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Research Article

Evolution of Perceived Vulnerability to Infection in Japan During the COVID-19 Pandemic

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The global pandemic triggered by the emergence of the highly contagious disease known as COVID-19 has brought about substantial shifts in the everyday lives of individuals across the globe. The present study aimed to elucidate the evolution of perceived vulnerability to disease (PVD) before, during, and after the pandemic by comparing PVD levels in Japan from 2018 to 2023. We analyzed longitudinal changes in perceived vulnerability to disease (PVD) using data collected in Japan across five time points (2018, 2020, 2021, 2022, and 2023). Data from 2018, 2020, and 2021 were obtained from publicly available datasets, while we collected data from 2022 and 2023 for this study. The results showed that although PVD (consisting of perceived infectability and germ aversion) increased significantly in the early stages of the pandemic in 2020, it decreased each year thereafter. By 2023, perceived infectability had declined to a level lower than in 2018, while germ aversion, although lower than in 2020, remained higher than pre-pandemic levels. This finding indicates a tendency to underestimate one's resistance to infection during the pandemic, while after the crisis abated, individuals tend to assess their resistance to infection more positively. In contrast, germ aversion continued to show a lasting effect, remaining elevated even three years after the peak. These results suggest that the pandemic may have introduced a dual effect: in addition to heightening sensitivity to infection prevention, it may have cultivated a sense of "overconfidence" regarding infection resistance. This overconfidence potentially contributes to a more relaxed attitude toward infectious disease risks, as individuals perceive themselves as resilient after enduring an unprecedented public health crisis.

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Introduction

COVID-19 pandemic in Japan

Since the first case of COVID-19 was reported in December 2019, the virus has spread globally from 2020 onward, not only posing a significant threat to human life but also fundamentally altering daily behaviors. Practices such as the routine wearing of masks and frequent use of alcohol-based sanitizers have become markedly more common compared to the pre-COVID-19 period, as individuals grew increasingly aware of the risk of viral transmission in daily life.

In Japan, however, these practices were not entirely new. Cultural norms such as mask-wearing were already well-established prior to the pandemic. Burgess and Horii[1] describe how mask-wearing in Japan reflects a cultural emphasis on hygiene and social responsibility, often practiced as a courtesy to prevent discomfort or illness in others. This cultural backdrop was further reinforced by governmental directives aimed at COVID-19 pandemic mitigation. Beyond voluntary precautions, governmental directives and societal norms enforced certain behavioral adjustments. Previous studies have shown that such behavioral shifts are often influenced by a combination of heightened risk perception and social norms, which play a critical role in shaping compliance with infection-preventive measures[2][3][4].

Notably, in May 2020, the Japanese government introduced a Practicing "New Lifestyle" aimed at COVID-19 pandemic mitigation[5]. This guidance emphasized: (1) Basic infection prevention measures for each person, such as "keep a distance of two meters as much as possible, or at least one meter, between two persons" and "wash your hands and face first when you get back home"; (2) Infection prevention related to traveling, including "Wash and sanitize hands frequently" and "Avoid gatherings in crowded places, close contact settings and closed spaces (three Cs)"; (3) Lifestyle for each scene of daily life (Shopping, Leisure, Sports etc., Public Transports, Meals, Family ceremonial occasions); and (4) New working styles, like remote work. These recommendations broadly reshaped everyday activities.

Moreover, from 2020, government and corporate-supported research efforts intensified to encourage behaviors designed to prevent COVID-19 transmission[6]. The rapid mobilization of public health campaigns and research initiatives during the pandemic highlights the intersection of policy, behavioral science, and health outcomes[7]. Thus, during the pandemic, Japanese citizens were expected to comply with new behavioral norms advocated by the government and research institutions to support infection prevention in daily practices.

Previous studies have examined psychological responses to the COVID-19 pandemic using various approaches. Longitudinal designs, such as those by Mertens et al.[8] and Schneider et al.[9], have focused on individual-level changes throughout the pandemic. Cross-sectional studies, such as Harper et al.[4] and Dryhurst et al.[3], have explored variations in risk perception and compliance behaviors at specific points in time. Together, these studies have provided a multifaceted understanding of pandemic-related psychological changes during the pandemic itself.

