



School tobacco policies and adolescent smoking in six European cities in 2013 and 2016: A school-level longitudinal study

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ARTICLE INFO

Keywords:

Tobacco smoking
Adolescent
School health promotion
Smoke-free policy
Smoking prevention
Longitudinal studies
Public health

ABSTRACT

Assessment of the effectiveness of school tobacco policies (STPs) in reducing adolescent smoking remains inconclusive. Previous studies took insufficient account of different dimensions of STPs, the different views of students and staff, and policy changes over time. This study assessed how a multidimensional STP, as perceived by students and staff, was associated with adolescent smoking over time in six European cities. The SILNE and SILNE-R surveys were conducted among students ($n = 18,502$) and staff ($n = 438$) in 38 schools in 2013 and 2016. Three dimensions (comprehensiveness, enforcement, and communication) were assessed and we calculated total STP scores. Multilevel logistic regressions estimated associations of STPs with adolescent smoking on and just outside school premises and with weekly smoking. Further analyses estimated associations between 2013 and 2016 STP changes and smoking outcomes in 2016, controlling for STP and smoking prevalence in 2013. On average, there were few increases in STP scores over time. Greater STP enforcement, as perceived by students, was associated with lower odds of weekly smoking (OR:0.93, 95%CI:0.89–0.97) and of smoking on school premises (OR:0.80, 95%CI:0.72–0.90). Higher total STP scores were associated with lower odds of smoking on school premises (OR:0.76, 95%CI:0.67–0.86), but not of smoking just outside premises or smoking weekly. Greater increases in STP scores over time were associated with lower odds of smoking on school premises in 2016 (OR:0.65, 95%CI:0.47–0.89). Well-enforced STPs may help reduce adolescent smoking at school. Schools should be supported in adopting comprehensive policies that also extend to the surroundings of their premises.

1. Introduction

School tobacco policies (STPs) aim to promote a smoke-free environment through the regulation of smoking by adolescents and staff members. However, evidence on their effectiveness in reducing adolescent smoking is inconsistent. Previous reviews showed that schools with formal STPs could have levels of smoking prevalence higher or lower than, or the same as, schools without them (Coppo et al., 2014; Galanti et al., 2013). Recent quasi-experimental studies found STPs to be effective in reducing second-hand smoking (Azagba et al., 2015) and susceptibility to future smoking (Cole et al., 2017). However,

methodological limitations, including variations in the definition of STPs, may have contributed to the inconsistency in their findings, leaving us uncertain as to the actual impact of STPs. Two issues in particular need further research: different dimensions of STPs and different perspectives on STPs.

Some studies measured STPs through only one dimension, e.g. whether students perceived a policy or whether the school director reported the policy (Azagba et al., 2015; Lipperman-Kreda et al., 2009; Rozema et al., 2018). Others considered STPs multidimensionally, measuring them through different dimensions (Evans-Whipp et al., 2010; Griesbach et al., 2002; Hamilton et al., 2003; Huang et al., 2010;

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<https://doi.org/10.1016/j.ypmed.2020.106142>

Received 3 October 2019; Received in revised form 12 May 2020; Accepted 14 May 2020

Available online 22 May 2020

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Kumar et al., 2005; Lovato et al., 2010; Moore et al., 2001; Piontek et al., 2008). Galanti et al. (2013) reviewed the current literature on the topic and concluded that some dimensions of policies had positive effects: a comprehensive, strictly enforced, consistent policy was more likely to lead to a decrease in smoking prevalence in schools. Since that review, very few studies have considered the multidimensionality of STPs (Cole et al., 2019; Kuipers et al., 2016). Those that did found that students in schools with stronger STPs were less likely to smoke on school premises (Kuipers et al., 2016) or report being current smokers (Cole et al., 2019). Kuipers et al. (2016), however, found that stronger policies had no effect on daily smoking. Both agreed on the importance of policy enforcement (Cole et al., 2019; Kuipers et al., 2016).

