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Original Research

Awareness and perceived educational needs regarding personalised medicine: Cross-country differences from a European survey

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ABSTRACT

Objectives: Health literacy is a well-known determinant of health outcomes and it is shaped by social and economic factors, with lower levels linked to decreased disease-specific knowledge and preventive health service utilization. Given rapid advancements in healthcare technology, particularly the rise of Personalised Medicine (PM) and the proliferation of genetic testing, enhanced health literacy is increasingly essential for making optimal use of these innovations.
Study design: Cross-sectional study.
Methods: We conducted a cross-sectional survey with 6581 participants from eight European Countries. The survey assessed awareness and perceived educational needs regarding PM and related technologies (genetic testing and digital health solutions) as elements of health literacy. Demographic factors such as age, education level, and geographical origin were analysed to determine their influence on the topics of interest.
Results: The findings indicate a high level of awareness regarding genetic testing (80.53%) and digital health solutions (54.29%), but lower familiarity with PM (47.76%). Overall, 41.88% of participants reported a high level of awareness. Despite 71.69% acknowledging the relevance of PM for individual health, a majority found information on the topic difficult to access (65.54%) and felt insufficiently informed (65.29%). Overall, 33.02% indicated that they were sufficiently informed about PM and related technologies.
Conclusions: Educational attainment emerged as a significant factor influencing awareness, with tertiary education being positively associated with higher awareness and lower educational needs in these areas. Additionally, the study revealed significant gender and country-specific variations in health literacy levels, with respondents from Hungary and Netherlands reporting higher awareness and lower educational needs.
Amid the exponential increase in health-related information and technologies, the findings underscore the critical need for targeted educational initiatives to improve health literacy and address citizens' needs.

1. Introduction

Health literacy—the ability to access, understand, and use health information effectively[1]—is a critical determinant of health outcomes and equity.[2,3] Limited health literacy is associated with lower disease-specific knowledge, reduced use of preventive services, higher incidence of chronic conditions, and increased mortality risk.[4–7] The European Health Literacy Survey (HLS-EU) revealed that socially disadvantaged groups, including those with lower education, income, or employment stability, are more likely to have inadequate health literacy.[8]

Over the past two decades, access to health-related information has grown exponentially, driven by digital advancements and the emergence of Personalised Medicine (PM).[9] p.m. utilises molecular profiling, medical imaging, and lifestyle data to tailor treatments to individuals.[10] The increasing availability of genetic testing and digital health solutions allow patients to collect, manage, and interpret personal health data, fostering greater involvement in their own healthcare decisions.[11]

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However, this shift requires enhanced health and digital literacy, which remains a challenge for many.[12–14]

In addition to health literacy, genetic literacy plays a crucial role in understanding genetic testing and its limitations.[15] Low genetic literacy can hinder informed decision-making, particularly among socially disadvantaged groups, exacerbating health disparities.[16,17] For example, linguistic and cultural barriers can discourage certain populations from undergoing genetic testing,[18] while individuals with lower education levels may struggle to interpret their genetic risk for diseases such as melanoma.[19]

As citizens become more active stakeholders in their health, they seek accessible health data, clear genetic information, privacy protection, and meaningful participation in healthcare decisions.[20] At the same time, concerns about data ownership, algorithmic transparency, and the potential for PM to widen health inequalities highlight the need for inclusive governance and public engagement.[21–23]

Health literacy is a multidimensional construct encompassing the ability to access, understand, appraise, and apply health-related information to make informed decisions.[1,8] Within this framework, awareness of PM – including genetic testing and digital health solutions – represents a specific and emerging domain of health literacy. The HLS-EU survey instrument operationalises health literacy across four core dimensions (access, understand, appraise, apply) and across three health domains (healthcare, disease prevention, health promotion).[8] Extending this model to PM-related knowledge is both conceptually grounded and practically relevant, as citizens who lack awareness of PM are less equipped to participate in shared clinical decision-making, to engage with direct-to-consumer genetic services, or to benefit equitably from innovations in precision health. In this study, 'awareness' and 'educational needs' are treated as distinct, though related, constructs: awareness refers to self-reported knowledge of PM concepts and tools, while educational needs refer to respondents' perceived desire for further information or training. High awareness does not preclude educational needs, and low awareness does not automatically translate into expressed need for education.

While previous studies within the HLS-EU framework have examined health literacy in general, they have not specifically addressed PM, genetic testing or digital health literacy as distinct concepts. Therefore, the novelty of these findings significantly contributes to our understanding of health literacy by exploring its newest and most complex aspects.

