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Psychosocial profiles of pandemic and health emergency preparedness: a latent class analysis across four European countries

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Abstract

Societal resilience during health emergencies relies, in addition to healthcare capacity and infrastructure, on citizen wellbeing, social cohesion and collective behaviour. The latter dimensions are often under-addressed in preparedness planning. To address this, we used a Latent class analysis to identify psychosocial and behavioural preparedness profiles from the March 2024 Pandemic and Emergency Preparedness and Behaviour survey conducted in Ireland, the Netherlands, Slovenia and Spain (N = 4,636). Three profiles emerged with relative consistency across countries: a Priority Support Group with low personal (mental health, resilience and social support) and societal (institutional trust and social cohesion) resources; an Individually Prepared Group with high personal resources; and a Collectively Prepared Group with high societal resources. Key determinants driving group memberships varied between countries, especially mental health, resilience and institutional trust. Young adults, women and people with lower education, living alone or with medical conditions were consistently more likely to belong to the Priority Support Group. We conclude that population variance in preparedness profiles was predominantly shaped by psychosocial resources rather than behaviours, highlighting the need for tailored interventions addressing personal and societal shortcomings by population profiles. Preparedness strategies should move beyond behavioural messaging and address psychosocial conditions that shape whether people can prepare.

Introduction

Public health emergencies have historically had devastating impacts on individuals, society and governments (1–4). The COVID-19 pandemic exposed the fragility and vulnerability of global systems and the relatively poor preparedness for such extraordinary events (3, 5–8), showing how international public health emergencies can exacerbate inequalities within and across countries (3, 7, 9, 10). Being prepared for a public health emergency is not only a matter of strong healthcare systems and emergency planning (institutional preparedness), but it also depends on public involvement at the community and individual levels (4, 11).

One key learning from the COVID-19 pandemic is the extent to which adherence to non-pharmaceutical measures and vaccination uptake informed by psychosocial and contextual determinants. For example, risk perception and trust in institutions and scientific sources were consistently associated with vaccine acceptance (12–14), while perceived severity and belief in the effectiveness of protective measures shaped adherence to handwashing and physical distancing over time (15). These psychosocial determinants are in turn deeply rooted in socio-ecological factors such as socioeconomic position and education (9, 13, 16, 17). In other words, they are systemic and slow to change (15, 18). Nonetheless, they are important to address: psychosocial factors such as mental health, well-being and social cohesion were not only impacted by health emergencies (19–22), pre-existing levels of these factors also influenced pandemic outcomes (23, 24). Taken together, individual health emergency preparedness is a complex multidimensional construct (18, 25, 26) and a product of collective beliefs about preparedness, resources and motivations that promote relevant behaviours (26–29). Investing in

psychosocial factors that determine preparedness is especially relevant during the cold phase of the emergency management cycle (18, 25), because no active emergency exists and efforts can create conditions that support societal resilience in the face of a future health emergency (27).

Literature has identified several psychosocial factors relevant to individual health emergency preparedness. At the personal level, mental health (19–21), resilience (30, 31) and social support (32, 33) shape how individuals cope with and recover from health emergencies. At the societal level, social cohesion (11, 24), trust in the government and trust in the healthcare system (4, 22, 23) influence adherence to protective measures (15, 16, 34) and pandemic outcomes (22–24). Risk perception has been identified as a key motivational factor for engaging with preparedness behaviours (35, 36), while perceived preparedness and household preparedness behaviours represent the dimension of individual readiness (27, 37).

The aforementioned research predominantly relies on variable-centred approaches, examining whether high scores on a given determinant co-occur with high values on preparedness outcomes (e.g., 12–16,22–24). An alternative, person-centred, approach is to look at groups of people that share certain patterns of scores on different preparedness-relevant psychosocial determinants or behaviours. This person-centred approach (38–41) allows for the uncovering patterns in the population that may explain differences in preparedness profiles between population groups (40) which otherwise often remain hidden (40, 41). For example, in a recent Nordic study on mental health and adverse psychosocial conditions (40), a variable-centred approach revealed that self-reported psychosomatic symptoms, low health and low life satisfaction were associated with adverse psychosocial conditions to a similar extent (five countries, N = 7,860). The person-centred approach, however, identified seven health profiles that were differentially associated with the outcomes: profiles associated with adverse school, interpersonal and personal conditions all included high psychosomatic complaints, but the profile characterised by psychosomatic complaints exclusively showed only average levels of these adverse conditions. In other words, the same indicator carried different meaning depending on the combination of indicators present, a distinction that the variable-centred approach could not capture. From a public health perspective, this distinction matters (38, 41, 42): interventions designed around single determinants tend to miss the complexity co-occurring vulnerabilities. A person-centred approach highlights these complexities and can directly inform the targeting and tailoring of preparedness strategies to the specific needs of identifiable population profiles.

Here we set out to address the complex multidimensional issue of preparedness, using a person-centred approach. One widely used method for doing so is by means of a Latent Class Analysis (LCA), a model-based statistical approach used to identify unobserved patterns within a population (35), by estimating the probability that individuals belong to different latent classes based on patterns across observed indicators (35, 40, 41).

This study aims to identify population profiles with different patterns of individual health emergencies preparedness, based on a multidimensional construct of psychosocial and behavioural factors across

four European countries (Ireland, the Netherlands, Slovenia, and Spain). Our priority is to identify these profiles in each country to inform national policy and supranational policy opportunities.

Materials and methods

Study design and population

The Pandemic and Emergency Preparedness and Behaviour survey (27) consists of an international, online cross-sectional panel survey on determinants and behaviours related to health emergency and pandemic-potential infection prevention and control. Data were collected in March 2024 in Ireland, the Netherlands, Slovenia and Spain. Per country, at least 1,000 participants were sampled, representative of each country population for age, gender and education level. The study was carried out in accordance with the Declaration of Helsinki. The Centre for Clinical Expertise at the Dutch National Institute for Public Health and the Environment (RIVM) assessed the study protocol (study number PLG-658) and verified whether the study complied with either the specific conditions as stated in article one of the Dutch law for Medical Research Involving Human Subjects (WMO) or with the EU Clinical Trial Directive (2001/20/EC). The study did not fulfil these conditions and received therefore a waiver for ethical approval.”. Informed consent from subjects was obtained upon panel participation.

Variables

A comprehensive description of the variables can be found in the Supplementary material (S1). Below we cover each variable in short. The full questionnaire is publicly available (43).

