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Cancer prevention literacy in Europe: a cross-sectional study

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Abstract

This study aimed to assess cancer prevention literacy (CPL) levels and awareness of the European Code Against Cancer (ECAC) among the adult population in the European Union (EU), as well as identify social determinants associated with CPL. A cross-sectional study was conducted (February–March 2024) via an online survey across 23 EU-countries ($n = 2312$). Multivariate logistic regression models examined associations between explanatory variables (age, gender, educational level, history of cancer, region, and digital health literacy [DHL] quartiles) and knowledge outcomes (CPL, ECAC awareness, and cancer prevention specific knowledge topics). Although 81.4% of participants demonstrated sufficient CPL, 61.1% were unaware of the ECAC. Men were less likely to have sufficient CPL than women (OR = 0.66, [0.49–0.89]), and participants with an education below the university level had lower odds of CPL than those with higher education (OR = 0.50, [0.39–0.64]). DHL was the strongest predictor of CPL, with, participants in the highest DHL quartile being more than three times more likely to have sufficient CPL than those in the lowest quartile (OR = 3.11, [2.12–4.67]). Having a personal or family history of cancer also increased the odds of sufficient literacy (OR = 1.47, [1.10–1.94]). The findings reveal that while overall CPL appears sufficient, ECAC awareness remains alarmingly low. Persistent social and gender inequalities exist; lower educational level, male gender, and older age were consistently associated with lower CPL. DHL emerged as a key CPL determinant. Coordinated and targeted interventions are required to address these social inequalities and maximize the ECAC's preventive impact across Europe.

Introduction

The European Union (EU) has developed a comprehensive framework to reduce the burden of cancer through the Europe's Beating Cancer Plan (EBCP), which includes concrete and ambitious actions that will support, coordinate, and complement member states' efforts to reduce the suffering caused by cancer [1]. The EBCP is centred on the idea that inequalities in cancer prevention and outcomes are unacceptable.

The European Code Against Cancer (ECAC) plays a central role in this policy framework [2]. The ECAC, a European Commission initiative that is scientifically coordinated by the International Agency for Research on Cancer (IARC), provides evidence-based recommendations aimed at reducing individual cancer risk through behavioural and preventive measures. It has been estimated that adhering to ECAC recommendations could prevent approximately 40% of cancer cases in Europe [3]. The fourth edition of the ECAC was published in 2014 [4] and has been the reference cancer prevention communication framework in Europe for over a decade. Although the fifth edition was recently launched, the present study was designed and conducted using the fourth edition as the updated version was not yet available at the time of data collection.

Despite its potential, awareness of the ECAC remains strikingly low among the general population. Only a few studies have systematically evaluated ECAC awareness at the European level, and together they reveal consistent evidence of limited familiarity and implementation [5–9]. Specifically, Ritchie et al. (2021) found very low awareness of the Code among adults, ranging from 2% to 21% across eight European countries, with notable regional variations in dissemination efforts [9]. The EBCP set the ambitious goal of ensuring that 80% of the population was aware of the ECAC by 2025 [1]; however, as of 2026, achieving this target remains a significant challenge, highlighting the need for continued efforts to strengthen dissemination strategies and public engagement.

To support these objectives, the EU has launched several strategic initiatives, such as the 'Boosting the Usability of the EU Mobile App for Cancer Prevention (BUMPER)' project [10] to enhance accessibility and public engagement with the ECAC recommendations through a scientifically developed and user-friendly mobile application for cancer prevention.

A prerequisite for understanding and applying cancer prevention messages is health literacy (HL) [11]. In an increasingly digital world where much health information is accessed online, HL is closely intertwined with digital environments. For this reason, our work focuses specifically on digital health literacy (DHL), which is HL as related to online health information when using digital devices [12]. In the specific context of cancer, cancer literacy describes the knowledge and skills that a layperson must possess to access, understand, and appraise the information and advice provided by the health system concerning cancer prevention, diagnosis, and treatment [13].

Previous research suggests that limited HL is associated with misinterpretation of medical information, inadequate self-management, poorer health outcomes, and higher hospitalization risk [14, 15]. In addition, evidence shows that disadvantaged social and socioeconomic conditions contribute to low HL levels [16, 17].

Despite the recognized importance of HL in cancer prevention, there is still a lack of comprehensive data on cancer prevention literacy (CPL) and awareness of the ECAC among European population. Understanding CPL levels and the associated social factors is essential for tailoring effective public health interventions and improving cancer prevention outcomes. Therefore, this study aimed to assess CPL levels and awareness of the ECAC among the adult population in the EU. In addition, it sought to identify social determinants associated with different CPL levels.