However, data from before the pandemic are crucial to fully understand how these psychological changes emerged and whether they represent deviations from pre-existing patterns. Although a previous study on individuals' perceived vulnerability to disease (PVD) before and during the COVID-19 pandemic has been conducted in France[10], such a study is exceedingly rare due to structural constraints, and no research like that has been conducted in Japan so far. Thus, this study uses data from pre-pandemic (2018), pandemic, and post-pandemic (2023) phases to examine PVD, which includes perceived infectability and germ aversion (more on this later). By explicitly incorporating pre-pandemic data, this study highlights how the pandemic reshaped psychological perceptions over time and presents a unique sequence of evidence tracking these changes across critical phases.

The Perceived Vulnerability to Disease

Infectious diseases pose a critical threat to humanity, comparable to disasters and famines[11]. Pandemics such as smallpox, plague, cholera, and Spanish flu have resulted in human losses on an unprecedented scale, surpassing even the tolls of the World Wars. Beyond their physical health risks, pandemics can also exert significant psychological effects, in part through physiological pathways such as inflammation, which has been linked to changes in mental health and well-being[12]. Historical accounts of pandemics underscore the importance of understanding the psychological and behavioral responses to infectious threats, which often persist beyond the immediate crisis[13][14]. The COVID-19 pandemic, too, spread across borders at a surprising rate due to globalization and modern infrastructure, leading to significant loss of life[15][16].

Throughout history, humanity has faced the threat of infectious diseases, which is believed to have led to the development of protection mechanisms against these threats through natural selection pressures[17]. The evolutionary perspective suggests that parasite stress has shaped both physiological and behavioral immune responses, emphasizing the adaptive nature of aversive behaviors in minimizing disease transmission[18][19].

Humans cannot directly perceive viruses or germs, which are common causes of infectious diseases. Consequently, responses to pathogens are generally categorized into two types: expelling pathogens that have entered the body or engaging in behaviors that avoid pathogen exposure altogether. The former includes involuntary responses such as sneezing, coughing, and fever, all part of the immune system's response[20]. In contrast to these automatic responses, the latter involves conscious, proactive behaviors influenced by perceived information and susceptibility, which are often explained within the framework of the behavioral immune system[21]. The behavioral immune system is an adaptation designed to preemptively detect potential sources of contamination and emphasize them through feelings of disgust, prompting avoidance to reduce the likelihood of exposure to pathogens. The system is activated to prevent or reduce physical contact with individuals contaminated by pathogens or with objects that have been contaminated[22]. Therefore, the behavioral immune system also influences interactions with others and social behaviors[23]. During pandemics, these responses often manifest as heightened pathogen avoidance behaviors, such as mask-wearing and social distancing[24]. Such infection prevention behaviors are driven by disease-related avoidance, an adaptive mechanism that reduces the likelihood of exposure to pathogens.

Protecting oneself from threatening pathogens requires an acknowledge of one's vulnerability to infectious diseases. Measuring perceived vulnerability to infection necessitates assessing one's subjective sensitivity to both the physiological immune system and the behavioral immune system. The PVD scale is a measure designed to assess this subjective susceptibility to infectious diseases[25]. The PVD scale has been widely utilized in both clinical and research settings to understand how perceived susceptibility influences health behaviors and risk perception during pandemics[26][27]. The PVD scale consists of two subscales: "perceived infectability," which assesses beliefs about one's own susceptibility to infectious diseases, and "germ aversion," which assesses emotional discomfort in contexts that connote an especially high potential for pathogen transmission[25]. The perceived infectability subscale contains seven items, measuring self-perceived vulnerability in the biological immune system's ability, while the germ aversion subscale includes eight items, assessing the sensitivity in the behavioral immune system based on aversion.

The Effect of the COVID-19 Pandemic on PVD and Behavior

Studies have reported that higher levels of PVD during the COVID-19 pandemic increase engagement in infection-preventive behaviors[26]. In Japan, higher PVD levels have been associated with an increased frequency of mask-wearing[27]. Furthermore, even in post-pandemic, the continuation of behaviors promoted during the pandemic—such as mask-wearing, sanitizing, and maintaining physical distance—has been documented[28]. This suggests that sustained infection-prevention behaviors may have solidified an elevated state of PVD. Specifically, the widespread transmission and severe impacts of the COVID-19 pandemic likely led to a heightened sense of perceived infectability, which may have stabilized at an elevated sensitivity. Behavioral immunity develops through learned experiences; thus, repeated engagement in preventive behaviors can lead to acquired aversions to certain stimuli[29]. Consequently, avoiding aerosol-transmitting behaviors such as sneezing and coughing by others, and even avoiding crowded places over a prolonged period, may have increased germ aversion and solidified at an elevated sensitivity.