STPs should also be considered from different perspectives. Students and school staff members may experience and perceive regulations differently. In their study, Lovato et al. (2006) took into account policy intention, policy implementation, and students' experience and found that students' perceptions of the policy predicted smoking, whereas the school's intention and reported implementation of the policy did not (Lovato et al., 2006). The most counter-intuitive results (e.g. association between strict rules and sanctions and a higher smoking prevalence) were found in studies based solely on students' reports (Galanti et al., 2013). Students and staff have a different relation to policy and, thus, different perceptions of it. This suggests a need for measurement of STPs based on reports from both students and staff in order to have a clearer picture and capture both perspectives.

Most European countries have improved their Tobacco Control Scale (TCS) score in recent years (Joossens and Raw, 2017). This shows that efforts are being made at the national level to reduce smoking. However, the TCS score does not cover school smoking bans, so there is no standard way of evaluating and comparing countries' efforts in the school setting. Moreover, few studies have yet explored changes in STPs over time and the effect of STP changes on smoking behaviours over time (Cole et al., 2017; Leatherdale and Cole, 2015; Rozema et al., 2018), even though attention has been drawn to the need for such studies (Adams et al., 2009; Barnett et al., 2007; Boris et al., 2009; Cole et al., 2019; Lippman-Kreda et al., 2009; Lovato et al., 2010; Lovato et al., 2006; Sabiston et al., 2009). It is essential to compare the association between STPs and smoking prevalence at several time points: STPs may decrease smoking rates, but higher smoking rates may also weaken the implementation of STPs or, on the contrary, motivate their implementation.

In the present study, we investigated changes in STPs and smoking between 2013 and 2016 in six European cities. We used a multi-dimensional measurement of STPs, based on students' and staff's perceptions, as well as a total STP score. Moreover, we looked into whether these components are associated with three smoking outcomes expected to have high, medium, or low sensitivity to STPs: smoking on school premises, smoking just outside school premises, and weekly smoking. Finally, we examined the impact of STP changes between 2013 and 2016 on smoking outcomes in 2016.

2. Methods

2.1. Design and study population

This study is based on data from the SILNE and SILNE-R surveys (Lorant et al., 2015). Data were collected in six European cities in six countries (Namur in Belgium, Tampere in Finland, Hanover in Germany, Latina in Italy, Amersfoort in the Netherlands, and Coimbra in Portugal) with different national tobacco regulations (Joossens and Raw, 2006, 2017). All countries in the sample have adopted comprehensive school smoking bans (Belgium in 2006, Portugal in 2007, Germany in 2008, Finland in 2010 and Italy in 2013), except the Netherlands, where decisions are taken at the school level (a comprehensive ban is planned for 2020). The selected cities were representative of their countries in terms of average income. More

information on the selection of cities and schools is available elsewhere (Lorant et al., 2015).

The first data collection took place between January and November 2013 in 50 schools. Three years later, 38 of the schools agreed to participate in a second data collection. The data were collected between September 2016 and October 2017 in the same schools and grades. In total, 18,502 students in grades corresponding to 14–16 years of age participated: 9305 students in 2013 (response rate: 85%) and 9197 in 2016 (response rate: 81%). Adolescents were asked about their tobacco use, family, and school environment. Additionally, school staff members from the same 38 schools reported on their school environment and tobacco policy. Over the two data collections, we gathered information from 438 staff members (216 in 2013 and 222 in 2016). See Supplementary Table A.1 for more information on the response rates. More information on the questionnaires and their validity, as well as on the data collection, is available elsewhere (Lorant et al., 2015). Ethical approvals were obtained in each city and updated for the second data collection (Lorant et al., 2015) (see Supplementary Material B).

2.2. Measurements

2.2.1. School tobacco policies

In order to assess STPs, we followed Galanti et al. (2013) and Kuipers et al. (2016) and defined them in terms of three dimensions: comprehensiveness, enforcement, and communication. When possible, we considered both student and staff perceptions to score the different dimensions. All scores described below were then aggregated at the school level and scaled to a 0–10 score (See Supplementary Table A.2). In 2016, one Finnish school refused to collect data from staff members, so we imputed the average score of other Finnish schools with the same socio-economic profile.

