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The Smokerface poster campaign for adolescent smoking prevention in schools: A cluster-randomized controlled trial

Christoph Wies [a,b], Julia Messner [a,c], Nicolas B. Merl [a,b], Jana T. Winterstein [a,b], Katharina Kommoss [d], Lena Jakob [e], Hannah M. Fahrner [e], Marlene Heckl [f], Ana Cirac [f], Janina L. Suhre [g], Fabian N. Fries [h], Hannah Spielmann [h], Werner Seeger [c], Felix Herth [i], David A. Groneberg [j], Henning Gall [c], Claudia Bauer-Kemeny [i], Lava Taha [k], Michael Kreuter [i], Stefan Fröhling [l], Ute Mons [m,n], Titus J. Brinker [a,*]

[a] Division of Digital Prevention, Diagnostics and Therapy Guidance, German Cancer Research Center (DKFZ), Heidelberg, Germany
[b] Medical Faculty, University Heidelberg, Heidelberg, Germany
[c] Universities of Gießen and Marburg Lung Center (UGMLC), Member of the German Center for Lung Research (DZL), Justus-Liebig-University of Gießen, Gießen, Germany
[d] Department of Dermatology, University Hospital Heidelberg, Heidelberg, Germany
[e] Department of Anesthesiology and Critical Care, University Medical Center, University of Freiburg, Freiburg, Germany
[f] Medical Faculty, Technical University of Munich, Munich, Germany
[g] Medical Faculty, University of Bonn, Bonn, Germany
[h] Saarland University Medical Center and Saarland University Faculty of Medicine, Homburg, Germany
[i] Pneumology and Critical Care Medicine, Thoraxklinik, University of Heidelberg, Heidelberg, Germany
[j] Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Goethe-University, Frankfurt, Germany
[k] Department of Otorhinolaryngology, Head and Neck Surgery, University of Erlangen-Nuremberg, Erlangen, Germany
[l] Division of Translational Medical Oncology, German Cancer Research Center (DKFZ) and National Center for Tumor Diseases (NCT) Heidelberg, Heidelberg, Germany
[m] Division of Primary Cancer Prevention, German Cancer Research Center (DKFZ), Heidelberg, Germany
[n] Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany

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ABSTRACT

Background: Tobacco use remains a leading cause of preventable morbidity and mortality and is commonly initiated in adolescence. We evaluated whether Smokerface-Poster, a low-intensity, appearance-based school campaign promoting a photoaging app, could attenuate smoking uptake among early adolescents.
Methods: In this two-arm cluster-randomized controlled trial, 126 German secondary schools (9797 grade 6/7 students; 96.0% were 11–13 years old; 51.4% male; 48.6% female) were allocated to intervention or control. Intervention schools displayed two classroom posters for 24 months. Smoking behavior was assessed at baseline and 24 months. As primary outcome, we investigated the between-group difference in the change in 30–day smoking prevalence, with a number needed to treat (NNT) of < 100 students predefined as clinically relevant per protocol.
Results: Baseline smoking prevalence was 7.4% in the control vs. 7.9% in the intervention group. At 24 months post-intervention, smoking prevalence increased by 19.2 %age points in control vs. 18.1 %age points in the intervention group (number needed to treat=93; adjusted ratio of odds ratios 0.87, 95% CI 0.69–1.09; $p = 0.228$). Favorable, non-significant patterns were also observed for anti-smoking intentions and attitudes.
Conclusion: Although the between-group difference was not statistically significant, the intervention reached the predefined threshold for clinical relevance, with an NNT of 93. This suggests that, for every 93 students exposed to the Smokerface-Poster campaign, one fewer adolescent would be expected to smoke over the two-year follow-up. Given its low cost of $< €50$ per 100 students, the intervention appears to be a promising approach to supporting school-based smoking prevention.

* Corresponding author.
E-mail address: titus.brinker@dkfz.de (T.J. Brinker).

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1. Introduction

Tobacco use remains a leading preventable cause of cancer-related morbidity and mortality worldwide, making adolescent tobacco prevention a major priority for both cancer prevention and public health [1,2]. Despite some progress in tobacco control, adolescent smoking continues to pose a serious public health challenge on a global scale. Recent estimates suggest that roughly 10% of youths aged 13–15 years (over 50 million individuals) are current tobacco users worldwide [3]. In high-income countries like Germany, youth smoking prevalence has declined substantially over the past two decades - from about one in five adolescents in the early 2000s to approximately one in fourteen by the mid-2010s [4,5]. Recent data, however, show a halt in the decreasing trend and even suggest increases in youth smoking [6]. While the long-term downward trend reflects the success of comprehensive tobacco control measures and prevention efforts, a substantial minority of German teenagers continues to smoke, and socioeconomic disparities persist, with adolescents from lower socioeconomic backgrounds being more likely to smoke than peers from higher socioeconomic backgrounds [7]. These patterns underscore the continued need for effective and equitable tobacco-prevention strategies for adolescents, particularly approaches that can be implemented at scale with limited personnel, time, and financial resources.

