# The role of smoking in social networks on smoking cessation and relapse among adults: A longitudinal study

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## ARTICLE INFO

## ABSTRACT

Understanding the spread of smoking cessation and relapse within social networks may offer new approaches to further curb the smoking epidemic. Whether smoking behavior among social network members determines smoking cessation and relapse of adults however, is less known.

For this study, longitudinal data of 4623 adults participating in the Dutch Longitudinal Internet Studies for the Social sciences (LISS) panel were collected in March 2013 with a follow-up in 2014. Logistic regression was used to examine the association between the proportion of smokers in social networks, and (1) smoking cessation (n = 762) and (2) smoking relapse (n = 1905). Analyses were adjusted for the size of the network, age, sex, and education.

Respondents with the largest proportion of smokers in their social network were less likely to quit smoking (OR = 0.25; 95% CI = 0.11–0.66) and more likely to experience a relapse (6.08; 3.01–12.00). Smoking cessation and relapse were most strongly associated with the proportion of smokers among household members and friends. The proportion of smokers in family outside the household was not related to smoking cessation and smoking relapse.

In conclusion, smoking behavior in social networks, especially among household members and friends, is strongly associated with smoking cessation and relapse. These findings further support the spread of smoking within social networks, and provide evidence for network-based interventions, particularly including household members and friends.

## 1. Introduction

Although smoking rates have declined in the past decade, smoking is still one of the leading preventable causes of death and the second highest contributing factor to the overall burden of disease globally (World Health Organization, 2015; RIVM, 2014; Murray and Lopez, 2013). In 2013, the smoking prevalence was around 23% in The Netherlands, which is comparable to the global smoking prevalence and that in the EU (World Health Organization, 2015; RIVM, 2014). In The Netherlands, smoking causes approximately 19,000 deaths annually, and at 13% it is the highest contributing risk factor to the overall burden of disease (RIVM, 2014). Thus, there remains a need to design new effective interventions, also because of the growing interest in so-called endgame strategies (McDaniel et al., 2016). The tobacco endgame suggests we should move beyond tobacco control toward an entirely tobacco free societies.

In 2008, Christakis and Fowler used unique data from the Framingham Study to show the spread of smoking via social networks members, including spouses, siblings, friends, and neighbors (Christakis and Fowler, 2008). Using logistic regression models, they assessed the relationship between contacts who quit smoking and smoking cessation of the subject in a dynamic social network over a 32-year period. Their findings suggested that spouses and friends, who quit smoking, were particularly relevant for smoking cessation. This may have important implications for the design of network-based interventions. Not only does it provide new targets for interventions, it also implies that interventions might be more effective since positive health behaviors might spread to others as well (Valente, 2012).

Further support for contagiousness of smoking behavior within social networks however, remains scarce. This is probably due to the inherent complexity to collect longitudinal information about smoking behavior in dynamic social networks. Studies investigating smoking behaviors in networks often focused on smoking initiation among adolescents, demonstrating that smoking behavior of social contacts is strongly associated with, and perhaps even the cause of, smoking initiation (Ennett et al., 2008; Go et al., 2010; Mercken et al., 2009; Valente et al., 2013). The influence of smoking behaviors of social network

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members on smoking cessation and smoking relapse in adult populations, however, has received far less attention. Studies primarily related the number or proportion of smokers among either spouses, households or neighborhoods to smoking cessation or relapse (Blok et al., 2013a; Holahan et al., 2012; Moore et al., 2014; Hymowitz et al., 1991). For example, smoking cessation is shown to be more likely in neighborhoods with a high prevalence of non-smokers (Blok et al., 2013a). Similarly, smoking relapse is more likely in households with a high number of smokers (Moore et al., 2014). Empirical evidence on the importance of the nature of social ties (e.g. household member, friend, family) is scarce as well.