While numerous multi-lab studies have examined emotional, cognitive, and behavioral responses to COVID-19 on a global scale (e.g., Lieberoth et al.[30]; Yamada et al.[31]; Wang et al.[32]), including meta-analytic syntheses[33], few studies have systematically tracked participant characteristics over a comprehensive period that spans both before and after the pandemic. This gap is particularly evident in the context of PVD. Despite its critical role in understanding behavioral immune responses, no research to date has longitudinally analyzed changes in PVD using data from pre-, during-, and post-pandemic periods within a single region.

The present study aimed to address this critical gap by leveraging data from 2018 to 2023 to investigate longitudinal changes in PVD among Japanese participants. By examining both perceived infectability and germ aversion, this study tries to provide valuable insights into how the COVID-19 pandemic has shaped subjective susceptibility to infectious diseases. Given the role of PVD in driving infection-preventive behaviors[25][18], understanding its long-term trajectory is essential for predicting and guiding public health responses in future pandemics.

Method

Ethics. This study was approved by the Research Ethics Committee of the Graduate School of Human-Environment Studies at Kyushu University (#2021-030).

Materials. In this experiment, data from a Japanese version of the Perceived Vulnerability to Disease scale[34] collected in 2018, 2020, 2021, 2022, and 2023 were analyzed. Japanese version of PVD scale consisted of 15 items with seven-points Likert scale (one = "Strongly Disagree" to seven = "Strongly Agree"). We calculated the average scores from the response points of the items in each subscale for perceived infectability and germ aversion.

Variables. Perceived infectability and germ aversion subscale scores were treated as dependent variables. Survey year was treated as an independent variable.

Data collection. Data for this study were derived from both newly collected surveys and publicly available datasets. The 2022 and 2023 datasets were specifically collected for this study via online surveys conducted on March 19, 2022, and March 20, 2023. Participants were recruited through Yahoo! Crowdsourcing, and responses were collected using Google Forms.

For earlier datasets, data from 2018, 2020, and 2021 were obtained from previously published studies. The 2018 dataset was reported by Yamada et al.[35], the 2020 dataset by Yonemitsu et al.[6], and the 2021 dataset by Fukukawa[36]. All datasets were collected using Yahoo! Crowdsourcing, applying consistent recruitment methods and similar exclusion criteria to ensure comparability across years. The data from 2018, 2020, and 2021 are open data explicitly permitted for secondary use. The 2018 data are licensed under CC0 1.0 Universal, the 2020 data under CC BY 4.0, and the 2021 data under CC BY 4.0, all of which allow use by third parties.

Participants. Participants for this study were recruited through Yahoo! Crowdsourcing, and responses were collected via Google Forms from Japanese individuals aged 18 years or older. By choosing to participate in the survey, individuals were considered to have provided informed consent, as stated in the survey instructions. Inclusion criteria required participants to be fluent in Japanese. Exclusion criteria included failing attention check questions, which consisted of simple arithmetic problems designed to ensure attentiveness, or providing incomplete responses. An "attention check calculation question" is a type of task often incorporated into research studies to assess participants' attentiveness and engagement during the study. For example, such a question might include a simple arithmetic problem or a specific instruction embedded within the text that participants must follow correctly. By analyzing the responses to these attention checks, researchers can identify inattentive participants and ensure the validity and reliability of their collected data. We prioritized ensuring that statistical comparisons could be conducted appropriately by considering the scale of the previous data and aimed for a sample size of approximately 2,000 participants.

The use of arithmetic-based attention checks is supported by prior research, which demonstrates their effectiveness in identifying inattentive respondents and improving data quality in web surveys (Conrad et al., 2017).

The 2018 dataset, obtained from Yamada et al.[35], included 1,366 participants (mean age = 43.5 years; 833 men, 533 women) after excluding 46 individuals with invalid responses. For the 2020 dataset, 1,304 participants were included in the PVD analysis, as reported in Yonemitsu et al.[6]. While detailed demographic information for the PVD-specific sample was not available, the sample was drawn from the same participant pool as the main analysis sample (1,104 participants, mean age = 46.45 years; 648 men, 456 women). Due to identical recruitment methods and exclusion criteria, it is reasonable to infer that the PVD analysis sample shared similar demographic characteristics. However, the mean age and gender distribution for the PVD analysis sample remain speculative and should be interpreted with caution. The 2021 dataset, obtained from Fukukawa[36], included 2,952 participants (mean age = 45.1 years; 1,633 men, 1,280 women, unknown = 35) after excluding 87 participants for incomplete or invalid responses.