School-based smoking prevention programs are a key component of adolescent tobacco control, but many traditional approaches face practical limitations [8,9]. Interventions that have shown efficacy in trials often require considerable resources like specially trained instructors (such as health educators or external providers) to deliver multi-session interventions in classrooms [10]. Broad implementation of such programs can be challenging, especially in schools with limited budgets or access to trained personnel. Indeed, few existing school-based initiatives are easily scalable to a wider range of schools due to high implementation costs and reliance on outside facilitators [11]. Additionally, even well-established programs tend to show only modest long-term effects on smoking initiation, suggesting room for improvement in both content and delivery methods. In sum, the key implementation gap is not merely the need for additional school-based smoking-prevention programs, but the lack of interventions that are low-cost, engaging, and scalable while requiring minimal staff training, classroom time, and external personnel [12–14].

Against this background, appearance-based photoaging interventions represent a promising low-burden approach, as they may engage adolescents through personalized visual feedback while requiring comparatively little classroom time and facilitator involvement. Appearance-focused “photoaging” interventions use digital technology to graphically depict the potential cosmetic consequences of smoking. The *Smokerface* app allows users to take a selfie and visualizes the likely effects of chronic smoking on their appearance by juxtaposing projected images of their future face as a smoker versus as a non-smoker [5,11,15–17]. Such personalized visual feedback exploits the fact that many teenagers are highly conscious of their looks and may respond strongly to the threat of visible premature aging [4,10]. In recent years, the use of photoaging technology has been piloted within school-based programs. Notably, the multinational Education Against Tobacco (EAT) initiative developed a classroom intervention in Germany, in which medical student volunteers guided secondary school students through interactive sessions incorporating the Smokerface app [9,18]. Early evaluations of this approach have indicated high student interest and potential preventative effects. A randomized trial of the EAT program reported trends toward lower smoking uptake in the intervention group (IG) compared to the control group (CG), with particularly positive results observed among female students and those from lower-education backgrounds [9,18]. These findings align with the notion that tailored, engaging tools like face-aging apps can enhance the impact of tobacco education [19]. However, this EAT model - involving in-person presentations by volunteer facilitators - still faces scalability constraints, and a larger cluster-randomized trial conducted in 144 schools found no statistically significant difference in smoking prevalence at the two-year follow-up [9,18]. This mixed evidence suggests that while photoaging interventions are a compelling concept, their delivery format may need to be optimized to achieve broad-scale effectiveness [9,18]. In theory, a poster campaign can be implemented across numerous schools with minimal staff and time requirements, leveraging students’ curiosity and peer discussion to drive engagement with the prevention message [20,21]. We therefore tested whether a facilitator-free poster campaign promoting the Smokerface app could attenuate the increase in 30-day cigarette-smoking prevalence over 24 months among students in German secondary schools.

2. Methods

2.1. Study design

The study was conducted as a two-arm, multicentre, cluster-randomized controlled superiority trial in regular German secondary schools. The trial protocol was prospectively registered at ClinicalTrials.gov (NCT02544360), approved by the Ethics Committee of the University of Giessen and the Ministries of Cultural Affairs of all participating federal states, and published in parallel [22].

Baseline assessments via paper-and-pencil questionnaires were carried out in 126 schools across six federal states between October 2015 and April 2016, after which schools were randomized centrally between February and May 2016. The intervention consisted of a poster campaign promoting the free photoaging app *Smokerface*; the posters were deployed after randomization by trained data collectors between March and June 2016. Follow-up surveys were administered after 6 months (September-December 2016), 12 months (March-June 2017), and 24 months (March-June 2018) post-intervention in the same way. The primary endpoint was the between-group difference in the change in cigarette-smoking prevalence from baseline to the 24-month follow-up. Secondary endpoints included shifts in smoking-related attitudes, rates of initiation and cessation, and app uptake. Details on the study design and concept can be found in the study protocol [22].

2.2. Participants

Students in 6th and 7th grade (12 years and older) attending general secondary schools in Germany were eligible for study inclusion. Schools that had previously participated in an EAT event featuring the *Smokerface* app were excluded from the trial. Recruitment took place via school administrations across six federal states (Baden-Wuerttemberg, Rhineland-Palatinate, Bavaria, North Rhine-Westphalia, Hesse, Thuringia).

A total of 9797 students from 126 schools consented to participate. Written informed consent was obtained from students and their parents or legal guardians before data collection. At enrolment, median cluster size was 57.5 students per school in the IG (interquartile range, IQR: 38–90) and 66 students per school in the CG (IQR: 46–104). All classes, including those in the CG where some students may have independently used the *Smokerface* app (‘contaminated’ classes), were retained in the primary analysis. App use in the CG was documented at the end of the study and used for a predefined sensitivity analysis.

2.3. Randomization

Randomization was performed at the school level after baseline assessment. We stratified the randomization by three factors: schools $>=$ 100 students vs. schools $<$ 100 students; school-level smoking prevalence at baseline $\geq$ 4.1% versus $<$ 4.1%; and participation versus non-participation in the anti-tobacco programme “Ohne Kippe”, as predefined in our published study protocol [22].

2.4. Intervention and monitoring

Two standardized DIN-A1 posters illustrating short- and long-term photoaging effects were placed in each classroom in the IG. Additional intervention components included letters to students, teachers, and parents, a raffle incentive, and a poster refresh after 12 months. Trained data collectors hung and documented the posters and sent email reminders regarding monitoring every second month during the first year. Posters were verified and replaced if damaged. App stability was tracked continuously and remained stable. Full details are provided in the intervention and monitoring sections of the trial protocol [22] and are summarized in Supplementary Material A. Poster examples are shown in Fig. 1.