This study used the Longitudinal Internet Studies for the Social sciences (LISS) panel from The Netherlands, which is a large prospective study. Apart from measures about the respondents' smoking behavior, it also includes information about smoking behavior among social network members. This provides a unique opportunity to examine: (1) whether smokers with more smoking social network members are less likely to quit smoking during follow-up, and (2) whether former smokers with more smoking social network members are more likely to relapse. Unlike Christakis and Fowler who related quitting among social network members to smoking cessation, we hypothesized that having more smoking social network members makes it more difficult to quit smoking and also easier to relapse because of the continuous visual cues (Christakis and Fowler, 2008; Caggiula et al., 2001). In addition, we assessed the dependence of these associations on specific types of social network ties, e.g. household members, close friends, and family members outside the household including parents and siblings.

## 2. Methods

### 2.1. Data

We used data from the Dutch LISS panel administered by CentERdata (Tilburg University, The Netherlands). It is a large Internet survey with almost 7000 individuals above the age of 15 years. The panel is based on a probability sample of households drawn from the population register and is therefore representative of the Dutch population (De Vos, 2010). The panel is operational since 2007. Every year, a longitudinal survey is set out, which covers a large variety of domains including education, income, work, housing, values, personality, time use and political views. More information about the LISS panel can be found in Scherpenzeel et al. (2010) and at: www.lissdata.nl.

For this study, we added several questions on smoking behaviors of respondents and of members in their social network to the routine data collection by CenterData. IRB approval was therefore not necessary for this study. All participants gave consent to participate in the LISS panel. These prospective data were collected in March 2013 with a follow-up in April 2014. All data were anonymous and made publically available through the LISS panel's website (CentERdata, 2016). Initially, 6562 respondents of the LISS panel were invited to fill out a questionnaire of which 5538 responded (84.4%). Of those, 5221 were approached for follow-up after one year, of which 4625 responded (88.6%). Only respondents who completed the questionnaire at both waves were included in our analysis. Subsequently, two subpopulations were identified: (1) smokers at baseline (n = 762), and (2) former smokers at baseline (n = 1905) (see Fig. 1).

### 2.2. Measures

Self-reported smoking status was assessed by asking respondents whether they currently smoked (yes/no), and whether they had ever smoked before (yes/no). Smoking cessation was defined as smoking at baseline but not during follow-up. Similarly, smoking relapse was defined as smoking during follow-up by former smokers at baseline. Former smokers were those who did not smoke at baseline, but reported to have smoked in the past.
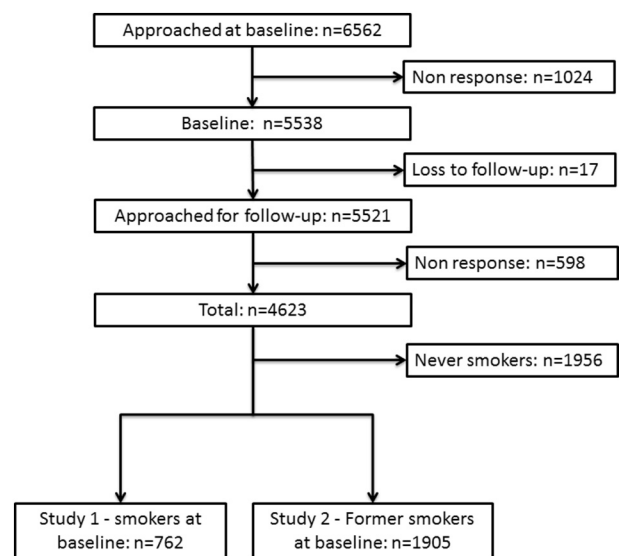


Fig. 1. CONSORT flow diagram.

Among the respondents who smoked at baseline, additional questions were asked regarding smoking frequency, smoking quantity and quit attempts. Every current smoker was asked whether he/she is a daily smoker or less than daily smoker, how many cigarettes per day (CPD) he/she smoked, and whether he/she had ever made a quit attempt (yes/no).

Respondents were asked to provide information about the composition of their social network and the smoking behaviors of all nominated social network ties. Specifically, each respondent was asked to name all household members, up to five closest friends, and all siblings and parents outside the household that were still alive at the time of the study. Close friends were defined as people with whom the respondent had close contact in the past six months. Siblings and parents outside the household together made up the group "family members outside the household". A respondent's total network size comprised all reported household members, friends, and family members outside the household.