Sociodemographic

Sociodemographic variables include gender (female, male) and age (recoded for the analysis in age groups 18–29, 30–49, 50–64, 65+). Education level (low, middle, high) was recoded based on the International Standard Classification of Education (44). Household members were assessed by asking whether participants lived alone (1 = does not live alone, 2 = lives alone). Medical risk group was evaluated by asking participants if they had any of a list of health problems (1 = not in medical risk group, 2 = in medical risk group). Migration background was assessed depending on whether participants and each of their parents were born in the country where the research was conducted (1 = no migration background, 2 = migration background).

Psychosocial and behavioural

All variables were dichotomised for the purpose of the Latent Class Analysis. Country-specific cut-offs were used if when available, and country-level medians otherwise. Below we briefly describe the cut off values (see Supplementary material S1 for details).

Mental health

The Mental Health Inventory (MHI-5) is a 5-item scale used to assess mental well-being (45), with each question being answered on a 6-point Likert scale from “Permanently [1]” to “Never [6]”. The total raw score (sum of all five items) ranged from 5 to 30, and was converted to a 0-100 scale, with higher scores indicating better mental health. Mental health was dichotomised (46) into in psychological distress (0–59) and positive mental wellbeing (60–100) (46).

Resilience

Resilience captures perceptions related to coping with and recovering from stressful events. It was measured according to the 3-item WHO tool for behavioural insights on COVID-19 (47). Each question was answered in a 5-point Likert scale, with the final mean score ranging for 1 (lowest possible resilience) to 5 (highest possible resilience). Scores were dichotomised into low versus high resilience using country-specific medians as cut-offs (high=above the median; low = at or below the median).

Social support

Social support was measured with the Oslo Social Support Scale (48). The cumulative 3-item score ranges from 3 to 14, where higher scores indicate stronger social support. Levels of social support were recoded into two groups (32, 33), distinguishing poor support (3 to 8) from moderate to strong support (9 to 14).

Social cohesion

The social cohesion items evaluated the subjective perceived closeness of relationships with country, region and neighbourhood. The items were adapted from the Inclusion of Other in the Self Scale (49). Item responses were averaged to create a mean social cohesion score ranging from 1 to 7, with higher scores indicating greater social cohesion. The resulting score was dichotomised into low (≤ country median) versus high (> country median) social cohesion using country-specific median cut-offs.

Trust in the Government and in the healthcare system

Questions about trust in institutions were adapted from European Social Survey (50). Both trust measures were split at the country median, with values above the median classified as high trust and values at or below the median classified as low trust.

Risk perception of future pandemics

Risk perception of future pandemics was assessed with an item from the European Commission CCBI disaster preparedness experimental survey (37). The likelihood of a highly contagious disease outbreak

was split in “High risk perception” (4, Somewhat to 6, Very likely) and “Low risk perception” (from 1, Very to 3, Somewhat unlikely) and “don’t know” responses were coded as missing.

Household preparedness behaviours

Home preparedness behaviours were adapted from the European Commission CCBI disaster preparedness experimental survey (37). They assessed specific actions taken to be prepared for a health emergency or disaster and people were asked whether they had implemented them or not. The final score is calculated by the sum of all behaviours reported by each participant. Participants were classified as reporting multiple household preparedness behaviours if their score exceeded the country-specific median; all other scores (at or below the median) were classified as few behaviours.

Perceived preparedness

Participants were asked to what extent they felt prepared for a lockdown imposed next month, and answers ranged from “Not at all prepared” [1] to “Very well prepared” [5]. Perceived preparedness variables were recoded as “Not prepared” (including not at all/not prepared/ neutral (1 to 3)) vs “Prepared” (including prepared/very well prepared (4 and 5)).

Analysis

Descriptive statistics

Descriptive analysis of all variables was conducted overall and by country. Results are presented as number of respondents (percentage) for sociodemographic, psychosocial and behavioural variables.

Latent Class Analysis

To identify profiles of individuals in the population, a Latent Class Analysis (LCA) was conducted for each country. Every psychosocial and behavioural variable was included in the model. To determine the optimal number of classes, a series of LCA models with two to five classes were fitted. Model fit of the class solutions were compared using the Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC), with lower values indicating better model fit (51, 52, 39). Model fit was also assessed using the Log Likelihood (LL), with higher values (i.e., less negative) indicating better model fit. To ensure model stability and reproducibility, each model was estimated using multiple random starting values (up to 100 repetitions across successive attempts), with solutions consistently converging to the same log-likelihood value. The size of each class was evaluated to ensure that identified profiles were substantively meaningful and not too small for reliable subsequent analysis. Models with at least one class comprising less than 10% of the sample were excluded (39, 53), to avoid unstable estimates in subsequent regression analyses, following the widely used rule of 10 events per variable (54). Entropy was used to assess classification accuracy, as it gives a global estimation of class separation. Higher values (closer to 1) indicate clearer class distinctions, with values over 0.9 considered ideal (39, 42). However, there is a lack of consensus on entropy thresholds for moderate class separation (39, 42),

therefore the final model selection was based on a balance between model fit, classification accuracy, class sizes, interpretability, and theoretical justification (39, 42, 51–53).

Following class enumeration, post-hoc classification diagnostics were conducted (see Supplementary Material S2). Unlike entropy, which provides a single summary of overall class separation, Average posterior probabilities (AvePP) allows assessment of classification quality at the level of each individual class (39). AvePP were assessed against the 0.70 threshold recommended for adequate class assignment accuracy (39, 53). Model adequacy was further assessed by comparing the estimated class proportions from the model with those obtained through modal assignment; classification was considered adequate when the assigned proportion fell within the 95% confidence interval of the estimated proportion (39). Concordance between estimated and observed proportions was inspected as a sensitivity check to evaluate distortion from classification error. To support class profile interpretation, chi-square tests were used to assess the association between each indicator and most-likely class assignment within each country, with Cramér's V as effect size measure (55, 56). Effect sizes were interpreted according to a six-category scheme (56): negligible (< 0.10), weak (0.10–0.19), moderate (0.20–0.39), relatively strong (0.40–0.59), strong (0.60–0.79) and very strong (≥ 0.80). Pairwise chi-square comparisons between all class pairs were conducted with Bonferroni correction. As these tests are based on modal class assignment, they should be interpreted as descriptive summaries of class differentiation rather than independent hypothesis tests (39, 53). These analyses are presented in Supplementary Material S3.