2.5. Outcomes

The primary endpoint was the between-group difference in the change in cigarette-smoking prevalence from baseline to the 24-month follow-up. The number-needed-to-treat (NNT) was also calculated following the protocol; as predefined, an NNT< 100 was judged as clinically relevant [22].

Secondary endpoints comprised: (i) the longitudinal change in smoking-related attitudes; (ii) the number of students who started smoking (initiation); (iii) the number of quitters (cessation); (iv) the change in the number of students who never smoked. An attitude score was calculated by coding responses to seven questions regarding smoking attitude ('pleasant', 'harmless', 'reasonable', 'exciting', 'safe', 'healthy', 'good') on a four-point scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) and adding up the scores.

Current smoking was defined as self-reported cigarette use on at least one day during the 30 days preceding the survey.

Self-reported smoking status was biochemically validated by carbon monoxide testing in a random subsample of approximately 2.4% of participants after 24 months (further details see Supplementary Material B, Tables S1 and S2).

2.6. Statistical analysis

All primary analyses followed the intention-to-treat principle, retaining all randomized clusters regardless of individual app use.

For the primary endpoint, we applied generalized linear mixed models (GLMMs) with a logit link function, including nested random intercepts for schools and classes to account for the clustered study design. The model included fixed effects for time, group allocation, and the time-by-group interaction, as well as school type as a predefined covariate. The intervention effect was expressed as a ratio of odds ratios derived from the time-by-group interaction.

To quantify the degree of clustering, the intra-class correlation coefficients (ICC) were estimated together with bootstrap-based confidence intervals. Based on the ICCs and the mean cluster size, the design effect was calculated according to the Kish formula [23].

Sensitivity analyses assessed the robustness of the primary findings using: (i) survey design-adjusted Wald tests, (ii) generalized estimating equations (GEE) with an exchangeable correlation structure, (iii) multiple imputation by chained equations (MICE; m = 20), and (iv) a worst-case imputation scenario in which students lost to follow-up were treated as smokers in the IG and as non-smokers in the CG at 24 months.

Secondary binary outcomes were analyzed using GLMMs analogous to the primary model. For continuous outcomes (attitude score), we estimated linear fixed-effects models with HC1 adjusted [24] cluster-robust standard errors clustered at the school level and report Cohen's d as standardized effect sizes [25].

A usage-based sensitivity analysis compared IG participants who reported app use with participants in the CG.

To account for multiple testing across secondary endpoints, p-values were adjusted using the Bonferroni-Holm procedure. All analyses were conducted in R (version 4.1.2) using the packages *data.table*, *survey*, *lme4*, *sandwich*, *lmtest*, *clubSandwich*, *mice*, *mitml*, *geepack*, and *ggplot2*.

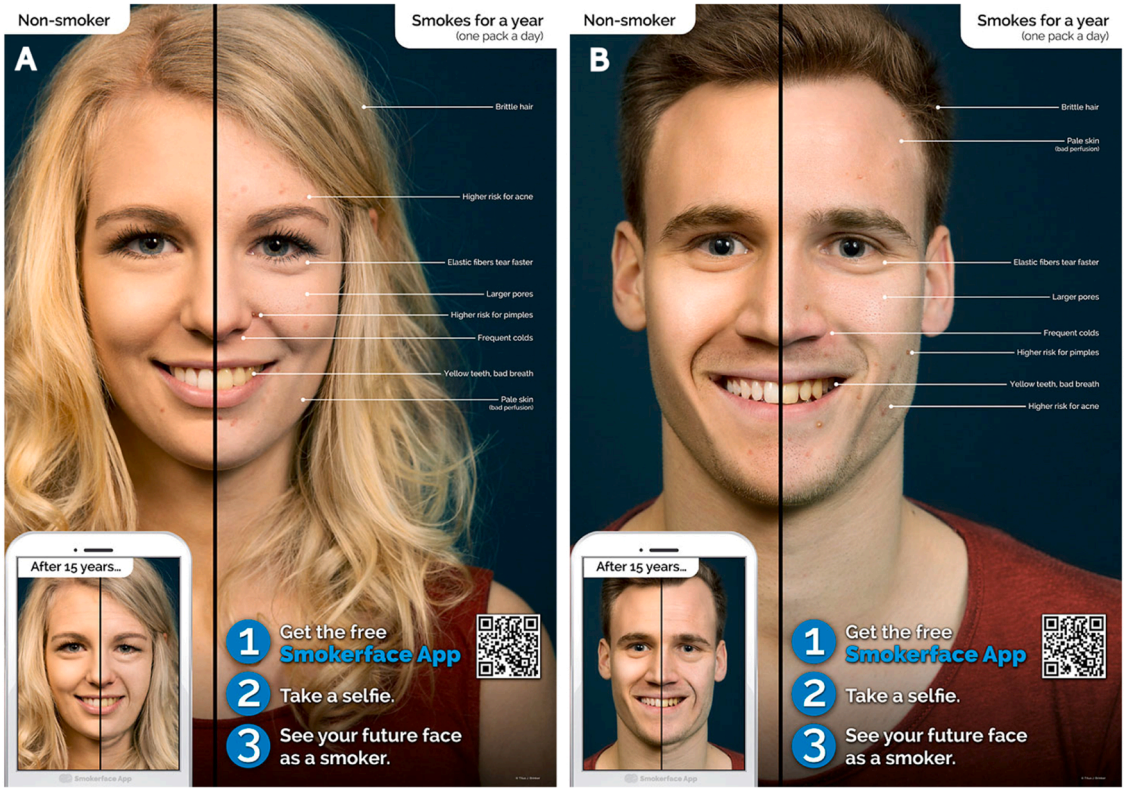


Fig. 1. (A) Female version and (B) male version of the intervention poster.