The European network staff eXchange for integrating precision health in Health Care Systems (ExACT) project,[24] a EU Horizon 2020-funded staff exchange programme, provided the specific context and rationale for designing a cross-national survey focused on these dimensions.

This study explores elements of health literacy by assessing awareness and perceived educational needs regarding PM and related technologies across eight European countries (Italy, Netherlands, France, Germany, Spain, Poland, Romania, and Hungary). It builds on earlier research[25] and extends to a survey of the Italian population.[26] To our knowledge, no prior cross-national survey has combined PM awareness, genetic testing familiarity, digital health solutions, and perceived educational needs within a single instrument administered simultaneously across eight European countries. This study therefore fills a gap in the existing literature, providing a baseline measurement that can inform both policy and future longitudinal research.

2. Methods

We designed a 37-question web questionnaire and divided it into four primary sections to investigate various aspects. Module A: knowledge and attitudes about PM; Module B: Genomic and health data sharing and use; Module C: governance; Module D: needs of users. We engaged the private company YouGov to disseminate the survey using YouGov's polling platform (https://yougov.co.uk/about/panel-methodology). We distributed the survey over a period of two weeks in April 2023. We selected participants for the YouGov survey based on demographic information to reflect the population distribution of their respective countries in terms of gender, age, and education level. The questionnaire's design and delivery methods is comprehensively described in a previously published manuscript[27] and this particular methods section is dedicated to the data preprocessing and analysis relevant to the specific objective of the study. YouGov employs a proprietary weighting methodology to ensure survey results are representative of the adult population in each participating country; data are weighted by age, gender, education, and region in line with national census data, and all results in the present study use these pre-computed, nationally representative weights. Full documentation of YouGov's sampling and weighting approach is publicly available at https://yougov.co.uk/about/panel-methodology.

For the specific purposes of this study, we restricted the analysis on part of the questionnaire, mostly Module A and D (full list of questions used in Supplementary File).

2.1. Development of indicators

We used some questions from the two modules to construct indicators for awareness and educational needs, following Hosmer and Lemeshow's methodology (Supplementary File: Table 1).

We constructed the "Awareness on PM and related technologies" indicator using responses from questions 1, 2, and 7, (Table 1). Similarly, we based the "Educational Needs on PM and related technologies " indicator on questions 28, 29, 31, and 32 (Table 1). We simplified the variables "*awareness on PM and related technologies*" and "*educational needs on PM and related technologies*", which initially consisted of multiple categories, into two levels, coding them as binary variables. In this context, the term "related technologies" refers specifically to genetic testing and digital health solutions (big data, health/patient portals) within the broader scope of PM. This collapsing was not performed solely for analytical convenience: in several instances, the original response scale yielded categories with insufficient cell counts to allow stable estimation, particularly in country-stratified analyses. Dichotomisation was therefore necessary to ensure analytical reliability and cross-country comparability. We acknowledge this choice as a limitation and discuss it accordingly.

We assigned a score of 1 to responses coded as "Yes", while assigning 0 to "No" or "Don't know" responses. We classified respondents who scored ≥75% on a given indicator as having higher awareness or lower educational needs, depending on the indicator. From a health literacy measurement perspective, both "No" and "Don't know" responses indicate the absence of awareness or knowledge, and are therefore operationally equivalent for the purposes of this study: a respondent who does

Table 1
Sample descriptive analysis (N = 6581).

Characteristics		Mean	SD
Age		48.49	15.96
		N	**%**
Gender	Male	3123	47.45
	Female	3458	52.55
Achieved tertiary education	No	4086	62.09
	Yes	2495	37.91
Country	France	1008	15.32
	Germany	1009	15.33
	Hungary	510	7.75
	Italy	1022	15.53
	Netherlands	1012	15.38
	Poland	509	7.73
	Romania	508	7.72
	Spain	1003	15.24
Awareness on PM and related technologies	No	3825	58.12
	Yes	2756	41.88
Educational needs on PM and related technologies	No	4408	66.98
	Yes	2173	33.02

not know whether they have heard of PM is, in terms of PM literacy, indistinguishable from one who has not. This coding approach is consistent with analogous instruments in the health literacy literature. The ≥75% threshold was informed by the 80% cut-off adopted by Sørensen et al. (2015)[28] and by other surveys using analogous composite indicator methodology.[29] Given the number of items composing each indicator in the present study, the 75% threshold allowed classification based on whole-number scores, avoiding the rounding that would arise with an 80% cut-off; the two thresholds are therefore practically equivalent for our indicators. As a sensitivity check, analyses were repeated using the 80% threshold and yielded results consistent with those reported, with no substantive differences in the direction, magnitude, or statistical significance of the associations observed.