Methods

Study design and population

An observational, descriptive and cross-sectional study was conducted between February and March 2024 to assess CPL and ECAC awareness among the EU population. The study sample comprised 2312 participants (aged ≥18 years) residing in 23 EU countries. Participants were recruited via a self-administered online questionnaire disseminated through social media platforms, partner institutional networks, and citizen associations within the BUMPER project [10] consortium, resulting in a non-probabilistic convenience sample. Participation was voluntary, informed consent was obtained prior to accessing the online questionnaire, and participants could withdraw at any time.

Variables and measures

The questionnaire was designed to assess multiple dimensions related to cancer prevention, including sociodemographic characteristics, DHL, personal and family history of cancer, awareness of the ECAC, and knowledge of evidence-based cancer prevention recommendations, hereafter conceptualized as CPL. The design process was informed by the expertise of the BUMPER project partners and the recommendations of the Health Literacy and Equity Guide for Digital Health Promotion [18].

The question bank was compiled from multiple validated sources, including the Health Information National Trends Survey (HINTS) [19]; the World Health Organization (WHO) [20]; the International Agency for Research on Cancer (IARC) [2]; the Survey of Cancer Risk Behaviours, Beliefs, and Social Drivers of Health in New Hampshire and Vermont [21]; and the Oncobarómetro [22] (Spanish Association Against Cancer). Questions were selected according to their relevance and strength of evidence, with exclusion criteria being a lack of strong supporting evidence and no direct association with cancer prevention.

Sociodemographic variables: age (<35; 35–44; 45–54; >54 years old), gender (female/male), educational level (below university degree; university degree or higher), region of residence (Northern Europe, Eastern Europe, Western Europe, Southern Europe), personal and/or family history of cancer (yes/no).

DHL: assessed through eight items following the Digital Health Literacy European Survey [12] to measure how easily participants can understand digital health information. Scores were calculated as the percentage of valid responses rated 'very easy' or 'easy'. Only participants with at least 80% valid responses were assigned a DHL score; otherwise, the score was considered missing. DHL was categorized into quartiles in four categories.

ECAC awareness: participants reported their prior knowledge of the ECAC, categorized as 'No, I don't know what it is', 'I have heard about it, but I haven't read it', or 'Yes, I have read it'.

Cancer prevention specific knowledge topics: was measured using 26 true/false statements related to the 4th Edition of the ECAC. Responses were coded as correct (right) or incorrect (wrong and 'I don't know' combined). These statements were grouped into 13 ECAC topics: smoking, second-hand smoke exposure, healthy bodyweight, physical activity, diet and nutrition, alcohol consumption, sun and ultraviolet (UV) exposure, environmental and occupational pollutants, radiation, breastfeeding, hormone replacement therapy (HRT), vaccination and infections, and cancer screening. Each topic was assessed with two statements. The variable was classified as low (0/2 correct), medium (1/2 correct), or high (2/2 correct) for each cancer prevention specific knowledge topic.

CPL: The primary outcome, was computed as the percentage of correct responses across all 26 items and categorized as insufficient (<50% correct) or sufficient (≥50% correct). This 50% threshold was established as a pragmatic operational cut-off to indicate baseline familiarity with at least half of the evidence-based recommendations, in the absence of a pre-validated standard metric for this specific item pool.

Statistical analysis

Descriptive statistics and contingency tables were used to characterize the sample and the distribution of ECAC awareness and CPL. Bivariate associations between sociodemographic variables and knowledge outcomes were assessed using chi-square tests.

Multivariate logistic regression models were constructed to examine the association between explanatory variables (age, gender, educational level, personal and/or family history of cancer, region, and DHL quartile) and knowledge outcomes (CPL and their cancer prevention specific knowledge levels). Fourteen separate models were estimated for each topic plus one model for CPL, all with insufficient knowledge as the reference category. Results are reported as odds ratios (ORs) with 95% confidence intervals (CIs).

To evaluate potential selection bias arising from the sample's demographic and geographical imbalances, stratified analyses were systematically conducted by gender, educational level, and region of residence. Analyses were performed using R software version 4.4.2 (R Core Team, 2025).

