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# Smoking Status of Parents, Siblings and Friends: Predictors of Regular Smoking? Findings from a Longitudinal Twin-family Study

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The relationship between regular smoking behavior and the smoking behavior of parents, siblings and friends was investigated using data from the Netherlands Twin Register. Cross-sectional analyses of data of 3906 twins showed significant associations between smoking behavior of the participant and smoking behavior of co-twin, additional brothers, parents of the same sex as the participant and friends. Those variables, together with age, explained 47% of the variance in smoking behavior. Longitudinal analyses of data from 2397 twins, who, in 1993, reported never to have smoked (regularly), showed that uptake of regular smoking two years later was predicted by having a smoking co-twin, smoking same-sex siblings, smoking mother and smoking friends. Males are, in contrast to females, at a later age still vulnerable to taking up regular smoking. The variables explained 21% of the variance. Sport participation, alcohol use, boredom susceptibility and neuroticism significantly added to the predictive value of this model. Including those additional factors increased the explained variance to 30%, and subsequently adding experimental smoking behavior further increased the explained variance to almost 50%. In summary, having smoking family members and friends, as well as lifestyle and personality factors are important predictors for the uptake of regular smoking. However, the experimental smoking behavior of the participant is equally important.

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Research consistently shows associations between adolescents' smoking behavior and smoking behavior of their parents, siblings and friends. In general, smoking behavior of parents and smoking behavior of adolescents is weakly associated, with risk ratios ranging from non-significant to 4.0 (Bauman et al., 2001; Boyle et al., 2001; Brenner & Scharrer, 1996; Distefan et al., 1998; Green et al., 1991; Herlitz & Westholm, 1996; Jensen & Overgaard, 1993; Maziak & Mzayek, 2000; Meijer et al., 1996; Moran et al., 2000; Sasco et al., 1993; Shamsuddin & Abdul Harris, 2000; Swan et al., 1997; Wang et al., 1995; Whitters et al., 2000). Most of these studies did not investigate the influence of a smoking father or mother separately for both sexes. Smoking siblings increase an adolescent's risk of smoking two to fourfold (Boyle et al., 2001; Jensen

& Overgaard, 1993; Maziak & Mzayek, 2000; Moran et al., 2000; O'Loughlin et al., 1998; Swan et al., 1997; Wang et al., 1995; Whitters et al., 2000). Two studies disentangled the influence of brothers and sisters but did not find large differences (Maziak & Mzayek, 2000; Swan et al., 1990). Only one study also took the sex of the participant into account and reported for both males and females a significant association between smoking behavior and having smoking same-sex siblings (Wang et al., 1995). In a univariate cross-sectional analysis on our own data from Dutch adolescents and young adults, we also observed that same-sex smoking family members influenced smoking behavior more than opposite-sex family members (Vink et al., 2003).

Having smoking friends increased the risk of becoming a smoker from two to almost 20 times (Alexander et al., 2001; Bauman et al., 2001; Herlitz & Westholm, 1996; Jensen & Overgaard, 1993; McNeill et al., 1988; Moran et al., 2000; Sasco et al., 1993; Swan et al., 1997; Wang et al., 1995). A large study by Wang et al. (1995) found that the odds ratio (OR) for smoking was higher when having a smoking same-sex best friend than when having a smoking opposite-sex best friend. In contrast, Swan et al. (1990) reported that a significant association was found between participants' smoking behavior and having smoking opposite-sex friends, not with having smoking same-sex friends.

Most studies described above are univariate — only four multivariate studies have simultaneously included smoking behavior of family members (parents and siblings) and peers (best friend or most friends). Three of these studies found that having smoking friends was the best predictor of smoking behavior of adolescents (Jensen & Overgaard, 1993; O'Loughlin et al., 1998; Wang et al., 1995). In contrast, McNeill et al. (1988) showed that the odds ratio for smoking siblings was slightly higher than for smoking peers,

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but peers were defined as the number of smokers in a school year and may not reflect the friends of the individual (McNeill et al., 1988).