2.2. Data analysis

We performed the statistical analysis using STATA 18.0 software (Stata Corporation, College Station, TX, USA).

We applied descriptive statistics to analyse the results, using absolute frequencies and percentages for categorical variables and means and standard deviations (SD) for continuous variables.

We conducted the analysis of determinants of awareness and educational needs through the development of multivariable logistic regression models. The models were adjusted for age, gender, country (with Italy as the reference category), and education level (with individuals without tertiary education as the reference group).

Initially, models were estimated separately for each of the two indicators. Subsequently, we re-evaluated the predictors for both indicators by including the other indicator as an additional covariate in the models. This step was undertaken to account for the potential interdependence between the two indicators, assuming they may exert mutual influence.

We expressed the influence of the independent variables on each binary outcome investigated as odds ratios (ORs) and 95% confidence interval (CI). We set statistical significance at a P-value <0.05.

The results are presented following this same structure: beginning with a general description of the sample, followed by separate sections dedicated to awareness and educational needs, respectively. A final section focuses on the associations between awareness and educational needs, taking into account mutual adjustment for the other indicator.

2.3. Ethics approval and consent to participate

We obtained ethical approval for this study from the Policlinico Universitario 'Agostino Gemelli' Ethics Committee, Rome (ID 5047) and Amsterdam UMC (reference 2022.0214).

We informed all participants about the purpose of the study and their rights as participants, including the voluntary nature of their involvement. We obtained consent prior to participation, ensuring that respondents understood their data would be used for research purposes while maintaining confidentiality and anonymity. We also made participants aware of their right to withdraw from the study at any time without any consequences.

3. Results

3.1. Sample description

The survey encompassed a total of 6581 participants from eight different European countries. The age varied from 18 to 89 years, with an average age of 48.5 years. 52.5% of the respondents were female, and 37.9% of the participants had achieved tertiary education. Central Europe, including countries like France, Germany, and the Netherlands, had the highest representation, with 46.03% of the respondents. Eastern Europe, which includes Hungary, Poland, and Romania, contributed 23.20% of the sample. Southern Europe, represented by Italy and Spain, comprised 30.77% of the respondents (Table 1).

On the whole, 41.88% of respondents declared higher awareness level and 33.02% lower perceived educational needs (Table 1).

3.2. Awareness of PM and related technologies

The majority of participants (80.53%) reported being aware of genetic testing. Nearly half of responders was aware of digital health solutions (54.29%), with lower levels of awareness for PM (47.76%). Approximately 44.4% of participants showed awareness of the association between genetic testing and PM (Table 2).

When examining the sources of knowledge regarding genetic testing, the primary factors included considerations associated with genetic testing for ancestry, fitness, or diets (27.87%). Other proportions were also attributable to personal experiences or acquaintance with individuals who underwent genetic testing for medical purposes (17.89%), hereditary disorders (16.07%), and educational pursuits within academic settings (16.64%).

In the context of genetic testing for medical applications, main uses are primarily associated with the maternal-child domain. Prenatal testing during pregnancy (50.85%) and the evaluation of the risk of transmitting a genetic disease to offspring (55.62%) are the most recognised. Additionally, 35.94% of respondents indicated they had had heard about the heel prick procedure for newborns, employed to identify genetic disorders prior to partaking in the survey. Approximately half of the surveyed individuals were familiar with genetic testing for diagnostic purposes or for assessing the risk of diseases. The detailed distribution of responses is reported in Table 2.

In the survey sample, 60.80% of participants indicated wanting to know outcomes derived from genetic tests. This percentage increases to 82.64% when considering situations involving preventive measures or available treatment options (Table 2).

Table 2
Awareness among survey respondents.

Awareness of topics related to Personalised Medicine (PM) ***(Which of the following terms had you heard about before this survey?)***	**N (tot = 6581)**	**%**
Personalised medicine	3143	47.76
Genetic testing	5300	80.53
Link between personalised medicine and genetic testing	1237	44.40
Digital health solution (big data, health/patient portals)	3573	54.29
Awareness of genetic testing application and results ***(Which of the following uses of genetic testing for medical purposes have you ever heard about prior to this survey?)***	**N. (tot = 5300)**	**%**
Diagnosis of a disease	2553	48.17
Assessment of risk to develop a specific disease, for the disease to be prevented or treated at an early stage	2583	48.74
Choice of the treatment for a disease (e.g. the choice of chemotherapy in case of cancer)	1890	35.66
Assessment of a specific drug in a person (e.g. to avoid wrong dosage or adverse effects)	1129	21.30
Assessment of the risk of passing a genetic disease to future children	2948	55.62
Prenatal testing during pregnancy	2695	50.85
Heel prick of newborn baby to detect a genetic disorder	1905	35.94
Other	41	0.62
None	300	4.56
In which cases would you like to know the results of a genetic test you have undergone?	**N. (tot = 6581)**	**%**
Always	4001	60.80
Only if preventive measures or treatments are available from the results	1490	22.64
I would not want to know myself, but I would want my doctor to know	388	5.90
I would not want myself or others to know	216	3.28
Don't know	486	7.38