Smoking behavior of social network members was assessed by asking the respondent to indicate for each social network tie whether he/she currently smoked, both at baseline and during follow-up. This information was used to calculate, the proportion of social network members that smoked at baseline and during follow-up (henceforth: proportion of smokers). This proportion was calculated for all social ties combined, as well as each type of social tie (i.e. household members, friends, and family members) separately.

Network size, age, sex, and educational level of the respondent were used as control variables. Adjustment for the size of the network was needed because the proportion of smokers is dependent on the size: a single smoker in a small network results in a higher proportion of smokers than in a large network. Also, the size itself might influence smoking cessation or relapse. It is known that smoking provides a way to cope with psychological mechanisms resulting from being socially isolated (Choi and Smith, 2013). Educational level was defined as the respondent's highest attained level of education, selected from eight levels ranging from primary to academic education. For the analyses, these were further categorized as follows: lower (primary and lower secondary), middle (higher secondary), and higher (tertiary) education. Educational level has proven to be a good indicator of socio-economic status in The Netherlands (Van Berkel-Van Schaik and Tax, 1990).

### 2.3. Analysis

Analyses were carried out separately for two subpopulations: smokers at baseline and former smokers at baseline. First the data was

**Table 1**
Characteristics of the study populations of smokers and former smokers.

| Variables | Smokers at baseline (N = 762) | Former smokers at baseline (N = 1905) |
|---|---|---|
| Smoking cessation, n (%) | 103 (13.5) | – |
| Smoking relapse, n (%) | – | 121 (6.4) |
| Proportion of smokers among[a], mean (SD) | | |
|   All social ties | 0.30 (0.28) | 0.15 (0.22) |
|   Household members | 0.25 (0.39) | 0.09 (0.25) |
|   Friends | 0.26 (0.35) | 0.13 (0.26) |
|   Family members outside the household | 0.13 (0.26) | 0.10 (0.24) |
| Network size, mean (SD) | | |
|   All social ties | 5.00 (3.00) | 5.00 (3.15) |
|   Household members | 1.20 (1.22) | 1.27 (1.14) |
|   Friends | 2.01 (1.83) | 1.88 (1.81) |
|   Family members outside the household | 1.80 (1.91) | 1.86 (1.92) |
| Age (years), mean (SD) | 49.6 (15.40) | 57.7 (14.70) |
| Female, n (%) | 367 (48.2) | 933 (49.0) |
| Education, n (%) | | |
|   Low | 285 (37.4) | 642 (33.7) |
|   Middle | 309 (40.6) | 672 (35.3) |
|   High | 168 (22.0) | 591 (31.0) |

Note: Study conducted in The Netherlands (2013–2014).

[a] Proportion of social network members who smoked at baseline (t = 0) and during follow-up (t = 1).

presented graphically as the proportion of (1) smoking cessation among the 762 smokers and (2) relapse among the 1905 former smokers for those with less than and those with >50% smokers in their social network.

Then, we specified logistic regression models where the respondent's smoking status was a function of the proportion of smokers in the social network. The model was adjusted for network size, age, sex and educational level. In separate logistic regressions, we examined the adjusted association of the proportion of smokers among social network members with (1) smoking cessation among smokers, and (2) smoking relapse among former smokers. In order to

investigate the importance of the type of social tie, these analyses were performed separately for the proportion of smokers among A) all social ties, B) household members, C) friends and D) family members outside the household.

Since the relationship between smoking cessation and the proportion of smokers among social network members might differ with smoking frequency and smoking quantity of the respondent, we also repeated the analysis stratified by daily smokers, occasional (1–5 CPD), light (6–10 CPD), moderate (11–15 CPD), moderate-heavy (16–20 CPD), and heavy (>21 CPD) smokers. All analyses were conducted with the statistical package R (version 3.2.2) (R Core Team, 2016).

## 3. Results

Descriptive characteristics of the two subpopulations are provided in Table 1. At baseline, the average age was approximately 50 years among smokers and 58 years among former smokers. In both sub-populations, each respondent had on average five social ties. Among smokers, approximately 14% reported not to smoke at follow-up. Of all social ties in this subpopulation, 30% were smokers. Smoking was more prevalent among friends. Among former smokers, about 6% reported to smoke at follow-up. In this subpopulation, the proportion of smokers among all social ties was on average 15%. Again the highest proportion was among friends.

