

Social profiles of cancer risk awareness and health behaviors among European adolescents. A cross-country study

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Abstract

Background: Cancer prevention during adolescence remains a major public health challenge. Although cancer-related risk behaviours emerge early in life, adolescents' engagement in these behaviours does not consistently align with their awareness of associated cancer risks.

Methods: Data were drawn from a cross-sectional online survey conducted within the SUNRISE project, including 4,054 adolescents aged 12–18 years from eight European countries. A two-step cluster analytic approach was applied, combining hierarchical clustering using Ward's method and k-means clustering. Clusters were defined based on engagement in unhealthy behaviours (smoking, alcohol consumption, unhealthy eating), cancer-risk perception and perceived health.

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Results: Five distinct adolescent profiles were identified: (1) The *Unconcerned and Mostly Healthy* (n = 918), characterised by low engagement in unhealthy behaviours, limited cancer-risk awareness associated with alcohol consumption and unhealthy eating, and good perceived health; (2) The *Health Savvy* (n = 1,868), who abstain from unhealthy behaviours, demonstrate high cancer-risk awareness, and report excellent health; (3) The *Unaware Health Risk-Takers* (n = 464), who frequently engage in unhealthy behaviours—particularly smoking and alcohol use—while underestimating associated cancer risks and reporting poorer health; (4) The *Health-Aware Risk-Takers* (n = 521), who engage heavily in unhealthy behaviours despite recognising their cancer risks and report average health; and (5) The *Health-Unaware Abstainers* (n = 283), who avoid unhealthy behaviours but display low cancer-risk awareness and average perceived health.

Conclusions: Adolescents' health behaviours and cancer-risk awareness cluster into distinct profiles not captured by socio-demographic characteristics alone, highlighting the need for profile-specific cancer prevention strategies.

Keywords: Adolescent health, Cancer prevention, Health inequalities, Risk behaviours, Cluster analysis.

Highlights

- Analysis of 4,054 adolescents in 8 European countries found five health-risk profiles.
- Adolescent profiles differ in unhealthy behaviors and cancer-risk perception.
- Adolescents' cancer prevention is a complex and requires multiple tailored approaches.

1. Introduction

Childhood cancers represent the leading cause of disease-related mortality among children and adolescents in countries participating in the WHO Small Countries Initiative, underscoring a persistent public health challenge for adolescents and young adults (AYAs) in Europe and beyond (Abraham et al., 2021). In 2020, AYAs accounted for more than 112,000 new cancer diagnoses and 12,700 cancer-related deaths in Europe, representing approximately 5% of all cancer diagnoses (Trama et al., 2023). Marked regional disparities persist:

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Western and Northern Europe report higher incidence rates but lower mortality, whereas Eastern European countries experience disproportionately high mortality despite lower incidence (Trama et al., 2023). These patterns indicate that cancer outcomes in young people are shaped not only by biological factors but also by structural and systemic determinants, including disparities in early detection, awareness, and access to effective care. Collectively, these factors position adolescence as a particularly vulnerable period for cancer prevention.

Health behaviours established during adolescence often persist into adulthood, with long-term implications for health outcomes (Campbell et al., 2020; World Health Organisation, 2023). Tobacco use, alcohol consumption, unhealthy diet, physical inactivity, and obesity are well-established contributors to cancer-risk (Champion et al., 2018; Abraham et al., 2021; Lawrence et al., 2025). Evidence from the Health Behaviour in School-aged Children (HBSC) study indicates that fewer than 40% of adolescents meet recommended fruit and vegetable intake, only 25% of boys and 15% of girls achieve WHO physical activity guidelines, and daily breakfast consumption continues to decline (Rakić et al., 2024). Comparable patterns are observed for smoking and alcohol use. Importantly, these behaviours frequently co-occur, amplifying both physical and psychosocial vulnerability; Champion et al. (2018), for example, identified “smokers and binge-drinkers” as exhibiting significantly higher levels of psychological distress (De Jans et al., 2026).

Despite the substantial burden of cancer, evidence from systematic reviews and school-based surveys indicates that adolescents tend to underestimate the role of everyday behaviours in cancer development, express uncertainty about how to reduce their risk, and often fail to recognise early warning signs (Abraham et al., 2021; Lawrence et al., 2025). Socioeconomic and cultural factors further exacerbate these inequalities, with adolescents from disadvantaged or migrant backgrounds reporting lower levels of cancer-related knowledge and more limited access to reliable health information (Lombardi & Sannella, 2020; Trama et al., 2023).

These challenges must be understood within broader contexts of social inequality, psychosocial stress, and community disconnection. Adolescents’ health practices are not merely individual lifestyle choices, but socially embedded behaviours shaped by peer norms, economic hardship, family structures, and community resources (Etzion & Romi, 2015). European studies similarly situate adolescent risk behaviours and mental health within wider social and structural frameworks (Koutra et al., 2014, 2016, 2020).

Conceptualising adolescents as socially situated actors requires analytical approaches capable of identifying meaningful patterns of risk and resilience rather than average effects. Typology-based methods, such as cluster analysis

and latent class analysis, offer a nuanced means of capturing this social embeddedness. Rather than examining isolated predictors, these approaches construct profiles based on the intersection of multiple dimensions, including health behaviours, risk awareness, psychosocial adjustment, and social integration. In doing so, they reveal patterns that demographic stratification alone cannot detect. For instance, Etzion and Romi (2015) identified four profiles of “youth at risk” based on school adjustment, personality traits, and social functioning, each characterised by distinct constellations of vulnerability and protection. Similarly, public health studies using clustering techniques have identified reproducible profiles of multiple health risk behaviours associated with variations in stress, self-efficacy (intention to change), and perceived health control (Champion et al., 2018).

Building on this framework, the present study applies hierarchical cluster analysis to a large cross-national dataset comprising more than 4,000 European adolescents. The analysis identifies relatively homogeneous groups based on adolescents’ perceptions of cancer-related behavioral risk and examines how modifiable lifestyle behaviors cluster alongside levels of risk awareness and psychosocial adjustment. By mapping distinct profiles, the study generates evidence to inform youth-centred and personalized prevention and intervention strategies aimed at reducing health inequalities.

