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ORIGINAL ARTICLE

Understanding health risk perception: insights from an eight-country panel study during the COVID-19 pandemic

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Abstract

Aim The COVID-19 pandemic highlighted the importance of individuals' risk perceptions and their impact on behaviour. Adequate risk perceptions help individuals adopt necessary precautions.

Subject and methods We conducted a longitudinal panel study analysing data across eight European countries from the European COVID Survey (ECOS). We used two generalised linear models with ordered logistic regression to analyse panel data comprising 82,052 observations from 11 waves of ECOS. Our aim was to investigate self-reported risk perception related to COVID-19 and its association with socioeconomic factors, health indicators, personal experiences with COVID-19 and trust in risk communication. We examined perceived susceptibility to SAR-CoV-2 infection and perceived risk to one's own health from COVID-19, interpreting these as dimensions of risk perception in accordance with the health belief model.

Results Women perceived higher susceptibility to SARS-CoV-2 infection than men. Regardless of gender, perceived susceptibility increased with age, peaking in the 35–44 age group before declining. In contrast, perceived risk to health consistently rose with age. Individuals who did not experience financial difficulties during the pandemic perceived lower health risk than those who did experience such difficulties. Moreover, individuals with higher education levels perceived greater susceptibility than those with lower levels. Other influencing factors included SARS-CoV-2 vaccination status, trust in information, attention to COVID-19 news and pandemic phase.

Conclusion Several socio-economic factors were associated with risk perceptions. Unvaccinated individuals, people with lower education levels and individuals with less trust in institutional information were more likely to underestimate their susceptibility to SARS-CoV-2 infection and their health risk due to COVID-19.

Keywords SARS-CoV-2 · Risk perception · Socio-economic factors · Europe · Socio-economic status · Factors of health

Introduction

Since early 2020, people worldwide have been contending with the diverse and wide-ranging consequences of the coronavirus disease 2019 (COVID-19) pandemic. Governments implemented various measures to safeguard public health and counter the rapid increase in cases and mortality rates. While these measures aimed to mitigate virus transmission, the spread of the virus strongly depended on individuals' behaviour, which was determined in large part by their perception of risk (Savadori and Lauriola 2020). Adequate perceptions of risks are shaped by knowledge and enable individuals to accurately assess the risk associated with an event (Tenkorang 2018). Thus, individuals who perceive themselves to be at high risk of infection with Severe Acute

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Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) are more likely to adopt preventive measures (Wise et al. 2020).

Research on SARS-CoV-2 has identified several individual-level risk factors that are associated with perceptions of COVID-19 risks, such as age, gender, income and education level (Cipolletta et al. 2022). Theoretical models such as the health belief model (HBM) offer explanatory frameworks for understanding how individuals respond to perceived risks and the manner in which these perceptions are manifested in their behaviour (Heydari et al. 2021). In the present paper, we employ two constructs of the HBM as our theoretical framework: perceived susceptibility and perceived severity, the latter of which we operationalise in our study as perceived risk to health. The HBM is one of the most widely used models in health research (Champion und Skinner 2008). Its comprehensive consideration of multiple factors and its adaptability across diverse health domains and populations makes it a valuable tool for predicting health behaviours (Orji et al. 2012).

The general relationship between socio-economic factors and risk perceptions is well documented. Examples of such factors include gender (Brown et al. 2021; Flynn et al. 1994; Kim et al. 2018; Siegrist et al. 2005), age (Brown et al. 2021; Kim et al. 2018; Siegrist et al. 2005; Reed-Thryselius et al. 2022), education (Brown et al. 2021; Reed-Thryselius et al. 2022) and income (Reed-Thryselius et al. 2022). Our study aims to provide information on self-reported risk perceptions during the COVID-19 pandemic as an example for a health shock and their association with socio-economic and health-related factors over time. Although risk assessment is not solely the responsibility of individuals, as evidenced by vaccination programmes, vaccine prioritisation and information campaigns, this research topic is important for addressing future health crises. The course of the COVID-19 pandemic, along with the evolution of risk and severity perceptions over time, provides valuable insights into how different groups perceive the risk of health crises and their likelihood of accepting or adopting preventive measures or policies. Our study analysed data collected from a large panel of residents of eight European countries at regular intervals throughout the COVID-19 pandemic as part of the European COVID Survey (ECOS). While our focus is on COVID-19, our findings might be applicable to future scenarios in which risk assessment largely rests with individuals and adherence to expert-recommended behaviour is crucial.

Methods

Data

We used data from 11 waves of the ECOS, which was conducted online between April 2020 and December 2022 across eight European countries: Denmark, France, Germany, Italy, the Netherlands, Portugal and the United Kingdom, as well as Spain, which was included in June 2021. Approximately 1000 respondents from each country participated in each wave, with the sample being representative of the national population in terms of region, age and gender. Only individuals aged 18 years or older could participate. All participants provided informed consent before taking part in the survey. The survey methodology is described in detail elsewhere (Sabat et al. 2020, 2023; Varghese et al. 2021; König et al. 2023).

Measurement of risk perceptions and their determinants

The HBM comprises several constructs that have evolved since the 1950s, adapting to various health-related contexts. In our study, we focused on two of these constructs: perceived susceptibility to illness and perceived severity of illness. Perceived susceptibility refers to an individual's assessment of the likelihood of contracting a particular illness in the future, whereas perceived severity refers to an individual's assessment of both the clinical and social consequences of an illness. These two constructs, when combined, constitute the perceived threat (Brown et al. 2021). When individuals perceive an increased threat and the potential benefits of adopting expert-recommended behaviours outweigh the costs, they are more likely to adopt these behaviours (Karimy et al. 2021). The HBM posits that the constructs of perceived susceptibility and perceived severity can influence individuals' health behaviour independently of the specific characteristics of any given health intervention, such as a vaccination campaign.