Comprehensiveness – staff's perception: The staff's perception of policy comprehensiveness was captured through three questions (yes/no): (1) where and to whom the policy applies, (2) when it applies, and (3) whether or not there is a smoking room for students, teachers, or visitors. The comprehensiveness score was obtained by taking the mean of all items, ranging from 0 (no) to 1 (yes) for each staff member. A score of 1 point was attributed for question (3) when there was no smoking room for students, teachers, or visitors, because the literature showed encouraging results for 100% smoke-free policies (Baillie et al., 2008; Fallin et al., 2015; Lee et al., 2011). The Kuder-Richardson Formula 20 (KR-20) was 0.84 in 2013 and 0.88 in 2016, implying good internal reliability.

Comprehensiveness – students' perception: Although the wording of the question had changed between the first and second data collections, the questions captured comparable information: whether there is a rule against smoking in their school. The score was either 0 (no rule or don't know) or 1 (existing rule). For the second version of the question, a score of 0 was attributed even if students were allowed to smoke only in certain areas, in order to distinguish schools that were tolerant from those that banned smoking not only indoors but everywhere on school grounds (Barnett et al., 2007).

Enforcement – staff's perception: The staff's perception of policy enforcement was measured through their reporting of the consequences for students caught smoking since the previous September. Previous research has shown that educational, health-related consequences should be emphasized more than punitive ones, as this reframes policy violations from a disciplinary issue to one of adolescent health (Hamilton et al., 2003; Pentz et al., 1989; Schreuders et al., 2017; Soteriades et al., 2003). Accordingly, we assigned 2 points if the staff member reported using at least one health-related consequence (e.g. requirement to participate in an assistance, education, or quit-smoking programme) and 1 point if they used at least one disciplinary consequence (e.g. warning issued, parents informed, detention), giving a maximum score of 3. We took the mean for each school staff member and divided by 3 to have a score ranging from 0 to 1. The highest score

was attributed when the school staff member reported no rule violation since last September.

Enforcement – students' perception: To capture students' perception of enforcement, we used the question that had been used to assess the existence of a policy (in the comprehensiveness dimension), but we focussed on whether they believed it to be strictly enforced (1 point if strictly enforced, 0 if not).

Communication – staff's perception: We captured the staff's perception of policy communication through two questions: (1) means used to communicate the policy and (2) procedures for informing students, families, staff, and visitors about it and about the consequences of violation. Each question contained different items. For each question, we attributed one point to each item and averaged them. The communication score was calculated as the mean of the two questions for each staff member (Cronbach's $\alpha = 0.55$ in 2013 and 0.44 in 2016).

Total scores: Overall student perception of the policy was calculated as the mean of student perception of comprehensiveness and enforcement (aggregated at the school level). We did likewise for the school staff's perception, but taking into account comprehensiveness, enforcement, and communication (aggregated at the school level). Finally, we computed a total STP score using the mean of both perceptions.

2.2.2. Outcome variables

We included three smoking outcomes, which we expected to be unevenly affected by STPs (Galanti et al., 2013): smoking on school premises would, we expected, be more affected than smoking just outside, which, in turn, would be more affected than weekly smoking.

Smoking on school premises and smoking just outside school premises (yes/no) were assessed among students who reported having smoked at least one cigarette over the last 30 days. Because of a translation error in the Portuguese survey, smoking on school premises was not measured in Coimbra.

We considered students who reported smoking at least one cigarette per week to be weekly smokers (Moore et al., 2001; Murnaghan et al., 2009).

2.2.3. Confounding variables

The analyses were controlled for age, gender, smoking environment at home, and student socio-economic status. These factors may be associated with adolescent smoking and schools with a higher smoking prevalence may struggle to implement STPs. The smoking environment included family smoking and smoking rules at home (Kuipers et al., 2016). Adolescents either had no, one, or two or more (step-)parent(s) who smoked. Additionally, adolescents were asked whether “no one is permitted to smoke at home”, “smoking is permitted in certain areas”, or “smoking is freely permitted in my home”; their responses were divided into two categories, “no smoking allowed” and “smoking allowed partly or freely”. Socio-economic status was measured using the adapted McArthur scale for subjective social status, youth version (Goodman et al., 2001). Students were asked to rank their family's social status within their country on a scale (worst-off to best-off). Adolescents were classified into five groups (4th and lower, 5th, 6th, 7th, and 8th and higher deciles).