Multinomial Logistic Regression

Subsequently, we investigated sociodemographic determinants of class membership using multinomial logistic regression. The dependent categorical variable was the participants' most likely latent class according to the selected class solution in the LCA. The independent variables included all the sociodemographic variables. Model coefficients were transformed into odds ratios (ORs) with 95% confidence intervals (CIs). Independence of observations was guaranteed by the study design, the outcome consisted of mutually exclusive class assignments. Cell sizes across all predictor-outcome combinations were inspected prior to modelling to ensure adequate representation. Multicollinearity was generally low (mean Variance inflation factors (VIF) ≈ 3), with higher values for age categories (VIF ≈ 6–12) attributable to dummy coding rather than substantive overlap. Model fit was evaluated using the likelihood ratio chi-square test and Nagelkerke R^2 as a measure of explained variance. Statistical significance ($p < 0.05$) and ORs were examined to determine which sociodemographic subgroups are more likely to belong to specific preparedness profiles.

A preregistration protocol was submitted to the Open Science Framework (OSF) before conducting the analyses (57); this preregistration is currently under embargo and not available for public consultation. All analyses were conducted in R (version 4.5.0) using a complete-case approach (i.e., participants with missing data on any variables required for a given analysis were excluded). LCA was performed using the *poLCA* package, and logistic regression was fitted using the *nnet* package. Survey weights were not applied, as poLCA does not support survey-weighted estimation. The study was reported in accordance

with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies (58).

Results

Descriptive statistics

4,636 participants from four European countries answered the survey (1,008 from Ireland, 1,000 from The Netherlands, 1,522 from Slovenia and 1,106 from Spain). Table 1 depicts overall and by-country descriptive statistics. Persons with a lower level of education were underrepresented in the Slovenian sample, and persons of older age (70+) were underrepresented in the Irish and Spanish samples (59).

Table 1
Sociodemographic characteristics and dichotomised psychosocial indicators overall and by country.

Gender	**Overall**	**Ireland**	**Netherlands**	**Slovenia**	**Spain**
	N (%)	**N (%)**	**N (%)**	**N (%)**	**N (%)**
Female	2460 (53.1%)	581 (57.6%)	519 (51.9%)	786 (51.6%)	574 (51.9%)
Male	2150 (46.4%)	420 (41.7%)	479 (47.9%)	736 (48.4%)	515 (46.6%)
Missing	26 (0.6%)	7 (0.7%)	2 (0.2%)	0 (0.0%)	17 (1.5%)
Age group					
18 to 29 years old	736 (15.9%)	221 (21.9%)	119 (11.9%)	235 (15.4%)	161 (14.6%)
30 to 49 years old	1863 (40.2%)	488 (48.4%)	257 (25.7%)	591 (38.8%)	527 (47.6%)
50 to 64 years old	1236 (26.7%)	204 (20.2%)	280 (28.0%)	462 (30.4%)	290 (26.2%)
65 years old and older	801 (17.3%)	95 (9.4%)	344 (34.4%)	234 (15.4%)	128 (11.6%)
Education					
High	1982 (42.8%)	474 (47.0%)	431 (43.1%)	708 (46.5%)	369 (33.4%)
Medium	1769 (38.2%)	394 (39.1%)	355 (35.5%)	780 (51.2%)	240 (21.7%)
Low	883 (19.0%)	140 (13.9%)	212 (21.2%)	34 (2.2%)	497 (44.9%)
Missing	2 (0.0%)	0 (0.0%)	2 (0.2%)	0 (0.0%)	0 (0.0%)
Living alone					
With others	3898 (84.1%)	847 (84.0%)	751 (75.1%)	1344 (88.3%)	956 (86.4%)
Alone	738 (15.9%)	161 (16.0%)	249 (24.9%)	178 (11.7%)	150 (13.6%)
Migration background					
Native	3666 (79.1%)	660 (65.5%)	761 (76.1%)	1252 (82.3%)	993 (89.8%)

Gender	Overall	Ireland	Netherlands	Slovenia	Spain
	N (%)	N (%)	N (%)	N (%)	N (%)
Migration background	946 (20.4%)	348 (34.5%)	215 (21.5%)	270 (17.7%)	113 (10.2%)
Missing	24 (0.5%)	0 (0.0%)	24 (2.4%)	0 (0.0%)	0 (0.0%)
Medical risk group					
No	3305 (71.3%)	753 (74.7%)	757 (75.7%)	938 (61.6%)	857 (77.5%)
Yes	1310 (28.3%)	255 (25.3%)	222 (22.2%)	584 (38.4%)	249 (22.5%)
Missing	21 (0.5%)	0 (0.0%)	21 (2.1%)	0 (0.0%)	0 (0.0%)
Mental Health					
Good mental health	2979 (64.3%)	570 (56.5%)	757 (75.7%)	1123 (73.8%)	529 (47.8%)
Poor mental health	1579 (34.1%)	438 (43.5%)	165 (16.5%)	399 (26.2%)	577 (52.2%)
Missing	78 (1.7%)	0 (0.0%)	78 (7.8%)	0 (0.0%)	0 (0.0%)
Resilience					
High resilience	1927 (41.6%)	409 (40.6%)	351 (35.1%)	681 (44.7%)	486 (43.9%)
Low resilience	2697 (58.2%)	599 (59.4%)	637 (63.7%)	841 (55.3%)	620 (56.1%)
Missing	12 (0.3%)	0 (0.0%)	12 (1.2%)	0 (0.0%)	0 (0.0%)
Social Support					
Moderate to high support	3255 (70.2%)	561 (55.7%)	800 (80.0%)	1118 (73.5%)	776 (70.2%)
Poor support	1368 (29.5%)	447 (44.3%)	187 (18.7%)	404 (26.5%)	330 (29.8%)
Missing	13 (0.3%)	0 (0.0%)	13 (1.3%)	0 (0.0%)	0 (0.0%)
Social Cohesion					
High social cohesion	2089 (45.1%)	463 (45.9%)	398 (39.8%)	689 (45.3%)	539 (48.7%)