We examined perceived susceptibility and perceived severity independently to assess their relationship with socioeconomic factors. In model I, we measured perceived susceptibility to SARS-CoV-2 using the survey statement 'My risk of contracting the coronavirus'. In model II, we measured perceived severity of illness using the survey statement 'Risk to my health from COVID-19'. This survey statement operationalises the construct of perceived severity as the perceived risk of COVID-19 to one's own health, following the framework of the HBM as outlined by (Champion und Skinner 2008). We understand both constructs jointly as risk perceptions. Both survey statements were Likert-scaled using five response options ranging from 'no risk at all' to 'very high risk', with higher scores indicating higher perceived risk.

We identified four main factors of risk perceptions in the literature in the context of the COVID-19 pandemic: (a) socio-economic factors, (b) health indicators, (c) COVID-19 experience and (d) trust in information. Table 1 details these factors and their operationalisation in the ECOS

Table 1 Factors of risk perceptions and their operationalisation

Category	Factor	Identified literature on COVID-19, risk perceptions and risk communication	Variable in ECOS[1]	Operationalisation
Socio-economic factors	Gender	Brown et al. 2021; Flynn et al. 1994; Kim et al. 2018; Siegrist et al. 2005	Gender	Binary (female, male)
	Age	Brown et al. 2021; Kim et al. 2018; Siegrist et al. 2005; Reed-Thryselius et al. 2022	Age	Six categories in years (18–24; 25–34; 35–44; 45–54; 55–64; 65 + years old)
	Education	Brown et al. 2021; Reed-Thryselius et al. 2022	Education	Three categories (low, medium, high), taking countries' education system into account
	Income	Reed-Thryselius et al. 2022	Ability to make ends meet	Four categories (with great difficulty, with some difficulty, fairly easily, easily)
Health indicators	Health status	Abrams and Greenhawt 2020; Alqahtani et al. 2021; Giordani et al. 2022; Malecki et al. 2021; Schoeni et al. 2021; Yan et al. 2021	EQ-5D-5L	Health problematisation score (5–25, higher score indicating b problems)
	SARS-CoV-2 vaccination status	Caserotti et al. 2021	Vaccination status	Three categories (yes, no, no vaccination available at time of survey)
COVID-19 experience	Following the news on COVID-19	Reed-Thryselius et al. 2022; Cori et al. 2020; Krause et al. 2020	Knowledge	Four categories (no knowledge, limited knowledge, some knowledge, a lot of knowledge)
	Direct experience through diagnosis	Caserotti et al. 2021	Diagnosis	Three categories (yes, confirmed; yes, but not (yet) confirmed; no)[2]
	Indirect experience through family and friends	Borges and Byrne 2022; Lecompte et al. 2022	Contact	Three categories expressing exposure to infected contacts (yes, confirmed; yes, but not (yet) confirmed; no)[1, 2]
Trust in risk communication	Trust in information	Flynn et al. 1994; Siegrist et al. 2005; Reed-Thryselius et al. 2022; Cori et al. 2020; Eitze et al. 2021; Hooker and Leask 2020	Trust in the information from institutions	Score for trust in information from three institutions: national government, European Union, World Health Organization (3–15, higher score indicates greater trust)

[1] Further detail can be found in Sabat and Neumann-Böhme et al. 2023 – The original variable contains the response category 'don't know', which we interpreted as a 'no' in our analysis

survey. Instead of using a metric variable for monthly household income, which is prone to reporting bias (Moore et al. 2000) and does not reflect discretionary income (i.e. income remaining after covering necessities), we measured income based on respondents' answer to a question about their ability to make ends meet (Table 1).

Health indicators were operationalised through individuals' health status and SARS-CoV-2 vaccination status. Following Neumann-Böhme et al. (2023), we operationalised health status using the EQ-5D-5L and summarised it into a score we call the 'health problematisation score' (also known as 'misery indices') due to the lack of country-specific tariffs for the EQ-5D-5L in some countries in our sample. The EQ-5D-5L comprises five domains (mobility, self-care, usual activities, pain/physical discomfort, anxiety/depression), each with five levels of severity, ranging from 'no problems' to 'severe problems. These levels were scored from one to five, with a total score of five indicating the best possible health state and a total score of 25 indicating the worst (König et al. 2023; Spronk et al. 2022). Self-reported SARS-CoV-2 vaccination status was operationalised using three categories ('yes', 'no', 'no vaccination available at the time of data collection'), with the last of these categories applied to early survey waves when vaccination was not available in specific countries.

COVID-19 experience was operationalised using three variables: knowledge about the disease (measured by the frequency of following COVID-19 news), direct experience (having been diagnosed with COVID-19) and indirect experience (SARS-CoV-2 infections within the immediate social circle). Following an approach similar to that of Carducci et al. (2019), we operationalized trust in risk communication by calculating a score reflecting trust in information from various institutions. This score was determined by summing the responses to three items: trust in information from the national government, the European Union and the World Health Organization, with each rated on a five-point Likert scale from 'not at all' to 'very much'. Thus, the trust score could range from 3 (no trust in institutions) to 15 (highest level of trust in institutions).