In view of the study results summarized above, it is tempting to conclude that much of the variance in smoking behavior can be explained by the smoking behavior of friends and family members. However, most of these studies have used a cross-sectional design. Cross-sectional studies are useful for suggesting hypotheses and can rule out possible causes when relationships between variables are not found. A longitudinal design may provide insight into the causal mechanisms. A study by Engels et al. (1999) assessed how associations between possible explanatory variables and smoking onset depended on the use of cross-sectional versus prospective designs. A set of variables was used which consisted of smoking-related beliefs and attitudes, self-efficacy and future intentions, sociodemographic factors as well as smoking behavior of parents, best friend and peer-group. The cross-sectional analyses showed strong associations between the smoking behavior of the participant and the smoking behavior of best friend and parents. However, over a period of 3 and 5 years, respectively 14% and 8% of the variance in change of smoking status from non-smoking to regular smoking could be predicted by the model variables. Smoking behavior of peers was excluded from this model (Engels et al., 1999).

In general, longitudinal studies on smoking have reported a small or non-significant influence of smoking parents, siblings and friends, but none of these studies explored the influence of smoking family members and friends separately for males and females (Distefan et al., 1998; McNeill et al., 1988; Oygard et al., 1995; West et al., 1999).

The goal of the present study was to analyze whether the variables that are cross-sectionally associated with smoking behavior also predict the uptake of regular smoking. This study is unique because, in addition to including the smoking behavior of parents (father and mother), siblings (brothers and sisters) and friends, the importance of genetic factors was assessed by comparing data from monozygotic (MZ) and dizygotic (DZ) twins. A higher association between smoking behavior of MZ twins compared to DZ twins may indicate genetic influences on smoking behavior because MZ twins are genetically identical while DZ twins share, on average, 50% of their DNA. We looked at three age groups: 12–15 years (legally not allowed to buy tobacco), 16–20 years old and 21–25 years old. Analyses were carried out separately for males and females to explore sex differences. Based on the literature we expected a high association between adolescents' smoking behavior and having smoking family members and friends in a cross-sectional analysis. To examine whether the same variables are involved in uptake of regular smoking we carried out a longitudinal analysis. In addition to smoking behavior of family and friends, other factors may influence the uptake of regular smoking. Lifestyle variables such as sport participation, alcohol use and religion have all been associated with smoking behavior (Tyas & Pederson, 1998). There is also consistent evidence for an association between smoking and depression, anxiety or neuroticism (Dierker et al., 2002). The present study will

explore whether these factors add to the prediction of regular smoking, when family and friends' smoking behavior is already included in the model.

## Methods

### Participants

This study is part of a longitudinal questionnaire study of the Netherlands Twin Register (NTR) that has assessed families with adolescent and young adult twins every 2/3 years since 1991 (Boomsma, 1998; Koopmans et al., 1999). For this paper, data from the 1993 and 1995 surveys were used. Sample selection and response rates are described in detail in Koopmans et al. (1994) and Boomsma et al. (2000). In 1993 and 1995, participants received a questionnaire booklet that contained personality inventories, items about health, lifestyle (including smoking, alcohol use and exercise), socioeconomic status and family structure. The 1993 questionnaire also contained a question about the smoking behavior of parents, siblings and friends. For the cross-sectional analyses, the study sample consisted of 3906 twins who participated in 1993: 669 MZ males, 532 DZ males from same-sex twin-pair, 535 DZ males from opposite-sex twin-pairs, 955 MZ females, 671 DZ females from same-sex twin-pairs and 544 DZ females from opposite-sex twin-pairs. For the longitudinal analyses, 2397 twins who had participated both in 1993 and in 1995 were included. This sample consisted of 399 MZ male twins, 328 DZ same-sex male twins, 309 males from opposite-sex twin-pairs, 636 MZ female twins, 400 DZ female twins and 326 females from opposite-sex twin-pairs. In 1993, the mean age of these twins was 17.7 ( $SD = 3.2$ ) for the females and 17.8 ( $SD = 3.1$ ) for the males.

### Smoking Status of the Twins, Siblings, Parents and Friends

The questionnaires contained three questions on smoking initiation: "Have you smoked a cigarette?", "Have you smoked during the last 12 months?" and "Have you smoked during the last 4 weeks?" The answer categories were: no, a few times to try, and yes. Another question was "How often do you smoke now?" with the answer categories: I have never smoked, I have quit smoking, I smoke less than once a week, I smoke several times a week but not every day, I smoke daily. Participants also reported the number of cigarettes they smoke per day or per week. Based on their answers participants were classified as never-smokers, experimental smokers, regular smokers or ex-smokers. The never-smokers and the experimental smokers were classified as non-regular smokers and the ex-smokers were excluded from the logistic regression analyses. Answers were checked for consistency across questions. Because the sample consisted of twins, six groups were created: having a non-smoking MZ co-twin, having a smoking MZ co-twin, having a non-smoking same-sex DZ co-twin and having a smoking same-sex DZ co-twin, having a non-smoking opposite-sex co-twin and having a smoking opposite-sex co-twin (Heath et al., 1998).