Fig. 2 illustrates the unadjusted estimates of the percentage of persons who stopped smoking and who relapsed during follow-up by the proportion of smokers among social network members. The percentage of respondents who quitted smoking was substantially lower with a high proportion of smokers among social network members. This relation was found for each type of social tie, except for the proportion of smokers among family members outside the household. Smoking relapse among former smokers was more likely when the proportion of smokers among network members was high.

Table 2 provides the adjusted odds ratios for the association between the proportions of smokers in social networks and smoking cessation of participants during follow up. Smoking cessation was less likely when the respondent had higher proportions of smokers among all social ties (OR = 0.25; 95% CI = 0.10–0.66), household members
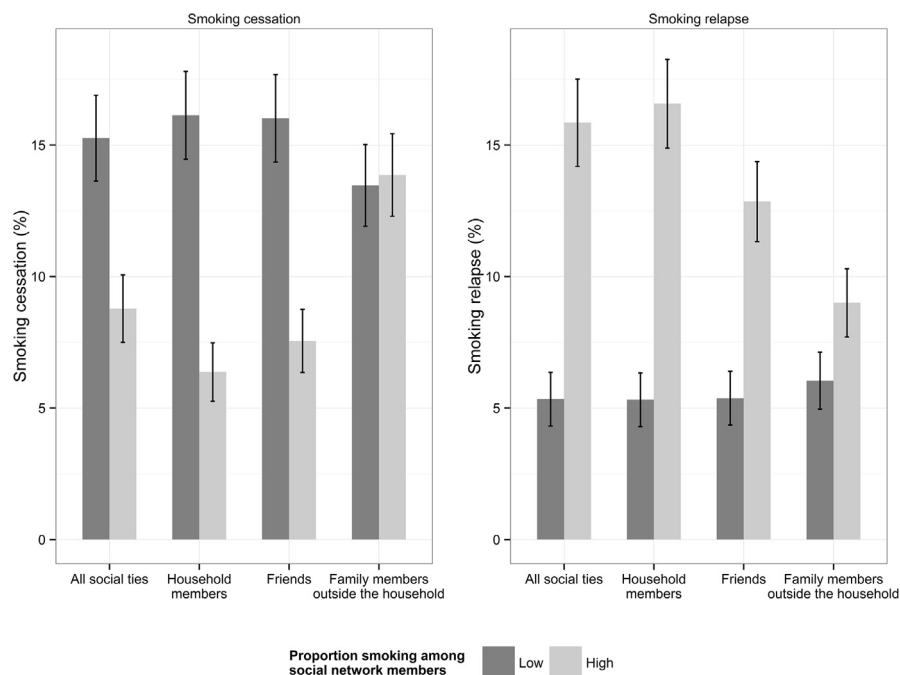


**Fig. 2.** Unadjusted estimates of the percentage of persons who stopped smoking and who relapsed during follow-up by the proportion of smokers among social network members. The proportion of smokers among social networks members was dichotomized into: low (≤50%) and high (>50%). Study conducted in The Netherlands (2013–2014).

**Table 2**
Adjusted associations between smoking cessation and the proportion among social network members.

| Variables | Smoking cessation (n = 762) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Proportion of smokers among[a] | | | | | | | | |
|   All social ties | 0.25 | 0.10–0.66 | – | – | – | – | – | – |
|   Household members | – | – | 0.27 | 0.12–0.56 | – | – | – | – |
|   Friends | – | – | – | – | 0.26 | 0.11–0.59 | – | – |
|   Family members outside the household | – | – | – | – | – | – | 1.02 | 0.43–2.24 |
| Network size | 0.94 | 0.87–1.01 | 0.97 | 0.80–1.17 | 0.97 | 0.85–1.10 | 0.97 | 0.86–1.09 |
| Age (10 yrs) | 0.94 | 0.82–1.08 | 0.96 | 0.83–1.10 | 0.94 | 0.82–1.08 | 0.98 | 0.85–1.12 |
| Sex – female | 1.29 | 0.84–1.98 | 1.23 | 0.81–1.88 | 1.32 | 0.86–2.03 | 1.2 | 0.79–1.84 |
| Education – low (ref) | – | – | – | – | – | – | – | – |
| Education – middle | 1.49 | 0.90–2.49 | 1.45 | 0.87–2.42 | 1.54 | 0.93–2.58 | 1.46 | 0.89–2.44 |
| Education – high | 1.93 | 1.10–3.41 | 1.71 | 0.97–3.00 | 2.06 | 1.16–3.65 | 1.97 | 1.13–3.44 |