For the 2022 and 2023 datasets, new data were collected specifically for this study. In the 2022 survey, a total of 2,176 individuals participated. Data from 17 participants who failed the attention check were excluded, leaving 2,159 participants (mean age = 47.04 years; *SD* of age = 11.85; 1,360 men, 768 women, 31 others). Similarly, in the 2023 survey, 2,074 individuals participated. Data from 40 participants who failed the attention check were excluded, leaving

2,034 participants for analysis (mean age = 49 years; *SD* of age = 11.91; 1,312 men, 709 women, 13 others).

Data analysis. The effect of survey year for the perceived infectability and germ aversion subscale scores were tested using a one-way analysis of variance (ANOVA). Additionally, to test for pairwise differences between survey years, multiple comparisons were performed using the Tukey-Kramer method.

Results

The 2022 and 2023 data obtained in this study are openly available in a repository (https://osf.io/fn9xa/). Figure 1 shows the main results. A one-way ANOVA was conducted using the perceived infectability subscale scores as the dependent variable, and the main effect of survey year was found to be significant ($F(4, 9822) = 41.804$, $p < .001$, $\eta^2 = .017$). The descriptive statistics were as follows: 2018 (*N* = 1382, *M* = 3.83, *SD* = 1.14), 2020 (*N* = 1304, *M* = 4.06, *SD* = 1.19), 2021 (*N* = 2948, *M* = 3.86, *SD* = 1.09), 2022 (*N* = 2159, *M* = 3.86, *SD* = 1.09), and 2023 (*N* = 2034, *M* = 3.60, *SD* = 1.10). Post hoc multiple comparisons indicated that perceived infectability in 2020, at the onset of the COVID-19 pandemic, was significantly higher than in 2018, 2021, 2022, and 2023 (2018 vs. 2020: $t(9822) = -5.542$, $p < .001$, $d = -0.214$; 2020 vs. 2021: $t(9822) = 3.93$, $p < .001$, $d = 0.1307$; 2020 vs. 2022: $t(9822) = 5.257$, $p < .001$, $d = 0.1844$; 2020 vs. 2023: $t(9822) = 11.894$, $p < .001$, $d = 0.4219$). There was no significant difference in perceived infectability between 2018 and the post-pandemic years of 2021 and 2022 (*p*s > .01). Notably, perceived infectability in 2023 was significantly lower than in 2018, 2020, 2021, and 2022 (2018 vs. 2023: $t(9822) = 5.966$, $p < .001$, $d = 0.2080$; 2021 vs. 2023: $t(9822) = 10.103$, $p < .001$, $d = 0.2912$; 2022 vs. 2023: $t(9822) = 7.688$, $p < .001$, $d = 0.2376$).

For the germ aversion subscale scores, a one-way ANOVA also revealed a significant main effect of survey year ($F(4, 9822) = 149.17$, $p < .001$, $\eta^2 = .057$). The descriptive statistics were as follows: 2018 (*M* = 4.33, *SD* = 0.98), 2020 (*M* = 5.10, *SD* = 1.06), 2021 (*M* = 4.68, *SD* = 1.00), and 2023 (*M* = 4.70, *SD* = 1.14). Post hoc multiple comparisons indicated that germ aversion in all survey years following 2018 was significantly higher than in 2018 (2018 vs. 2020: $t(9822) = -19.81$, $p < .001$, $d = -0.765$; 2018 vs. 2021: $t(9822) = -20.768$, $p < .001$, $d = -0.677$; 2018 vs. 2022: $t(9822) = -9.822$, $p < .001$, $d = -0.3384$; 2018 vs. 2023: $t(9822) = -10.226$, $p < .001$, $d = -0.3565$). No significant decrease in germ aversion was found between 2020 and 2021 ($p = .145$), but germ aversion in 2022 and 2023 was significantly lower than in 2020 (2020 vs. 2022: $t(9822) = 11.839$, $p < .001$, $d = 0.4152$; 2020 vs. 2023: $t(9822) = 11.193$, $p < .001$, $d = 0.3971$).