In 1993, the twins were asked to report if their father, mother, co-twin, brother(s), sister(s) were non-smokers, ex-smokers, smoked sometimes, smoked 1–10 cigarettes a day or smoked more than 10 cigarettes a day. Based on these

answers, parents and siblings were classified as non-smokers or regular smokers in 1993. Parents received a survey themselves and were also classified as regular smokers or non-regular smokers based on their self-reported data using the same criteria as for the twins. For 3165 fathers and 3497 mothers both self-reported data and reports from their children were available: 97% of the answers from father and twin and 98% of the answers from mother and twin were in agreement. When available, parent self-report data were used to classify each parent as a non-smoker or a regular smoker, otherwise the smoking status reported by their children was used. Furthermore, in 1993 the twins were asked how many of their friends were regular smokers. The answer categories were: no one, a few friends, half of the friends, most friends, all friends. The question was answered by 3828 participants.

#### Additional Variables

Additional variables that were explored in the longitudinal analyses were: alcohol use (less than weekly alcohol use, more than 1 glass a week), regular sport participation (yes, no), religion (no religion, religious but not actively participating, religious and actively participating), tea and coffee use (no, more than 1 cup a day). In addition, the scales of the Amsterdamse Biografische Vragenlijst, (Neuroticism, Somatic anxiety, Extraversion and Test attitude) (Wilde, 1970), the scales of the Zuckerman Sensation Seeking Questionnaire (Boredom susceptibility, Disinhibition, Experience seeking and Thrill and adventure seeking) (Zuckerman, 1971) and the Beck Depression Inventory (Beck et al., 1961) were included. For the personality variables, the 30% highest scores were classified as "high", the 30% lowest scores as "low" and the remaining (40%) as "medium". For the Beck Depression Inventory, the 30% highest scores were classified as "high", and the remaining (70%) as low.

#### Data Analyses

Binary logistic regression analyses were carried out separately for male and female twins. Nagelkerk's  $R^2$  was used to index the explained variance.

1. Cross-sectional analyses were carried out on the 1993 data to evaluate the association between the participants' smoking behavior and the smoking status of family members and friends. Ex-smokers were excluded from the analyses. The dependent variable was the smoking status of the twin (regular smoker: yes/no).
2. Longitudinal analyses were performed to explore whether the smoking behavior of family members and friends in 1993 predicted uptake of regular smoking in 1995. To focus on uptake of regular smoking, only never smokers or experimental smokers in 1993 were included in the analyses. The dependent variable was smoking status in 1995 (regular smoker: yes/no).
3. Next, a longitudinal analysis was performed to explore whether, in addition to smoking family and friends, other factors such as alcohol use, regular sport participation, religion, tea use, coffee use, personality and depression significantly predict the uptake of regular smoking. The significant variables from the first longitudinal analyses were entered in the model at the first step. At the second step, the influence of additional variables was explored using the forward conditional method. Interaction effects between age and the other variables were examined but excluded from the model when not significant.

## Results

### Prevalence of Smoking

Table 1 shows that for both males and females, the percentage regular smokers increased from the young adolescents, legally not allowed to buy tobacco (12–15 years), to the older adolescents (16–20) and young adults (21–25 years). Furthermore, for all age groups the percentage regular smokers was higher in 1995 than in 1993.