In the multivariable analysis, tertiary education was a significant determinant affecting awareness, displaying ORs ranging from 1.14 to 2.57 (Table 4). Age exhibited an association with increased awareness, displaying a direct association with PM (OR 1.004 95%CI 1.001-1.007), genetic testing (OR 1.01 95%CI 1.01-1.02) and awareness of digital health solutions (OR 1.005 95%CI 1.002-1.009). In examining the impact of age, older respondents manifested stronger awareness of PM, genetic testing and digital health solutions. Finally, the female gender positively influenced knowledge concerning genetic testing (OR 1.37 95%CI 1.21-1.56) and awareness of digital health solutions (OR 1.17 95%CI 1.06-1.30).

Regarding the diverse national contexts, compared to Italy, Hungarian citizens had an increased awareness on PM and genetic testing (PM: OR 1.88 95%CI 1.51-2.34; Genetic Testing: OR 2.09 95%CI 1.46-2.98). Respondents from Poland demonstrated heightened awareness regarding genetic testing (OR 2.68 95%CI 1.82-3.96). Furthermore, respondents from Poland and the Netherlands exhibited higher knowledge concerning digital health solutions (OR 1.25 95%CI 1-1.57 and OR 2.33 95%CI 1.92-2.84 respectively) (Table 3).

3.3. Educational needs on PM and related technologies

Most people don't think to have adequate knowledge about PM (65.29%), while recognizing its value for individuals' health (71.69%), and don't think information about PM is easily accessible (65.54%) (Table 4).

People with low perceived knowledge about PM express their need to know more about personal benefit (n = 2,717, 63.23%), research benefits (n = 2,210, 51.43%), reduce costs (n = 2,052, 47.75%), clinical outcomes (n = 1,984, 46.17%), and data management and privacy (n = 1,693, 39.40%).

The most reliable sources of information are healthcare providers (80.57%), schools and university (71.39%), specialised website (60.99%), and institutional communication (58.58%) (Table 4).

The majority of respondents are in favour (strongly in favour n = 1,478, 22.46%; somewhat in favour n = 2,532, 38.47%) the application of PM into clinical practice.

Younger age is associated with better perceived accessibility of information about PM and perceived adequate knowledge about PM (OR 0.996 95%CI 0.992-0.999). Having achieved tertiary education was a positive predictor of perceived adequate knowledge about PM (OR 1.25 95%CI 1.11-1.40), perceived benefit of PM for individuals' health (OR 1.56 95%CI 1.39-1.76), and being in favour of the application of PM into clinical practice (OR 1.56 95%CI 1.40-1.73). Comparing countries to Italy, Hungary and Romania show higher perception of accessibility of information about PM (OR 1.88 95%CI 1.50-2.35; OR 2.48 95%CI 1.99-3.1, respectively), knowledge about PM, and perceived benefits. Hungarian respondents are more in favour of the application of PM into clinical practice (OR 1.33 95%CI 1.04-1.69), while respondents in other countries are against it (France: OR 0.44 95%CI 0.37-0.53; Germany: OR 0.44 95%CI 0.37-0.53; Netherlands: OR 0.54 95%CI 0.45-0.65; Poland: OR 0.64 95%CI 0.51-080) (Table 5).

3.4. Predictors of awareness and educational needs

Predictors of awareness and educational needs about PM and related technologies were gender, country of origin and tertiary education. A direct association was observed between higher awareness and lower needs (OR 2.79, 95%CI 2.50-3.12) (Supplementary File: Table 2). Female gender was associated with lower awareness, after adjusting for needs (OR 0.77, 95%CI 0.70-0.86). Assuming Italy as a reference, Hungary and Netherlands reported higher awareness (OR 1.67 95%CI 1.34-2.10; OR 1.57 95%CI 1.31-1.89, respectively) (Supplementary File: Table 2).