Statistical analysis

We used two generalised linear models with ordered logistic regressions to identify predictive variables for the two dimensions of risk perception. The models estimated associations between (a) perceived susceptibility to SARS-CoV-2 infection (model I) or perceived risk to health of COVID-19 disease (model II) and (b) the variables related to socio-economic factors, health indicators, COVID-19 experience and trust in risk communication described above. Additionally, we controlled for country fixed-effects and time fixed-effects to mitigate potential bias from unobserved heterogeneity across countries and time periods (Hijzen and Martin 2013). We chose Italy as a reference category due to its early experience with the COVID-19 pandemic in Europe (Bontempi 2021). Time fixed-effects were operationalised by quarterly dummies from the second quarter of 2020 (Q2/2020) to the fourth quarter of 2022 (Q4/2022). We used descriptive statistics to present the demographic data of the participants and the chi-square test to evaluate the significance of associations between risk perception and socio-economic variables. We calculated odds ratios (ORs), 95% confidence intervals (CIs) and robust standard errors (RSEs) to aid in the interpretation of coefficients. We conducted all data analysis using Stata version 16.1.

Results

Sample characteristics

Listwise deletion of observations with missing data yielded a total of 82,052 observations from 11 survey waves. The sample was roughly balanced in terms of gender, with 51.93% female participants. The average age of respondents was 48 years (standard deviation, SD 16.34), with the largest proportion of observations coming from the 65+ age group (21.23%). Table 2 presents a descriptive overview of the variables used, stratified by country.

Perceived susceptibility to SARS-CoV-2

Table 3 shows the results of the ordered logistic regression analysis for both perceived susceptibility to SARS-CoV-2 (model I) and perceived risk to health from COVID-19 (model II). The results of our analyses indicate that women tended to perceive a slightly higher susceptibility to SARS-CoV-2 compared to men (*OR* 1.03; $p = 0.052$). The perceived susceptibility increased with age, peaking in the 35–44 year age group (*OR* 1.58; $p < 0.001$), and then declined in older age groups, relative to the age group of 18–24 year-olds.

Individuals with higher education levels perceived their susceptibility to SARS-CoV-2 to be slightly higher than those with lower levels of education (*OR* 1.06; $p = 0.005$), while individuals with medium education levels did not significantly differ from the lower education group (*OR* 1.02; $p = 0.397$). The perception of susceptibility decreased with individuals' ability to make ends meet. Those who perceived their susceptibility was lowest were those who reported making ends meet easily during the pandemic compared to those who indicated great difficulty in making ends meet (*OR* 0.50; $p < 0.001$).

There was a strong association between respondents' health problematisation score and perceived susceptibility to SARS-CoV-2, implying that as health problems increase, so

Table 2 Characteristics of sample

	All countries ($N = 82,052$) (%)	Denmark (= 10,968) (%)	France (= 11,017) (%)	Germany (= 10,969) (%)	Italy (= 11,044) (%)	Netherlands (= 10,898) (%)	Portugal (= 10,980) (%)	Spain (= 5143) (%)	United Kingdom (= 11,028) (%)
Perceived susceptibility to SARS-CoV-2 (model I)									
No risk at all	6.76	6.42	5.96	8.26	5.51	11.75	5.02	4.78	5.37
Low risk	22.61	32.08	21.22	24.59	21.76	9.49	25.81	23.85	28.03
Medium risk	46.33	43.1	46.77	41.23	44.08	56.86	46.27	45.03	46.72
High risk	18.26	13.89	20.68	18.83	2.95	17.79	16.93	19.87	17.96
Very high risk	6.04	4.51	5.36	7.09	7.71	4.1	5.97	6.47	7.29
Perceived risk to health due to COVID-19 (model II)									
No risk at all	10.57	13.99	8.16	10.73	9.12	16.09	9.46	8.46	7.53
Low risk	22.97	30.22	20.01	22.23	22.32	14.69	27.03	25.74	22.96
Medium risk	35.57	31.03	35.77	33.19	36.54	39.99	36.2	34.84	36.58
High risk	20.89	16.75	25.21	21.61	21.74	20.89	18.69	20.57	21.49
Very high risk	10.00	8.02	10.86	12.24	10.28	8.33	8.62	10.38	11.44
Socio-economic factors									
Gender									
Male	48.07	47.88	47.00	48.36	48.09	47.87	48.45	49.00	48.37
Female	51.93	52.12	53.00	58.64	51.91	52.13	51.55	51.00	51.63
Age in years									
18–24	8.93	9.11	9.10	7.88	7.71	9.23	10.51	8.03	9.42
25–34	15.95	14.30	15.65	13.98	15.37	14.60	20.74	15.81	17.10
35–44	19.01	17.51	18.54	17.15	19.48	18.68	22.04	21.70	18.44
45–54	18.65	18.72	17.95	18.46	18.25	19.41	19.34	19.41	18.12
55–65	16.21	17.29	16.12	17.87	15.40	17.33	15.14	14.97	15.91
65 +	21.23	23.09	22.63	25.67	23.80	20.75	12.23	20.09	21.00
Education level									
Low	20.33	18.16	15.00	20.19	24.70	27.12	15.01	31.56	16.94
Medium	39.62	29.05	46.99	48.14	49.53	40.27	34.74	23.35	36.14
High	40.05	52.79	39.01	31.66	25.77	21.60	50.25	45.09	46.92
Ability to make ends meet									
With great difficulty	8.79	8.50	12.06	7.65	11.12	7.63	6.44	10.05	7.54
With some difficulty	36.38	31.40	43.35	37.31	46.68	34.47	27.97	42.54	30.56
Fairly easily	40.75	40.34	36.11	40.55	34.95	38.47	56.06	35.37	41.29
Easily	14.07	19.77	8.48	14.49	7.25	19.44	9.50	12.04	20.62
Health indicators									
Health problematisation score (mean)[1]	7.47	7.93	7.46	7.94	7.10	7.49	6.76	6.95	7.89
SARS-CoV-2 vaccination									
Yes	49.95	48.36	45.77	46.50	47.85	47.01	47.62	86.56	49.66
No	7.93	6.42	9.33	8.17	8.06	7.99	7.66	13.44	5.30
Not available at the time of data collection	42.12	45.22	44.89	45.33	44.36	45.00	44.72	-	45.03
Trust in information from institutions									
Trust in information from institutions score (mean)[2]	13.21	14.07	12.13	13.00	12.92	13.49	14.17	12.97	12.76