2.3. Statistical analyses

Prior to the main analyses, Pearson's chi-squared tests and Students' *t*-tests were conducted to describe our study sample and check for significant differences between 2013 and 2016, both at the individual and school level. For these tests, we directly standardized the rates according to age.

Then, we conducted various multilevel logistic regression analyses (clustered at the school level, nested by city). First, we examined the association between STP dimensions (independent variables) and smoking outcomes (dependent variables). In all models, we controlled

Table 1

Evolution of the characteristics of the student sample (n = 18,502), SILNE-R study in six EU cities, 2013–2016.

	2013 (n = 9305) %	2016 (n = 9197) %	p-value ^d
Cities – countries			< 0.0001
Namur – Belgium	20.9	21.1	
Tampere – Finland	16.1	16.6	
Hanover – Germany	8.3	5.7	
Latina – Italy	21.4	21.6	
Amersfoort – the Netherlands	12.9	14.9	
Coimbra – Portugal	20.4	20.3	
Age (mean, std)	15.3 (1.1)	15.1 (1.0)	< 0.0001
12–14	23.7	29.1	
15	38.8	41.4	
16–17	34.6	27.1	
18–19	2.9	2.5	
Male	47.3	50.0	0.0002
Weekly smoker ^a	18.62	14.53	< 0.0001
Smoking on school premises ^{a,b}	36.72	28.30	< 0.0001
Smoking just outside school premises ^{a,c}	41.44	42.20	< 0.0001
Family smoking			0.0004
No (step-)parent smoking	53.0	55.9	
One (step-)parent smoking	26.4	25.1	
Two or more (step-)parents smoking	20.6	19.0	
Smoking rules at home			0.1237
Nowhere	62.8	61.4	
Certain areas	30.8	32.1	
Everywhere	6.4	6.5	

^a Age-standardized rates.

^b Among adolescents who smoked within the last 30 days, excluding Coimbra, where smoking on school premises was not measured (n = 1971 in 2013; n = 1530 in 2016).

^c Among adolescents who smoked within the last 30 days (n = 2471 in 2013; n = 1856 in 2016).

^d P-values of differences between 2013 and 2016, calculated with Pearson's chi-squared tests and Students' *t*-tests.

for the year of data collection and included the school as random intercept. In a first model, we included the dimensions simultaneously. In a second model, we additionally controlled for age, gender, and socio-economic status. In a final model, we also included the smoking environment at home. Second, we replicated the analyses with the total STP score as independent variable. Finally, we assessed the association between 2013 and 2016 STP changes (independent variable) and the different outcomes in 2016 (dependent variables). Model 1 only included STP changes. In model 2, we added the STP score in 2013 and smoking prevalence in 2013. In model 3, we controlled for age, gender, socio-economic status, and smoking environment at home. We reported in the tables the results from our final models, which include all covariates together. Analyses were conducted in SAS Enterprise Guide 7.12 HF3.

3. Results

Table 1 presents characteristics of the sample in both years. Fewer students reported smoking at least once a week in 2016 (14.5%) than in 2013 (18.6%, $p < 0.0001$). This decrease was noticeable in all cities. Significantly fewer smokers reported smoking on school premises (36.7% in 2013 and 28.3% in 2016, $p < 0.0001$). However, a similar proportion of smokers reported smoking just outside school premises in both years (41.4% in 2013 and 42.2% in 2016, $p < 0.0001$).

Table 2 shows the changes in STP dimension scores and total STP scores, as perceived by staff and students, between 2013 and 2016. Overall, there was an increase in every STP dimension, except staff's perception of enforcement. But these changes were small. There were many variations between schools. The dimension that varied most over

Table 2

Evolution of the scores for dimensions of STPs, according to students and school staff members, and total scores ($n = 38$ schools), by year (mean (std)), SILNE-R study in six EU cities, 2013–2016.