Younger age (OR 0.996 95%CI: 0.992-0.999) was a predictor of lower educational needs. Using Italy as the reference country, coming from Hungary, Netherlands, Poland, Romania and Spain appear to be a predictor of lower educational needs (Hungary: OR 1.81 95%CI 1.44-2.27; Netherlands: OR 1.43 95%CI 1.18-1.73; Poland: OR 1.65 95%CI 1.30-2.09; Romania: OR 2.88 95%CI 2.29-3.62; Spain: OR 1.35 95%CI 1.11-1.64) (Supplementary File: Table 2).

4. Discussion

This study investigates the public's level of awareness and citizens' educational needs on PM and related technologies across eight European countries. In particular, the results showed a consistent awareness of genetic testing and PM, as well as of the association between the two. This aspect could be linked to the widespread use of genetic testing in healthcare and public health, since genetic tests have been used as a diagnostic, prognostic and screening tools for a long time.[30,31] The survey shows that about half of the respondents are aware of the application of genetic testing as a tool for disease diagnosis and a greater share are aware of the use of genetic testing as an assessment of the risk of transmitting a genetic disease to offspring. This may be linked to the higher awareness in women, given the relevance of genetic tests in breast cancer, a prevalent disease among women, or prenatal testing performed in pregnancy. Considering other variables, a significant

Table 3
Predictors of awareness on Personalised Medicine (PM), genetic testing, digital health solution, and of the composite indicator "Awareness of PM and related technologies".

Variable	Knowledge of PM		Knowledge of Genetic Testing		Knowledge of Digital Health Solution		Awareness of PM and related technologies	
	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value
Age	1.004 [1.001-1.007]	0.02	1.01 [1.01-1.02]	<0.001	1.005 [1.002-1.009]	<0.001	0.999 [0.996-1.002]	0.63
Country (ref: Italy)								
France	0.61 [0.51-0.73]	<0.001	0.74 [0.59-0.93]	0.01	0.59 [0.49-0.70]	<0.001	0.67 [0.56-0.81]	<0.001
Germany	0.64 [0.53-0.76]	<0.001	0.63 [0.50-0.78]	<0.001	0.41 [0.34-0.49]	<0.001	0.55 [0.46-0.66]	<0.001
Hungary	1.88 [1.51-2.34]	<0.001	2.09 [1.46-2.99]	<0.001	1.22 [0.98-1.52]	0.08	1.92 [1.54-2.39]	<0.001
Netherlands	2.46 [2.05-2.95]	<0.001	0.34 [0.28-0.43]	<0.001	2.33 [1.92-2.84]	<0.001	1.70 [1.42-2.03]	<0.001
Poland	0.61 [0.48-0.76]	<0.001	2.68 [1.82-3.96]	<0.001	1.25 [1.00-1.57]	0.05	0.62 [0.49-0.77]	<0.001
Romania	1.83 [1.48-2.27]	<0.001	0.52 [0.40-0.68]	<0.001	0.35 [0.28-0.43]	<0.001	0.54 [0.43-0.68]	<0.001
Spain	1.3 [1.09-1.55]	<0.001	1.08 [0.84-1.39]	0.55	0.61 [0.51-0.73]	<0.001	1.10 [0.92-1.32]	0.30
Gender (ref: Male)								
Female	0.91 [0.82-1.01]	0.06	1.37 [1.21-1.56]	<0.001	1.17 [1.06-1.30]	<0.001	0.77 [0.70-0.85]	<0.001
Education								
Achieved tertiary education	1.14 [1.03-1.27]	0.02	1.73 [1.51-1.99]	<0.001	1.68 [1.51-1.88]	<0.001	1.89 [1.70-2.10]	<0.001

Note: Abbreviations: PM - Personalised Medicine, OR – Odds Ratio, CI – Confidence interval.
Model adjusted for age (continuous variable), country (categorical variable, reference: Italy), gender (categorical variable, reference: male), education (categorical variable, reference: not achieved tertiary education).

Table 4
Citizens' educational needs on Personalised Medicine (PM) and related technologies.