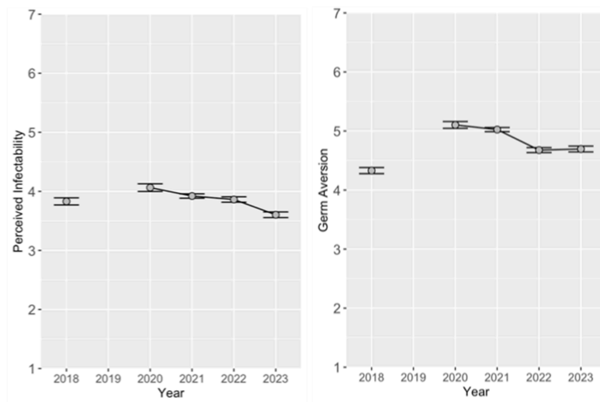

Figure 1. Mean scores of PVD subscales by year. The error bars denote 95% confidence intervals. Left: Results for the perceived infectability subscale. Right: Results for the germ aversion subscale.

Discussion

In this study, we hypothesized that the COVID-19 pandemic would lead to an elevated PVD and that this heightened level would be maintained in the post-pandemic period. Our findings confirm a significant increase in both perceived infectability and germ aversion during the early stages of the pandemic, particularly in 2020 compared to pre-pandemic levels in 2018. This supports the hypothesis that the pandemic would elevate PVD. Furthermore, the observed increase followed by a year-over-year decline highlights the dynamic nature of PVD, suggesting that it may not remain permanently elevated even in the aftermath of a global health crisis.

These findings provide crucial evidence on the temporal dynamics of PVD and underscore the importance of longitudinal data in capturing such changes. By comparing pre- and post-pandemic data, our study addresses a critical gap in the literature. Existing research has largely focused on PVD during the pandemic without baseline comparisons from before the outbreak (e.g., Makhanova & Shepherd[24]; Shook et al.[37]). Our results advance the understanding of how subjective vulnerability evolves over time, particularly under prolonged health crises.

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The present results contrast with reports of continued voluntary infection-prevention behaviors post-pandemic. However, the continuation of behaviors such as mask-wearing, even after government recommendations ceased, may be explained by social considerations, where individuals maintain preventive measures due to concerns about others' evaluations[38]. This suggests that while PVD itself declines, behavioral adaptations shaped during the pandemic may persist for reasons beyond subjective vulnerability.

These findings highlight distinct patterns for perceived infectability and germ aversion over time. However, the demographic composition of the samples varied slightly across years, which could influence these results. For instance, the mean age increased in later datasets (e.g., 43.5 years in 2018 vs. 49 years in 2023), and the proportion of male participants rose slightly. These factors may partially account for differences in PVD scores, particularly in 2020, where detailed demographic data for the PVD-specific sample were unavailable. Although recruitment methods were consistent across years, caution is warranted when interpreting year-to-year differences.

Focusing on perceived infectability, although it initially increased in June 2020, by March 2022, it had returned to a level not significantly different from pre-COVID-19 levels. In Japan, the last state of emergency for COVID-19 was declared in September 2021, and 2022 marked the period when daily life and behaviors gradually began to revert to pre-pandemic norms. This return to normalcy may have contributed to the decrease in perceived infectability to pre-COVID-19 levels, alongside the lifting of governmental restrictions, likely contributed to the decline in perceived infectability[7]. Additionally, the decrease in perceived infectability may be influenced by the increase in vaccination rates. While COVID-19 vaccines were still in clinical trials in June 2020, vaccinations began in February 2021[1], and by March 2022, many individuals had already received their third booster dose. Thus, the perception that one's body had become more resistant to infectious diseases due to vaccination may have contributed to the decrease in perceived infectability, warranting further examination of this point.

The most unusual result was the significant decrease in perceived infectability in March 2023, where it was even lower than pre-pandemic levels. Results of multiple comparisons for 2023 and other years indicated that perceived infectability did not simply revert to pre-pandemic levels after the turmoil of the pandemic but instead suggested an increased self-assessment of resilience to infectious diseases compared to before the pandemic. This phenomenon may be partially explained by risk compensation theory, which posits that individuals adjust their behaviors and perceptions based on perceived levels of protection[39][14]. Similarly, as literature has pointed out[40], excessive exposure to pandemic-related information can lead to "coronavirus blindness," where individuals become desensitized to the perceived severity of the pandemic. This may be attributed to factors such as multiple vaccine doses and a comparison of one's own symptoms with those of severe cases, leading individuals to view themselves as having a body resilient enough to survive the pandemic. It is currently unclear whether this decrease in perceived infectability is temporary or sustained. Therefore, continuous surveys are necessary to monitor this trend in the future.