Dimensions	Scores (0–10)		Change between 2016 and 2013 ^a		
	2013	2016	Mean (std)	Min	Max
Staff's perception	6.1 (1.1)	6.1 (1.1)			
Comprehensiveness	7.6 (1.5)	7.8 (1.4)	0.2 (1.8)	−5.4	4.5
Enforcement	4.9 (2.1)	4.3 (1.8)	−0.6 (1.9)	−6.0	2.2
Communication	5.9 (1.5)	6.3 (1.2)	0.4 (1.4)	−3.7	4.6
Students' perception	5.9 (2.0)	6.2 (2.4)			
Comprehensiveness	7.9 (1.8)	8.0 (2.5)	0.1 (2.4)	−8.5	4.1
Enforcement	3.8 (2.6)	4.3 (2.9)	0.5 (1.9)	−4.0	4.9
Total STP score	6.0 (1.3)	6.1 (1.5)	0.1 (1.1)	−4.0	2.0

^a Change = STP score in 2016 - STP score in 2013.

time, in both perceptions, was comprehensiveness: some schools improved a lot; others worsened considerably. The comprehensiveness dimension was also the one that showed the highest scores, while enforcement showed the lowest, according to both staff and students. Overall, staff and student perceptions of STPs were significantly correlated in both 2013 and 2016 ($r = 0.45$, $p = 0.0043$ in 2013 and $r = 0.46$, $p = 0.0034$ in 2016). Their scores were significantly correlated for policy comprehensiveness in both years too ($r = 0.45$, $p = 0.0042$ in 2013 and $r = 0.55$, $p = 0.0003$ in 2016) and for policy enforcement in 2016 ($r = 0.51$, $p = 0.0010$), but not in 2013 ($r = 0.20$, $p = 0.2328$).

Scores for each dimension differed greatly between cities (See Supplementary Table A.3), but there were few significant changes. Four cities showed a positive, but not significant, trend in total STP scores: Namur in Belgium, Tampere in Finland, Latina in Italy, and Coimbra in Portugal. In 2016, Coimbra had the highest STP score, followed by Tampere and Hanover. The biggest change occurred in Amersfoort in the Netherlands, where the overall total STP score in schools decreased from 5.7 to 4.2 out of ten.

Table 3a presents the associations between STP dimensions and various smoking outcomes. Only a higher student perception of enforcement was associated with lower odds of smoking on school premises; this persisted after controlling for confounding variables. Regarding smoking just outside the school premises, we did not find any significant effect of any dimension. Finally, students' perception of greater policy enforcement was associated with lower odds of weekly

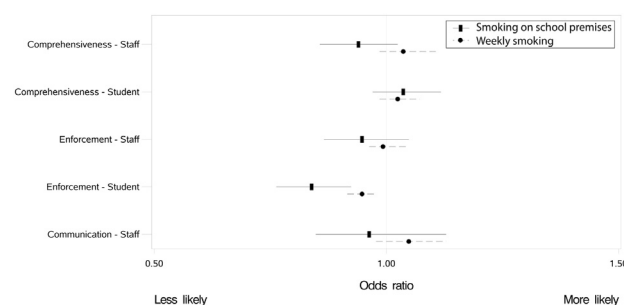


Fig. 1. Smoking on school premises and weekly smoking according to STP dimensions (staff and student perceptions, 0–10): odds ratio (95% confidence interval), SILNE-R study in six EU cities, 2013–2016.

smoking. This effect was still present after controlling for confounders. See Fig. 1 for a visual representation of the findings on smoking on school premises and on weekly smoking.

Table 3b shows the associations between total STP score and smoking outcomes. A higher total STP score was associated with lower odds of smoking on school premises. This association persisted after controlling for confounders. Total STP scores were not associated with smoking just outside school premises or with weekly smoking.

Table 4 presents the associations between STP changes over time and outcomes in 2016. “STP change over time” is the difference between the 2016 STP score and the 2013 STP score. A positive difference meant that the STP score had increased. Larger increases in STP scores were associated with lower odds of smoking on school premises in 2016, but this association only became significant when controlling for the STP score in 2013 and smoking prevalence in 2013. This effect persisted after controlling for confounding variables. However, there was no significant association between increases in STP scores over time and other outcomes in 2016, i.e. smoking just outside school premises and weekly smoking.