Results

Table 1 presents the characteristics of the 2312 participants and the bivariate associations with CPL. Overall, the mean percentage of correct CPL responses was 0.64 (not shown in the table). In total 81.4% of the sample was classified as having sufficient CPL, while 18.6% showed an insufficient level. Participants were relatively evenly distributed across age groups, and while differences in CPL by age did not reach statistical significance, a marginal association was observed ($P = .064$). The sample was predominantly female (81.73%) and a statistically significant association was found between gender and CPL ($P < .001$), with women more frequently demonstrating sufficient literacy than men (83.1% vs. 74.2%). Most respondents resided in Southern Europe (59.5%), followed by Western (15.7%), Eastern (13.3%), and Northern (11.4%) Europe. Regional differences in CPL were statistically significant ($P < .001$), with the highest proportion of

Table 1. Sample characteristics and bivariate analysis

Sample characteristics	Total sample *N* (%) = 2312 (100%)	Insufficient CPL *N* (%) = 430 (18.6%)	Sufficient CPL *N* (%) = 1882 (81.4%)	*P*-value[a]
Age (years)				.064
<35	654 (28.42%)	133 (20.34%)	521 (79.66%)	
35–44	502 (21.82%)	91 (18.13%)	411 (81.87%)	
45–54	498 (21.64%)	103 (20.68%)	395 (79.32%)	
>54	647 (28.12%)	100 (15.46%)	547 (84.54%)	
Gender				<.001
Female	1874 (81.73%)	316 (16.86%)	1558 (83.14%)	
Male	426 (18.50%)	110 (25.82%)	316 (74.18%)	
Other	3 (0.13%)	2 (66.67%)	1 (33.33%)	
Region of residence				<.001
Northern Europe	262 (11.44%)	14 (5.34%)	248 (94.66%)	
Eastern Europe	305 (13.31%)	43 (14.10%)	262 (85.90%)	
Southern Europe	1363 (59.52%)	285 (20.91%)	1078 (79.09%)	
Western Europe	360 (15.72%)	84 (23.33%)	276 (76.67%)	
Educational level				<.001
University degree or higher	1587 (68.64%)	241 (15.19%)	1346 (84.81%)	
Below university degree	725 (31.36%)	189 (26.07%)	536 (73.93%)	
DHL (quartile)				<.001
<37.6 (lowest)	693 (32.10%)	178 (25.69%)	515 (74.31%)	
37.6-62.5	520 (24.09%)	91 (17.50%)	429 (82.50%)	
62.6-87.5	508 (23.53%)	66 (12.99%)	442 (87.01%)	
>87.5 (highest)	438 (20.29%)	38 (8.68%)	400 (91.32%)	
Personal or family history of cancer				.001
No	450 (19.58%)	106 (23.56%)	344 (76.44%)	
Yes	1848 (80.42%)	321 (17.37%)	1527 (82.63%)	
ECAC awareness				<.001
No awareness	1413 (61.12%)	310 (21.94%)	1103 (78.06%)	
Aware, but not read	679 (29.37%)	107 (15.76%)	572 (84.24%)	
Read	220 (9.52%)	13 (5.91%)	207 (94.09%)	

Sociodemographic factors associated with cancer prevention literacy.
DHL, Digital Health Literacy.
a: Wilcoxon rank sum test; Pearson's Chi-squared test with simulated *P*-value (based on 2000 replicates).

sufficient CPL observed in Northern Europe (94.7%) and the lowest in Western Europe (76.7%). Regarding educational level, 68.6% of participants held a university degree or higher. Educational attainment was positively associated with CPL ($P < .001$) and 84.8% of participants with a higher educational level had sufficient CPL compared with 73.9% of those with lower educational levels. DHL scores were distributed across quartiles (32.1%, 24.1%, 23.5%, and 20.3%, respectively) and showed a clear positive gradient with CPL ($P < .001$). The proportion of sufficient CPL increased steadily from 74.3% in the lowest DHL quartile to 91.3% in the highest. Personal or family history of cancer was reported by 80.4% of participants and was significantly associated with sufficient CPL (82.6% vs. 76.4%; $P = .001$). Awareness of the ECAC was limited: 61.1% were unaware of it, 29.4% had heard of it but not read it, and 9.5% had read it. ECAC awareness was strongly associated with CPL ($P < .001$), and sufficient CPL was most frequently found among those who had read the ECAC (94.1%), followed by those who were aware of the ECAC but had not read it (84.2%) and those who were not aware of it (78.1%).

Table 2 presents participant characteristics according to ECAC awareness, classified as 'No awareness', 'Aware but not read', and 'Read'. Overall, significant associations were observed between ECAC awareness and age, gender, region of residence, educational level, DHL, and CPL. Age differences were found ($P < .001$): the oldest group (aged >54 years) were more likely to have read the ECAC (39.8%), whereas the majority of participants in the 'No awareness' category belonged to the youngest age group (31.5%). Gender differences were statistically significant ($P = .008$). Women accounted for 79.5% of the 'No awareness' group, 84.2% of the 'Aware but not read' group, and 86.1% of the 'Read' group. Regional differences were evident ($P < .001$): Eastern Europeans accounted for 24.9% of those who had read the ECAC compared with 9.0% of the 'No awareness' group, while Western Europeans were more common among the 'No awareness' group (19.6%) than the 'Read' group (4.7%). A higher educational level was associated with ECAC awareness, with 77.3% of readers holding a university degree versus 69.6% in the 'No awareness' group. Furthermore, DHL showed a strong positive gradient ($P < .001$): participants in the highest DHL quartile were overrepresented among those who had read the ECAC (34.0%) compared with those who were unaware of it (15.7%), while individuals in the lowest quartile were more frequent among the 'No awareness' group (35.4%) than the 'Read' group (25.9%). Finally, CPL was strongly associated with ECAC awareness ($P < .001$). The proportion of participants with sufficient CPL increased progressively from 78.1% of those who were unaware of the ECAC to 94.1% of those who had read it.