Questions on educational needs about benefits, knowledge and accessibility of PM	Definitely (N, %)	Somewhat (N, %)	Not really (N, %)	Not at all (N, %)	Don't know (N, %)
Do you think you have adequate knowledge about personalised medicine?	291 (4.42)	1435 (21.81)	2761 (41.95)	1536 (23.34)	558 (8.48)
Do you think that personalised medicine would be beneficial for individuals' health?	2142 (32.55)	2576 (39.14)	505 (7.67)	181 (2.75)	1177 (17.88)
Do you think information about personalised medicine is easily accessible by citizens?	425 (6.46)	1843 (28.00)	2388 (36.29)	675 (10.26)	1250 (18.99)
How reliable would you say each of the following media is to deliver information about personalised medicine?	**Very reliable (N, %)**	**Somewhat reliable (N, %)**	**Not very reliable (N, %)**	**Not reliable at all (N, %)**	**Don't know (N, %)**
TV	428 (6.50)	2036 (30.94)	2183 (33.17)	1294 (19.66)	640 (9.72)
Newspapers, magazines, broadsheets	364 (5.53)	2146 (32.61)	2252 (34.22)	1140 (17.32)	679 (10.32)
Specialised websites	884 (13.43)	3130 (47.56)	1343 (20.41)	460 (6.99)	764 (11.61)
Social media posts	268 (4.07)	1032 (15.68)	2323 (35.30)	2336 (35.50)	622 (9.45)
Radio broadcasts	414 (6.29)	2223 (33.78)	2211 (33.60)	929 (14.12)	804 (12.22)
Schools and university	1461 (22.20)	3237 (49.19)	889 (13.51)	295 (4.48)	699 (10.62)
Institutional communication	950 (14.44)	2905 (44.14)	1218 (18.51)	424 (6.44)	1084 (16.47)
Healthcare providers (doctors, hospitals …)	2417 (36.73)	2885 (43.84)	596 (9.06)	186 (2.83)	497 (7.55)

Table 5
Predictors of perceived adequate knowledge about Personalised Medicine (PM), perceived benefit of PM for individuals' health, support for its application in clinical practice, perceived accessibility of information about PM, and of the composite indicator "Educational Needs on PM and related technologies".

Variable	Perceived adequate knowledge about PM		Perceived benefit of PM for individuals' health		In favour of the application of PM into clinical practice		Perceived accessibility of information about PM		Educational Needs	
	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value	OR (95%CI)	p-value
Age	0.991 [0.987-0.994]	<0.001	1.02 [1.01-1.02]	<0.001	1.01 [1.01-1.02]	<0.001	0.989 [0.986-0.992]	<0.001	0.996 [0.992-0.999]	0.01
Gender (ref: Male)										
Female	0.90 [0.80-1.00]	0.06	1.11 [1.00-1.24]	0.06	0.98 [0.88-1.08]	0.65	0.91 [0.82-1.01]	0.08	0.93 [0.84-1.03]	0.16
Country (ref: Italy)										
France	0.88 [0.71-1.09]	0.25	0.50 [0.41-0.61]	<0.001	0.44 [0.37-0.53]	<0.001	0.95 [0.78-1.16]	0.64	0.78 [0.64-0.95]	0.02
Germany	0.81 [0.66-1.01]	0.06	0.44 [0.36-0.53]	<0.001	0.44 [0.37-0.53]	<0.001	0.96 [0.79-1.17]	0.67	0.78 [0.63-0.94]	0.01
Hungary	1.67 [1.32-2.12]	<0.001	1.42 [1.08-1.85]	0.01	1.33 [1.04-1.69]	0.02	1.88 [1.50-2.35]	<0.001	2.05 [1.64-2.56]	<0.001
Netherlands	1.75 [1.43-2.13]	<0.001	0.78 [0.64-0.95]	0.01	0.54 [0.45-0.65]	<0.001	1.90 [1.58-2.29]	<0.001	1.59 [1.32-1.92]	<0.001
Poland	1.58 [1.25-2.01]	<0.001	0.82 [0.64-1.05]	0.11	0.64 [0.51-0.80]	<0.001	1.50 [1.19-1.88]	<0.001	1.43 [1.14-1.80]	<0.001
Romania	1.75 [1.38-2.22]	<0.001	1.34 [1.03-1.74]	0.03	1.07 [0.85-1.35]	0.56	2.48 [1.99-3.10]	<0.001	2.37 [1.90-2.95]	<0.001
Spain	1.00 [0.811-1.24]	0.99	1.05 [0.85-1.29]	0.68	0.89 [0.74-1.08]	0.25	1.67 [1.38-2.02]	<0.001	1.36 [1.12-1.65]	<0.001
Education										
Achieved tertiary education	1.25 [1.11-1.40]	<0.001	1.56 [1.39-1.76]	<0.001	1.56 [1.40-1.73]	<0.001	1.01 [0.91-1.13]	0.83	1.22 [1.09-1.36]	<0.001