2. Methodology

2.1 Study design

The study is based on a cross-sectional online survey of 5,074 adolescents aged 12 to 19 years from eight European countries^h. The sample was stratified by gender, age, area of residence (urban/rural), type of school, and migration background. The survey was conducted as part of a European research project aimed at developing a school-based intervention platform for primary cancer prevention among adolescents in eight European countries. Data were gathered in Belgium, Cyprus, Greece, Italy, Romania, Slovenia, Spain, and Switzerland. Its purpose was to explore differences in adolescents’ engagement in unhealthy behaviours, cancer-risk perceptions, and intentions to reduce these behaviours to inform tailored interventions. The methodology draws on the Health Belief

^h Deliverable 1.1, Large online cross-sectional survey. Annex 6 Situation analysis in urban and rural schools of Europe and definition of risk-based cancer prevention pathways. This project has received funding from the European Union’s Horizon Europe research and innovation programme under grant agreement No 101136829.

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Model (HBM), developed by Rosenstock (1974) and later expanded by Becker (1974), which emphasises the importance of individual perceptions in determining health behaviour.

For this study, we conducted a cluster analysis of a sample of 4,054 adolescents aged 12–18 which was our focus. We therefore decided not to analyse the 1,020 young adults over the age of 18 in this cluster for at least two reasons: Firstly, they were only present in a few of the countries involved in the project. Secondly, the weighting procedure significantly increased the importance of this group, which could invalidate the results of the largest group — adolescents aged 12–18.

The cluster analysis was performed to categorise respondents based on their current behaviours, health status, and risk perceptions.

2.2 Ethical approval

Ethical approval was obtained from the Ethics Committee of the Faculty of Political and Social Sciences at Ghent University on 25 March 2024 (approval number 2024-14)ⁱ. The study was pre-registered on the Open Science Framework (<https://osf.io/c52yv>).

2.3 Sample

Data were collected through schools in eight European countries using the Qualtrics platform. Although recruitment instructions were standardised across countries and aimed to ensure diversity in gender, age, school location, school type and migration status, recruitment procedures varied slightly in response to local practices and regulatory requirements. A detailed description of the recruitment process is provided in the Appendix A.

In total, 7,857 questionnaires were partially or fully completed by adolescents, of which 5,074 were considered valid after quality control

ⁱ Specifically, ethical approval was obtained from the HMU Research and Ethics Committee (number 12213) and the Directorate of Secondary Education of the Prefecture of Heraklion (number F23/7306) for Greece and from the Research Committee of the FISABIO Foundation for Spain.

^j The sampling error was 1.4%. After data quality control, 332 questionnaires were removed due to missing information (i.e. answers to questions). Of the incomplete questionnaires, 502 were considered valid. The criterion used for validation was the degree of completeness of the questionnaire, i.e. 70% of the answers given.

(Deliverable 1.1)^k. For the cluster analysis, three inclusion criteria were applied during data cleaning, resulting in an analytical sample of 4,054 adolescents: (1) age between 12 and 18 years; (2) a minimum survey completion rate of 70%; and (3) provision of informed consent and assent from both parents and adolescents.

To correct for deviations in gender distribution within countries and for differences in country-level representation relative to Eurostat population statistics, a two-step weighting procedure was applied. Final weights were normalized to a mean of 1 to prevent inflation of the effective sample size. All analyses were conducted using the weighted sample. An overview of participant characteristics by country is presented in Table 1.

Table 1. Unweighted Sample Characteristics

Country	N	Age bands (N)	Age (Mean)	Gender	Migration background
Greece	489	12-13: 141 14-15: 240 16-18: 108	14.44 (<i>SD</i> = 1.34)	46.4% male, 49.5% female, 4.1% other	14.3%
Switzerland	435	12-13: 21 14-15: 189 16-18: 225	15.76 (<i>SD</i> = 1.64)	49.8% male, 49.3% female, 0.9% other	49.7%
Slovenia	127	12-13: 3 14-15: 10 16-18: 114	16.67 (<i>SD</i> = 1.16)	50.8% male, 48.3% female, 0.8% other	13.4%
Spain	190	12-13: 45 14-15: 65 16-18: 80	14.87 (<i>SD</i> = 1.62)	37.6% male, 53.8% female, 8.6% other	25.8%
Cyprus	19	12-13: 0 14-15: 4 16-18: 15	16.79 (<i>SD</i> = 1.40)	38.9% male, 61.1% female, 0% other	31.6%
Italy	902	12-13: 8 14-15: 245 16-18: 649	16.30 (<i>SD</i> = 1.32)	47% male, 49.9% female, 3.1% other	22.5%
Belgium	1351	12-13: 365 14-15: 482 16-18: 504	14.86 (<i>SD</i> = 1.77)	45% male, 52% female, 2.9% other	22.1%
Romania	541	12-13: 82 14-15: 168 16-18: 291	15.50 (<i>SD</i> = 1.65)	27.1% male, 70.5% female, 2.3% other	3.3%
<i>Total</i>	4054	12-13: 665 14-15: 1403 16-18: 1986	15.38 (<i>SD</i> = 1.72)	43.6% male, 53.4% female, 3% other	22.8%

^k Deliverable 1.1, *Large online cross-sectional survey*. Annex 6 Situation analysis in urban and rural schools of Europe and definition of risk-based cancer prevention pathways. This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101136829.

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2.4 Measurement Instrument

The full survey instrument is available in the preregistration document; the present study reports only the measures used for cluster formation and profiling (Table 2).