Figure 1 presents adjusted odds ratios with 95% CIs from multivariable logistic regression analyses examining associations between sociodemographic factors, DHL, personal or family history of cancer, and CPL, adjusted for region of residence. In particular, gender and educational level were significant predictors of CPL. Men had lower odds of having sufficient CPL than women (0.66 [0.49, 0.89]), and participants with an education below the university level were less likely to demonstrate sufficient literacy compared to those with a university degree or higher (0.50 [0.39, 0.64]). DHL exhibited a strong positive gradient, as higher quartiles were associated with progressively increasing odds of sufficient CPL. Participants in the highest quartile (>87.5) were more than three times more likely to have sufficient CPL than those in the lowest quartile (3.11 [2.12, 4.67]), indicating a clear dose–response association. Personal or family history of cancer was also positively associated with CPL. Individuals reporting a history of cancer had higher odds of sufficient literacy than those without such a history (1.47 [1.10, 1.94]). Finally, age was not significantly associated with CPL after adjusting for other covariates, although participants aged over 54 tended to have slightly higher odds compared with the youngest group (1.18 [0.82, 1.68]).

Table 2. Population characteristics according to ECAC awareness

	No awareness *N* (%) = 1413 (61.1%)	Aware but not read *N* (%) = 679 (29.4%)	Read *N* (%) = 220 (9.5%)	*P*-value[a]
Age (years)				<.001
<35	444 (31.49%)	160 (23.70%)	50 (23.15%)	
35–44	350 (24.82%)	129 (19.11%)	23 (10.65%)	
45–54	299 (21.21%)	142 (21.04%)	57 (26.39%)	
>54	317 (22.48%)	244 (36.15%)	86 (39.81%)	
Gender				.008
Female	1120 (79.49%)	569 (84.17%)	185 (86.05%)	
Male	289 (20.51%)	107 (15.83%)	30 (13.95%)	
Region of residence				<.001
Northern Europe	146 (10.39%)	94 (13.99%)	22 (10.33%)	
Eastern Europe	127 (9.04%)	125 (18.60%)	53 (24.88%)	
Southern Europe	856 (60.93%)	379 (56.40%)	128 (60.09%)	
Western Europe	276 (19.64%)	74 (11.01%)	10 (4.69%)	
Educational level				.001
University degree or higher	984 (69.64%)	433 (63.77%)	170 (77.27%)	
Below university degree	429 (30.36%)	246 (36.23%)	50 (22.73%)	
DHL (quartiles)				<.001
<37.6 (lowest)	465 (35.39%)	173 (27.33%)	55 (25.94%)	
37.6–62.5	334 (25.42%)	153 (24.17%)	33 (15.57%)	
62.6–87.5	309 (23.52%)	147 (23.22%)	52 (24.53%)	
>87.5 (highest)	206 (15.68%)	160 (25.28%)	72 (33.96%)	
Level of CPL				<.001
Insufficient	310 (21.94%)	107 (15.76%)	13 (5.91%)	
Sufficient	1103 (78.06%)	572 (84.24%)	207 (94.09%)	

DHL, Digital Health Literacy; CPL, Cancer prevention literacy.
a: Wilcoxon rank sum test; Pearson's Chi-squared test with simulated *P*-value (based on 2000 replicates).