### Cross-sectional Associations

Table 2 presents the cross-sectional associations between the participants' smoking behavior and that of their parents, co-twin, additional siblings and friends. For males,

**Table 1**

Smoking Status in 1993 and 1995 for 3 Age Groups Separately for Males and Females  $n$  (%)

Smoking phase	12–15 years		16–20 years		21–25 years		Total	
	1993	1995	1993	1995	1993	1995	1993	1995
<b>Males</b>								
Never smoked	501 (89.1)	240 (73.6)	555 (65.0)	241 (46.1)	166 (53.5)	72 (38.5)	1222 (70.8)	553 (53.4)
Tried but not regularly smoked	42 (7.5)	43 (13.2)	99 (11.6)	90 (17.2)	35 (11.3)	38 (20.3)	176 (10.2)	171 (16.5)
Regular smoker	16 (2.8)	36 (11.0)	193 (22.6)	172 (32.9)	98 (31.6)	67 (35.8)	307 (17.8)	275 (26.5)
Ex-smoker	3 (0.5)	7 (2.1)	7 (0.8)	20 (3.8)	11 (3.5)	10 (5.3)	21 (1.2)	37 (3.6)
Total:	562 (100.0)	326 (100.0)	854 (100.0)	523 (100.0)	310 (100.0)	187 (100.0)	1726 (100.0)	1036 (100.0)
<b>Females</b>								
Never smoked	594 (87.6)	297 (65.0)	753 (72.6)	350 (54.5)	292 (68.5)	135 (51.5)	1639 (76.6)	782 (57.5)
Tried but not regularly smoked	50 (7.4)	88 (19.3)	119 (11.5)	127 (19.8)	40 (9.4)	48 (18.3)	209 (9.8)	263 (19.3)
Regular smoker	32 (4.7)	62 (13.6)	157 (15.1)	152 (23.7)	86 (20.2)	61 (23.3)	275 (12.8)	275 (20.2)
Ex-smoker	2 (0.3)	10 (2.2)	8 (0.8)	13 (2.0)	8 (1.9)	18 (6.9)	18 (0.8)	41 (3.0)
Total:	678 (100.0)	457 (100.0)	1037 (100.0)	642 (100.0)	426 (100.0)	262 (100.0)	2141 (100.0)	1361 (100.0)

smoking was associated with having a smoking father but not having a smoking mother, while for females smoking was associated with having a smoking mother not father. A significant association was found for having smoking brothers, for both males and females but not for having smoking sisters. The twins' smoking behavior was significantly associated with that of their co-twin. Using participants with a non-smoking MZ co-twin as the reference group, highest odds ratios were found for having a smoking MZ co-twin, followed by having a smoking same-sex DZ co-twin and finally having a smoking DZ opposite-sex co-twin. The adolescents' smoking behavior was strongly associated with the smoking behavior of friends, with odds ratios being higher when most or all friends smoked than when half of the friends smoked. Compared to the youngest group, the risk to be a regular smoker was higher for the participants aged 16–20 and 21–26 years. Interaction effects between the different age groups and the other variables in the model were not significant and therefore excluded from the model. The efficacy of the model in explaining smoking behavior was 47% for both males and females (Table 2).

**Changes in Smoking Behavior**

Most of the participants who did not smoke or only tried smoking in 1993 were still not smoking regularly in 1995,

10% took up regular smoking and 2.5% became ex-smokers. Most of the regular smokers in 1993 were also regular smokers in 1995, only 7.7% quit smoking (Table 3).

Table 4 shows the results of the longitudinal regression analyses, performed to assess the effect of the smoking behavior of parents, siblings and friends in 1993 on the uptake of regular smoking behavior in 1995. Non-smoking females with a smoking mother have a higher risk of becoming a regular smoker 2 years later. Having a smoking father did not influence the uptake of regular smoking for both males and females. Regular smoking in 1995 was predicted by having a smoking same-sex siblings (other than co-twin) in 1993, but not by having a smoking opposite-sex siblings. Using participants with a non-smoking MZ co-twin as the reference group, highest odds ratios were found for having a smoking MZ co-twin. Having a smoking same-sex DZ co-twin formed a higher risk of taking up regular smoking than having a non-smoking same-sex DZ co-twin. This pattern was not found for having a smoking/non-smoking opposite-sex DZ co-twin. Having smoking friends in 1993 significantly predicted transition to regular smoking in 1995, for both males and females. Age entered the model for females only, with lower odds of becoming a regular smoker for participants aged 21–25 year. The total model explained 21% and 22% of the variance for males and females, respectively (Table 4).