Table 2 (continued)

	All countries ($N=82,052$) (%)	Denmark (=10,968) (%)	France (=11,017) (%)	Germany (=10,969) (%)	Italy (=11,044) (%)	Netherlands (=10,898) (%)	Portugal (=10,980) (%)	Spain (=5143) (%)	United Kingdom (=11,028) (%)
COVID-19 experience									
Knowledge									
No knowledge	1.48	2.20	3.47	1.40	0.55	0.87	0.50	1.44	1.41
Limited knowledge	9.38	13.17	15.16	10.35	5.01	5.52	5.60	6.24	12.26
Some knowledge	43.85	36.64	50.00	50.27	39.58	47.92	42.27	34.47	44.71
A lot of knowledge	45.29	47.99	31.37	37.98	54.86	45.69	51.63	57.85	41.62
Previous infection with SARS-CoV-2[3]									
Yes, confirmed	11.72	12.14	8.73	8.47	10.58	12.97	11.71	19.72	13.73
Yes, but not (yet) confirmed	2.75	2.49	3.20	1.56	1.96	4.51	1.14	3.15	4.22
No	85.53	85.38	88.06	89.97	87.46	82.53	87.16	77.13	82.05
Indirect experience with COVID-19[3]									
Yes, confirmed	47.44	44.65	36.92	35.97	52.88	55.26	55.68	73.11	38.75
Yes, but not (yet) confirmed	3.78	3.76	4.97	2.34	3.02	5.03	2.15	2.66	5.72
No	48.78	51.60	58.10	61.68	44.10	39.71	42.18	24.23	55.53
Quarter (n)									
Q2/2020	13,584	1916	1889	1974	2002	1900	1933	0	1970
Q3/2020	6799	980	962	964	952	978	987	0	976
Q4/2020	6418	951	912	944	913	902	877	0	919
Q1/2021	7068	1012	1012	1008	1009	1006	1005	0	1016
Q2/2021	13996	1756	1994	1890	1952	1840	1706	889	1969
Q3/2021	9599	1310	1094	1165	1124	1225	1372	1197	1112
Q4/2021	3521	287	553	521	568	383	328	341	540
Q1/2022	4798	729	586	486	489	639	708	678	483
Q2/2022	8112	1003	1000	1010	1017	1008	1021	1030	1023
Q4/2022	8157	1024	1015	1007	1018	1017	1048	1008	1020

[1] 5–25, higher score indicates higher health problematisation score

[2] 3–15, higher score indicates greater trust

[3] The original variable contains the response category 'don't know', which we interpreted as a 'no' in our analysis

too does perceived risk (*OR* 1.08; $p<0.001$). Furthermore, individuals who reported being unvaccinated or not having been vaccinated perceived a lower infection risk compared to those who reported having already received at least one dose of the vaccine (*OR* 0.75; $p<0.001$).

Participants who reported being more informed or having higher trust in information from official institutions also reported having greater perceived susceptibility to SARS-CoV-2. Those who indicated not having experienced a previous infection with SARS-CoV-2 perceived a lower susceptibility to SARS-CoV-2 than those who reported a previous infection (*OR* 0.62; $p<0.001$). The same could be observed for indirect experience with COVID-19.

Regarding geographical differences, compared to respondents in Italy, those in France reported a higher perceived susceptibility to SARS-CoV-2 (*OR* 1.16; $p<0.001$), while respondents in all other surveyed countries reported lower perceived susceptibility (*OR* < 1; $p<0.001$). The one exception was the UK, where no difference was found compared to Italy (*OR* 1.04; $p=0.121$).

Perceived susceptibility to SARS-CoV-2 varied over time. It initially increased, peaking in Q4/2020 (*OR* 1.75; $p<0.001$), then gradually decreased to early-pandemic levels by Q3/2021 (*OR* 1.06; $p=0.078$). This was followed by a steep increase in Q4/2021 (*OR* 1.74; $p<0.001$) and Q1/2022 (*OR* 1.72; $p<0.001$) and a subsequent gradual decline in