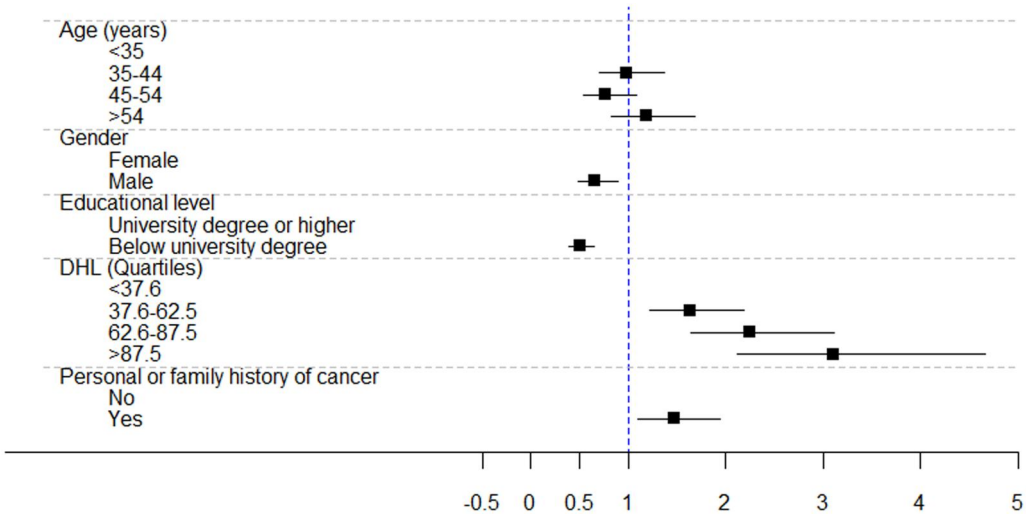

Figure 1. Multivariable analysis of cancer prevention literacy. Adjusted for region of residence. DHL, Digital Health Literacy; OR, odds ratio; CI, confidence interval.

Several notable patterns were found in the cancer prevention specific knowledge topics (Table 3). Older participants (i.e. >54 years old) compared to the youngers (i.e. <35 years old) were more likely to have knowledge on pollution (2.41 [1.06, 5.88]), radiation (1.44 [1.04, 1.98]), breastfeeding (2.41 [1.06, 5.88]), and screening (3.20, [1.96, 5.40]). Conversely, older age was associated with lower odds of having knowledge on diet (0.45 [0.33, 0.62]) and alcohol consumption (0.58 [0.38, 0.88]). Men compared to women were less likely to have knowledge about UV exposure (0.33 [0.13, 0.85]), breastfeeding (0.52 [0.40, 0.66]), HRT (0.51 [0.40, 0.65]) and vaccination (0.75 [0.59, 0.96]). Participants with an education below the university level compared to those with university degree or higher had reduced odds across multiple domains, including smoking (0.54 [0.35, 0.85]), second-hand smoke exposure (0.52 [0.35, 0.77]), pollution (0.47 [0.26, 0.83]), radiation (0.64 [0.51, 0.81]), breastfeeding (0.62 [0.51, 0.76]), vaccination (0.62 [0.51, 0.76]), and screening (0.62 [0.46, 0.86]). DHL showed strong positive associations. Participants in the highest quartile compared to those in the lowest quartile had markedly higher odds of having knowledge on smoking (6.17 [2.65, 18.0]), healthy bodyweight (2.50 [1.81, 3.51]), physical activity (1.95 [1.43, 2.67]), diet (2.01 [1.49, 2.73]), HRT (2.51 [1.92, 3.28]), vaccination (2.11 [1.59, 2.83]), and screening (1.87 [1.17, 3.09]). Personal or family history of cancer was associated with higher odds of knowledge regarding pollution (2.73 [1.50, 4.86]), but was not significantly associated with other domains.

Supplementary Table S1 shows the stratified analyses by gender, educational level, and region of residence. The directional associations and statistical significance of the main predictors remained consistent across all strata, supporting the internal validity and robustness of the non-stratified multivariable model results.

Table 3. Multivariable analysis of population characteristics associated with cancer prevention specific knowledge topics