Table 2. Measures Construct

	Item	Response scale
Overall perceived health	Overall perception of health was assessed using a 10-step ladder representing physical and mental health. Participants were asked to indicate the step that best reflected their average health during the past four weeks.	0 = worst possible health, 10 = best possible health
Acceptance of health condition (Bloem et al., 2020)	Are you at peace with your health condition?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Is the way you function physically and mentally acceptable to you?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Are you okay with your health as it is right now?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
Perceived control (Bloem et al., 2020)	Do you think you have a lot of influence on your health condition?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Do you feel that you have control over your health condition?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Is your health condition largely under your own control?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Do you think your current actions will influence your future health?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
Social support (Oslo Social Support Scale)	How many people are so close to you that you can count on them in case of serious personal problems?	none; 1–2; 3–5; ≥5
	How much interest and concern do people show in what you do?	none; little; some; much; a lot
	How easy is it to obtain practical help from friends if needed?	very difficult; difficult; possible; easy; very easy

	Item	Response scale
Sources of health information	How often do you consult the following sources when confronted with a health problem?	1 = never; 2 = rarely; 3 = sometimes; 4 = fairly often; 5 = very often
	Parents	1–5 Likert scale
	Physician	1–5 Likert scale
	Teachers	1–5 Likert scale
	Friends	1–5 Likert scale
	Internet or social media	1–5 Likert scale
	Social media influencers	1–5 Likert scale
	Books and magazines	1–5 Likert scale
	Other sources (specified by the participant)	1–5 Likert scale
Cancer-related risk perceptions	Do you think the following behaviors increase the risk of developing cancer?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Smoking tobacco and/or electronic cigarettes	1–5 Likert scale
	Alcohol consumption	1–5 Likert scale
	Unhealthy diet	1–5 Likert scale
Perceived cancer threat	Do you believe that getting cancer is a severe condition?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
	Do you think it is likely that you will develop cancer at some point in your life?	1 = not at all; 2 = probably not; 3 = not sure; 4 = probably; 5 = definitely
School-based health education	How often do you receive information at school about cancer prevention?	1 = never; 2 = rarely; 3 = sometimes; 4 = fairly often; 5 = very often
	How often do you receive information about how unhealthy diet and addictive substances (e.g., smoking, alcohol) can cause health problems?	1 = never; 2 = rarely; 3 = sometimes; 4 = fairly often; 5 = very often
Health behaviors	At present, how often do you smoke cigarettes or electronic nicotine products?	never; < once/week; once/week; several times/week; daily
	At present, how often do you consume alcoholic beverages?	never; < once/week; once/week; several times/week; daily
	At present, how often do you consume the following food groups? – Fast food	never; < once/week; once/week; several times/week; daily
	Salty snacks	never; < once/week; once/week; several times/week; daily

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Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
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	Item	Response scale
	Sugary snacks	never; < once/week; once/week; several times/week; daily
	Processed or red meat	never; < once/week; once/week; several times/week; daily
	Sugar-sweetened beverages	never; < once/week; once/week; several times/week; daily
Sociodemographic variables	Age	continuous (years)
	Gender identity	male; female; non- binary; prefer not to say; other (specified)
	Country of residence	categorical
	Born in the country of residence	yes; no; do not know
	Mother born in the country of residence	yes; no; do not know
	Father born in the country of residence	yes; no; do not know

Behavioral and psychographic variables were assessed using five-point Likert-type scales, except for current health status, which was measured using a 10-rung health ladder (0 = worst possible health; 10 = best possible health).

Cluster formation was based on three domains. First, engagement in unhealthy behaviors was assessed for smoking or vaping, alcohol consumption, and unhealthy eating. Smoking or vaping and alcohol consumption were measured using single items (1 = never; 5 = daily). Unhealthy eating was assessed using five items capturing the frequency of consumption of fast food, salty snacks, sugary snacks, processed or red meat, and sugar-sweetened beverages; these items were averaged to create a composite unhealthy eating score. Second, perceived cancer-risk was assessed separately for smoking or vaping, alcohol consumption, and unhealthy eating using five-point Likert-type scales (1 = not at all; 5 = definitely). Third, current health status was assessed using the health ladder.

All clustering variables were standardized prior to analysis. Smoking or vaping, alcohol consumption, and unhealthy eating were entered separately, resulting in a total of seven clustering variables.

Clusters were subsequently profiled using perceived cancer severity and perceived cancer threat, health acceptance, perceived health control, social support, health information sources and topics, and sociodemographic characteristics, including gender, age, country of residence, and migration background.

2.5 Statistical analysis

All statistical analyses were conducted using SPSS version 31. Engagement in smoking or vaping, alcohol consumption, and unhealthy eating, perceived cancer-risk associated with each behaviour, and current health status were standardised as z-scores and entered as active variables in a hierarchical cluster analysis. Prior to clustering, intercorrelations among variables were examined to assess potential multicollinearity. Ward's method with squared Euclidean distance was applied, as it minimises within-cluster variance and maximises between-cluster differentiation (Ward, 1963; Everitt et al., 2011).

The optimal number of clusters was determined through inspection of the dendrogram, examination of changes in agglomeration coefficients, and comparison with non-hierarchical (k-means) solutions. A five-cluster solution was retained based on considerations of stability, interpretability, and consistency with previous research on adolescent health behaviours. K-means clustering was subsequently applied to refine cluster membership and support cluster interpretation and labelling.

Clusters were profiled using illustrative variables not included in the clustering procedure, including perceived cancer severity and threat, health acceptance, perceived health control, social support, health information sources and topics, and sociodemographic characteristics (gender, age, country of residence, and migration status). One-way analyses of variance (ANOVAs) were conducted for continuous variables, with significant omnibus tests followed by least significant difference (LSD) post hoc comparisons. V-tests were used to identify variables that significantly characterised clusters, with absolute values greater than 2 indicating statistical significance at approximately the 95% confidence level. Associations with categorical variables were examined using chi-square tests, with adjusted residuals inspected to interpret cell contributions (Agresti, 2007). All tests were two-tailed ($p < .05$), and effect sizes were reported where appropriate.

3. Findings

3.1 Descriptive statistics and multicollinearity check among cluster variables

Table 3 presents the Pearson correlations among the seven variables used for cluster formation. All variables were standardised prior to analysis. Most associations were small to moderate in magnitude. Two stronger correlations emerged: perceived cancer-risk associated with smoking was strongly correlated with perceived cancer-risk associated with alcohol consumption ($r = .61$, $p <$

Social Profiles of Cancer Risk Awareness and Health Behaviours Among
European Adolescents. A Cross-Country Study
Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
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.001), and smoking or vaping behaviour was strongly associated with alcohol consumption ($r = .49$, $p < .001$). No correlation coefficient exceeded .80, indicating that multicollinearity was not a concern.