Gender	Overall	Ireland	Netherlands	Slovenia	Spain
	N (%)	N (%)	N (%)	N (%)	N (%)
Low social cohesion	2526 (54.5%)	545 (54.1%)	581 (58.1%)	833 (54.7%)	567 (51.3%)
Missing	21 (0.5%)	0 (0.0%)	21 (2.1%)	0 (0.0%)	0 (0.0%)
Trust in Government					
High trust	1979 (42.7%)	386 (38.3%)	447 (44.7%)	652 (42.8%)	494 (44.7%)
Low trust	2517 (54.3%)	581 (57.6%)	533 (53.3%)	832 (54.7%)	571 (51.6%)
Missing	140 (3.0%)	41 (4.1%)	20 (2.0%)	38 (2.5%)	41 (3.7%)
Trust in Health System					
High trust	1855 (40.0%)	342 (33.9%)	380 (38.0%)	644 (42.3%)	489 (44.2%)
Low trust	2532 (54.6%)	615 (61.0%)	579 (57.9%)	827 (54.3%)	511 (46.2%)
Missing	249 (5.4%)	51 (5.1%)	41 (4.1%)	51 (3.4%)	106 (9.6%)
Risk Perception					
High risk perception	2555 (55.1%)	565 (56.1%)	588 (58.8%)	720 (47.3%)	682 (61.7%)
Low risk perception	1735 (37.4%)	366 (36.3%)	317 (31.7%)	752 (49.4%)	300 (27.1%)
Missing	346 (7.5%)	77 (7.6%)	95 (9.5%)	50 (3.3%)	124 (11.2%)
Preparedness Behaviour					
Multiple behaviours	1759 (37.9%)	347 (34.4%)	495 (49.5%)	481 (31.6%)	436 (39.4%)
Few behaviours	2741 (59.1%)	661 (65.6%)	498 (49.8%)	912 (59.9%)	670 (60.6%)
Missing	136 (2.9%)	0 (0.0%)	7 (0.7%)	129 (8.5%)	0 (0.0%)
Perceived Preparedness					
Prepared	1792 (38.7%)	289 (28.7%)	313 (31.3%)	789 (51.8%)	401 (36.3%)

Gender	Overall	Ireland	Netherlands	Slovenia	Spain
	N (%)	N (%)	N (%)	N (%)	N (%)
Not prepared	2844 (61.3%)	719 (71.3%)	687 (68.7%)	733 (48.2%)	705 (63.7%)

Latent Class Analysis

Model selection

Latent class models with two to five classes were estimated per country (Table 2). In all countries, AIC decreased and LL increased as the number of classes increased up to the 5-class model. Other criteria, however, supported selection of models with fewer than 5 classes. In Ireland, we selected the 3-class model. This was because it had the best model fit according to BIC, and because the 3- and 5-class models had the highest Entropy, but the 5-class model included one class that was too small for subsequent analysis (< 10%). In the Netherlands, we selected the 4-class model, because although the BIC favoured the 3-class model, the Entropy of the 3-class model was substantially lower than in the 4-class model. The 5-class solution was not selected, because although Entropy was highest for this model, it included one class that was too small for subsequent analysis (< 10%). In Slovenia, we selected the 3-class model, because it had the best model fit according to BIC, with comparable Entropy values and suitable class sizes compared to other models. In Spain, we selected the 3-class model, because although the BIC values of the 2- and 3-class model were comparable, AIC and LL favoured the 3-class model. The Entropy values of the 4- and 5- class models were higher than in the 3-class model, but both included a class that was too small for further comparison (9 and 10%).

Table 2
Fit indices and class accuracy for latent class models with two to five classes, estimated by country.

Country	Classes	AIC	BIC	Log Likelihood	Entropy	Smallest class proportion
Ireland	2	10095.3	10185.9	-5028.6	0.55	45.1%
	3	10009.8	10148.2	-4975.9	0.65	25.2%
	4	9976.6	10162.6	-4949.3	0.61	19.8%
	5	9966.5	10200.2	-4934.3	0.65	3.1%
Netherlands	2	8836.8	8926.0	-4399.4	0.60	28.2%
	3	8770.2	8906.4	-4356.1	0.56	20.8%
	4	8751.4	8934.6	-4336.7	0.68	17.5%
	5	8744.5	8974.6	-4323.2	0.71	4.2%
Slovenia	2	14684.3	14782.2	-7323.2	0.58	42.1%
	3	14547.5	14696.9	-7244.7	0.59	27.4%
	4	14508.8	14709.7	-7215.4	0.58	13.9%
	5	14488.9	14741.3	-7195.5	0.61	11.7%
Spain	2	10204.6	10295.3	-5083.3	0.54	46.4%
	3	10158.1	10296.5	-5050.0	0.53	27.6%
	4	10133.2	10319.4	-5027.6	0.61	9.0%
	5	10125.1	10359.0	-5013.5	0.60	10.4%

Selected class solutions showed moderate Entropy values (< 0.68), conveying moderate uncertainty about class assignment to respondents. However, across countries, average posterior probabilities (AvePP) values ranged between 0.71 and 0.90 across all 13 classes (see Supplementary Material 2), exceeding the 0.7 threshold and suggesting most respondents have been assigned to classes with reasonably high probability, allowing for meaningful interpretation of the selected class solutions. Additionally, model-estimated class proportions fell within the 95% confidence interval of the assigned proportions for all classes across the four countries (Supplementary Material S2), and estimated and observed item-response probabilities showed close agreement (Supplementary Figure S1.1-S1.4), further supporting model adequacy.

Class interpretation

Class description and naming were based on observed variance in personal resources (mental health, resilience and social support) and societal resources (social cohesion, trust in the government and trust

in the healthcare system). Two profiles emerged consistently across the four countries, whereas two profiles showed some distinctiveness by country (Fig. 1).

We describe each profile below with emphasis on the determinants identified as most discriminant between classes within each country for observed proportions (Supplementary Material S3). Mental health was consistently the strongest discriminator, with strong to very strong effects across all four countries (V = 0.60–0.88). Resilience, social support, institutional trust and social cohesion showed moderate to strong effects (V = 0.30–0.80). Risk perception and self-perceived preparedness showed weaker effects (V = 0.14–0.32), while household preparedness behaviours emerged as a strong differentiator only in the Netherlands (V = 0.68).

Priority Support Group (Ireland, Spain, the Netherlands, Slovenia). This was the largest group in Ireland (47.5%) and Spain (36.2%), the second in Slovenia (32.5%) and the smallest in the Netherlands (14.4%). It was characterised by few people reporting personal and societal resources. The number of people reporting high personal resources ranged from 17% (Spain) to 36% (Ireland, Slovenia) for high mental health, from 1% (Slovenia) to 30% (Spain) for resilience, and from 41% (Ireland) to 55% (the Netherlands) for social support. Societal resources were low as well, with percentage of people reporting high social cohesion ranging from 19% (the Netherlands) to 34% (Slovenia) and high trust in institutions from 2% (Ireland) to 37% (Slovenia). Notably, in Spain high mental health was reported less frequently than resilience (17% vs 30%), whereas the opposite pattern was observed in the other three countries.