Finally, we performed a robustness analysis, including in our models whether schools delivered smoking prevention activities, as this may confound the association between STPs and smoking outcomes. We found out that the findings were very similar to those of our original analyses.

4. Discussion

Few studies have analysed the effectiveness of STPs on smoking on

Table 3

(a) Smoking-related outcomes according to STP dimensions (staff and student perceptions, 0–10) (b) Smoking-related outcomes according to total STP score (0–10), multilevel logistic regression: odds ratio (confidence interval), SILNE-R study in six EU cities, 2013–2016.

	Adjusted OR (95%CI)		
	Smoking on school premises ^a	Smoking just outside school premises	Weekly smoking
(a) STP dimensions ^b			
Year (ref = 2013)	0.64 (0.52–0.81)	1.01 (0.86–1.18)	0.75 (0.68–0.83)
Comprehensiveness – staff	0.92 (0.82–1.02)	1.06 (0.98–1.16)	1.03 (0.98–1.09)
Comprehensiveness – student	1.03 (0.96–1.10)	1.05 (0.99–1.11)	1.02 (0.98–1.06)
Enforcement – staff	0.93 (0.83–1.04)	0.94 (0.87–1.01)	0.99 (0.95–1.04)
Enforcement – student	0.80 (0.72–0.90)	1.01 (0.94–1.08)	0.93 (0.89–0.97)
Communication – staff	0.95 (0.81–1.11)	0.93 (0.84–1.03)	1.04 (0.97–1.11)
(b) Total STP score			
Year (ref = 2013)	0.61 (0.51–0.73)	1.03 (0.89–1.18)	0.76 (0.69–0.83)
STP score	0.76 (0.67–0.86)	1.10 (0.99–1.22)	0.98 (0.91–1.04)

(a) Model: Year and dimensions included simultaneously, school as random effect, controlling for confounding variables (age, gender, socio-economic status, family smoking, and smoking environment at home)

(b) Model: Effect of the total STP score, school as random effect, controlling for confounding variables (age, gender, socio-economic status, family smoking, and smoking environment at home)

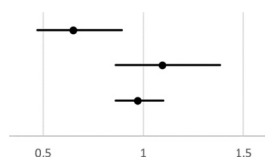
^a Analyses of smoking on school premises do not include Coimbra.

^b All dimensions are measured on a 0–10 scale.

Table 4

Associations between outcomes measured in 2016 and the change in STP over time, multilevel logistic regression: odds ratio (confidence interval), SILNE-R study in six EU cities, 2013–2016.

Dependent variables	Adjusted effect of STP change (OR, 95%CI)
Smoking on school premises ^a	0.65 (0.47–0.89)
Smoking just outside school premises	1.09 (0.86–1.38)
Weekly smoker	0.97 (0.86–1.10)



Model: Effect of STP change (STP2016 – STP2013), school as random effect, controlling for the STP score in 2013 and smoking prevalence in 2013, and other confounding variables (age, gender, socio-economic status, family smoking, and smoking environment at home).

^a Analyses of smoking on school premises do not include Coimbra.

school premises, although it should be their first target. Higher total STP scores were associated with a lower likelihood of smoking on school premises. This is in line with the conclusions of previous cross-sectional studies (Adams et al., 2009; Kuipers et al., 2016; Lipperman-Kreda et al., 2009; Watts et al., 2010). Moreover, an improvement in STPs over time lead to a decrease in smoking on school premises. STPs therefore fulfilled their primary role: smokers in schools with stronger STPs had decreased access to smoking and non-smokers were not exposed to smoking on school grounds.