3. Results

Overall, 126 schools with a total of 9797 students participated in this study. Initially, we assigned 66 schools (5208 students) to the IG and 60 schools (4589 students) to the CG.

During the study, 17 schools (3620 students overall; 2228 of IG, 1392 of CG) were lost to follow-up. At the end of the study, the IG comprised 2980 students from 54 schools and the CG comprised 3197 students from 55 schools (see Fig. 2).

At baseline, the two study arms were highly comparable: gender distribution was equal, the mean age was slightly below 12 years, and nearly all students were in 6th or 7th grade, the developmental period during which initial experimentation with cigarettes typically begins. Only 7–8% of students reported having ever smoked, providing sufficient scope to detect new uptake. The proportion of families with a migration background varied by less than five percentage points between groups. The main imbalance concerned school type, with grammar-school classes being more frequent in the CG and regular secondary schools being correspondingly over-represented in the intervention group; this factor was therefore carried forward as a covariate in subsequent adjusted analyses. A complete overview of the baseline profile is provided in Table 1.

The campaign achieved high visibility in the IG, with 2200 of 2925 students (74.8%) recognizing the poster. App uptake was lower, with 608 students in the IG (20.8%) and 11 students in the CG (0.3%) reporting app use. Details on how the posters were received are shown in Supplementary Material A, Figure S1.

Among students lost to follow-up, baseline predictors of dropout were examined by logistic regression. Baseline smokers were more likely to drop out (OR 1.573, 95% CI 1.005–2.462, $p = 0.048$), and older age was independently associated with dropout (OR 1.264 per year, 95% CI 1.061–1.504, $p = 0.009$). Sex, school type, migration background, and group allocation were not significantly associated with dropout. This pattern suggests that data are missing at random (MAR) conditional on observed baseline characteristics.

The estimated school-level ICC was 0.023 (95% bootstrap CI: 0–0.046), with total clustering ICC (school + class) of 0.107. The corresponding design effect based on school-level clustering was 3.47.

The primary GLMM showed a directionally favourable but statistically non-significant intervention effect. The time × group interaction yielded a ratio of odds ratios (ROR) of 0.870 (95% CI 0.693–1.091; $p = 0.228$).

Sensitivity analyses yielded consistent estimates and did not materially change the interpretation of the primary analysis. The adjusted Wald test yielded $p = 0.802$. The GEE model showed an ROR of 0.868 (95% CI 0.591–1.276; $p = 0.472$), and multiple imputation showed an ROR of 0.872 (95% CI 0.694–1.096; $p = 0.241$). In the worst-case imputation scenario, the ROR was 1.056 (95% CI 0.843–1.322;