Individually Prepared Group (Ireland, Spain, the Netherlands, Slovenia). This was the largest group in the Netherlands (40.0%), the second in Ireland (30.7%) and the smallest in Spain (28.5%) and Slovenia (26.1%). It was characterised by people with higher personal resources, but with fewer societal resources relative to other groups in the same country. Percentage of people reporting high personal resources ranged from 88% (Slovenia) to 100% (Ireland, the Netherlands) for mental health, from 43% (the Netherlands) to 89% (Spain) for resilience, and from 75% (Slovenia) to 93% (Spain) for social support. Regarding societal resources, the percentage of people reporting high social cohesion ranged from 29% (Slovenia) to 69% (Ireland) and high trust in institutions from 10% (Slovenia) to 67% (Spain).

Collectively Prepared Group (Ireland and Spain). This group was the smallest in Ireland (21.8%) and the second in Spain (35.3%). It was characterised by people with higher societal resources (particularly trust in institutions) than personal resources relative to other groups in the same country. The percentage of people reporting high societal resources was 56% (Ireland) and 60% (Spain) for social cohesion, and 62% (Spain) to 83% (Ireland) for institutional trust. Regarding personal resources, only 39% and 44% reported high mental health, and 26% and 23% high resilience in Ireland and Spain, respectively. Finally, 42% reported high social support in Ireland and 82% in Spain.

Individually and Collectively Prepared Group (Slovenia and the Netherlands). This was the largest group (41.4%) in Slovenia. In the Netherlands, two Individually and Collectively Prepared Groups emerged: the Behaviourally Engaged subgroup (24.0% of participants) and the Behaviourally Unengaged subgroup (21.6%). Individually and Collectively Prepared Groups were characterised by higher personal and

societal resources relative to other groups in their country. Regarding personal resources, at least 92% of people reported high mental health, and at least 88% reported high social support in the Netherlands and Slovenia. The groups also showed frequent reports of strong resilience relative to the other groups within the same country (46% in the Netherlands and 67% in Slovenia). Regarding societal resources, 56–64% of people reported high social cohesion (at least 20 point higher than other groups), and high institutional trust ranged from 68% (the Netherlands) to 80% (Slovenia).

In the Netherlands, the two Individually and Collectively Prepared Groups differed on engagement with household preparedness behaviours: 100% reported high engagement in the Behaviourally Engaged subgroup, whereas 0% did in the Behaviourally Unengaged subgroup.

Key discriminant variables by country

Although similar profiles were identified across countries, groups varied in relative weighting for each determinant. Overall, we note strong similarity in composition of preparedness profiles between Spain and Ireland, whereas Slovenia and the Netherlands show more distinct patterns for equivalent profiles. Below we outline some of the key differences at variable level by country.

In Ireland, trust in the government showed to be strongest discriminant (V = 0.80), followed by mental health (V = 0.60) and resilience (V = 0.50). In Spain, this pertained to resilience (V = 0.70), mental health (V = 0.69) and trust in the healthcare system (V = 0.54). Slovenia showed a more balanced pattern, with mental health (V = 0.69), resilience (V = 0.63), trust in healthcare system (V = 0.60) and government (V = 0.59), all contributing to distinction between groups to a similar degree. The Netherlands was the most distinct case relative to the other countries: mental health showed to be the strongest discriminant (V = 0.88), followed by trust in the healthcare system (V = 0.72) and preparedness behaviour (V = 0.68), making it the only country where preparedness behaviour played a meaningful role in group differentiation.

Detailed country-specific characteristics of each preparedness profile are reported in Supplementary Material S3.

Perceived preparedness and household preparedness behaviours

Perceived preparedness was broadly associated with personal and societal resource levels in three out of four countries. This was the most evident in Slovenia, where the group combining high personal and societal resources showed the highest estimated perceived preparedness across the study (66%). Ireland followed a similar pattern, while in Spain, estimated perceived preparedness did not differ between prepared groups, suggesting that having resources enhances self-perceived preparedness regardless of which type of resources.

Household preparedness behaviour on the other hand, only weakly differentiated profiles in Spain, suggesting that in most countries the profile structure was driven by psychosocial resources rather than concrete actions.

The Netherlands departed from these patterns entirely. Estimated perceived preparedness was similarly low across the Individually Prepared (23%), the Individually and Collectively Prepared Behaviourally Unengaged (28%) and the Priority Support (21%), despite markedly different personally and societal resource profiles. Only the Individually and Collectively Prepared Behaviourally Engaged showed higher estimated perceived preparedness (52%), paired with the distinctive feature of higher household behavioural preparedness (100%) suggesting that concrete action rather than resource availability impulses an important part of the feeling of preparedness. This may offer a model for understanding how to translate psychosocial readiness into concrete action: even when resources are present, perceived preparedness appears to require behavioural engagement. In other countries, where perceived preparedness tracks more closely with resource levels.

Multinomial Logistic Regression

Given the relatively low entropy observed across the LCA models, indicating moderate classification certainty, regression analyses were restricted to participants assigned to their most likely latent class with a maximum posterior probability of ≥ 0.70. This subsample comprised 691 participants in Ireland, 914 in Slovenia, 632 in Spain, and 561 in the Netherlands, representing 79.8%, 71.6%, 73.3%, and 70.9% of each country's analytical sample respectively. The Individually Prepared Group was the reference in the multinomial logistic regression. Odds ratios and confidence intervals are presented in Fig. 2.

All four models showed statistically significant overall fit (likelihood ratio χ^2: Ireland = 125.0, df = 18; Slovenia = 141.0, df = 18; Spain = 152.8, df = 18; Netherlands = 121.6, df = 27; all $p < 0.001$). Nagelkerke R^2 ranged from 0.163 (Slovenia) to 0.242 (Spain), indicating modest but acceptable explanatory power. Predictor-by-outcome cell-size diagnostics showed no empty cells. However, three cells with fewer than 10 observations were identified: in Slovenia, low education in the Individually and Collectively Prepared group (N = 6) and in the Individually Prepared Group (N = 2); and in the Netherlands, age 18–29 years in the Individually and Collectively Prepared Behaviourally Engaged subgroup (N = 4). These sparse cells were considered when interpreting the corresponding estimates.