When decomposing STP scores, only student-perceived enforcement was significantly associated with lower odds of smoking on school premises. This suggests that only sufficient enforcement, as perceived by students, prevents them from smoking on school premises. The importance of enforcement has been mentioned many times in the literature (Adams et al., 2009; Cole et al., 2017; Evans-Whipp et al., 2010; Galanti et al., 2013; Griesbach et al., 2002; Leatherdale and Cole, 2015; Lipperman-Kreda et al., 2009; Lovato et al., 2006; Moore et al., 2001; Rozema et al., 2016; Wakefield et al., 2000). Evans-Whipp et al. (2010) even suggested that it might be better for schools to focus on increasing student awareness of STPs and on making implementation efforts, rather than on the details of the policy. Paradoxically, student-perceived enforcement remained low in both waves. This finding is a matter of concern: it could mean that students still observe smoking in the school environment or that they perceive monitoring to be inconsistent (Wium and Wold, 2011). To ensure strict student-perceived enforcement, schools should therefore opt for zero-tolerance policies and well-thought-out consequences to discourage rule infringement. However, few schools seem to actually use such sanctioning systems. The low scores for staff-perceived enforcement may be explained by the low use of health-related consequences, which were weighted more heavily in our scores than disciplinary ones. Previous research suggests that punitive consequences have little impact on reducing smoking and that schools should therefore be encouraged to also use education and counselling strategies (Booth-Butterfield et al., 2000; Hamilton et al., 2003; Pentz et al., 1989; Turner and Gordon, 2004). Similarly, Terry and Zhang (2016) found that an enforcement plan that provides cessation resources was a significant predictor of a decrease in adolescent smoking.

STPs are also relevant beyond the school premises. However, consistently with other studies (Darling et al., 2005; Evans-Whipp et al., 2010; Huang et al., 2010; Kuipers et al., 2016; Lovato et al., 2010; Piontek et al., 2008; Sabiston et al., 2009), we did not find an association between higher STP scores and weekly smoking. This may imply that STPs did not affect smoking behaviour outside schools. Nonetheless, we need to keep in mind that STPs are part of a broader approach to reducing smoking (Darling et al., 2005; Lantz et al., 2000; Lipperman-Kreda and Grube, 2009). Previous research suggested that STPs may generate personal anti-smoking attitudes among adolescents, which then impact their actual behaviour (Lipperman-Kreda and Grube, 2009). However, it could be argued that this indirect aim of STPs, i.e. to denormalize smoking, is unlikely to be achieved because the rules cease

to apply right outside the school (Adams et al., 2009; Rozema et al., 2018).

Higher total STP scores and change in total STP scores over time were not significantly associated with smoking just outside school premises, although both odds ratios pointed towards a positive association. Previous studies have suggested that banning smoking on school premises may displace smoking to just outside the premises (Evans-Whipp et al., 2004; Watts et al., 2010). Schreuders et al. (2017) explained that adolescents may avoid sanctions by looking for alternative locations for smoking. We cannot rule out that some displacement may have occurred in our sample. Nonetheless, this paper suggests that STPs do not have any impact on smoking in the vicinity of schools. This raises another issue: students smoking at the school entrance may actually have the unexpected and undesirable effect of increasing the visibility of tobacco. Schools may therefore be recommended to consider extending the ban to the immediate area surrounding the school premises, if this falls within their jurisdiction (Watts et al., 2010). This would decrease the visibility of tobacco and therefore the perception of its social acceptability (Alesci et al., 2003).

On average, there was no significant increase in scores for STP dimensions over time. Amersfoort was the only city with a substantial decrease in the total STP score between 2013 and 2016: this may be explained by the fact that smoking areas were made available for students in some schools. Few schools in our European sample provided such facilities. According to the literature, the presence of smoking areas, whether for students or for teachers only, sends mixed messages to students (Booth-Butterfield et al., 2000; Bowen et al., 1995; Fallin et al., 2015; Piontek et al., 2007). Similarly, a more recent study on college students found that 100% smoke-free policies are more effective in reducing smoking prevalence than policies allowing designated smoking areas (Bennett et al., 2017).

The results of the robustness analysis show that STP effectiveness was not dependent on whether schools had organized smoking prevention activities. The effectiveness of interventions, including prevention programmes, remains unclear (Galanti et al., 2013; Leiva et al., 2018). More research is needed on decomposing the different components of such interventions; schools should be guided to implement evidence-based tobacco prevention activities, to prevent any undesired effects (Cole et al., 2017; Leatherdale and Cole, 2015).