Table 3 Logistic regression models

				Perceived susceptibility to SARS-CoV-2 (model I) ($n = 82{,}052$)				Perceived risk to health from COVID-19 (model II) ($n = 82{,}052$)
	OR	RSE	[95% CI]	*p* value	OR	RSE	[95% CI]	*p* value
Socio-economic factors								
Gender								
Male	1 (Ref.)				1 (Ref.)			
Female	1.03	(0.01)	[1.00; 1.05]	0.052	1.02	(0.01)	[0.99; 1.05]	0.144
Age in years								
18–24	1 (Ref.)				1 (Ref.)			
25–34	1.45	(0.04)	[1.37; 1.53]	< 0.001	1.69	(0.05)	[1.61; 1.80]	< 0.001
35–44	1.58	(0.04)	[1.50; 1.67]	< 0.001	2.13	(0.06)	[2.02; 2.25]	< 0.001
45–54	1.39	(0.04)	[1.32; 1.47]	< 0.001	2.32	(0.06)	[2.20; 2.45]	< 0.001
55–65	1.26	(0.04)	[1.19; 1.34]	< 0.001	2.97	(0.08)	[2.81; 3.14]	< 0.001
65 +	1.08	(0.03)	[1.02; 1.14]	0.005	3.41	(0.09)	[3.23; 3.60]	< 0.001
Education level								
Low	1 (Ref.)				1 (Ref.)			
Medium	1.02	(0.02)	[0.98; 1.06]	0.397	1.01	(0.02)	[0.97; 1.04]	0.710
High	1.06	(0.02)	[1.02; 1.10]	0.005	1.02	(0.02)	[0.98; 1.06]	0.256
Ability to make ends meet								
With great difficulty	1 (Ref.)				1 (Ref.)			
With some difficulty	0.86	(0.03)	[0.81; 0.91]	< 0.001	0.81	(0.02)	[0.77; 0.85]	< 0.001
Fairly easily	0.70	(0.02)	[0.66; 0.74]	< 0.001	0.62	(0.02)	[0.58; 0.65]	< 0.001
Easily	0.50	(0.02)	[0.47; 0.53]	< 0.001	0.43	(0.01)	[0.40; 0.46]	< 0.001
Health indicators								
Health problematisation score	1.08	(0.00)	[1.07; 1.08]	< 0.001	1.16	(0.00)	[1.15; 1.16]	< 0.001
SARS-CoV-2 vaccination								
Yes	1 (Ref.)				1 (Ref.)			
No	0.75	(0.02)	[0.71; 0.79]	< 0.001	0.79	(0.02)	[0.75; 0.83]	< 0.001
Not available at the time of data collection	1.08	(0.03)	[1.03; 1.13]	0.001	1.02	(0.02)	[0.97; 1.06]	0.479
Trust in information from institutions								
Trust in institutions score	1.11	(0.00)	[1.11; 1.11]	< 0.001	1.12	(0.00)	[1.11; 1.12]	< 0.001
COVID-19 experience								
Knowledge								
No knowledge	1 (Ref.)				1 (Ref.)			
Limited knowledge	0.92	(0.07)	[0.80; 1.06]	0.255	0.86	(0.06)	[0.77; 0.99]	0.034
Some knowledge	1.36	(0.10)	[1.18; 1.56]	< 0.001	1.24	(0.08)	[1.09; 1.41]	0.001
A lot of knowledge	1.77	(0.13)	[1.54; 2.04]	< 0.001	1.67	(0.11)	[1.46; 1.91]	< 0.001
Previous infection with SARS-CoV-2[1]								
Yes, confirmed	1 (Ref.)				1 (Ref.)			
Yes, but not (yet) confirmed	0.89	(0.04)	[0.81; 0.97]	0.007	0.95	(0.04)	[0.87; 1.04]	0.260
No	0.62	(0.02)	[0.59; 0.65]	< 0.001	0.96	(0.02)	[0.92; 1.00]	0.083
Indirect experience with COVID-19[1]								
Yes, confirmed	1 (Ref.)				1 (Ref.)			
Yes, but not (yet) confirmed	1.03	(0.04)	[0.96; 1.10]	0.436	1.05	(0.04)	[0.98; 1.13]	0.129
No	0.63	(0.01)	[0.61; 0.65]	< 0.001	0.84	(0.02)	[0.81; 0.86]	< 0.001
Other								
Quarter								
Q2/2020	1 (Ref.)				1 (Ref.)			

Table 3 (continued)

				Perceived susceptibility to SARS-CoV-2 (model I) ($n=82,052$)		Perceived risk to health from COVID-19 (model II) ($n=82,052$)		
	OR	RSE	[95% CI]	*p* value	OR	RSE	[95% CI]	*p* value
Q3/2020	1.51	(0.04)	[1.42; 1.60]	< 0.001	1.39	(0.04)	[1.31; 1.47]	< 0.001
Q4/2020	1.75	(0.05)	[1.65; 1.86]	< 0.001	1.53	(0.04)	[1.45; 1.63]	< 0.001
Q1/2021	1.45	(0.04)	[1.37; 1.53]	< 0.001	1.39	(0.04)	[1.31; 1.47]	< 0.001
Q2/2021	1.24	(0.03)	[1.18; 1.30]	< 0.001	1.31	(0.03)	[1.25; 1.37]	< 0.001
Q3/2021	1.06	(0.03)	[0.99; 1.12]	0.078	1.11	(0.03)	[1.05; 1.18]	< 0.001
Q4/2021	1.74	(0.07)	[1.62; 1.88]	< 0.001	1.29	(0.04)	[1.20; 1.39]	< 0.001
Q1/2022	1.72	(0.06)	[1.60; 1.85]	< 0.001	1.10	(0.04)	[1.03; 1.18]	0.005
Q2/2022	1.18	(0.04)	[1.11; 1.26]	< 0.001	0.94	(0.03)	[0.89; 1.00]	0.064
Q4/2022	1.16	(0.04)	[1.08; 1.24]	< 0.001	0.95	(0.03)	[0.89; 1.01]	0.113
Country		(0.04)						
Italy	1 (Ref.)				1 (Ref.)			
Denmark	0.56	(0.01)	[0.54; 0.59]	< 0.001	0.57	(0.01)	[0.54; 0.60]	< 0.001
France	1.16	(0.03)	[1.10; 1.22]	< 0.001	1.45	(0.04)	[1.38; 1.52]	< 0.001
Germany	0.91	(0.02)	[0.86; 0.96]	< 0.001	1.04	(0.03)	[0.99; 1.10]	0.105
Netherlands	0.86	(0.02)	[0.82; 0.91]	< 0.001	0.88	(0.02)	[0.84; 0.93]	< 0.001
Portugal	0.74	(0.02)	[0.70; 0.78]	< 0.001	0.89	(0.02)	[0.84; 0.93]	< 0.001
Spain	0.88	(0.03)	[0.82; 0.94]	< 0.001	1.09	(0.04)	[1.03; 1.16]	0.006
UK	1.04	(0.03)	[0.99; 1.09]	0.121	1.23	(0.03)	[1.17; 1.29]	< 0.001
N	82,052				82,052			