Priority Support Group. In all four countries, individuals in older age groups were less likely to be in the Priority Support Group relative to 18-29-year-olds (Ireland: 50–64: OR = 0.26, $p < 0.001$; 65+: OR = 0.09, $p < 0.001$; Spain: 30–49: OR = 0.27, $p < 0.001$; 50–64: OR = 0.14, $p < 0.001$; 65+: OR = 0.03, $p < 0.001$; Slovenia: 50–64: OR = 0.39, $p = 0.003$; 65+: OR = 0.28, $p = 0.001$; the Netherlands: 30–49: OR = 0.38, $p = 0.024$; 50–64: OR = 0.23, $p < 0.001$; 65+: OR = 0.10, $p < 0.001$). In Ireland, Spain, and Slovenia, being a woman (vs men; Ireland: OR = 2.38, $p < 0.001$; Spain: OR = 3.07, $p < 0.001$; Slovenia: OR = 2.01, $p < 0.001$), having an underlying health condition (vs none; Ireland: OR = 3.61, $p < 0.001$; Spain: OR = 3.95, $p < 0.001$; Slovenia: OR = 3.13, $p < 0.001$), and living alone (vs not; Ireland: OR = 2.87, $p < 0.001$; Spain: OR = 2.53, $p = 0.004$; Slovenia: OR = 1.90, $p = 0.040$) also increased the likelihood of belonging to this group. Lower

education (vs high) was significant only in Ireland (medium: OR = 1.68, p = 0.019; low: OR = 2.71, p = 0.004) and Spain (medium: OR = 1.83, p = 0.037; low: OR = 2.44, p < 0.001).

Collectively Prepared Group (Ireland and Spain). Compared to the Individually Prepared Group, in both Ireland and Spain, individuals in older age groups were less likely to be in the Collectively Prepared Group relative to 18-29-year-olds (Ireland: 50–64: OR = 0.27, p < 0.001; 65+: OR = 0.19, p < 0.001; Spain: 50–64: OR = 0.39, p = 0.020; 65+: OR = 0.23, p = 0.001). Having an underlying health condition (vs none) also increased the likelihood of belonging to this group (Ireland: OR = 2.71, p < 0.001; Spain: OR = 2.34, p = 0.004). Being a woman (vs men) was significant only in Spain (OR = 2.00, p = 0.001), while having a migration background (vs none; OR = 1.80, p = 0.016) was significant only in Ireland.

Individually and Collectively Prepared Group (Slovenia and the Netherlands). Compared to the Individually Prepared Group, in Slovenia, being aged 30–49 (vs 18–29; OR = 0.51, p = 0.023) and having medium education (vs high; OR = 0.56, p = 0.001) were associated with lower odds of belonging to the Individually and Collectively Prepared Group. In the Netherlands, low education (vs high) reduced the odds of belonging to both the Behaviourally Engaged (OR = 0.27, p < 0.001) and Behaviourally Unengaged (OR = 0.23, p < 0.001) subgroups. Beyond this shared predictor, the two subgroups diverged: being aged 65+ (vs 18–29) was associated with higher odds of belonging to the Behaviourally Engaged subgroup (OR = 4.04, p = 0.022), although this estimate should be interpreted cautiously due to the small number of 18-29-year-olds in this group (N = 4). For the Behaviourally Unengaged subgroup, being aged 50–64 (OR = 0.38, p = 0.031) and 65+ (OR = 0.39, p = 0.036) and medium education (vs high; OR = 0.58, p = 0.048) were associated with lower odds of membership.

Discussion

The main goal of this study was to identify profiles characterised by similar psychosocial patterns of pandemic and health emergency preparedness among the general population of each of four European countries (Ireland, Spain, the Netherlands and Slovenia). Identifying common patterns of preparedness across countries provides valuable input for supranational policy development on pandemic and emergency resilience, while identification of cross-national differences leverages directions for national-specific policies.

Although class labels represent predominant patterns, rather than discrete, mutually exclusive categories, three broad preparedness profiles emerged across all countries: a Priority Support Group (the largest in Ireland and Spain), an Individually Prepared Group (the largest in the Netherlands) and a Collectively Prepared Group. In Slovenia and the Netherlands, the latter group combined collective and individual preparedness, to form a Collectively and Individually Prepared Group. In the Netherlands, this group further splits by engagement in household preparedness behaviours. We find some overlap in preparedness indicators across groups, meaning that the identified groups reflect predominant tendencies rather than discrete, mutually exclusive profiles.

People in the Priority Support Group reported low levels of personal and societal resources and generally showed the smallest number of people perceiving themselves as prepared and engaging in household preparedness behaviours, suggesting that it can be seen as the most vulnerable group to the impact of health emergencies. This aligns with literatures suggesting that high risk-perception in a population who lack personal and societal resources may lead to inaction, reflected in lower engagement with preparedness behaviours, both for health emergencies and other disasters (35, 60). In all countries, participants in the Priority Support Group were more often young (18–29 years old). In three out of four countries, women, people living alone, and those with a medical condition were also more likely to belong to this group. This pattern is consistent with vulnerabilities observed during the active phase of the COVID-19 pandemic (1, 20–22, 30, 35, 61, 62),and other health emergencies (26, 30).

Those in the Individually Prepared Group were defined by strong personal resources but weaker societal resources. Although this profile appeared in all four countries, the pattern was more pronounced in Slovenia and the Netherlands. In Ireland and Spain, the same group reported moderate societal resources, possibly suggesting a reflection of higher baseline institutional trust (63) in these countries. We also note that in all four countries, older participants were increasingly likely to belong to the Individually Prepared Group rather than the Priority Support Group, which may reflect personal resilience built through greater life experience (20, 30) or more stable social networks (32).

The third group differed between countries. In Ireland and Spain, we observed a Collectively Prepared Group, characterised by high institutional trust but lower personal resources, suggesting these individuals may primarily rely on societal infrastructures to face a future health emergency (11, 64). This is in line with a body of literaturethat shows population trust in the healthcare system and government relate to institutional preparedness perception wellbeing and adherence to protective behaviours (4, 19, 20, 22, 34, 65). In both countries, younger adults and those with a medical condition were more likely to be Collectively prepared than older adults and those without a medical condition. This may reflect greater reliance on state provisions than on personal relationships (30, 62). In Slovenia and the Netherlands, we observed an Individually and Collectively Prepared Group combined This group has high personal and societal resources, representing the most comprehensively prepared group. Perceived preparedness was also elevated, reflecting the importance of both resource dimensions for feeling prepared. In both countries, those with lower education were less often allocated to this group, suggesting that the most comprehensively prepared profile may be less accessible to those with fewer educational resources (61, 62). In the Netherlands, this profile split into two subgroups with equivalent psychosocial resources, but strikingly different levels of engagement with household preparedness behaviours. This suggests that concrete actions, rather than resources alone may be what translates into feeling prepared in this country (17).