	Smoking	Second-hand smoke	Healthy bodyweight	Physical activity	Diet	Alcohol
Age (years)						
<35	Ref	Ref	Ref	Ref	Ref	Ref
35–44	0.47 (0.22, 0.96)	0.69 (0.40, 1.18)	0.83 (0.62, 1.11)	0.85 (0.63, 1.13)	0.58 (0.42, 0.80)	0.97 (0.63, 1.51)
45–54	0.28 (0.14, 0.55)	0.85 (0.47, 1.51)	0.86 (0.63, 1.17)	0.77 (0.57, 1.05)	0.51 (0.37, 0.70)	0.65 (0.42, 0.99)
>54	0.60 (0.28, 1.23)	1.01 (0.57, 1.80)	1.18 (0.86, 1.62)	0.89 (0.66, 1.21)	0.45 (0.33, 0.62)	0.58 (0.38, 0.88)
Gender						
Female	Ref	Ref	Ref	Ref	Ref	Ref
Male	0.63 (0.37, 1.11)	0.92 (0.56, 1.57)	0.86 (0.66, 1.12)	1.11 (0.85, 1.46)	0.80 (0.61, 1.06)	0.73 (0.51, 1.05)
Educational level						
University degree or higher	Ref	Ref	Ref	Ref	Ref	Ref
Below university degree	0.54 (0.35, 0.85)	0.52 (0.35, 0.77)	0.72 (0.58, 0.90)	0.77 (0.62, 0.96)	0.50 (0.40, 0.62)	0.83 (0.60, 1.10)
DHL (quartiles)						
<37.6	1.00	1.00	1.00	1.00	1.00	1.00
37.6–62.5	1.68 (1.01, 2.86)	1.02 (0.64, 1.65)	1.37 (1.05, 1.79)	1.25 (0.96, 1.62)	1.61 (1.23, 2.11)	1.29 (0.90, 1.87)
62.6–87.5	2.58 (1.44, 4.95)	1.60 (0.94, 2.81)	1.54 (1.17, 2.02)	1.31 (1.00, 1.71)	1.70 (1.29, 2.24)	1.12 (0.78, 1.60)
>87.5	6.17 (2.65, 18.0)	1.34 (0.77, 2.43)	2.50 (1.81, 3.51)	1.95 (1.43, 2.67)	2.01 (1.49, 2.73)	2.12 (1.35, 3.42)
Personal or family history of cancer						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.41 (0.81, 2.35)	1.35 (0.84, 2.10)	1.15 (0.88, 1.48)	1.24 (0.96, 1.59)	1.18 (0.91, 1.53)	0.93 (0.64, 1.33)

	UV exposure	Pollution	Radiation	Breastfeeding	HRT	Vaccination	Screening
Age							
<35	Ref	Ref	Ref	Ref	Ref	Ref	Ref
35–44	1.61 (0.52, 6.02)	1.60 (0.78, 3.43)	0.99 (0.73, 1.33)	1.61 (1.23, 2.10)	0.88 (0.68, 1.13)	0.86 (0.66, 1.14)	1.28 (0.88, 1.89)
45–54	3.35 (0.79, 23.0)	3.11 (1.27, 8.81)	1.01 (0.74, 1.38)	1.31 (1.00, 1.73)	0.96 (0.73, 1.25)	0.80 (0.60, 1.06)	1.95 (1.25, 3.11)
>54	2.14 (0.62, 8.76)	2.41 (1.06, 5.88)	1.44 (1.04, 1.98)	1.62 (1.24, 2.13)	1.13 (0.86, 1.47)	0.71 (0.54, 0.94)	3.20 (1.96, 5.40)
Gender							
Female	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Male	0.33 (0.13, 0.85)	0.89 (0.46, 1.80)	1.16 (0.87, 1.56)	0.52 (0.40, 0.66)	0.51 (0.40, 0.65)	0.75 (0.59, 0.96)	0.74 (0.52, 1.08)
Educational level							
University degree or higher	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Below university degree	0.30 (0.12, 0.73)	0.47 (0.26, 0.83)	0.64 (0.51, 0.81)	0.62 (0.51, 0.76)	0.93 (0.76, 1.14)	0.62 (0.51, 0.76)	0.62 (0.46, 0.86)
DHL (quartiles)							
<37.6 (lowest)	Ref	Ref	Ref	Ref	Ref	Ref	Ref
37.6–62.5	1.43 (0.50, 4.66)	2.00 (1.02, 4.15)	1.29 (0.98, 1.70)	1.15 (0.90, 1.46)	1.24 (0.98, 1.57)	1.20 (0.94, 1.53)	1.37 (0.94, 2.01)
62.6–87.5	3.49 (0.90, 23.0)	4.06 (1.77, 11.0)	1.48 (1.11, 1.96)	1.40 (1.10, 1.80)	1.65 (1.30, 2.11)	1.28 (1.00, 1.65)	1.58 (1.07, 2.38)
>87.5 (highest)	1.05 (0.34, 3.97)	3.06 (1.26, 9.18)	1.70 (1.24, 2.35)	2.00 (1.52, 2.63)	2.51 (1.92, 3.28)	2.11 (1.59, 2.83)	1.87 (1.17, 3.09)
Personal or family history of cancer							
No	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Yes	1.56 (0.56, 3.93)	2.73 (1.50, 4.86)	1.10 (0.84, 1.43)	1.09 (0.86, 1.37)	0.90 (0.72, 1.14)	1.19 (0.94, 1.50)	0.96 (0.65, 1.38)

(OR), CIs, Adjusted for region of residence. Ref: Reference; DHL, Digital Health Literacy.