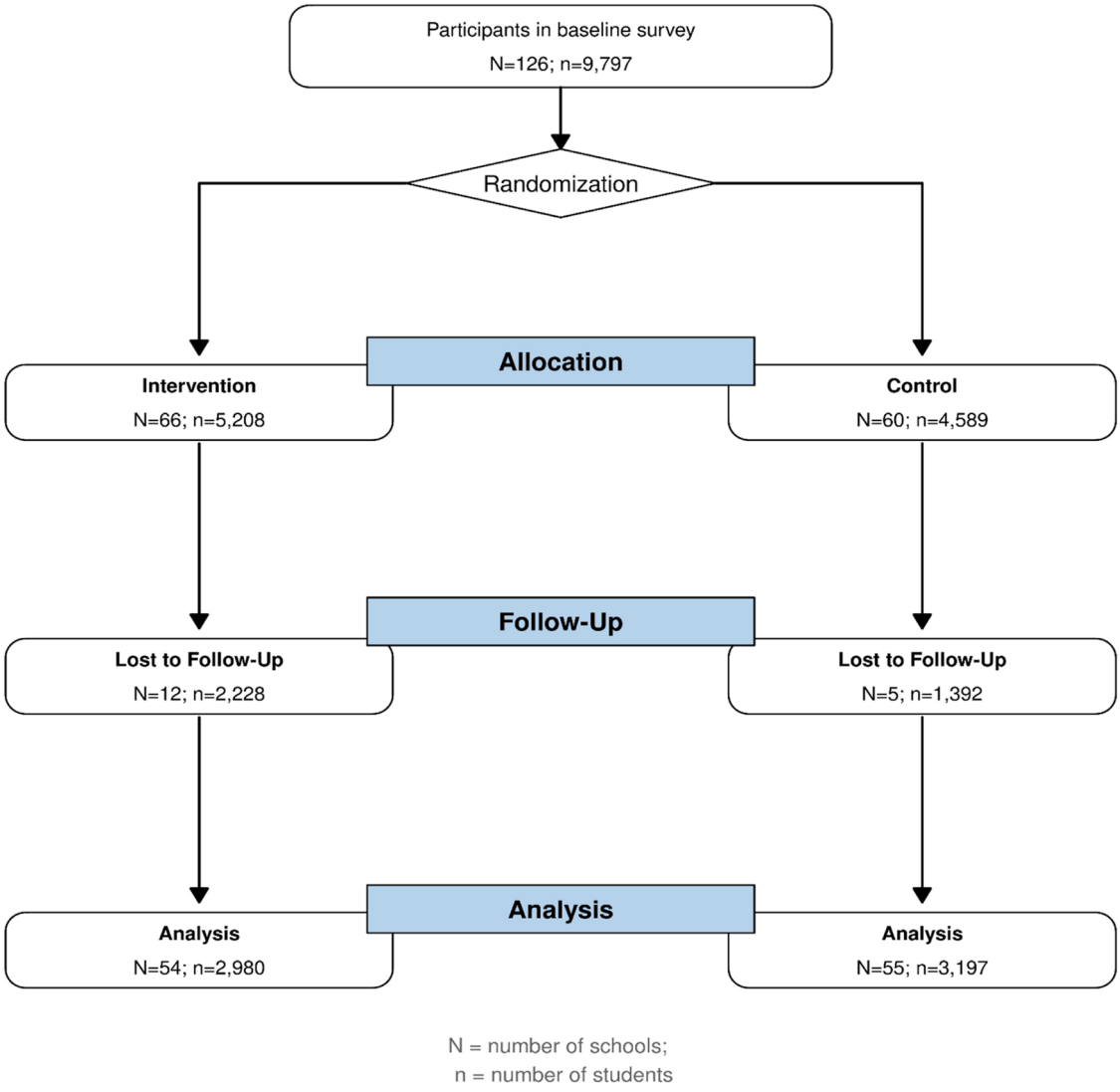


Fig. 2. CONSORT flowchart of the study population throughout the trial. Note that "n" refers to the number of students, while "N" refers to the number of schools.

Table 1
Baseline characteristics of study participants by group allocation.

Feature	Category	Intervention	Control	Whole population
Gender				
	Male	1478 (49.6%)	1699 (53.1%)	3177 (51.4%)
	Female	1502 (50.4%)	1498 (46.9%)	3000 (48.6%)
Age				
	< 11	20 (0.6%)	17 (0.6%)	37 (0.6%)
	11	926 (29.0%)	7007 (26.7%)	1723 (27.9%)
	12	1423 (47.8%)	1525 (47.7%)	2948 (47.7%)
	13	640 (21.5%)	615 (19.2%)	1255 (20.3%)
	> 13	103 (3.5%)	110 (3.4%)	213 (3.4%)
	Missing	0 (0.0%)	1 (0.0%)	1 (0.0%)
Grade				
	6th grade	1445 (48.5%)	1593 (49.8%)	3038 (49.2%)
	7th grade	1535 (51.5%)	1604 (50.2%)	3139 (50.8%)
School type*				
	Comprehensive school	240 (8.1%)	0 (0.0%)	240 (3.9%)
	Grammar school	730 (24.5%)	1091 (34.1%)	1821 (29.5%)
	Intermediate secondary school	796 (26.7%)	692 (21.6%)	1488 (24.1%)
	Regular secondary school	958 (32.1%)	1381 (43.2%)	2339 (37.9%)
	Other	256 (8.6%)	33 (1.0%)	289 (4.7%)
Parents born abroad				
	Yes	872 (29.3%)	767 (24.0%)	1639 (26.5%)
	No	2059 (69.1%)	2383 (74.5%)	4442 (71.9%)
	Missing	49 (1.6%)	47 (1.5%)	96 (1.6%)
Current smoking				
	No	2676 (89.8%)	2887 (90.3%)	5563 (90.1%)
	Yes	229 (7.7%)	230 (7.2%)	459 (7.4%)
	Missing	75 (2.5%)	80 (2.5%)	155 (2.5%)
Age		12.01 ± 0.81	11.96 ± 0.81	11.98 ± 0.81

*School type categories reflect the German secondary school system. "Comprehensive school" (Gesamtschule) combines multiple educational tracks and allows all graduation pathways. "Grammar school" (Gymnasium) provides the academic track leading to the university entrance qualification (Abitur). "Intermediate secondary school" (Realschule) offers a mid-level track ending with the intermediate certificate (Mittlere Reife). "Regular secondary school" (Hauptschule) focuses on basic general education and vocational preparation, usually ending after grade 9. "Other" includes special schools, alternative school forms, or private schools.

p = 0.637).

Throughout the 24-month follow-up, smoking prevalence increased more than fourfold in both groups, but to a slightly lower extent in the Smokerface intervention group. This corresponded to an approximately 13% relative attenuation in the increase in smoking prevalence (ROR = 0.87), although the confidence interval included the null. A similar directionally favourable pattern was observed for smoking cessation, with slightly more students quitting smoking in the intervention group. Secondary outcome estimates were imprecise and did not provide evidence for statistically significant between-group differences. Full numbers are shown in Table 2.

Table 2
Within-group changes in primary and secondary outcomes over time and between-group differences in within-group changes.