Note: Abbreviations: PM - Personalised Medicine, OR – Odds Ratio, CI – Confidence interval.
Model adjusted for age (continuous variable), country (categorical variable, reference: Italy), gender (categorical variable, reference: male), education (categorical variable, reference: not achieved tertiary education).

extent of awareness on the topics of PM and genetics/genomics is highlighted among older interviewees, in line with other surveys exploring public perception and general knowledge of genomic research and medicine outside of Europe.[32,33]

However, the effect sizes associated with age are very modest (OR 1.004–1.01), and caution is warranted in interpreting this association as a substantive finding. A plausible contextual explanation is that older respondents may have had greater lifetime exposure to the healthcare system – for instance through chronic disease management or genetic counselling – which may confer familiarity with some PM-related concepts. This finding should not be generalised beyond the specific populations studied, and future research should explore whether this pattern holds across different cultural and healthcare contexts.

The focus on genetic testing applications and the particular distribution of responses may not only need to be considered in light of the increasing access to genetic testing within health care, but also outside of it, especially when considering direct-to-consumer (DTC-GT) genetic testing.[34] This type of test reflects the fact that tests are now widely accessible beyond the healthcare sector. It may also factor in the large percentage of respondents who are aware of tests designed to provide information about ancestry, physical traits, or diet. The DTC-GT industry has grown in recent years, with entertainment-purpose tests being the best-selling, also considering that regulatory requirements for DTC-GT are blurred and vary between countries;[29,35] this aspect probably could explain some of the differences in awareness and educational needs observed across countries. Other factors that may influence the differences across countries include the normative framework—that is, the set of legal, regulatory, and institutional policies guiding the

adoption and implementation of digital health solutions—as well as the presence of national and international initiatives. These elements place countries in varying positions regarding the topics analysed, as highlighted by the results of the logistic regressions. For example, looking at the knowledge on digital health solutions, Poland, Hungary, Netherlands, and Italy have a higher level of knowledge than other countries. In Italy this mirrors the availability of European funding related to Next Generation EU and the Italian National Recovery and Resilience Plan;[36] new digital platforms have been implemented to digitalise and share health data,[37,38] to enhance the adoption of the electronic health record (EHR) and telemedicine.

On the other hand, the share of respondents who know about digital health solutions is surprisingly low. This may be surprising when you consider the increasing use of technology in healthcare over the past two decades.[39] This aspect also shows variability across countries. For example, the survey showed greater awareness of digital health solutions in healthcare in France. Since 2016 the French government has implemented a computerised data system called SNDS (Système National des Données de Santé), effectively digitizing the national health system and probably bringing health professionals and patients closer to the collection and use of health data.[40]

Regarding citizens' needs, our findings reveal significant gaps in the accessibility and comprehension of PM-related information. A substantial majority of respondents (65.54%) indicated that information about PM is not easily accessible, while a similar proportion (65.29%) reported lacking adequate knowledge about PM. This perception of limited accessibility and knowledge aligns with previous studies that have identified similar knowledge gaps in genomic medicine and PM across different population.[41] For instance, Mackert et al. found that even among individuals with adequate general health literacy, understanding specialised medical fields like PM posed significant challenges.[42]

The survey results highlight clear preferences regarding trusted information sources, with healthcare providers emerging as the most reliable source (80.57% considering them reliable or very reliable), followed by academic institutions (71.39%), and specialised websites (60.99%). This hierarchy of trust mirrors findings from other studies investigating public trust in health information sources.[43] Similar to our findings, a systematic review by Diviani et al. found that healthcare providers consistently ranked as the most trusted source for complex medical information, particularly when dealing with emerging technologies and personalised approaches to healthcare.[44]

Age and education emerged as significant predictors of educational needs, with younger respondents and those with tertiary education reporting lower educational needs for additional information. This finding aligns with previous research showing that educational attainment significantly influences health literacy and understanding of complex medical concepts.[45,46] However, our finding regarding age contrasts with some studies that found older adults expressing fewer educational needs about new medical technologies,[47] suggesting that cultural or contextual factors might play a role in shaping these perceptions.