**Table 2**

Cross-sectional Association (Odds Ratio and 95% CI) Between Smoking Behavior of Twins and Smoking Behavior of their Father, Mother, Co-twin, Additional Brothers or Sisters and Friends in 1993. Odds Adjusted Simultaneously for the Other Factors. Age Group was also Included in the Analyses. R Square and Number of Participants is Shown at the Bottom of the Table. Dependent Variable is Regular Smoking (yes/no) of Participant in 1993

Factors	Category	Males		Females	
		OR	95% CI	OR	95% CI
Father	Non-smoker in 1993	1		—	
	Smoker in 1993	<b>1.48</b>	1.06–2.07	—	
Mother	Non-smoker in 1993	—		1	
	Smoker in 1993	—		<b>1.53</b>	1.06–2.21
Co-twin	Non-smoking MZ co-twin in 1993	1		1	
	Smoking MZ co-twin in 1993	<b>10.41</b>	5.60–19.37	<b>21.82</b>	11.70–40.71
	Non-smoking DZ ss co-twin in 1993	1.56	1.26–3.04	1.37	0.81–2.32
	Smoking DZ ss co-twin in 1993	<b>8.70</b>	4.83–15.67	<b>11.87</b>	5.96–23.66
	Non-smoking DZ os co-twin in 1993	<b>2.39</b>	1.47–3.87	<b>2.13</b>	1.23–3.68
Brothers	Smoking DZ os co-twin in 1993	<b>8.28</b>	4.23–16.20	<b>6.48</b>	3.54–11.86
	Non-smoking brother(s) in 1993	1		1	
	Smoking brother(s) in 1993	<b>2.56</b>	1.47–4.47	<b>2.65</b>	1.56–4.50
Sisters	No additional brother(s)	<b>1.65</b>	1.12–2.43	1.29	0.85–1.95
	Non-smoking sister(s) in 1993	—		—	
	Smoking sister(s) in 1993	—		—	
Friends	No additional sister(s)	—		—	
	No one/a few smoking in 1993	1		1	
	Half of the friends smoke in 1993	<b>3.26</b>	2.13–4.99	<b>4.93</b>	3.05–7.97
Age of participant in 1993	Most/all friends smoke in 1993	<b>7.25</b>	4.97–10.58	<b>10.22</b>	6.83–15.28
	12–15 years	1		1	
R <sup>2</sup>	16–20 years	<b>6.46</b>	3.35–12.44	<b>2.73</b>	1.57–4.77
	21–25 years	<b>10.44</b>	5.19–21.02	<b>3.99</b>	2.15–7.38
N	Nagelkerk R square	0.468		0.473	
	Number of participants	1541		1910	

Note: — = variable did not enter the model, OR in bold = category is significantly associated with regular smoking behavior.

**Table 3**

Changes in Smoking Behavior (Smoking Status in 1993 and 1995)

Smoking status in 1993 ↓	Smoking status in 1995 →			Total
	never smoked/ tried smoking	regular smoker	ex-smoker	
never smoked/ tried smoking	1769 (86.8%)	218 (10.7%)	51 (2.5%)	2038 (100%)
regular smoker		332 (92.2%)	28 (7.7%)	360 (100%)
Total	1769 (73.7%)	550 (22.9%)	78 (3.3%)	2397 (100%)

**Table 4**

Longitudinal Association (Odds Ratio and 95% CI) Between Smoking Behavior of Twins in 1995 and the Smoking Behavior of their Father, Mother, Co-twin, Additional Brothers or Sisters and Friends in 1993. Odds Adjusted Simultaneously for the Other Factors. Age Group was also Included in the Analyses. R Square and Number of Participants is Shown at the Bottom of the Table. Dependent Variable is Regular Smoking (Yes/No) of Participant in 1995