RSE robust standard errors; *OR* odds ratios

[1] The original variable contains the response category 'don't know', which we interpreted as a 'no' in our analysis

Q2/2022 (*OR* 1.18; $p < 0.001$) and Q4/2022 (*OR* 1.16; $p < 0.001$). Country-specific time trends are presented in Fig. 1.

Figure 1 shows the predicted probability of respondents perceiving the highest possible susceptibility and risk to health during the COVID-19 pandemic (category 5; very high risk), adjusted for all explanatory variables in the regression model (i.e. socioeconomic factors, health indicators, COVID-19 experience and confidence in risk communication).

Risk to health from COVID-19

The model examining the perceived risk to health from COVID-19 shows some distinct findings (Table 3). There were no associations between gender or education level and the perceived risk to health. In addition, the perceived risk to health continuously increased with age, mirroring the trends in perceived susceptibility up to the second quarter of 2021, albeit with less pronounced fluctuations.

In the third quarter of 2021, the perceived risk to health was still higher than in the second quarter of 2020 (*OR* 1.11; $p < 0.001$), but this increase was only maintained for one quarter (Q4/2021). Thereafter, the perceived risk to health from COVID-19 tended to be even lower compared to the initial phase of the pandemic in the first quarter of 2022 (*OR* 1.10; $p = 0.005$) and the second quarter of 2022 (*OR* 0.95; $p = 0.064$). In the last quarter of 2022 there is no association (*OR* 0.94; $p = 0.113$).

The time- and country-specific results for perceived risk to health from COVID-19 were generally in line with the findings for susceptibility, i.e. the perceived risk to health is highest for France in comparison to Italy. However, in this model, respondents in the UK reported a higher perceived risk to health compared to Italy (*OR* 1.23; $p < 0.001$), and there was no difference in perceived risk to health in Germany, again compared to Italy (*OR* 1.04; $p = 0.99$). The perceived risk to health also varies over time with an increase till the last quarter of 2020 (*OR* 1.53; $p = 0.04$). This is followed by a continuous decline until the last quarter of 2021 (*OR* 1.29; $p = 0.04$), whereas there is no significant effect in the following quarters.