Table 3. Correlation Table

	Alcohol Use	Unhealthy eating	Cancer- Risk Smoking	Cancer- Risk Alcohol Use	Cancer-Risk Unhealthy eating	Health Status
Smoking	$r = .49$ $p < .001$	$r = .12$ $p < .001$	$r = -.08$ $p < .001$	$r = -.06$ $p < .001$	$r = -.01$ $p = .658$	$r = -.16$ $p < .001$
Alcohol Use	*	$r = .19$ $p < .001$	$r = -.09$ $p < .001$	$r = -.11$ $p < .001$	$r = .03$ $p = .039$	$r = -.11$ $p < .001$
Unhealthy Eating		*	$r = .04$ $p = .012$	$r = .01$ $p = .374$	$r = -.001$ $p = .966$	$r = -.07$ $p < .001$
Cancer-Risk Smoking			*	$r = .61$ $p < .001$	$r = .13$ $p < .001$	$r = .05$ $p = .002$
Cancer-Risk Alcohol Use				*	$r = .31$ $p < .001$	$r = .07$ $p < .001$
Cancer-Risk Unhealthy eating					*	$r = .03$ $p = .038$

Descriptive statistics for engagement in unhealthy behaviours, perceived cancer-risk, and self-rated health are reported in Table 4. Overall, adolescents reported low engagement in unhealthy behaviours. Approximately 72% indicated that they never smoked cigarettes or electronic nicotine products, and 47.5% reported never consuming alcoholic beverages. Daily smoking was reported by 8% of participants, whereas daily alcohol consumption was rare (<1%; $N = 37$). Among adolescents who reported alcohol use, most indicated drinking less than once a week (35.7%) or once a week (11.7%). Mean scores for unhealthy eating were higher than for smoking and alcohol consumption, suggesting that unhealthy food consumption occurred approximately once per week on average.

As shown in Table 4, awareness of cancer-risk was highest for smoking ($M = 4.41$; median = 5), indicating strong agreement that smoking increases cancer-risk. Perceived cancer-risk related to alcohol consumption ($M = 3.88$, $SD =$

1.12) and unhealthy eating ($M = 3.39$, $SD = 1.13$) was slightly lower but still moderate to high, with median scores of 4 for both behaviours.

Finally, self-rated health scores reported in Table 4 indicate generally good perceived health, with a mean score of 7.96 out of 10 ($SD = 2.01$). Only 9% of participants rated their health at five or below, suggesting that poor perceived health was relatively uncommon in the sample.

Table 4. Mean Scores on Cluster Variables

	Mean	Median	SD
Alcohol use	1.75	2.00	.89
Smoking	1.67	1	1.26
Unhealthy eating	3.12	3.20	.65
Cancer-risk alcohol use	3.88	4.00	1.12
Cancer-risk smoking	4.41	5	1.05
Cancer-risk unhealthy eating	3.39	4.00	1.13
Health status	7.96	8.00	2.01

3.2 Determining the Number of Clusters

A first step in determining the optimal number of clusters was hierarchical clustering using Ward's method. An inspection of the agglomeration schedule and the dendrogram indicated possible two-, three-, or five-cluster solutions.

Next, these cluster solutions were entered into a K-Means cluster analysis. We explored the two-, three-, and five-cluster solutions and examined the number of participants in each cluster to identify the most suitable solution. The five-cluster solution produced the most distinct and meaningful profiles based on seven variables, so we decided to proceed with this solution. We labelled and described each cluster based on the mean scores on cluster variables (see Table 5 and Table 6).

3.3 Clusters description

Cluster 1 (weighted $N = 918$; unweighted $N = 997$), the second largest group, is labelled *Unconcerned and Mostly Healthy*. Adolescents in this cluster report low engagement in unhealthy behaviours. They consume unhealthy foods occasionally, report alcohol uses close to the sample average (ranging from never to less than once a week), and do not smoke. While perceived cancer-risk associated with alcohol consumption and unhealthy eating is below the sample average, perceived cancer-risk related to smoking is around the average, indicating relatively high-risk awareness. Overall, members of this cluster report good health.

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Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
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Cluster 2 (weighted N = 1,868; unweighted N = 1,796), the largest group, is labelled *Health Savvy*. Adolescents in this cluster abstain from unhealthy behaviours, demonstrate high awareness of cancer risks associated with these behaviours, and report excellent health.

Cluster 3 (weighted N = 464; unweighted N = 433), labelled *Unaware Health Risk-Takers*, is characterised by more frequent engagement in unhealthy behaviours than the sample average, particularly smoking and, to a lesser extent, alcohol consumption. Adolescents in this cluster perceive these behaviours as less risky than the sample average and report substantially poorer health.

Cluster 4 (weighted N = 521; unweighted N = 535), labelled *Health-Aware Risk-Takers*, reports the highest levels of engagement in unhealthy behaviours. Although members of this cluster engage in these behaviours more frequently than those in Cluster 3, they report higher perceived cancer-risk for alcohol consumption and unhealthy eating, while perceived cancer-risk related to smoking is slightly below the sample average. Self-rated health in this cluster is close to the sample average.

Cluster 5 (weighted N = 283; unweighted N = 293), labelled *Health-Unaware Abstainers*, consists of adolescents who do not engage in unhealthy behaviours but report low perceived cancer-risk associated with these behaviours. Perceived cancer-risk for both alcohol consumption and smoking are considerably lower than the sample average, while self-rated health is average.

Table 5. Mean Scores of Clusters on Cluster Variables

	Unconcerned and Mostly Healthy	The Health Savvy	The unaware health risk- takers	The health- aware risk- takers	The health- unaware abstainers
Alcohol use	.02	-.45	.18	1.51	-.15
Smoking	-.39	-.47	.97	1.69	-.33
Unhealthy eating	.26	-.22	-.03	.52	-.31
Cancer-risk alcohol use	-.52	.56	-.21	.12	-1.89
Cancer-risk smoking	.08	.45	-.03	-.09	-3.00
Cancer-risk unhealthy eating	-.98	.47	-.31	.40	-.18
Health status	.12	.29	-1.47	.05	.04

Table 6. ANOVA F-Test K-Means Cluster Analysis

	F-statistic	p-value
Smoking	1646.16	< .001
Alcohol Use	658.93	< .001
Unhealthy Eating	86.76	< .001
Cancer-Risk Smoking	2627.01	< .001
Cancer-Risk Alcohol Use	873.50	< .001
Cancer-Risk Unhealthy eating	550.86	< .001
Health Status	411.27	< .001

3.4 Cluster profiles

Illustrative variables used to describe the clusters included perceived severity and threat of cancer, health control, health acceptance, social support, information sources and topics, as well as socio-demographic characteristics such as gender, age, country of residence, and migration status.