Factors	Category	Males		Females	
		OR	95% CI	OR	95% CI
Father	Non-smoker in 1993	—		—	
	Smoker in 1993	—		—	
Mother	Non-smoker in 1993	—		1	
	Smoker in 1993	—		<b>1.92</b>	1.21–3.04
Co-twin	Non-smoking MZ co-twin in 1993	1		1	
	Smoking MZ co-twin in 1993	<b>4.58</b>	1.40–14.99	<b>11.64</b>	3.34–40.58
	Non-smoking DZ ss co-twin in 1993	1.60	0.84–3.04	<b>1.90</b>	1.08–3.37
	Smoking DZ ss co-twin in 1993	3.03	0.90–10.19	<b>7.72</b>	2.44–24.48
	Non-smoking DZ os co-twin in 1993	<b>3.11</b>	1.69–5.70	<b>2.39</b>	1.32–4.30
	Smoking DZ os co-twin in 1993	3.24	0.81–12.89	1.27	0.39–4.14
Brothers	Non-smoking brother(s) in 1993	1		—	
	Smoking brother(s) in 1993	<b>3.61</b>	1.56–8.29	—	
	No additional brother(s)	1.05	0.63–1.73	—	
Sisters	Non-smoking sister(s) in 1993	—		1	
	Smoking sister(s) in 1993	—		<b>3.61</b>	1.39–9.42
	No additional sister(s)	—		1.62	0.98–2.69
Friends	No one / a few smoking in 1993	1		1	
	Half of the friends smoke in 1993	<b>4.79</b>	2.09–10.97	<b>2.70</b>	1.35–5.37
	Most / all friends smoke in 1993	<b>13.13</b>	5.62–30.68	<b>9.39</b>	4.65–18.98
Age of participant in 1993	12–15 years	—		1	
	16–20 years	—		0.67	0.41–1.11
	21–25 years	—		<b>0.38</b>	0.18–0.80
$R^2$	Nagelkerk R square	<b>0.210</b>		<b>0.218</b>	
$N$	Number of participants	<b>770</b>		<b>1068</b>	

Note: — = variable did not enter the model, OR in bold = category is significantly associated with regular smoking behavior, ss = same-sex, os = opposite sex, MZ = monozygotic, DZ = dizygotic.

Next, the logistic regression was repeated with the significant variables of the first longitudinal logistic regression analyses entered at the first step and the additional variables sport participation, alcohol use, coffee and tea use, religion, depression and personality scores entered at the second step. The odds of being a regular smoker in 1995 were significantly higher for twins who used alcohol, had a high boredom susceptibility score or a high neuroticism score in 1993 and significantly lower for twins who exercised regularly in 1993. The model explained 31% of the variance for males and 30% of the variance for females (Table 5).

Earlier smoking status may account for some of the variance in changes in smoking status at a later wave (see West et al., 1999). Table 3 shows that 218 participants who did not smoke in 1993 became regular smokers in

1995. Of these participants 138 (63%) had already experimented with smoking in 1993. In a final step we added the 1993 smoking behavior to the model. This showed that the likelihood of taking up regular smoking was 15 and 23 times higher for males and females respectively who had already experimented with smoking in 1993 compared to participants who had never smoked in 1993. The explained variance increased markedly to 47% for males and 49% for females.

## Discussion

### Cross-sectional Analyses

Participants' smoking behaviour was found to be associated with the smoking behavior of same-sex parents as the

**Table 5**

Additional Predictors of Uptake of Regular Smoking in 1995. Never-smokers and Experimental Smokers in 1993 Were Selected. At the First Step the Significant Variables from the First Longitudinal Analyses Were Entered in the Model. At the Second Step Alcohol use, Regular Sport Participation, Religion, Tea and Coffee use, Personality and Depression Were Entered. Odds Adjusted Simultaneously for the Other Factors

Factors	Category	Males		Females	
		OR	95% CI	OR	95% CI
Mother	Non-smoker in 1993	X		1	
	Smoker in 1993	X		<b>1.89</b>	1.17–3.06
Co-twin	Non-smoking MZ co-twin in 1993	1		1	
	Smoking MZ co-twin in 1993	<b>6.46</b>	1.81–22.99	<b>13.95</b>	4.06–47.93
	Non-smoking DZ co-twin in 1993	1.54	0.79–3.01	<b>2.00</b>	1.10–3.64
	Smoking DZ co-twin in 1993	2.88	0.77–10.83	<b>10.93</b>	3.11–38.41
	Non-smoking DZ os co-twin in 1993	<b>2.32</b>	1.23–4.39	<b>2.54</b>	1.38–4.68
	Smoking DZ os co-twin in 1993	1.82	0.44–7.57	1.69	0.48–5.95
Brothers	Non-smoking brother(s) in 1993	1		X	
	Smoking brother(s) in 1993	<b>4.40</b>	1.86–10.39	X	
	No additional brother(s)	0.98	0.58–1.66	X	
Sisters	Non-smoking sister(s) in 1993	X		1	
	Smoking sister(s) in 1993	X		<b>2.86</b>	1.06–7.23
	No additional sister(s)	X		1.63	0.97–2.75
Friends	No one / a few smoking in 1993	1		1	
	Half of the friends smoke in 1993	<b>4.49</b>	1.88–10.72	<b>2.86</b>	1.35–6.05
	Most / all friends smoke in 1993	<b>10.38</b>	4.19–25.71	<b>7.30</b>	3.35–15.87
Age	12–15 years	X		1	
	16–20 years	X		<b>0.37</b>	0.20–0.70
	21–40 years	X		<b>0.27</b>	0.11–0.63
Sport participation	No	1		1	
	Yes	<b>0.49</b>	0.29–0.84	<b>0.60</b>	0.37–0.98
Alcohol use	No alcohol use/ less than 1 glass /week	1		1	
	More than 1 glass /week	<b>1.66</b>	1.00–2.76	<b>3.43</b>	1.94–6.07
Boredom susceptibility	Low	1		1	
	Medium	<b>2.62</b>	1.25–5.49	1.07	0.56–2.03
	High	<b>3.66</b>	1.71–7.85	<b>2.42</b>	1.33–4.42
Neuroticism	Low	1		1	
	Medium	<b>1.95</b>	1.08–3.55	1.54	0.80–2.96
	High	<b>2.65</b>	1.35–5.19	<b>2.31</b>	1.20–4.45
$R^2$	Nagelkerk R square	0.308		0.300	
$N$	Number of participants	755		1068	