Note: Study conducted in The Netherlands (2013–2014).
[a] Proportion of social network members who smoked at baseline (t = 0) and during follow-up (t = 1).

(OR = 0.27; 95% CI = 0.12–0.56), and friends (OR = 0.26; 95% CI = 0.11–0.59). The proportion of smokers among family members outside the household did not show a relationship with smoking cessation.

Table 3 shows that among former smokers, higher proportions of smoking among all social ties increased the odds of smoking relapse (OR = 6.08; 95% CI = 3.01–12.00). Of all social ties, the proportion smokers among household members (OR = 4.33; 95% CI = 2.54–7.18) and friends (OR = 2.68; 95% CI = 1.44–4.83) showed a significant association with smoking relapse as well. Our results did not show a relation between smoking relapse and the proportion of smokers among family members outside the household.

Table 4 presents the stratified analysis for smoking cessation. When we stratified for daily smokers only, results did not differ from the complete analysis (see Table 2). Among occasional and light smokers, smoking cessation was less likely with high proportions of smokers among all social ties. Also among moderate to heavy smokers, a high proportion of smokers among all social ties, and in particular among friends, made it less likely to quit smoking. Smoking cessation was not related to smoking behavior among moderate smokers.

## 4. Discussion

This study assessed the role of smoking in social networks on smoking cessation and smoking relapse in a Dutch adult population. Clearly, those with the largest proportion of smokers among their social network members were less likely to quit and more likely to experience a relapse. In addition, the type of social tie appeared to be important: smoking of household members and friends was strongly associated with smoking cessation and relapse, whereas the smoking behavior of family members outside the household was not.

Our findings support the significance of smoking behaviors in social networks for adult smoking cessation and relapse (Christakis and Fowler, 2008; Moore et al., 2014; Zhou et al., 2009). Smoking behaviors of others in social networks may have undesirable influences through peer pressure and modeling smoking behaviors (Mercken et al., 2009; Lakin and Chartrand, 2003). It also supports the idea that smoking behaviors might be contagious (Blok et al., 2013b). Given the addictiveness of smoking, consistent visual cues of smoking by social network members may make it harder for a smoker to quit and easier for a former smoker to relapse smoking (Caggiula et al., 2001).

With regard to the importance of social ties, our study is among the first to empirically demonstrate that smoking behavior of household members and friends are both important for smoking cessation and relapse in adults. Our results further indicate that smoking among friends is most important for moderate to heavy smokers, whereas smoking among household members is most important for occasional and light smokers. These findings may suggest the need for network-based interventions to target different people for occasional, light, and moderate to heavy smokers.

Surprisingly, smoking behavior of family members outside the household appeared to have no significant relation to smoking cessation or relapse, after adjusting for other factors. This seems contradictory to earlier findings by Christakis and Fowler, which suggest that socially close contacts are most important to explain smoking cessation (Christakis and Fowler, 2008). However, as our estimates for the family member outside the household show very wide confidence intervals, these are consistent with both positive and negative effects on smoking cessation and relapse. It may reflect that some respondents have more frequent contact (i.e. closer contact) with their family members than others. Since our data did not include a proxy for closeness of contacts, we were not able to test this hypothesis.

