222 group is the reference category. Models are adjusted for sex, mother’s age, birthweight, parental
 223 SEC and each block of variables.



224 The additional analysis between long-term smoking and ACEs is presented in Figure 3. The
 225 association was attenuated when variables from the young adulthood life stage were added to
 226 the model, namely a low level of education, unemployment, a child born before 23y. However,
 227 ACEs remained associated with persistent smoking (Model 3, $RRR_{\text{persistent smoking}} = 1.50 [1.24;$
 228 $1.81]$ for one ACE; $RRR_{\text{persistent smoking}} = 1.54 [1.12; 2.12]$ for two or more ACEs).

229 **Figure 3: Relative risk ratios for additional models adjusting for variables from the young**
 230 **adulthood life stage between ACEs and long-term smoking.** Estimates are from multinomial
 231 logistic regression model where the never smoker group is the reference category. Models are
 232 adjusted for sex, mother’s age, birthweight, parental SEC and each block of variables.



233 Supplemental Tables C.1; D.1; E.1 and F.1 in Appendices contain the results of these figures
 234 presented in table format.

235 Discussion

236 In this prospective UK cohort, in which 20.9% of individuals experienced one adversity in
 237 childhood and 6.4% two or more, we found evidence that these exposures were associated in a
 238 graded fashion with smoking outcomes. Children who experienced one, or two or more
 239 adversities had a consistently higher risk of initiating smoking in adolescence, to smoke heavily
 240 at 16y and to smoke persistently thereafter. These findings are consistent with a previous study
 241 where adverse childhood experiences were strongly associated with smoking initiation, heavy
 242 smoking and subsequent persistence (11). The associations between ACEs and risk for smoking
 243 initiation, amount of smoking at 16y and persistent smoking were weaker when adjusting for
 244 childhood mediating factors. Family factors and conscientiousness were the strongest
 245 contributors to the risk of smoking initiation and persistence associated with ACEs. ACEs
 246 remained associated with persistent smoking after adjusting for education level, age at first

247 child and employment. These findings suggest that ACEs should be examined as an important
248 upstream determinant of initiation and maintenance of smoking. Our results offer several
249 insights with respect to previous studies.

250

251 Growing evidence indicates that exposure to toxic stress early in life can lead to mood
252 dysregulation in childhood which can in turn result in the initiation and persistence of smoking.
253 Anxiety, anger, or depression, may induce early smoking initiation, as smoking provides an
254 immediate pharmacological or psychological benefit in coping with the strain of life's stressors.
255 using the reward circuit and dopamine delivery (6,43). Beyond the benefit of dopamine,
256 nicotine intake can lead to structural modifications of the brain that are also strongly implicated
257 in the mechanisms of addiction (4). Early smoking initiation during adolescence, which may be
258 a period when the physiological effects of nicotine are exacerbated (44) and brain systems
259 exhibit plasticity, can have lasting effects into adulthood leading to nicotine dependence and
260 persistent smoking. In addition, exposure to toxic stress early in life may result in alterations in
261 various biological systems and neural circuits (45), including emotional processing of threat
262 and reward, and may therefore induce increased nicotine susceptibility (46). Therefore, early
263 smoking combined with exposure to toxic stress in early life can cumulatively lead to a higher
264 overall susceptibility to nicotine addiction (46). Additionally, nicotine intake can increase the
265 onset of anxiety disorders (47) in turn, reinforcing the need for nicotine to reduce them, while
266 worsening these anxiety disorders over time in a vicious circle of interdependence (48).
267 Subsequently, individuals with anxiety or stress disorders are less likely to overcome craving
268 and smoking withdrawal symptoms, which promotes the maintenance of smoking addiction
269 (49).

270 Our *a priori* assumption was that early life socioeconomic position could modulate the effects
271 of ACEs on smoking behaviour, since disadvantaged socioeconomic background has been

272 identified as a determinant of smoking behaviour (50). Our results highlighted that
273 socioeconomic background plays a minimal role in the association between ACEs and the
274 smoking (Appendices Table G.1) in agreement with previous studies (51,52).

275 Among the five blocks of variables investigated in the present study, the most important
276 potential pathways identified were family factors and conscientiousness. To establish
277 mechanisms and mediation, further analyses using causal inference approaches are required.

278 Later in the life course, early parenthood, low level of education and unemployment, played a
279 role in explaining the association between persistent smoking and ACEs, consistent with
280 previous findings (50). Based on our results, we hypothesize that these factors may contribute
281 to a chain of risk exposing individuals to chronic stress with consequences for their wellbeing
282 in adulthood. The association between ACEs and persistent smoking were maintained after
283 adjustment for early adulthood variables.

284

285 There are several limitations in this study. First, the measurement of ACEs may be limited as it
286 only considers the child's circumstances at ages 7, 11, and 16, combining different indicators
287 with different potential effects. However, this measure captures severe circumstances that we
288 hypothesized as being chronically stressful. Misclassification bias may have occurred in
289 relation to adversity categories, namely when considering the sensitive nature of the questions.
290 For this reason, we constructed the ACEs variable conservatively. Second, attrition is a problem
291 in cohort studies, increasing the potential for selection bias in the remaining sample. We dealt
292 with this by carrying out multiple imputation of missing data, a recommended method to avoid
293 the interpretation of biased results. Third, it is also possible that we misclassified individuals
294 when constructing the smoking initiation and long-term smoking variables due to the self-
295 reported nature of the data. Furthermore, the construction of the smoking variable at age 23

296 took into account those who smoked cigars, pipes, and resulted in a heterogeneous group of
297 individuals in the current smoking category. However, sensitivity analyses showed similar
298 results for this group, justifying their inclusion. We used parental occupation at birth to control
299 for socioeconomic background. Other results could have been obtained using other
300 socioeconomic variables. However, additional analyses (not reported here) showed that other
301 socioeconomic measures, such as parental education and family income, had little effect in the
302 association between ACEs and smoking. Finally, we may have overlooked variables or
303 assumptions contributing to the relationship between ACEs and smoking initiation and long-
304 term smoking. Therefore, it is probable that residual confounding factors are present, and that
305 our estimates of the impact of ACEs on smoking are overestimated.

306 The strengths of this study lie in its prospective design, with a large sample size and data
307 collected in great detail and across the life course, allowing us to control for numerous
308 confounding and mediating variables to understand the causal sequence of events. While many
309 studies examine early adversity using retrospective questions, which are subject to recall bias,
310 we used prospective information on ACEs.

311

312 Using longitudinal prospective data covering 42 years of the life course, in a large sample from
313 a representative cohort study, we provide evidence that stressful events during childhood are
314 strong determinants of smoking initiation and long-term smoking, independently of the
315 socioeconomic background. Our results emphasize the importance of considering ACEs in
316 smoking prevention and the need for targeted prevention for adolescents, from all
317 socioeconomic groups, who have experienced adversity.

318

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323

324 **Disclosure of interest**

325 All authors disclose any financial and personal competing interest. CJ received funding from
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