Note: X = variable not included in the analyses as it was not significant in the previous analysis (Table 4), OR in bold = category is significantly associated with regular smoking behavior, ss = same-sex, os = opposite-sex, MZ = monozygotic, DZ = dizygotic

participant, brothers, co-twin and friends. In general, those results are in line with most of the literature on this topic (Brenner & Scharrer, 1996; Green et al., 1991; McNeill et al., 1988; Whithers et al., 2000). Compared to other cross-sectional studies of smoking, this study is unique because it included having a smoking MZ/DZ co-twin. Results showed a genetic influence on smoking behavior since the OR for having a smoking MZ co-twin was higher than the OR for having a smoking DZ co-twin. The genetic influences seem sex-dependent because the OR for having a smoking DZ same-sex co-twin was higher than the OR for having a smoking opposite-sex co-twin.

Results also showed that age was an important factor; the risk of becoming a regular smoker was significantly higher for 16- to 20-year-old and for 21- to 25-year-old participants than for 12- to 15-year-old participants.

#### Longitudinal Analyses with Smoking Family and Friends

The longitudinal analyses showed that having a smoking co-twin, smoking same-sex siblings and smoking friends

were predictors of the uptake of regular smoking for both males and females. Having a smoking father was not a significant predictor of transition to regular smoking while having a smoking mother was a significant predictor for females only. Two longitudinal studies found that mother's smoking, not father's smoking, predicted the transition from non-smoking to regular smoking (Engels et al., 1999; Oygard et al., 1995) while two longitudinal studies did not find an independent effect of parental smoking on uptake of regular smoking (Distefan et al., 1998; West et al., 1999). The influence of parental smoking thus seems to be small or insignificant, but when an effect is found having a smoking mother seems to be more important than having a smoking father.

The analyses showed that having smoking same-sex siblings (co-twin or other siblings), not having smoking opposite-sex siblings, significantly predicted transition to regular smoking two years later. Two longitudinal studies that included sibling smoking did not distinguish smoking

brothers or sisters (Oygard et al., 1995; West et al., 1999). As far as we know, our study is the first one that investigates the influence of smoking brothers and sisters in a longitudinal analysis separately for males and females. The finding that only the smoking same-sex sibling(s) predicted the uptake of regular smoking indicates that different mechanisms for the uptake of regular smoking behavior occur in males and females.

The transition to regular smoking was significantly predicted by having a smoking co-twin. If genetic factors are important for smoking behavior, it is expected that participants with a smoking MZ co-twin would have a high genetic liability for smoking themselves because MZ twins are genetically identical. In general, DZ twins share only 50% of their genes. It is therefore expected that participants with a smoking DZ co-twin have a lower risk of becoming smokers themselves. If sex differences are important it is expected that having a smoking same-sex DZ co-twin is a higher risk than having a smoking opposite-sex DZ co-twin. Our results showed that, compared to having a non-smoking MZ co-twin, odds ratios for having a smoking MZ co-twin were higher than for having a smoking DZ co-twin, suggesting that genetic factors were involved in the transition to regular smoking. Heath et al. (1998) used the same approach in a sample of twins and their results were also consistent with a significant genetic influence on smoking (Heath et al., 1998). Those findings are in line with the classical twin studies using different approaches like structural equation modeling. Those studies have shown that regular tobacco use is largely heritable (Heath & Madden, 1995; Sullivan & Kendler, 1999).