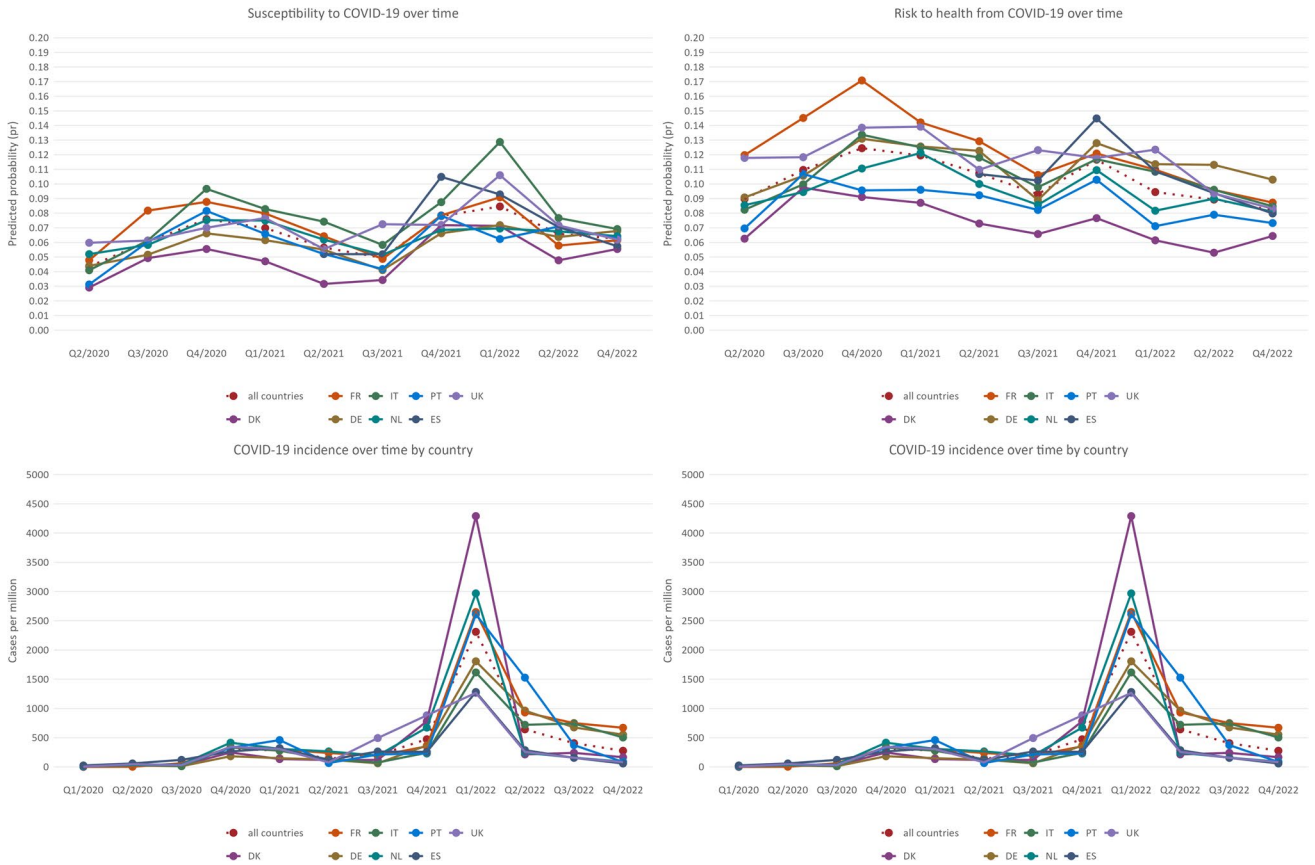

Fig. 1 Predicted susceptibility, predicted risk to health compared to incidence over time. For this graph, country-specific fixed effects (FEs) have been added to the previous regressions. The probabilities refer to the highest category of perceived susceptibility/risk (very high). The actual incidence figures from the second quarter of 2020 to the end of 2022 serve as a comparison to the perceived risk. Data for the first quarter of 2020 and the third quarter of 2022 are not available with ECOS data. Source of incidence: WHO COVID-19 Dashboard (2023)

Discussion

In this study, we analysed large samples of panel data from eight European countries to investigate how socio-economic factors, health status, COVID-19 experience and trust in risk communication were associated with perceived susceptibility and perceived risk to health during the COVID-19 pandemic, using two dimensions of the health belief model (HBM).

We found that women generally had a higher perceived susceptibility to SARS-CoV-2 infection than men. For both genders, perceived susceptibility increased with age, peaking at ages 35–44, followed by a steady decline. In contrast, perceived health risk consistently rose with age. Those without financial difficulties during the pandemic perceived a lower health risk than those facing financial challenges. Higher education levels were associated with increased perceived susceptibility. Additionally, SARS-CoV-2 vaccination status, trust in information, engagement with COVID-19 news and the pandemic phase were all influential factors in risk perception.

Bridging the gap between perceived and actual risk is essential, particularly in the context of infectious diseases, because insufficient awareness can potentially manifest itself in behaviour that leads to increased exposure and transmission rates. Our study found no gender difference in the perception of health risk, which might be attributable to both genders being equally aware of the health impacts of COVID-19 disease. In contrast, other research in risk perception found that women usually rate involuntary risks higher than men (Brown et al. 2021), which is in line with evidence that adult women are more aware of healthy behaviours than men and use health services more frequently (Kim et al. 2018).

At first glance, the age-related results suggest contrasting perceptions of susceptibility between the 65+ and 18–24 year age groups. However, the observation that perceived susceptibility initially increases with age, peaks in the 35–44 year age group, and then decreases again (yet

remains higher than in the youngest group), may be due to several factors. For instance, older individuals typically have fewer social contacts in leisure and work settings, which could lead them to perceive a lower risk of infection compared to young adults, who typically have more active social lives (Dahlberg 2021). Moreover, being more vulnerable to COVID-19, older individuals tend to take the risks to their own health more seriously (Hayden et al. 2023) and report stronger adherence to protective measures (Varghese et al. 2021). As a consequence, COVID-19 protective measures have disproportionately increased isolation among older individuals compared to younger ones (Palmer et al. 2020). This is also in line with our findings that perceived risk to health increases with age.

In terms of educational attainment, individuals with higher levels of education perceived a greater susceptibility to SARS-CoV-2 compared to those with lower levels, although no differences were noted in the perception of health risk by this factor. Previous studies suggest that higher educational attainment is associated with more conscious health behaviour (Margolis 2013), which may contribute to heightened perceived susceptibility (Reed-Thryselius et al. 2022). Additionally, perceived susceptibility and perceived risk to health decreased among those with greater financial stability during the pandemic. Furthermore, those with higher education and income levels were more often able to reduce their exposure to the virus through means such as remote work or online shopping, suggesting that the pandemic may have exacerbated existing inequalities (Falk et al. 2023).

We also found associations between health indicators, such as health status and SARS-CoV-2 vaccination status, and perceived susceptibility and risk. These associations are not surprising because health indicators can act as proxies for one's perceived risk during the COVID-19 pandemic, particularly given that the perceived risk is associated with the degree of exposure to the virus. The pandemic poses a particular risk to exposed populations with pre-existing health conditions or challenging life circumstances (Farley et al. 2020).