3.4.1 Socio-demographic characteristics

Age. There are significant but small age differences between clusters ($F(4, 4048) = 67.71, p < .001, \eta^2 = .063$). “The Health-Aware Risk-Takers” cluster consists of the oldest participants ($M = 16.35, SD = 1.40$), followed by “The Unaware Health Risk-Takers” ($M = 16.02, SD = 1.50$). These two groups are significantly older than the other three groups, “The Unconcerned and Mostly Healthy” ($M = 15.28, SD = 1.61$), “The Health Savvy” ($M = 15.23, SD = 1.70$), and “The Health-Unaware Abstainers” ($M = 15.17, SD = 1.61$).

The V-test (see Table 7) indicates that age is especially characteristic of the clusters “The Health-Aware Risk-Takers” and “The Unaware Health Risk-Takers.”

Table 7. V-Tests.

The Unconcerned and mostly healthy	4,01	2,79	1,77	3,5	2,45	1,39	1,37
The Health Savvy	4,12	2,98	1,75	3,22	2,37	1,31	1,6
The Unaware health Risk-Takers	3,11	2,48	1,54	3,24	2,6	1,32	1,51
The Health Aware Risk-Takers	3,67	2,61	1,62	3,65	2,74	1,63	1,55
The Health unaware abstainers	3,52	2,76	1,83	3,32	2,41	1,68	1,63

Social Profiles of Cancer Risk Awareness and Health Behaviours Among
European Adolescents. A Cross-Country Study
Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
Andreas Triantafyllidis, Alessandro Sproviero, SUNRISE research group

Gender. A Chi² analysis shows small, but significant gender differences between clusters ($\chi^2(8) = 64.71, p < .001$, Cramer's $V = .091$). There are an equal number of males and females in “*The Unconcerned and Mostly Healthy*,” “*The Health Savvy*,” and “*The Health Aware Risk-Takers*” groups. The adjusted residuals indicate that there are significantly less males and more females than expected in “*The Unaware Health Risk-Takers*”, while there are significantly less females and more males in “*The Health Unaware Abstainers*” (see Table 8).

Table 8. Gender differences

		Males	Females	Other
Unconcerned and Mostly Healthy	Count	439	416	41
	Percentage	49%	46.4%	4.6%
	Adjusted residual	.8	-.8	.0
The Health Savvy	Count	865	857	84
	Percentage	47.9%	47.5%	4.5%
	Adjusted residual	.2	-.2	-.1
The unaware health risk-takers	Count	144	272	26
	Percentage	32.6%	61.5%	5.9%
	Adjusted residual	-6.8	6.2	1.4
The health-aware risk-takers	Count	261	230	16
	Percentage	51.5%	45.4%	3.2%
	Adjusted residual	1.8	-1.1	-1.7
The health-unaware abstainers	Count	165	95	15
	Percentage	60%	34.5%	5.5%
	Adjusted residual	4.2	-4.5	.7

Migration status. A chi-square analysis revealed small but statistically significant differences in migration background across clusters ($\chi^2(4) = 18.82, p < .001$, Cramer's $V = .068$). Examination of the adjusted residuals suggests a slight underrepresentation of adolescents with a migration background in the 'Unconcerned and Mostly Healthy' cluster and a slight overrepresentation in the 'Health-Unaware Abstainers' cluster (see Table 9). However, given the small effect size, these differences should be interpreted with caution as they have limited practical significance.

Table 9. Migration Status

		Yes	No
Unconcerned and Mostly Healthy	Count	172	746
	Percentage	18.7%	81.3%
	Adjusted residual	-2.7	2.7
The Health Savvy	Count	395	1473
	Percentage	21.1%	78.9%
	Adjusted residual	-1.2	1.2
The unaware health risk-takers	Count	115	349
	Percentage	24.8%	75.2%
	Adjusted residual	1.5	-1.5
The health-aware risk-takers	Count	128	393
	Percentage	24.6%	75.4%
	Adjusted residual	1.5	-1.5
The health-unaware abstainers	Count	82	200
	Percentage	29.1%	70.9%
	Adjusted residual	3.0	-3.0

Country of residence. A Chi-square analysis revealed small but statistically significant differences in cluster distribution across countries ($\chi^2 (28) = 383.81, p < .001$, Cramer's $V = .154$). Greek adolescents were overrepresented in the *Health-Unaware Abstainers* cluster. Swiss adolescents were underrepresented in the *Unconcerned and Mostly Healthy* cluster and overrepresented in the *Health-Aware Risk-Takers* and *Health-Unaware Abstainers* clusters. Spanish adolescents were overrepresented in the *Unconcerned and Mostly Healthy* and *Health Savvy* clusters and underrepresented in the remaining three clusters. No significant differences were observed for Slovenian and Cypriot adolescents.

Italian adolescents were overrepresented in the *Unaware Health Risk-Takers*, *Health-Aware Risk-Takers*, and *Health-Unaware Abstainers* clusters and underrepresented in the *Health Savvy* cluster. Belgian adolescents were overrepresented in the *Unconcerned and Mostly Healthy* cluster and underrepresented in the *Health-Aware Risk-Takers* and *Unaware Health Risk-Takers* clusters. Finally, Romanian adolescents were significantly overrepresented in the *Health Savvy* and *Health-Aware Risk-Takers* clusters and

Social Profiles of Cancer Risk Awareness and Health Behaviours Among
European Adolescents. A Cross-Country Study
Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
Andreas Triantafyllidis, Alessandro Sproviero, SUNRISE research group

underrepresented in the *Unconcerned and Mostly Healthy* and *Unaware Health Risk-Takers* clusters.