The country-specific variations, particularly the higher educational needs in France and Germany compared to Italy, suggest that cultural and healthcare system differences may influence how citizens perceive their knowledge gaps and information needs. These findings are consistent with previous European studies that have documented significant cross-national variations in health literacy and educational needs.[48,49] Research by Sørensen et al. on health literacy across European countries has similarly highlighted how healthcare system organization and cultural factors can influence citizens' perceived knowledge needs and information-seeking behaviours.[28]

Interestingly, our analysis revealed a direct association between literacy and needs (adjusted OR 2.79, 95%CI: 2.50-3.12), suggesting that individuals with higher health literacy levels are more likely to recognise and articulate their educational needs. This pattern contradicts what has been observed in other areas of health education, where increased literacy often leads to greater awareness of knowledge gaps and a stronger desire for ongoing education.[50,51] This phenomenon, sometimes referred to as the "knowledge-awareness paradox," has been documented in studies of genetic literacy and other complex medical fields.[52]

These findings emphasise the importance of developing targeted educational strategies that consider both the preferred information channels and the varying needs of different population segments. Previous successful interventions in improving public understanding of complex medical concepts have similarly emphasised the need for tailored approaches that account for demographic and cultural variations.[53,54] The results also suggest that educational initiatives might be most effective when delivered through trusted healthcare providers and academic institutions, a finding that echoes recommendations from previous studies on health communication strategies.[55]

Overall, our study results highlight the necessity of enhancing the general population's knowledge as part of increased health literacy, particularly in contemporary topics such as PM and genetic testing. This aligns with findings from other studies.[56] Furthermore, our results highlight how some sociodemographic factors, such as education and age, can correlate with citizens' knowledge and their level of literacy. This data is crucial for recognizing essential components to factor in when devising and executing new training approaches for citizens.[57] In particular, according to our findings, a training initiative directed at citizens should consider the following aspects:

- the intended audience for training, which can encompass the broader public or specific demographic groups such as youth, seniors, those at higher risk for particular conditions, women, etc;
- the subjects on which citizens should be trained, with significant themes identified from our research including that of digital health solutions.

Moreover, another crucial factor to contemplate when formulating training strategies targeted at the population is the involvement of professionals in the training process. Although our study did not delve into this aspect, enhancing citizens' literacy requires the engagement of suitably trained healthcare professionals, along with experts from fields like sociology and communication.[58] This is particularly compelling considering that healthcare providers are regarded as one of the most reliable sources of information about PM, even exceeding the credibility of institutional communication.

4.1. *Strengths and limitations*

This study should be considered in light of some limitations and strengths. It is possible that the results may have been influenced by biases related to the voluntary nature of responses, as participation was voluntary, and biases related to the under-coverage of certain population groups not reached by the survey administration method. However, we attempted to overcome typical survey biases by collecting a large sample, balancing closed-ended questions with open-ended ones, and explaining concepts to facilitate understanding of the questions and provide key information on the topics discussed. Additionally, the online administration mode may have disproportionately excluded individuals with low digital literacy or limited internet access, potentially underestimating the very educational needs this study aims to measure. The cross-sectional design prevents causal inference: all findings should be interpreted as associations reflecting a single point in time, rather than causal or directional relationships. The potential influence of translation and cultural adaptation of survey items across eight countries with different languages and healthcare contexts may also affect cross-national comparability and should be considered when interpreting country-level differences. Furthermore, the decision to collapse response categories into binary indicators – while analytically justified by insufficient cell counts in stratified analyses – may have reduced granularity.

Similarly, the coding of "Don't know" responses together with "No" responses, while operationally justified from a health literacy measurement perspective, is acknowledged as a limitation; future work could explore the two categories separately to assess response-pattern heterogeneity. The regression models were adjusted for a limited set of covariates (age, gender, education, country), selected a priori based on data availability and established relevance in health literacy research; unmeasured confounders – such as prior healthcare experience, health insurance status, or health system access – may exist and could not be controlled for. Some statistically significant associations have modest effect sizes; their practical or clinical relevance should not be overstated. Finally, the available published literature does not permit a sufficiently systematic cross-national comparison of structural determinants – such as national genomics strategies, health education policies, or digital infrastructure – that may underlie the country-level differences observed. Findings are therefore reported descriptively to identify gaps and country-level heterogeneity rather than to derive causal explanations or policy prescriptions.

Despite the limitations described, considering the importance of citizens' literacy in the decision-making process in healthcare, this survey provides policymakers with a useful analysis of the state of the art in Europe.

4.2. Conclusion

The study found broad awareness of genetic testing and digital health solutions among Europeans but identified a lesser familiarity with PM. The study also revealed significant country-specific variations in health literacy levels. These findings underscore the need for educational interventions to increase health literacy to effectively navigate the advancements in PM and genetic testing and improve health outcomes.

Ethical approval

We obtained ethical approval for this study from the Policlinico Universitario 'Agostino Gemelli' Ethics Committee, Rome (ID 5047) and Amsterdam UMC (reference 2022.0214).

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Declaration of competing interest

None to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2026.106381.

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