Interestingly, unvaccinated individuals perceived lower susceptibility and health risk than individuals who had received at least one dose of the vaccine, despite being at higher risk due to a lack of vaccine-induced immune protection. Aside from these individuals exhibiting more risk-loving preferences in general, which then lead to unwillingness to vaccinate, this perception may also be explained by not regarding vaccination as necessary, often influenced by vaccine scepticism (Phillips et al. 2022; Sabat et al. 2023).

Previous studies have shown that trust in certain entities influences perceived risk (Giordani et al. 2022; Malecki et al. 2021), which is in line with our results. Our findings indicate that perceived risk of infection increases with the level of trust people have in information from institutions and their knowledge about the disease. However, individual variation in perceived risks arises from different reference points. Risks that are initially underestimated may be revised on the basis of external, official statistics. This has implications for behaviour: other studies have found a positive association between trust in government and willingness to engage in behaviours that help societies combat the COVID-19 pandemic (Han et al. 2023; Gotanda et al. 2021). Indeed, trust in the government is a known correlate of vaccine willingness and vaccine hesitancy worldwide (Sabat et al. 2023; Trent et al. 2022; Schernhammer et al. 2022).

Relative to Italy, our findings indicate a higher perceived risk of infection among respondents from France. In contrast, respondents from Denmark, Germany, the Netherlands, Portugal and Spain reported lower perceived susceptibility. Interestingly, perceived susceptibility and perceived risk to health did not always correspond to the actual pandemic incidence or to each other. A particularly striking example is Denmark in the first quarter of 2022, where despite a high incidence of infections, perceived susceptibility to infection was comparatively low compared to Italy.

These findings are largely consistent with the statistics of incident cases per million, except for Denmark and the Netherlands. Both countries showed consistently lower perceived susceptibility and risk to health compared to Italy, despite high incidence rates, particularly in Q1/2022. This disparity could be due to country-specific latent factors, such as cultural attitudes towards risk, health care accessibility or national measures undertaken to protect vulnerable groups. For example, Germans have been found to be more risk-averse than individuals in other countries (Asaria et al. 2023). These results highlight that risk perception is dynamic and influenced by various factors, including observation, experience, information and changing circumstances, such as the availability of a vaccine.

Policy implications

The results of our study indicate that certain groups, especially those who are unvaccinated, have low education levels, or have less trust in public institutions, are more likely to perceive both their susceptibility to SARS-CoV-2 and the risk it poses to their health as lower. This observation underscores the importance of distinguishing between objective and subjective risk assessments. Risk research has demonstrated that there is often a substantial gap between perceived and objectively assessed risks (Cainzos-Achirica and Blaha 2015). This misperception may stem from misinformation, especially since public risk perceptions often depend on trust in the institutions responsible for promoting technologies such as new vaccines and for managing risks (Siegrist and Cvetkovich 2000).

Our findings suggest that these individuals in these groups may have underestimated the infectivity of the virus. Perceived susceptibility, combined with perceived risk to health, plays an important role in motivating health-protective behaviours and can influence virus transmission during pandemics (Clavel et al. 2021). To bridge the gap between perceived and actual risk, proactive public health initiatives are essential. This might include tailored campaigns targeting populations likely to underestimate their susceptibility and health risks. Governments and organisations involved in risk communication should focus on the effectiveness of their messaging, tailoring it to different societal groups and using a variety of communication channels. Furthermore, strategies should be developed to strengthen the credibility of national governments and people's trust in them, addressing widespread information gaps and preparing for future health crises beyond COVID-19.

Limitations

Our findings are subject to certain limitations. First, our analysis was based only on the self-perception of respondents. Owing to data constraints, it was not possible to assess or operationalise the objective susceptibility to SARS-CoV-2 or the actual risk it posed to an individual's health. Second, the ECOS survey was used here as an unbalanced panel, meaning that consistent participation from the same individuals across all survey waves was not guaranteed. This limits our ability to establish causal relationships and confines our results to the analysis of correlations.

Conclusion

Our findings show that socio-economic factors and health-related determinants are associated with the risk perceptions of individuals across Europe in the context of the COVID-19 pandemic. In particular, individuals who reported being unvaccinated, having low levels of education or having less trust in information from institutions were more likely to perceive their susceptibility to SARS-CoV-2 and the risk it posed to their health as being low. Addressing these perceptions requires distinguishing between objective and subjective risk assessments, which was not feasible in this study. For public health campaigns to be effective, there is a need to bridge the gap between actual and perceived risks. Such campaigns should not only encourage individuals to take societal responsibility but also aim to provide accurate and detailed information, thereby fostering a more accurate perception of risks among the general population.

Authors' contributions AR, CB and TS conceptualised and designed the study. CB, SNB, IS, AT, JS, JVE, PPB, TS and WB curated the data. AR conducted the statistical analysis. AR, CB, AH and TS interpreted the data. AR and CB drafted the manuscript. CB, AH, TS, SNB, IS, AT, JS, JVE, PPB and WB critically revised the paper for important intellectual content. AH and TS supervised the study.

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Availability of data and material The ECOS project collected research data for scientific purposes. These data are hosted at Universität Hamburg and can be made accessible to researchers upon reasonable request.

Code availability Not applicable.

Declarations

'WiSo Laboratories Declaration of compliance with Terms of Use and Ethical Standards' of Universität Hamburg.

Ethics approval All participants indicated consent prior to filling in the questionnaire.

Consent to participate All participants included in this study provided informed consent.

Consent for publication All authors read and approved the final manuscript.

Conflicts of interest The authors declare no conflict of interest.

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