A limitation of this study was the use of self-reported smoking status that was measured fairly crude due to limited space in the survey. This might have resulted in an underestimation of smoking among

**Table 3**
Adjusted associations between smoking relapse and the proportion smokers among social network members.

| Variables | Smoking relapse (n = 1905) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Proportion of smokers among[a] | | | | | | | | |
|   All social ties | 6.08 | 3.01–12.00 | – | – | – | – | – | – |
|   Household members | – | – | 4.33 | 2.54–7.18 | – | – | – | – |
|   Friends | – | – | – | – | 2.68 | 1.44–4.83 | – | – |
|   Family members outside the household | – | – | – | – | – | – | 1.04 | 0.48–2.06 |
| Network size | 0.99 | 0.93–1.06 | 0.89 | 0.74–1.05 | 1.02 | 0.91–1.14 | 0.95 | 0.84–1.05 |
| Age (10 yrs) | 0.64 | 0.56–0.71 | 0.62 | 0.55–0.70 | 0.64 | 0.57–0.72 | 0.63 | 0.56–0.70 |
| Sex – female | 0.80 | 0.54–1.18 | 0.77 | 0.52–1.14 | 0.80 | 0.54–1.18 | 0.81 | 0.55–1.18 |
| Education – low | – | – | – | – | – | – | – | – |
| Education – middle | 0.81 | 0.50–1.31 | 0.76 | 0.47–1.21 | 0.77 | 0.48–1.23 | 0.74 | 0.46–1.18 |
| Education – high | 1.17 | 0.73–1.88 | 1.05 | 0.66–1.69 | 1.07 | 0.67–1.72 | 1.01 | 0.64–1.61 |

Note: Study conducted in The Netherlands (2013–2014).
[a] Proportion of social network members who smoked at baseline (t = 0) and during follow-up (t = 1).

**Table 4**
Adjusted associations between smoking cessation and the proportion of smokers among social network members stratified by smoking frequency and quantity.

| Variable | Smoking cessation | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Frequency | | | | Quantity[a] | | | | | | | |
| | Daily smokers (n = 488) | | Occasional (n = 138) | | Light (n = 220) | | Moderate (n = 161) | | Moderate-heavy (n = 121) | | Heavy (n = 88) | |
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| Proportion of smokers among[b] | | | | | | | | | | | | |
| All social ties | 0.26 | 0.10–0.66 | 0.48 | 0.08–2.33 | 0.02 | 0.001–0.25 | 1.59 | 0.25–9.02 | 0.02 | 0.0003–0.41 | 0.38 | 0.02–4.07 |
| Household members | 0.31 | 0.13–0.67 | 0.21 | 0.03–0.98 | 0.09 | 0.01–0.51 | 0.78 | 0.18–2.79 | 0.30 | 0.02–1.72 | 0.74 | 0.03–8.89 |
| Friends | 0.29 | 0.10–0.72 | 0.61 | 0.14–2.24 | 0.07 | 0.01–0.53 | 1.00 | 0.14–5.34 | 0.02 | 0.002–0.50 | 0.00 | -Inf - Inf |
| Family outside the household | 1.16 | 0.44–2.73 | 1.22 | 0.17–6.66 | 0.13 | 0.003–1.59 | 1.96 | 0.35–8.72 | 1.26 | 0.08–11.32 | 3.00 | 0.02–123 |

Note: All analyses are adjusted for network size, age, sex, and education. Study conducted in The Netherlands (2013–2014).
[a] Occasional(1–5 cigarettes per day); light (6–10 CPD); moderate (11–15 CPD); moderate-heavy (16–20 CPD); heavy (>21 CPD).
[b] Proportion of social network members who smoked at baseline (t = 0) and during follow-up (t = 1).

respondents (Connor Gorber et al., 2009). However, self-reported smoking status has shown to be reliable when measured under optimized conditions, such as assuring anonymity (Dolcini et al., 1996). Also, smoking behaviors of social ties were measured based on self-reported perceptions of the respondent, which may be biased (Henry et al., 2011). Former studies have shown that smokers tend to overestimate friends' smoking behavior, which then could result in an overestimation of the importance of smoking in social networks (Henry et al., 2011; Iannotti and Bush, 1992). However, a recent study comparing egocentric and sociometric measures (i.e. self-reported by the social tie) showed that the level of agreement was high (Valente et al., 2013).