Feature	Comparison	OR [95% CI]	p-value
Primary outcome			
	Control: 24 months vs. baseline	5.08 [4.32;5.96]	< 0.001
	Intervention: 24 months vs. baseline	4.14 [3.75; 5.18]	< 0.001
	Intervention vs. Control (ROR*)	0.87 [0.69; 1.09]	0.228
Secondary outcomes			
	Students who still never smoked: Intervention vs. Control (ROR*)	1.02 [0.84; 1.25]	0.820
	Students who started smoking: Intervention vs. control (ROR*)	0.96 [0.80; 1.15]	0.626
	Quitter: Intervention vs. Control (ROR*)	1.19 [0.75; 1.88]	0.455
	Students who still smoke: Intervention vs. Control (ROR*)	0.98 [0.70; 1.37]	0.914

*ROR: ratio of odds ratios.

Within the follow-up period, smoking prevalence increased in both study arms, with a final between-group difference of just over half a percentage point in favour of the Smokerface campaign. Design-adjusted χ^2 tests showed no statistically significant association between group allocation and smoking status at baseline (p = 0.678) or after 24 months (p = 0.802). In absolute terms, the 24-month risk difference was 0.57 % age points, corresponding to a number needed to treat of 175. Given the low implementation cost, this would translate into approximately €70 per prevented case, assuming poster costs of €5 per poster. The underlying prevalence trajectories are displayed in Figure 3.

Subgroup analyses did not show statistically significant evidence of effect modification by gender or school type. Among males, the ROR was 0.901 (95% CI 0.664–1.224; p = 0.506), and among females, the ROR was 0.909 (95% CI 0.631–1.311; p = 0.610). For grammar schools, the ROR was 0.650 (95% CI 0.363–1.165; p = 0.148), while for non-grammar schools, the ROR was 0.958 (95% CI 0.743–1.236; p = 0.744). The strongest exploratory trend was observed in grammar schools; however, the study was not powered for subgroup analyses, and these findings should be interpreted as exploratory. Table 3 shows detailed estimates.

Attitude sum-scores showed right skewness at both time points (baseline: 1.73; 24-month follow-up: 1.65). Attitude scores changed similarly over time in both groups, with no statistically significant time-by-group interaction in the HC1 cluster-robust model (p = 0.721). The

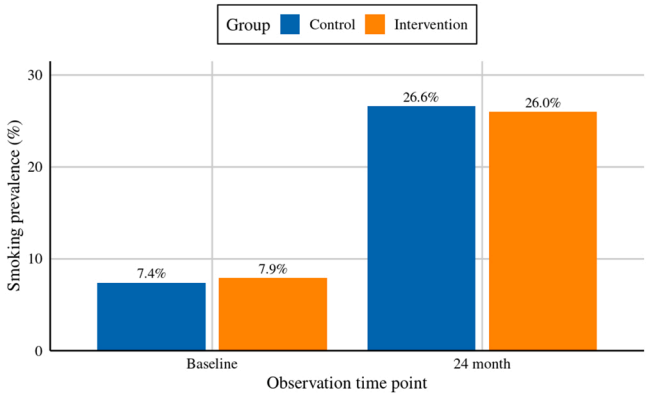


Fig. 3. Prevalence of current smoking by group allocation over time. Survey design-adjusted Wald tests showed no statistically significant association between smoking prevalence and group allocation at baseline (p = 0.678) or after 24 months (p = 0.802).

Table 3
Within-group changes in primary outcome (students who currently smoke) over time and between-group differences in within-group changes by gender and school type subgroups.

Subgroup	Comparison	OR [95% CI]	p-value
Male			
	Control: 24 months vs. baseline	4.24 [3.41; 5.28]	< 0.001
	Intervention: 24 months vs. baseline	3.83 [3.08; 4.75]	< 0.001
	Intervention vs. Control (ROR*)	0.90 [0.66; 1.22]	0.506
Female			
	Control: 24 months vs. baseline	6.70 [5.19; 8.64]	< 0.001
	Intervention: 24 months vs. baseline	6.09 [4.67; 7.94]	< 0.001
	Intervention vs. Control (ROR*)	0.91 [0.63; 1.31]	0.610
Grammar school			
	Control: 24 months vs. baseline	7.59 [5.06; 11.39]	< 0.001
	Intervention: 24 months vs. baseline	4.94 [3.24; 7.52]	< 0.001
	Intervention vs. Control (ROR*)	0.65 [0.36; 1.17]	0.148
Other school types			
	Control: 24 months vs. baseline	4.59 [3.83; 5.50]	< 0.001
	Intervention: 24 months vs. baseline	4.40 [3.67; 5.26]	< 0.001
	Intervention vs. Control (ROR*)	0.96 [0.74; 1.24]	0.744

*ROR: ratio of odds ratios

standardized effect size was negligible (Cohen's d = 0.027). Adjustment for multiple testing did not change the interpretation of the secondary analyses. The absolute risk difference at 24 months was 0.57 %age points.

In the exploratory usage-based sensitivity analysis, the IG was restricted to students who reported downloading the Smokerface app (n = 608), while the CG was restricted to students who did not report app use (n = 3161). The ROR estimate was 1.145 (95% CI 0.76–1.72; p = 0.515), which should be interpreted with caution because low app uptake may have diluted the intention-to-treat effect and may have introduced selection bias into this usage-based comparison.