Focusing on germ aversion, its trends from 2018 to 2022 were similar to those of perceived infectability, showing an increase in 2020 followed by a gradual decline in subsequent years. This decrease may also suggest that vaccination contributed to a reduced aversion to behaviors associated with the risk of droplet infection. However, the trend in 2023 differs from that of perceived infectability. Results of multiple comparisons indicated that, although germ aversion significantly decreased from 2020, it remained significantly higher than in 2018. This suggests that aversion based on the behavioral immune system, may be more susceptible to prolonged influence from threats of pandemics than self-assessments of biological immunity. Additionally, the increase in germ aversion before and during the COVID-19 pandemic has also been reported in France[10]. This suggests that changes in avoidance behaviors driven by the behavioral immune system may be consistent across some cultural contexts. These findings reveal that even after experiencing a pandemic that drastically altered lifestyles, peak sensitivity gradually declines over time. However, the fact that germ aversion remained significantly higher than pre-COVID-19 levels in 2018 suggests that lifestyle changes and heightened awareness of viral threats have maintained a certain level of aversion.

This sustained elevation of germ aversion observed in Japan through 2023 may reflect not only individual psychological changes but also broader cultural and societal influences. For example, mask-wearing has been a long-standing norm in Japan, often linked to hygiene practices and social expectations rather than solely individual health concerns[1]. This cultural foundation may have facilitated the persistence of heightened germ aversion, even as governmental recommendations for mask-wearing and other preventive behaviors were relaxed. Furthermore, Japan's reliance on voluntary compliance during the pandemic, as opposed to strict mandates, may have contributed to the sustained elevation of germ aversion observed in 2023. This approach, emphasizing social responsibility over enforcement, likely enhanced behaviors such as mask-wearing and hygiene practices, even as official recommendations were relaxed. While this study may be hard to directly compare Japan's patterns to those of other cultural contexts due to the natural experiment-like nature of the COVID-19 pandemic (unless other studies similar to our study in other regions are reported in other regions), the persistence of heightened germ aversion underscores the potential influence of cultural norms and policy approaches on long-term psychological responses to pandemics. However, such patterns can only be robustly tested in future global health crises, as direct experimental manipulation is neither ethical nor feasible. In the interim, cross-cultural comparisons using existing datasets, meta-analyses of similar constructs across different regions, or computational models simulating cultural and policy scenarios could provide valuable insights.

This study has several limitations that warrant consideration. First, the demographic information for the 2020 PVD-specific sample was not directly available, and inferences were made based on the main analysis sample reported in Yonemitsu et al.[6]. While this approach is reasonable given the consistency of recruitment methods, it introduces some uncertainty. Second, the datasets did not include detailed socio-economic or educational background information, which may influence PVD. The PVD can vary depending on gender and age[41]. Additionally, the behavioral immune system associated with PVD is connected to social behaviors. This highlights the importance of incorporating detailed demographic information in studies using the PVD scale. Future studies should aim to collect more comprehensive demographic data to enhance the comparability of samples across years. Finally, while this study utilized a repeated cross-sectional design with consistent methods, the absence of individual-level longitudinal data limits our ability to track changes in PVD within the same participants over time.

In this study, while peak levels of sensitivity were not sustained, it was evident that aversion to infection-related behaviors remained stronger than pre-pandemic levels over a period of several years. Additionally, the pandemic appears to have introduced a dual effect: beyond increasing sensitivity to infection prevention, it may have fostered a sense of "overconfidence" in infection resistance, potentially leading to a more relaxed stance towards infectious disease risks, given that people perceive themselves as resilient for having survived an unprecedented crisis. Moving forward, it is essential to continue research on PVD while also comparing it with available international data to explore the underlying causes of sensitivity changes induced by the pandemic.

Statements and Declarations

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Competing interests

No potential competing interests to declare.

Authors' contributions

All authors contributed equally to the writing of this manuscript.

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