The risk of taking up regular smoking 2 years later is 9 and 13 times higher, for females and males respectively, when most or all friends smoke compared to participants with either no or just a few smoking friends. This finding is in line with a study that reported that uptake of smoking in the next 4 years was predicted by having a best friend who smoked (Distefan et al., 1998) but in contrast with two longitudinal studies that did not find friends' smoking a significant predictor for the uptake of regular smoking (Engels et al., 1999; Oygard et al., 1995). One of those studies explored the uptake of regular smoking in a 3- and 5-year period (Engels et al., 1999) and the other used an 8- and 10-year interval (Oygard et al., 1995). Another study reported that friends' smoking at age 15 increased the likelihood of uptake by up to 10 times over the next year, but did not extend to later years. When those participants had smoking friends at age 18, they were three times as likely to become a regular smoker over a 3-year period (West et al., 1999). This suggests that the age of the participant could be important but different results could also be due to the duration of the follow-up period. Possibly the association with smoking friends is higher when the period is shorter. This could be caused by the fact that individuals select a peer group with similar smoking behavior and friendships may change when the smoking behavior becomes dissimilar (Bauman & Ennet, 1996). It is important not to overlook the possibility that the selection mechanism could be based on the genotype of the participant. Similarity of friends' behavior might be caused by an active

genotype-environment (GE) interaction that occurs when a particular genotype is associated with the selection or creation of a particular environmental circumstance (Rowe, 2002).

It should be noted that self-reported data were used to determine the smoking status of twins and parents, but the smoking status of siblings and friends was reported by the twins. Bauman et al. described that perceived reports of friends' drug use were more strongly correlated than actual reports to adolescent drug use (Bauman & Ennet, 1996; Bauman & Fisher, 1996). Although according to the authors the effect is not very large, the reported OR for friends' and siblings' smoking in our study might have been overestimated. However, we do not expect this effect to be very large because we found a large agreement between parent self-report and the reports of the children on the smoking behavior of their parents.

For females, the odds of taking up regular smoking is significantly lower for 21–25 year olds. For males, no differences between the three age groups were found. This suggests that women, if regular smoking behavior is not established before age 20, have a low chance of taking up regular smoking. In contrast, even at later age males are still vulnerable to take up regular smoking.

#### Additional Longitudinal Analyses

The variables in the cross-sectional analyses explained 46% of the variance in males and 47% in females (Nagelkerk  $R^2$ ) while the same variables in the longitudinal analyses explained 21% of the variance in males and 22% in females. These results imply that although having smoking siblings and friends significantly predicted the uptake of regular smoking, other factors are involved in the transition from non-smoking to regular smoking. A study of Engels et al. (1999) also showed high correlations between explanatory variables and smoking in a cross-sectional analyses while the explained variance in a longitudinal design was much lower.

We found that in addition to having smoking family members and friends, alcohol use, high boredom susceptibility and high neuroticism scores significantly predicted the uptake of smoking 2 years later while sport participation was a protective factor against the uptake of regular smoking. Adding those variables increased the explained variance slightly from 21% to 31% for males and from 22% to 30% for females. The explained variance increased noticeably to 47% for males and 49% for females when the smoking behavior of the participant in 1993 was added. It seems that, although other factors are important for the uptake of regular smoking, it is most important whether participants have already experimented with smoking. To prevent adolescents and young adults from regular smoking it is important to keep adolescents from experimentation with smoking in the first place.

In summary, the uptake of regular smoking can only be predicted by a wide variety of genetic and environmental factors such as smoking family members, smoking friends, personality and lifestyle. This study has shown that having a smoking co-twin, having smoking same-sex siblings, having smoking friends and, for females only, having a

smoking mother, significantly predicts the uptake of regular smoking 2 years later.

Sport participation, alcohol use, boredom susceptibility and neuroticism significantly added to the predictive value of this model. However, subsequently including the 1993 smoking behavior of the participant increased the explained variance markedly.

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