Taken together, the Smokerface campaign showed a directionally favourable but statistically non-significant attenuation of smoking uptake. After 24 months, current smoking had increased to 26.6% in the CG versus 26.0% in the IG. The adjusted ROR was 0.87 (see Table 2), corresponding to a 13% relative attenuation in the increase in smoking prevalence, an absolute risk difference of 0.57 %age points, and a number needed to treat of 175. Our low-cost intervention would translate into approximately €70 per non-smoking adolescent, assuming two posters per class at €5 per poster and 25 students per class. Subgroup analyses showed no statistically significant effect modification by gender or school type (see Table 3), and secondary outcomes, initiation among baseline never-smokers, and attitude scores were consistent with the overall direction and magnitude of the primary analysis (see Table 2 and Supplementary Material C, Figure S2).

Biochemical validation reached approximately 50% of the planned sample size (151 of 6177 students; 2.4% of cases) and included 4 biochemically validated smokers and 147 biochemically validated non-smokers. Fisher's exact test did not indicate a statistically significant association between self-reported and biochemically validated smoking status, although the analysis was limited by the small number of biochemically validated smokers. Exact details are shown in Supplementary Material B, Tables S1 and S2.

4. Discussion

The Smokerface poster campaign trial evaluated whether a low-cost, facilitator-free, appearance-based intervention, consisting of two large face-aging posters encouraging students to try the free Smokerface app, could prevent an increase in early-adolescent smoking during the vulnerable transition from sixth to seventh grade. Conducted in 126 German secondary schools and followed over two academic years, this study is, to our knowledge, the largest and longest evaluation of an appearance-based, facilitator-free adolescent tobacco-prevention strategy to date. This study was conducted in the context of a steady but incomplete decline in youth smoking; about one in fourteen German teenagers still smokes, with uptake concentrated in lower-socioeconomic strata despite extensive tobacco-control legislation [26–29]. Schools remain a logical delivery channel for youth prevention, yet many established curricula rely on trained educators and multi-session delivery, limiting real-world scalability [30]. Against this backdrop, a poster-and-app package costing less than €50 per school for two laminated prints per classroom, requiring no classroom time, and achieving high visibility among students represents a scalable low-intensity prevention approach. The primary analysis showed a directionally favourable but statistically non-significant effect, with an approximately 13% relative attenuation in the two-year increase in 30-day smoking compared with controls. The absolute risk difference at 24 months was 0.57 %age points, corresponding to an NNT of 175. Assuming poster costs of €5 per poster, this translates to approximately €70 per prevented case. This estimate should be interpreted cautiously given the statistical uncertainty around the intervention effect.

The most direct comparators to this trial are the facilitator-led EAT trials, which integrate the same Smokerface app into interactive 90-minute classroom sessions delivered by medical students [19]. The original German EAT RCT reported a non-significant 1.4% gap in smoking prevalence after one year, whereas a trial conducted in Brazil observed a significant 6% gap after 12 months. The present poster-only approach therefore represents the conservative end of this spectrum. Broader meta-analyses of school programs generally report relative risk reductions between 5% and 15% over similar follow-up periods, with social-influence curricula tending to outperform information-only formats. Within that frame, a ~13% attenuation is directionally consistent but clearly at the lower margin of practical relevance [30–35].

Several mechanisms may underlie the modest effect. The behavioral economics literature suggests that simply knowing that a resource exists rarely matches the motivational jolt delivered by direct, socially engaging experiences [36,37]. The intervention targeted cosmetic concerns, highly salient in early adolescence, but did not actively reinforce the message over time; curiosity may have diminished long before the critical age when experimentation with tobacco turns into habitual use. Moreover, a recent cross-national analysis showed that individual-level factors, most notably smoking-permissive home environments, are the strongest predictors of actual cessation success, suggesting that a poster intervention operating at the school level may have limited reach into the domestic contexts where smoking behavior is ultimately consolidated [38].

Nevertheless, the trial's methodological strengths reinforce its conclusions. Cluster randomization and pre-registration mirrored the approach used in earlier EAT work; school retention (87%) and student retention (63%) compare favorably with analogous two-year studies; and fidelity monitoring confirmed poster visibility alongside objective uptake metrics from app download logs. Equally important is scalability: mailing two DIN-A1 prints and a stakeholder letter is logistically trivial for most school systems and could easily be integrated into routine health-promotion budgets without the need for external staff.

Some limitations should be considered when interpreting the findings. Attrition occurred at both the individual and school levels and reduced the effective sample size, particularly for subgroup analyses, which are generally more vulnerable to loss of precision [39]. Students

who smoked at baseline and older students were more likely to be lost to follow-up, but group allocation was not associated with dropout, and the observed pattern was compatible with missingness conditional on measured baseline characteristics. The imbalance in school type was addressed by covariate adjustment in the primary analysis. Potential contamination cannot be fully excluded because the Smokerface app was freely available; however, reported app use in the control group was very low, suggesting that any dilution of the between-group contrast was probably limited. Moreover, the study drew schools from six federal states, although one federal state, Rhineland-Palatinate, was lost completely to follow-up, which may constrain national generalizability. Smoking status was self-reported and may therefore be affected by social-desirability bias or other forms of misclassification [40]. The biochemical validation subsample was small and included few biochemically validated smokers; it should therefore be interpreted as insufficiently powered to assess potential misclassification rather than as evidence for or against the validity of self-reported smoking status.