Discussion

The findings of this study show that, although CPL levels were generally sufficient in the surveyed sample across the EU, awareness of the ECAC was low. Furthermore, social inequalities were observed, suggesting persistent differences in access to and understanding of cancer prevention information. More than 60% of participants reported that they were unaware of the ECAC, highlighting a shortfall in the dissemination and visibility of this key public health resource, while also indicating that population-level capacity to engage with prevention guidance remains uneven. Given the central role of the ECAC in EBCP [1], these findings underscore the importance of CPL as a prerequisite for ECAC uptake. They point to ongoing challenges in integrating the Code into preventive strategies, health education, and clinical practice. These results are consistent with previous research demonstrating low ECAC awareness levels across Europe. Thus, the multi-country omnibus survey conducted by the Association of European Cancer Leagues (ECL) in 2015 found that only 10% of respondents across five EU member states had heard of the ECAC, with wide variation between countries ranging from 1% in the UK to 17% in Poland [7]. Evidence from Ritchie et al. [9] further reinforces the low level of ECAC awareness across Europe, with only 21% of respondents having heard of the ECAC in a multi-country study across eight European countries with data collection in 2017. Similarly, single-country studies also found low awareness levels among the general public in Sweden (4%) in 2024 [5], as well as among Spanish medical and nursing students and family medicine residents (23.2%) between 2016 and 2017 [6], despite the fact that the latter are future or current health professionals. Another Spanish study with data collection in 2017 showed that eight out of ten medical and nursing students and half of primary care professionals did not know about the ECAC [8], underscoring persistent deficits in professional training and dissemination.

Age emerged as an important determinant of CPL and topic-specific knowledge. Older participants showed consistently lower knowledge regarding diet, alcohol consumption, and other modifiable risk factors. Previous evidence indicates that older adults exhibit lower cancer awareness [23]. This pattern indicates that age-related disparities may limit engagement with contemporary cancer prevention messages and highlights the need for age-tailored communication strategies.

Gender differences were also evident. Women demonstrated higher overall CPL and greater awareness across several domains, particularly breastfeeding, HRT, and vaccination. In line with previous multi-country findings [9], women appear to be more motivated to adopt preventive behaviours and more engaged with health information. In contrast, men showed lower odds of having sufficient CPL, reinforcing evidence of gender gaps in preventive knowledge and engagement.

Educational level showed a strong and consistent association with CPL. Participants with an education below the university level had significantly lower odds of having sufficient CPL and demonstrated reduced knowledge across multiple domains, including smoking,

second-hand smoke exposure, healthy bodyweight, diet, physical activity, UV exposure, pollution, radiation, vaccination, and cancer screening. These findings suggest the presence of a social gradient in cancer prevention knowledge, in line with previous European research [7], and reflect structural inequalities that shape access to and understanding of health information.

DHL was the most consistent and robust predictor of sufficient CPL. A clear dose–response association was observed across DHL quartiles, with participants in higher quartiles showing substantially greater odds of achieving sufficient CPL. This highlights the central role of digital competencies in accessing, understanding, and critically appraising cancer prevention information in an increasingly digital health environment. DHL appears to function as a key enabling factor that amplifies the benefits of formal education and facilitates engagement with prevention guidance such as the ECAC.

These findings are aligned with a broader evidence base showing that socioeconomic position and health literacy are central determinants of cancer-related knowledge, beliefs, and preventive behaviours across countries. A consistent pattern emerges in the literature: individuals with a lower socioeconomic status or lower health literacy tend to be less capable of recognizing cancer symptoms and risk factors, hold more fatalistic beliefs about cancer outcomes, and are more likely to endorse misinformation, all of which contribute to delayed help-seeking and lower engagement in prevention activities. Recent studies in Spain [24, 25], the UK [26], and the United States [14, 15] demonstrate persistent social gradients in cancer knowledge and fatalistic beliefs, reinforcing the conclusion that structural and educational inequalities shape unequal opportunities to understand and act upon cancer prevention recommendations.

Despite sufficient knowledge of cancer prevention recommendations, awareness of the ECAC remained low (61.1% unaware). This suggests that evidence-based cancer prevention messages are reaching the population, but not under the ECAC. At the same time, our findings indicate that having read the ECAC may contribute to higher CPL. Strengthening the visibility of the ECAC as a unified and trusted framework could complement existing communication efforts and further support CPL.

Furthermore, the association found in our study between DHL and CPL highlights the potential of digital tools to reduce inequalities in cancer prevention. When designed with usability, accessibility, and evidence-based content in mind, mobile apps and online platforms can increase engagement with preventive recommendations and support informed decision-making.

This study's wide geographic coverage, including participants from 23 EU countries is a major strength. Furthermore, in light of our findings and the existing evidence, a set of highly visual and easy-to-understand factsheets was developed to improve public awareness of the ECAC, including an overview of its 12 recommendations and topic-specific materials on key prevention areas. These materials are freely available in all EU languages to support informed decision-making [27].