Another limitation might be the short follow-up period. Generally, smoking cessation is a slow process and smokers may make multiple attempts before successfully quitting smoking (Hymowitz et al., 1997). It is very likely that smokers at baseline who reported not to smoke during follow-up, might still be in the process of quitting smoking, and that our observations of smoking cessation is merely just another quit attempt. Similarly, smoking relapse among former smokers at baseline might actually be a failed quit attempt. However, further adjusting our analysis for quit attempt (yes/no) did not alter our results.

A main concern when studying the role of social networks on health-related behaviors or health in general, is homophily (McPherson et al., 2001). People tend to select others with similar behaviors as their friends, which may explain to some extent the change in behaviors. This phenomenon can also be observed in our data. At baseline, the proportion of smokers in social networks was twice as high among smokers as compared to former smokers. In our study however, selection seems to be less of a problem because family members are not selected, and household members are only to some extent selected.

We also did not account for any contextual effects (Manski, 1993; Cohen-Cole and Fletcher, 2008). People may be exposed to common environmental factors, such as availability of smoking, which may to some extent cause them to quit or restart smoking. Our data did not contain any geographic or physical environmental measures, except for the degree of urbanization. Further adjusting our models for urbanization did not influence our results.

## 5. Conclusions

In conclusion, this study supports the finding that smoking cessation and smoking relapse are influenced by smoking behaviors of members in the social network. This association has now been demonstrated for a specific network consisting of household members, friends, and family members. Smoking behaviors of household members and friends are the most important to explain smoking cessation and relapse. Based on these findings, network-based interventions targeting household members or groups of friends may be most promising to establish a significant further reduction of the smoking prevalence. Collectively reducing the proportion of smokers in social networks might not only enforce others to quit smoking too, but might also make smoking relapse less likely.

## References

Van Berkel-Van Schaik, A.B., Tax, B., 1990. Towards a Standard Operationalisation of Socio-economic Status for Epidemiological and Socio-medical Research. Ministerie van WVC.

Blok, D.J., de Vlas, S.J., van Empelen, P., Richardus, J.H., van Lenthe, F.J., 2013a. Changes in smoking, sports participation and overweight: does neighborhood prevalence matter? Health Place 23, 33–38.

Blok, D.J., van Empelen, P., van Lenthe, F.J., Richardus, J.H., de Vlas, S.J., 2013b. Unhealthy behaviour is contagious: an invitation to exploit models for infectious diseases. Epidemiol. Infect. 141 (3), 667–669.

Caggiula, A.R., Donny, E.C., White, A.R., Chaudhri, N., Booth, S., Gharib, M.A., et al., 2001. Cue dependency of nicotine self-administration and smoking. Pharmacol. Biochem. Behav. 70 (4), 515–530.

CentERdata, 2016. LISS Panel. ([cited 2015; Available from: http://www.lissdata.nl/dataarchive/).

Choi, H.J., Smith, R.A., 2013. Members, isolates, and liaisons: meta-analysis of adolescents' network positions and their smoking behavior. Subst. Use Misuse 48 (8), 612–622.

Christakis, N.A., Fowler, J.H., 2008. The collective dynamics of smoking in a large social network. N. Engl. J. Med. 358 (21), 2249–2258.

Cohen-Cole, E., Fletcher, J.M., 2008. Is obesity contagious? Social networks vs. environmental factors in the obesity epidemic. J. Health Econ. 27 (5), 1382–1387.

Connor Gorber, S., Schofield-Hurwitz, S., Hardt, J., Levasseur, G., Tremblay, M., 2009. The accuracy of self-reported smoking: a systematic review of the relationship between self-reported and cotinine-assessed smoking status. Nicotine Tob. Res. 11 (1), 12–24.

De Vos, K., 2010. Representativeness of the LISS Panel 2008, 2009, 2010. CentERdata, Tilburg.

Dolcini, M.M., Adler, N.E., Ginsberg, D., 1996. Factors influencing agreement between self-reports and biological measures of smoking among adolescents. J. Res. Adolesc. 6 (4), 515–542.