This present study is the first to consider the multidimensionality of STPs and both students' and staff perceptions, while looking at changes over time in different outcomes related to adolescent smoking. However, it has several limitations. First, the survey was self-administered and no biochemical markers were used to validate adolescents' tobacco use. However, self-reports seem to be a reliable tool for measuring tobacco use (Brener et al., 2003; Maatoug et al., 2016). Second, the wording of some questions changed between 2013 and 2016 in order to achieve greater accuracy and not all dimensions of STPs were presented in the questionnaires. Thus, some dimensions were not measured using the most optimal questions. Likewise, information was missing on the communication of the policy as perceived by students.

Third, we did not control for school-level confounders, e.g. characteristics of the school neighbourhood or whether students could leave school premises during breaks. Fourth, the Dutch and German samples were smaller, as some schools did not agree to participate in a second data collection because it was too time-consuming. In Hanover, Germany, a school reform had just increased teachers' and school principals' workloads and caused some schools to close or merge. Moreover, the participation rate in this city was very small in 2016 as the data were collected in the week before summer holidays, when absenteeism was above average. Finally, we did not include e-cigarettes, although they are the subject of increasing concern (Kinnunen et al., (under review); Milicic et al., 2018). Our findings may, however, be relevant for schools seeking to target adolescent vaping as well. Further research should cover vaping outcomes and should explicitly include policies directed against this specific behaviour when measuring STPs.

5. Conclusion

Across schools, there was little strengthening of STPs over time. Only student-perceived enforcement of STPs was associated with lower odds of smoking on school premises and of weekly smoking. Overall, greater improvements in STP scores were found to decrease smoking on school premises, but not smoking just outside school premises or weekly smoking. The findings of the present study have important policy implications. To reduce smoking on school premises, it is necessary to maintain strong STPs. More efforts could be made to enforce strict STPs through the adoption of a comprehensive policy (without exceptions) – i.e. smoke-free schools – and focussing attention on health-related consequences, through counselling and educational approaches, when rules are broken. Moreover, STPs limited to the school grounds may lead to smoking just outside school. This may have negative consequences, by increasing the visibility of smoking. It could, accordingly, be worthwhile to consider extending STPs to school entrances and close surroundings. Most of these policy implications have been set out in a policy brief developed to help schools to effectively implement STPs (<http://hdl.handle.net/2078.1/227683>).

CRedit authorship contribution statement

Nora Mélard:Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft.**Adeline Grand:**Conceptualization, Methodology, Resources, Data curation, Writing - review & editing.**Pierre-Olivier Robert:**Conceptualization, Resources, Writing - review & editing.**Mirte A.G. Kuipers:**Methodology, Resources, Writing - review & editing.**Michael Schreuders:**Resources, Writing - review & editing.**Arja H. Rimpelä:**Writing - review & editing, Project administration, Funding acquisition.**Teresa Leão:**Resources, Writing - review & editing.**Laura Hoffmann:**Resources, Writing - review & editing.**Matthias Richter:**Writing - review & editing, Project administration, Funding acquisition.**Anton E. Kunst:**Writing - review & editing, Project administration, Funding acquisition.**Vincent Lorant:**Conceptualization, Methodology, Resources, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Acknowledgments

We would like to thank all school staff members and students who participated in the study. We would like to acknowledge our colleagues involved in the collection of the SILNE WP5 data: Jaana Kinnunen, Geatano Roscillo, Pierre-Olivier Robert, and Joanna Alves, as well as the SILNE-R WP8 data: Pauline A.W. Nuyts, Michael Schreuders, Diego Marandola, Teresa Leão, Pierre-Olivier Robert, Adeline Grand, Jaana Kinnunen, Laura Hoffmann, and Martin Mlinaric. We would like to acknowledge the work done by Mostafa Berdii and Adeline Grand on the

data management. We would like to thank Séverine Guisset and the SMCS-UCLouvain team for their precious assistance with statistics and Martin McGarry for the English editing.

Funding

This study is part of the SILNE-R project “Enhancing the effectiveness of programmes and strategies to prevent smoking by adolescents: a realist evaluation comparing seven European countries”, which was supported by the European Union's Horizon 2020 research and innovation programme under the SILNE-R Grant Agreement number 635056. The Belgian team was also supported by a grant from the FNRS: Crédit de Recherche n°23593456.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jypmed.2020.106142>.

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