Identifying distinct preparedness profiles has direct implications for intervention targeting. Rather than addressing single psychosocial determinants in isolation, a person-centred approach allows policymakers to design interventions tailored to the specific combination of strengths and vulnerabilities that characterise each group. The Priority Support Group (present in all four countries) represents the

most critical target, requiring simultaneous investment across multiple domains rather than isolated actions. Country-specific profiles further nuance these priorities: for example, the Collectively Prepared Group (Ireland and Spain), where personal resources are lower but institutional trust is relatively high, may benefit most from interventions that strengthen personal coping capacity while leveraging existing institutional trust as a communication channel. More broadly, the psychosocial domains offering greatest leverage for intervention differ by national context, supporting the need for context-sensitive preparedness strategies.

We also take insight from similarity in country profiles. Mirroring of policies may be best suited between Spain and Ireland, and the Netherlands and Slovenia respectively given the patterned similarity observed.

Strengths of this study are the identification of shared preparedness profiles across four European countries, providing input for supranational policy while capturing meaningful country-specific variations. It balances international comparability with local specificity, and the supplementary use of chi-square tests and Cramér's V on observed proportions added rigour to class interpretation by identifying the most discriminant determinants within each country and characterising overlap between classes. In terms of limitations, we acknowledge that all class solutions showed moderate entropy, implying some classification uncertainty, though high average posterior probabilities) and large effect sizes suggest main findings are robust to classification error. Moderate entropy reflects overlap in psychosocial indicators across classes, which limits the sharpness of class boundaries and should be considered when interpreting both the class profiles and the regression findings. Furthermore, the analyses were unweighted, which may be particularly relevant given the underrepresentation of persons with lower education in Slovenia and older adults (70+) in Ireland and Spain (59). Finally, the study compared only high-income European countries, which limits generalisation of results to other social, cultural and economic contexts. Extending the survey to low- and middle-income countries and culturally diverse contexts is key to assess class stability in health emergency preparedness. Addressing the long-term stability of these patterns may serve as a suitable next step for expanding this research.

This study has several implications for public health policy. Across all four countries, the Priority Support Group was characterised by low personal and societal resources, suggesting that enabling movement towards more prepared profiles requires a comprehensive approach addressing multiple psychosocial domains simultaneously rather than isolated interventions. Within this shared foundation, country-specific profiles indicate where emphasis may be the most productive. Specifically, Ireland may benefit from investing in institutional trust and government communication credibility. We suggest that Spain may benefit from prioritising the strengthening of citizen resilience and leveraging widely its trusted healthcare channels. For Slovenia, a holistic approach addressing both personal and societal resources may be best suited, particularly with a focus on institutional trust. In the Netherlands we suggest prioritising mental health support and enabling concrete preparedness actions, alongside broader resilience building.

Finally, we want to stress the importance of intervening in a cold phase. Psychosocial factors take time to strengthen and are unlikely to change in the face of an emergency (23, 24). Empowering the most vulnerable demographic groups with psychological tools and community-based support may enhance mental and social wellbeing (11, 19, 22) and reduce the impact of public health emergencies in the long term. An equity focus is strongly suggested, with attention to the youth, women, people with lower education, and depending on the country, those with medical conditions, migrant backgrounds or living alone. Risk communication strategies should be tailored to the most vulnerable groups and surveillance of the demographic groups most often in the Priority Support Group is crucial in future public health emergencies.

Conclusion

This study identified cross-nationally consistent preparedness profiles across four European countries, supporting international monitoring efforts while capturing meaningful local variations. A Priority Support Group emerged in all contexts as the most vulnerable to future health emergencies, though the determinants driving profile differentiation varied by country, supporting the need for context-sensitive strategies. Our data suggest differential patterns of psychosocial and behavioural preparedness, where perceived preparedness appears more closely associated with psychosocial resources than with preparedness behaviours. This calls for developing targeted interventions that address both personal and societal dimensions of health emergency preparedness during cold phases across European contexts.

Declarations

Consent for publication

Not applicable.

Data Availability

Data are available from the authors upon reasonable request to the corresponding authors.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CSR: Conceptualisation, Formal analysis, Methodology, Writing - original draft. MvD and JGS: Conceptualisation, Methodology, Supervision, Writing - review & editing. JF and CRB: Supervision, Writing - review & editing. MB: Conceptualisation, Methodology, Data curation, Writing - review & editing. HJK and AD: Methodology, Writing - review & editing. HR, MF, MRB, MS, MR, DL, ABC, AHG, CD: Writing - review & editing