Sensitivity analyses using multiple imputation and worst-case scenarios did not materially change the interpretation of the primary analysis. By focusing on the transition from sixth to seventh grade, our study may have missed the critical smoking initiation period occurring at age 15 and beyond, when smoking uptake rates typically peak among adolescents [41].

In summary, the Smokerface poster intervention showed a directionally favourable but statistically non-significant attenuation of smoking uptake over 24 months. Although the effect of the intervention in the tested form appears insufficient to support broad implementation as a stand-alone strategy, its low cost, simple implementation, and high visibility speak in favor of further development rather than discontinuation. In this regard, a systematic review and meta-analysis found that AI-generated health communication content significantly increases user interaction on social media compared with human-generated content, highlighting the potential of generative AI tools to amplify the reach and engagement frequency of appearance-based prevention messages on digital platforms [42]. Complementary evidence demonstrates that AI-generated social media influencers can deliver targeted cancer prevention messages at very low cost, suggesting that digitally scalable strategies could extend poster-based school interventions into the social media channels most frequented by adolescents [43]. Enhancing interactivity, boosting engagement frequency and embedding modest face-to-face components could be promising strategies for future campaigns. Until such iterations demonstrate clearer efficacy, the poster-and-app concept should be viewed as a low-intensity adjunct rather than a stand-alone solution within comprehensive school tobacco-control strategies.

5. Conclusion

In this cluster-randomized trial, the low-cost, facilitator-free Smokerface poster intervention showed a directionally favourable but statistically non-significant attenuation of smoking uptake over 24 months. Although statistically non-significant, the observed increase of smoking between the two arms was 5.6% less in the classes with the Smokerface posters than in the control group (number needed to treat=93). Delivering Smokerface-poster at a total cost of $<$ €50 per 100 students with no external staff required, would have saved about one adolescent smoker per 100 exposed adolescents in the two years. This inexpensive, facilitator-free, appearance-based campaign may offer a scalable low-intensity adjunct to school tobacco prevention, warranting engagement-focused refinement.

Given the low implementation cost of below €50 per school, further development and evaluation appear justified. Rather than being deployed on its own, the intervention could be refined and combined with complementary, evidence-based prevention components within a comprehensive tobacco-control program. Future studies should focus on increasing participant engagement, strengthening repeated exposure to the prevention message, and ensuring adequate statistical power while accounting for clustering. Until stronger evidence is available, the intervention should be considered a low-intensity adjunct rather than a stand-alone prevention strategy.

CRediT authorship contribution statement

Claudia Bauer-Kemeny: Writing – review & editing, Resources, Data curation, Conceptualization. **Ana Cirac:** Writing – review & editing, Resources, Data curation, Conceptualization. **Stefan Fröhling:** Writing – review & editing, Supervision, Data curation, Conceptualization. **Janina L. Suhre:** Writing – review & editing, Resources, Data curation, Conceptualization. **Ute Mons:** Writing – review & editing, Validation, Resources, Methodology, Conceptualization. **Hannah M. Fahrner:** Writing – review & editing, Resources, Data curation, Conceptualization. **Lava Taha:** Writing – review & editing, Resources, Data curation, Conceptualization. **Marlene Heckl:** Writing – review & editing, Resources, Data curation, Conceptualization. **Michael Kreuter:** Writing – review & editing, Resources, Data curation, Conceptualization. **Werner Seeger:** Writing – review & editing, Resources, Data curation, Conceptualization. **Julia Messner:** Writing – review & editing, Resources, Data curation, Conceptualization. **Felix Herth:** Writing – review & editing, Resources, Data curation, Conceptualization. **Nicolas B. Merl:** Writing – original draft, Validation. **Brinker Titus Josef:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization. **Fabian N. Fries:** Writing – review & editing, Resources, Data curation, Conceptualization. **Hannah Spielmann:** Writing – review & editing, Resources, Data curation, Conceptualization. **Christoph Wies:** Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation. **Lena Jakob:** Writing – review & editing, Resources, Data curation, Conceptualization. **David A. Groneberg:** Writing – review & editing, Resources, Data curation, Conceptualization. **Jana T. Winterstein:** Writing – original draft, Validation. **Henning Gall:** Writing – review & editing, Resources, Data curation, Conceptualization. **Katharina Kommoss:** Writing – review & editing, Resources, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used GPT−5 (OpenAI) and DeepL–Write to improve grammar and spelling and Claude-Opus−4.5 (Anthropic) to refine author-developed code for creating the visualizations and figures. The author(s) reviewed and edited the output as needed and take full responsibility for the content of the published article.

Data and Code sharing

All data and code relevant to this study are publicly available via figshare (https://doi.org/10.6084/m9.figshare.32508207).

Declaration

The author Titus Brinker is an Editor of the EJC and was not involved in the editorial review or the decision to publish this article.

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Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: TJB programmed the *Smokerface* App and is therefore formally the owner/rights holder. In 2017, he was offered and accepted 500 Euro per year from another German tobacco prevention charity (ginko Stiftung für Prävention, Germany) to license the *Smokerface* App for their school-based prevention efforts, with no influence on this study. TJB is also the owner of Smart Health Heidelberg GmbH, a software company which develops digital health apps. Werner Seeger received consulting fees from United Therapeutics, Tiakis Biotech AG, Liquidia, Pieris Pharmaceuticals, Abivax, Pfizer, Medspray BV, outside the submitted work. The other authors declare no conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ejca.2026.116898.

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