Table 10. Country differences

		Greece	Switzerland	Slovenia	Spain	Cyprus	Italy	Belgium	Romania
Unconcerned and Mostly Healthy	Count	55	33	18	311	4	304	118	75
	Percentage	6%	3.6%	2%	33.9%	0.4%	33.1%	12.9%	8.2%
	Adjusted residual	-6	-2.6	-1	2.4	-4	-5	5.8	-4.9
The Health Savvy	Count	129	87	36	706	14	449	149	298
	Percentage	6.9%	4.7%	1.9%	37.8%	0.7%	24%	8%	16%
	Adjusted residual	1.1	-1.6	-3	9.0	1.9	12.2	-6	5.3
The unaware health risk-takers	Count	24	21	9	81	0	263	22	39
	Percentage	5.2%	4.5%	1.9%	17.5%	0%	57.8%	4.7%	8.4%
	Adjusted residual	-1.2	-8	-1	-6.6	-1.7	11.6	-2.9	-3.1
The health-aware risk-takers	Count	25	44	15	87	2	236	28	53
	Percentage	4.8%	8.5%	2.9%	16.7%	0.4%	45.4%	5.4%	10%
	Adjusted residual	-1.6	3.5	1.5	-7.4	-5	6.0	-2.5	2.2
The healthy-unaware abstainers	Count	28	29	3	60	1	114	17	30
	Percentage	9.9%	10.3%	1.1%	21.3%	0.4%	40.4%	6%	10.6%
	Adjusted residual	2.5	3.9	-1.2	-3.6	-4	2.4	-1.4	-1.2

3.5 Behavioral and Psychographic Differences

We next describe cluster differences in psychosocial characteristics; mean scores for all variables are reported in Table 11.

Health acceptance. Clusters differed significantly in the extent to which adolescents accepted their current health status ($F(4, 4052) = 158.22, p < .001, \eta^2 = .14$; overall mean = 3.96). V-tests indicated that health acceptance was most characteristic of the *Unaware Health Risk-Takers* and *Health Savvy* clusters. Adolescents in both clusters reported the highest levels of health acceptance, which is consistent with their more positive self-rated health.

Perceived control over health. Significant but small differences were observed across clusters in perceived control over health ($F(4, 4052) = 72.75, p < .001, \eta^2 = .067$; overall mean = 3.97). The *Health Savvy* cluster reported significantly higher perceived control than all other clusters. In contrast, V-tests indicated that the *Unaware Health Risk-Takers* and *Health-Unaware Abstainers* scored significantly below the overall mean, indicating lower perceived control over their health.

Social support. Clusters also differed significantly in perceived social support, although effect sizes were small ($F(4, 4052) = 46.11, p < .001, \eta^2 = .044$; overall

mean = 3.50). Adolescents in the *Unaware Health Risk-Takers* and *Health-Unaware Abstainers* clusters reported lower levels of social support than the sample average, indicating fewer perceived relational resources. Nevertheless, all clusters scored above the scale midpoint, suggesting that adolescents generally perceived at least some degree of support from their social environment.

Perceived cancer severity and susceptibility. Across all clusters, cancer was perceived as a severe disease (mean scores > 4 on a 5-point scale), while perceived susceptibility was lower (mean scores < 3.5), indicating general uncertainty about personal cancer-risk. Small but significant differences emerged between clusters for perceived severity ($F(4, 4052) = 37.44, p < .001, \eta^2 = .036$; overall mean = 4.74) and perceived susceptibility ($F(4, 4052) = 36.11, p < .001, \eta^2 = .034$; overall mean = 2.95), with the latter approximating the scale midpoint.

The *Health-Unaware Abstainers* perceived cancer as least severe, with this variable being highly characteristic of the cluster, and reported lower perceived susceptibility than other groups. In contrast, *Health-Aware Risk-Takers* perceived cancer as less severe than the sample average but reported higher perceived susceptibility. For the *Unconcerned and Mostly Healthy* cluster, the pattern was reversed: adolescents perceived cancer as more severe than average while reporting lower-than-average susceptibility.

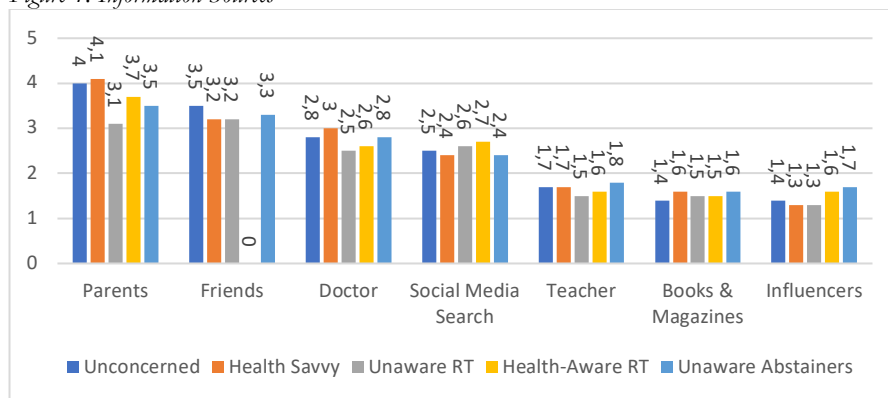
Table 11. Mean Scores Behavioral and Psychographic Differences

	Acceptance of Health	Control over Health	Social Support	Cancer Severity	Cancer Susceptibility
Average mean	3.96	3.97	3.50	4.74	2.95
Unconcerned and Mostly Healthy	4.08	3.96	3.58	4.79	2.83
The Health Savvy	4.15	4.11	3.61	4.81	2.95
The unaware health risk-takers	3.09	3.57	3.06	4.74	3.16
The health-aware risk-takers	3.89	4.02	3.50	4.63	3.24
The health-unaware abstainers	3.85	3.68	3.32	4.28	2.48

3.6 Information sources

A repeated measures ANOVA shows that there are significant interaction effects between cluster membership and consultation of different sources in case of health problems ($F = 29.49$, $p < .001$, $\text{Partial } \eta^2 = .029$), see Figure 1. While parents and friends are the most important information sources for all clusters; influencers, books and magazines and teachers are the least important information source. Parents are a more important information source for “*The Health Savvy*” and “*The Unconcerned and Mostly Healthy*” clusters. While the doctor is a significantly more important information source than the internet for “*The Unconcerned and Mostly Healthy*”, “*The Health Savvy*”, and “*The Health Unaware Abstainers*”, both sources are equally important for “*The Unaware Health Risk-Takers*” and “*The health Aware Risk-Takers*”.