Nevertheless, this study has some limitations due to the overrepresentation of women, individuals with university education, and participants from Southern Europe in the study sample, the descriptive percentages reported here should not be considered definitive baseline estimates for the general adult population of the European Union. Nevertheless, the internal validity of our findings is supported by the consistency of the stratified analyses by gender, educational level, and region, which showed that the identified social and digital gradients remained stable across demographic and regional subgroups. In addition, the online format likely excluded digitally disconnected populations, potentially underestimating CPL inequalities. In addition, the cross-sectional design precludes causal inferences regarding the association between DHL and CPL. Although CPL is recognized as essential for cancer prevention, comparable European data on CPL and ECAC awareness remain scarce, largely due to the absence of standardized measurement tools, an issue recently addressed with the development of the Cancer Prevention Literacy Questionnaire [28]. As this instrument was unavailable at the time of study design, our questionnaire combined items from multiple validated sources.

In summary, female gender, higher educational level, and DHL were the strongest and most consistent predictors of overall CPL and topic-specific knowledge, whereas lower educational level, male gender, and older age were associated with reduced knowledge across multiple domains. DHL showed the most consistent effect, highlighting its importance for improving cancer prevention awareness. Although overall CPL levels appear sufficient, significant social and gender inequalities continue to exist, underscoring the need for coordinated, accessible, and equity-oriented strategies to maximize the preventive potential of the ECAC and reduce the cancer burden across European populations.

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Author contributions

Paula Romeo-Cervera: questionnaire design, questionnaire dissemination, data analysis, interpretation of results, and manuscript writing. Mercedes Vanaclocha-Espí: data analysis and interpretation. Marina Pinto-Carbó, Teresa de Pablo-Pardo, Furqan Ahmed, Teresa Seum, Cristiana Fonseca, and Stephan Van den Broucke: contributed to questionnaire design, questionnaire dissemination, and interpretation of results. Helena Ros Comesana: questionnaire dissemination. Mireia Gandía-Prat and Óscar García-Sauret: contributed to the study. Maria-Jose Lopez-Espinosa: data analysis and interpretation. Ana Molina-Barceló: questionnaire design, dissemination, data analysis, interpretation of results, and overall supervision. All authors critically reviewed and approved the final manuscript and provided valuable input and suggestions for improvement.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Ethical consideration

The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and relevant Spanish and European legislation on biomedical research and data protection. Participants were fully informed about the study objectives, context, and estimated time for completion. Participation was entirely voluntary, and participants could withdraw at any time without providing any explanation.

Before accessing the online questionnaire, all participants provided informed consent through the statement:

'Your participation in this study is completely voluntary. You may withdraw at any time without giving any reason. The data you provide will be treated confidentially in accordance with the Spanish Organic Law 3/2018 on the protection of personal data and guarantee of digital rights. You have the right to access, oppose, correct, cancel, limit processing, restrict, or request deletion of your data. You may also request a copy of your data or transfer it to a third party. Complaints can be submitted to the Spanish Data Protection Agency if your rights are not respected. The principal investigator, Dr. Ana Molina Barceló, Coordinator of the Cancer and Public Health Research Area at FISABIO, will provide any additional information you may require. For inquiries, please contact bumper-app@fisabio.es'.

Only participants who selected 'Yes, I agree' were included in the study. Those who declined were not allowed to access or complete the online questionnaire. The survey was designed respectfully, using clear and simple language suitable for all educational levels. No personally identifiable information was collected, and the resulting database was fully anonymized. Data access was restricted to authorized personnel only and stored on FISABIO's central servers in Valencia, which comply with current ethical and legal standards, include user-based access controls, and keep backups for 5 years. Project partners and collaborating citizen associations only disseminated the online questionnaire link and had no access to the collected data.

There was no planned follow-up contact with participants. The study protocol was submitted to the Ethics Committee and was not implemented until full approval was obtained. The study received a favourable ethical opinion from the Research Ethics Committee of FISABIO (CEI-SP, Ref 20231219/07, 19 December 2023).

Data availability

The data supporting the findings of this study are available upon request from the corresponding author.

Key points

- Although 81.4% of participants demonstrated sufficient CPL, 61.1% were unaware of the ECAC.
- Participants with a university degree or higher were significantly more likely to have sufficient CPL (84.8%) compared to those with an education below university level (73.9%), highlighting education as a key determinant of cancer prevention knowledge.
- Higher DHL was associated with substantially increased odds of sufficient CPL, showing a clear dose–response association; participants in the highest DHL quartile were three times more likely to have sufficient CPL than those in the lowest quartile.
- Persistent social and gender inequalities exist: lower educational level, male gender, and older age were consistently associated with lower CPL.

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