Ennett, S.T., Faris, R., Hipp, J., Foshee, V.A., Bauman, K.E., Hussong, A., et al., 2008. Peer smoking, other peer attributes, and adolescent cigarette smoking: a social network analysis. Prev. Sci. 9 (2), 88–98.

Go, M.H., Green, H.D., Kennedy, D.P., Pollard, M., Tucker, J.S., 2010. Peer influence and selection effects on adolescent smoking. Drug Alcohol Depend. 109 (1–3), 239–242.

Henry, D.B., Kobus, K., Schoeny, M.E., 2011. Accuracy and bias in adolescents' perceptions of friends' substance use. Psychol. Addict. Behav. 25 (1), 80–89.

Holahan, C.J., North, R.J., Holahan, C.K., Hayes, R.B., Powers, D.A., Ockene, J.K., 2012. Social influences on smoking in middle-aged and older women. Psychol. Addict. Behav. 26 (3), 519–526.

Hymowitz, N., Sexton, M., Ockene, J., Grandits, G., 1991. Baseline factors associated with smoking cessation and relapse. MRFIT Research Group. Prev. Med. 20 (5), 590–601.

Hymowitz, N., Cummings, K.M., Hyland, A., Lynn, W.R., Pechacek, T.F., Hartwell, T.D., 1997. Predictors of smoking cessation in a cohort of adult smokers followed for five years. Tob. Control. 6 (Suppl. 2), S57–S62.

Iannotti, R.J., Bush, P.J., 1992. Perceived vs. actual friends' use of alcohol, cigarettes, marijuana, and cocaine: which has the most influence? J. Youth Adolesc. 21 (3), 375–389.

Lakin, J.L., Chartrand, T.L., 2003. Using nonconscious behavioral mimicry to create affiliation and rapport. Psychol. Sci. 14 (4), 334–339.

Manski, C.F., 1993. Identification of endogenous social effects - the reflection problem. Rev. Econ. Stud. 60 (3), 531–542.

McDaniel, P.A., Smith, E.A., Malone, R.E., 2016. The tobacco endgame: a qualitative review and synthesis. Tob. Control. 25 (5), 594–604.

McPherson, M., Smith-Lovin, L., Cook, J.M., 2001. Birds of a feather: homophily in social networks. Annu. Rev. Sociol. 27, 415–444.

Mercken, L., Snijders, T.A., Steglich, C., de Vries, H., 2009. Dynamics of adolescent friendship networks and smoking behavior: social network analyses in six European countries. Soc. Sci. Med. 69 (10), 1506–1514.

Moore, S., Teixeira, A., Stewart, S., 2014. Effect of network social capital on the chances of smoking relapse: a two-year follow-up study of urban-dwelling adults. Am. J. Public Health 104 (12), e72–e76.

Murray, C.J., Lopez, A.D., 2013. Measuring the global burden of disease. N. Engl. J. Med. 369 (5), 448–457.

R Core Team, 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

RIVM, 2014. Volksgezondheid Toekomst Verkenning: Een gezonder Nederland. Bilthoven, RIVM.

Scherpenzeel, A.C., 2010. "True" longitudinal and probability-based internet panels: evidence from The Netherlands. In: Das, M., Das, M., Ester, P., Kaczmirek, L. (Eds.), Social and Behavioral Research and the Internet: Advances in Applied Methods and Research Strategies. Taylor & Francis, Boca Raton, pp. 77–104.

Valente, T.W., 2012. Network interventions. Science 337 (6090), 49–53.

Valente, T.W., Fujimoto, K., Soto, D., Ritt-Olson, A., Unger, J.B., 2013. A comparison of peer influence measures as predictors of smoking among predominately Hispanic/Latino high school adolescents. J. Adolesc. Health 52 (3), 358–364.

World Health Organization, 2015. WHO Report on the Global Tobacco Epidemic.

Zhou, X., Nonnemaker, J., Sherrill, B., Gilsenan, A.W., Coste, F., West, R., 2009. Attempts to quit smoking and relapse: factors associated with success or failure from the ATTEMPT cohort study. Addict. Behav. 34 (4), 365–373.