Figure 1. Information Sources



Information at school. Small significant differences appear between clusters for information about cancer prevention ($F(4, 4052) = 10.03$, $p < .001$, $\eta^2 = .010$) and cancer risks of unhealthy behaviors ($F(4, 4052) = 37.16$, $p < .001$, $\eta^2 = .035$). It is remarkable that adolescents received much less information about cancer prevention ($M = 1.90$, $SD = .94$) in school compared to potential health problems caused of unhealthy behaviors ($M = 3.49$, $SD = 1.19$). While “*The Health Savvy*” and “*The Health Aware Risk-Takers*” clusters are better informed at school about cancer and unhealthy behaviors, “*The Unconcerned and Mostly Healthy*”, “*The Unaware Health Risk-Takers*”, and “*The Health Unaware Abstainers*” are less informed (see Table 12).

The differences in cancer-related information received by the student groups can be attributed, above all, to the variety of schools involved in the survey (around forty). These schools are in both urban and rural areas, and

health education programmes are neither uniform nor equally frequent or effective. Consequently, students' socioeconomic backgrounds and access to information also impact them in different ways.

Table 12. Information at school

		Information about cancer prevention	Information about health risks of unhealthy behaviours
Unconcerned and Mostly Healthy	Mean	1.86	3.22
	SD	.85	1.12
The Health Savvy	Mean	1.97	3.68
	SD	.93	1.17
The unaware health risk-takers	Mean	1.67	3.34
	SD	.91	1.17
The health-aware risk-takers	Mean	1.95	3.65
	SD	1.05	1.08
The health-unaware abstainers	Mean	1.88	3.10
	SD	1.01	1.38

4. Discussion

Taken together, the findings reveal five distinct groups of adolescents, categorised from a psychosocial and contextual perspective. The engagement of these groups in unhealthy behaviours, their perceptions of health, and their awareness of cancer risk reflect lifestyles influenced by different economic and social conditions and norms (see note 'a')

The largest cluster, *Health Savvy*, exemplifies a protective health lifestyle characterised by abstention from unhealthy behaviours, high awareness of cancer-related risks, and excellent self-rated health. Adolescents in this cluster report high health acceptance, strong perceived control over health, and supportive social environments, indicating favourable distributions of psychosocial and relational resources. Their higher exposure to school-based health information suggests closer alignment with institutional health knowledge. Although they perceive cancer as a severe disease, their uncertainty regarding personal susceptibility reflects a common adolescent risk appraisal pattern. This cluster is overrepresented among younger adolescents and those

Social Profiles of Cancer Risk Awareness and Health Behaviours Among
European Adolescents. A Cross-Country Study

Lia Lombardi, Kleio Koutra, Liselot Hudders, Steffi De Jans, Alessandra Sannella,
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living in Spain, Italy, and Romania. From a public health perspective, this group appears relatively advantaged and may be a lower priority for targeted prevention.

In contrast, the two clusters characterised by frequent engagement in unhealthy behaviours illustrate differentiated pathways of social inequality. The *Unaware Health Risk-Takers* cluster combines high behavioural risk with low cancer-risk awareness, poorer health, weaker social support, and reduced perceived control, reflecting cumulative disadvantage across multiple psychosocial dimensions. Their higher perceived susceptibility to cancer suggests risk without agency, positioning this group as particularly vulnerable. The overrepresentation of older adolescents, females, and Italian participants points to the intersection of age, gender, and national contexts in shaping health inequalities. This cluster represents a critical target for interventions addressing both behavioural risk and structural constraints on health-related agency.

The *Health-Aware Risk-Takers* cluster highlights a different inequality mechanism, namely the disjunction between knowledge and behaviour. Despite higher awareness of cancer risks and greater exposure to school-based prevention, adolescents in this group engage most frequently in unhealthy behaviours. Their relatively strong perceived control and positive self-rated health may sustain risk-taking practices embedded within peer cultures and social norms. At the same time, lower health acceptance may indicate openness to behavioural change. This cluster, overrepresented among older adolescents and those from Italy, Switzerland, and Romania, underscores how awareness alone is insufficient to reduce risk in the absence of supportive social conditions.

The remaining two clusters, *Unconcerned and Mostly Healthy* and *Health-Unaware Abstainers*, further illustrate that low behavioural risk does not necessarily correspond to social advantage. Both groups abstain from unhealthy behaviours and report good health but exhibit limited cancer-risk awareness and lower access to health information, indicating forms of symbolic and informational inequality. The *Health-Unaware Abstainers* report lower health acceptance, reduced perceived control, and weaker social support, alongside lower perceived cancer severity and susceptibility. Their overrepresentation among males, adolescents with a migration background, and Greek, Italian, and Swiss participants points to structurally patterned exclusion from health knowledge and resources.

Overall, these findings demonstrate that adolescent health behaviours and cancer-risk perceptions are embedded within broader social and structural contexts. The identified clusters reflect distinct configurations of advantage and disadvantage, reinforcing the need for prevention strategies that move beyond

individualised approaches and address the social determinants underpinning adolescent health inequalities.

5. Practical Implications

Taken together, these findings highlight an uneven landscape of health engagement among European adolescents and indicate where, geographically and demographically, tailored prevention strategies are likely to have the greatest impact.

First, it is noteworthy that the largest cluster in the sample comprises *Health Savvy* adolescents who do not (frequently) engage in unhealthy behaviours, report excellent health, and demonstrate high cancer-risk awareness. These adolescents are among the youngest in the sample, suggesting that reinforcement strategies may be particularly appropriate. Prevention initiatives for this group should aim to consolidate existing healthy behaviours, reinforce abstinence from unhealthy practices, and sustain awareness of cancer-related risks. Their strong perceived social support and high sense of control over health represent important resources that can be leveraged in reinforcing interventions.

Reinforcement-based strategies are also relevant for the smallest cluster, *Health-Unaware Abstainers*. Although adolescents in this group abstain from unhealthy behaviours, they display low awareness of cancer risks and perceive cancer as less severe and themselves as least susceptible compared with other clusters. This group is younger on average and includes a higher proportion of males and adolescents with a migration background. For these adolescents, reinforcing current healthy behaviours should be combined with targeted information on cancer risks and prevention to address informational gaps and misperceptions.

A second key implication concerns the two clusters characterised by frequent engagement in unhealthy behaviours, which predominantly include the oldest adolescents in the sample. The *Unaware Health Risk-Takers* cluster requires interventions focused on increasing awareness of the health risks associated with unhealthy behaviours, particularly smoking, which is most prevalent in this group. Given their poorer self-rated health, lower health acceptance, and reduced perceived control, these adolescents may benefit from practical guidance and skills-based support aimed at enhancing agency and facilitating behaviour change.