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Figures

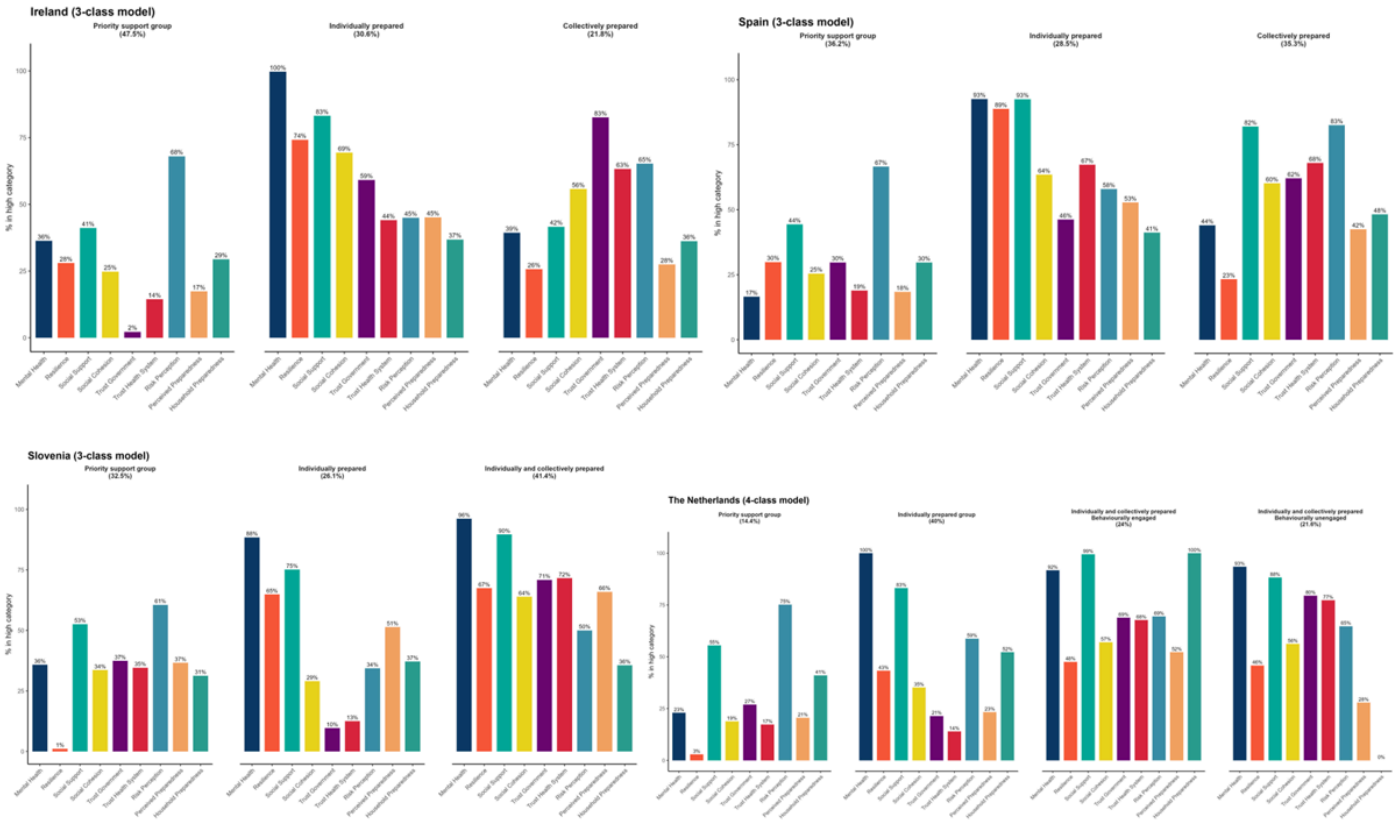


Figure 1

Country-specific LCA class profiles showing estimated presence of high scores on preparedness indicators. Panels A–D represent Ireland (A), Spain (B), Slovenia (C), and the Netherlands (D), respectively.

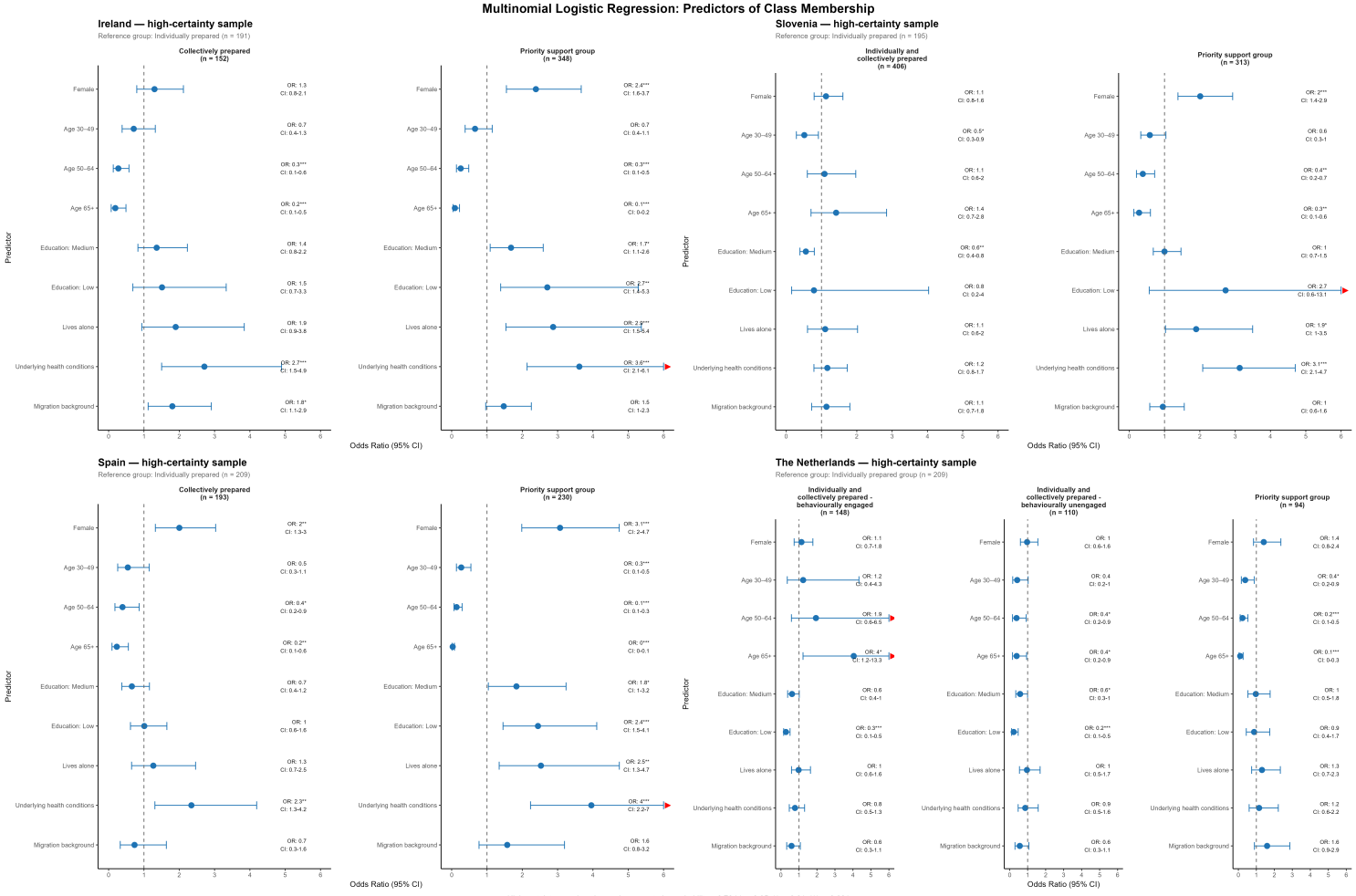


Figure 2

Multinomial logistic regression results: Odds ratios (OR) for predictors of latent class membership across four European countries: Ireland, Spain, Slovenia and the Netherlands. Forest plots display OR and 95% confidence intervals (CI) for sociodemographic and health-related predictors of class membership, using the Individually Prepared Group as reference category in each country. The red arrow (►) indicates OR exceeding the display limit of 6.0. Significance levels: * p<0.05, ** p<0.01, *** p<0.001.

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