In contrast, for the *Health-Aware Risk-Takers*, increasing knowledge about health risks may be less effective, as adolescents in this cluster already demonstrate high risk awareness. Despite this, they engage most frequently in

unhealthy behaviours, suggesting that prevention strategies should address perceived susceptibility and challenge optimistic risk appraisals. This group perceives cancer as less severe than average but reports the highest perceived likelihood of developing cancer later in life. As parents and peers are key sources of health information for these adolescents, interventions should extend beyond the individual to include the broader social environment. Emphasising how changes in health behaviours can reduce cancer susceptibility may be a particularly relevant message for this group.

Finally, the *Unconcerned and Mostly Healthy* cluster may benefit from interventions targeting unhealthy eating behaviours, as adolescents in this group engage in such behaviours while perceiving relatively low cancer-risk associated with them. This cluster, overrepresented among Belgian and Spanish adolescents, should be provided with clear information on the cancer risks of unhealthy dietary practices, alongside practical guidance to support behaviour change. Their relatively high perceived control over health represents a potential facilitator that can be mobilised to promote healthier eating patterns.

6. Conclusion

This study contributes to a growing body of evidence emphasising the role of social determinants in shaping health trajectories from early life by identifying socially and territorially patterned profiles of adolescent health behaviours and cancer-risk awareness. A population health approach to preventing cancer in adolescents must move beyond encouraging individual behavioural changes and address the structural conditions that enable or constrain healthy choices. Equity-oriented, tailored prevention strategies implemented early in adolescence could play a crucial role in reducing future cancer inequalities across Europe.

The limitations of the study

One of the limitations of the study is its cross-sectional design, which only allows associations to be established between behaviours, risk perceptions and health status, rather than causal relationships. In addition, the data are based on self-reports from adolescents, which may be affected by social desirability bias or recall errors, thereby reducing the accuracy of the information collected. Another limitation relates to differences in recruitment procedures across countries, which may have introduced variation in sample composition and affected cross-national comparability.

Finally, while the exclusion of individuals over 18 and the use of clustering techniques are useful for identifying profiles, they involve a degree of arbitrariness in the solutions obtained, thus limiting the generalisability of the findings.

CRedit authorship contribution statement

Lia Lombardi: Conceptualization, Research aims, Writing (review & editing), Original draft, Methodology, Article design, Formal analysis, Presentation of the published work, Visualisation.

Kleio Koutra: Oversight and leadership responsibility, Mentorship external to the core team, Presentation of the published work, Visualization, Writing (Review & Editing), Original Draft.

Liselot Hudders: Methodology design, Creation of models, Data Curation, Formal Analysis, Application of statistical tools and methods, Oversight and leadership responsibility for the research activity, Presentation of the published work, Writing, Original Draft.

Steffi De Jans: Data collection, Original Draft.

Alessandra Sannella: Oversight, Visualisation.

Alessandro Sproviero: Cluster design (first data and draft), Formal Analysis, Application of statistical formal techniques, Supervision of statistical data and results.

Andreas Triantafyllidis: Funding acquisition

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process.

During the preparation of this work the author(s) used Microsoft Copilot and ChatGPT to check grammar and advice on the interpretation of the hierarchical cluster analysis. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Declaration of Interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Social Profiles of Cancer Risk Awareness and Health Behaviours Among
European Adolescents. A Cross-Country Study
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Appendix A. Data collection procedure per country

In **Belgium**, the survey was distributed through email to school principals and teachers who later on distributed the survey via the online school mail platforms to parents and pupils. To boost participation rates, some schools were contacted via telephone to explain the study in detail and ask for their cooperation. A certification of participation was provided to all schools that participated and reached more than five participants. In addition, 10 duo-movie tickets were raffled among the participants.

In **Switzerland**, former and current participants of a local study with students (secondary and upper secondary students) were invited to partake in the survey by SMS. Additionally, schoolteachers from previous studies of the research center, who work with students of the target age group were informed by email about the survey and requested to distribute it among their students. Each participant who completed the survey received an incentive of 10 CHF (approximately 10 Euros).

In **Spain**, the survey was shared through multiple channels depending on the school context. The link was emailed to principals and teachers, who distributed it via school mailing platforms. Some schools allowed completion at home, while others provided access during school hours in computer rooms. The survey was also promoted through newsletters, social media, scout groups, sports clubs, and youth associations. Schools and organizations were contacted online or in person to explain the study and boost participation.

In **Cyprus**, the survey was distributed both face to face and through online platforms. Consent forms for minors were provided directly to parents, students, and educators. School visits were organized to inform management and teachers about the project's goals. The survey was also shared with universities, sports associations, and youth centers. Clear information about the purpose of the survey was provided to participants and parents. These actions aimed to increase awareness and encourage higher participation rates.

In **Italy**, the survey was sent to principals and teachers by email after initial meetings or calls. School leaders requested parental consent for minors or direct consent from students over 18. Distribution occurred mainly through each school's online platforms. In some cases, the link was emailed directly to parents and students. Seven schools administered the survey during school hours in classrooms or computer rooms. All participating schools received a certificate of participation.

In **Greece**, principals were first informed about the survey and procedures. The survey was shared with parents and students via school online mail platforms. Collaborators visited schools daily to oversee and collect completed questionnaires. The survey link was sent electronically to students after parental consent was obtained. Researchers' presence helped clarify doubts and encouraged participation. An empowerment initiative highlighted the survey's importance, and schools received participation certificates.

In **Slovenia**, the survey involved both secondary and primary schools. Schools were personally contacted to obtain consent to participate. Parental consent was collected in paper form, and the survey was conducted at school. Headteachers or social workers distributed the link and consent forms to selected classes. Schools were contacted again by phone or email to confirm cooperation. To expand nationally, invitations were emailed to most grammar and primary schools, often through personal contacts.

In **Romania**, a top-down dissemination strategy was adopted. A formal collaboration was established with the Regional School Inspectorate. The inspectorate distributed the survey and consent forms to secondary schools. Both urban and rural schools were included to ensure a representative sample. Principals were asked to involve teachers in distributing the survey to students. This multi-level approach aimed to maximize reach and ensure effective administration.