Journal of Psychopathology and Behavioral Assessment (2025) 47:54
https://doi.org/10.1007/s10862-025-10223-x

Health Anxiety Across Pandemic Waves: Psychometric Assessment and Measurement Invariance of the Infectious Disease Outbreak Anxiety Scale Over Time

Maria Moutinho[1,2] · **Tiago Ferreira**[2,3] · **Carla Cunha**[1,2]

Accepted: 22 May 2025 / Published online: 24 June 2025

Abstract
The present paper examines the psychometric properties and measurement invariance of the Infectious Disease Outbreak Anxiety Scale (IDOAS) across three phases of the COVID-19 pandemic: the first and second waves (2020 and 2021), and post-pandemic phase (2023/2024). Study 1 assesses the validity and reliability of the IDOAS through exploratory and confirmatory factor analyses, supporting a three-factor structure (factors: "Disease Outbreak Concerns", "Impact on Routines and Safety Behaviors", and "Contamination Concerns"), demonstrating good internal consistency. Study 2 employs a multigroup confirmatory factor analysis to investigate measurement invariance across the three samples. Measurement invariance was not established across the three time points of data collection, especially for the post-pandemic phase. Findings reveal significant shifts in how health anxiety is experienced over time. This study emphasizes the evolving nature of COVID-19-related anxiety and underscores the importance of developing tools specifically designed to assess health anxiety related to infectious diseases and fear of contagion for future outbreaks.

Keywords Infectious diseases · COVID-19 · Health anxiety · Psychometric properties · Measurement invariance

The global health crisis triggered by COVID-19 highlighted the importance of understanding and assessing health-anxiety, not only during critical periods of the pandemic but also in subsequent stages of recovery and adaptation. The Infectious Disease Outbreak Anxiety Scale (IDOAS), adapted from the *Swine Flu Inventory,* developed by Wheaton and colleagues (2011) has been used as a tool to assess specific anxiety related to the COVID-19 pandemic. However, its validity and consistency across different phases of the pandemic and in post-pandemic scenarios has not been fully investigated yet. The present paper aims to fill this gap by examining the factorial structure of the IDOAS and assess its measurement invariance at three time points: during the first and second waves of the pandemic and in the post-pandemic period.

✉ Carla Cunha
ccunha@umaia.pt

[1] UMAIA – University of Maia, Avenida Carlos de Oliveira Campos, Maia, Portugal

[2] Center for Psychology at University of Porto, Porto, Portugal

[3] FPCEUP - Faculty of Psychology and Education Sciences of the University of Porto, Porto, Portugal

The Importance of Anxiety in Health During Infectious Disease Times

The World Health Organization (WHO) highlights anxiety as one of the main factors influencing global mental health, especially during pandemics and infectious disease outbreaks (WHO, 2020, 2021). During the COVID-19 pandemic, various studies have shown a significant increase in anxiety levels among global populations (Chen et al., 2023; WHO, 2020). A study conducted in 2021 indicated that cases of anxiety doubled since the beginning of the pandemic, affecting more than 1 billion people worldwide (Smith & Jones, 2021). These data evidences the physical effects of the pandemic but also its psychological ramifications. When a health threat is perceived, whether through outbreaks of viral diseases (e.g., COVID-19, H1N1 influenza, SARS) (Asmundson and Taylor, 2020; Wijnant et al., 2020; Wu et al., 2009) or other pathologies (e.g., AIDS, Lyme disease) (Kelly et al., 1998; Steere et al., 2003),

anxiety emerges as a natural and significant response (Taylor & Asmundson, 2004). This anxiety is fueled by uncertainty, fear of the unknown, and potential life risk, leading to significant health concerns (Asmundson and Taylor, 2003; Taylor & Asmundson, 2004). Anxiety in infectious diseases extends beyond the individual scope, also affecting social, political, and economic dynamics (Mahoney & McEvoy, 2012; Smith and Jones, 2018). Fear of contagion can trigger avoidance behaviors, distrust towards health authorities, and dissemination of misinformation. These behavior patterns can, in turn, complicate efforts for prevention, control, and response to infectious disease outbreaks (Bavel et al., 2020). Furthermore, anxiety in these situations is associated with a significant increase in rates of anxiety and depression disorders, affecting mental health (Gallagher et al., 2020; Liu et al., 2020). These issues may persist even after disease control, requiring adequate assessment tools.

Defining and Measuring Health Anxiety: Understanding the Construct

Health anxiety is characterized by an exaggerated assessment of the probability of becoming ill and an amplified perception of the negative consequences associated with having a serious illness (Salkovskis et al., 2002; Wheaton et al., 2010). Health anxiety can manifest in various situations, from fear of virus exposure to worry about the personal and social consequences of the disease (Abramowitz & Braddock, 2008; Taylor & Asmundson, 2004). Various instruments assess health anxiety, focusing on the intensity and impact of anxiety on various aspects of people's lives (Tyrer et al., 2016). Among the instruments for assessing this construct are the Short Health Anxiety Inventory (SHAI; Salkovskis et al., 2002) and the Worry Illness Questionnaire (WI-7; Warwick & Salkovskis, 1989), which quantify health anxiety and physical symptoms. However, these tools do not capture the full range of anxiety experiences or context-specific concerns (e.g., the impact of media reports or lockdowns on health anxiety) and fail to account for other important factors, such as the effect of health anxiety on daily functioning (e.g., avoidance of social interactions and public places due to fear of contracting COVID-19).

The Swine Flu Inventory, developed by Wheaton and colleagues (2011), is an effective tool for assessing health anxiety and behaviors related to infectious diseases, particularly during pandemics. This instrument evaluates concerns about virus transmission, severity, and preventive measures, offering insights into health anxiety during global health crises. It is designed to be adaptable for various public health emergencies, capturing detailed perceptions and responses to such events. During the COVID-19 pandemic, the Swine Flu Inventory was adapted to create the Infectious Disease Outbreak Anxiety Scale (IDOAS). This adaptation addresses the specific concerns related to COVID-19, including virus spread, contamination fears, and exposure to outbreak information. The revised instrument aims to improve the screening and assessment of distress related to COVID-19 at this specific stage, securing also the possibility of being applicable to other future infectious disease outbreaks. However, the lack of studies upon the factorial structure of the original the Swine Flu Inventory raises questions about its factorial structure, reliability, and validity in different contexts or over time. While the number of factors consistently remains at two (e.g. Shabani et al., 2023—10 items; Factor 1: "*COVID-19* Fear" and the Factor 2: "*COVID-19* Safety Behaviors"; Bösch & Inauen, 2022—9 items: Factor 1: "*COVID-19* Fear" and the Factor 2: "Risk perception *COVID-19*"), the number of items has varied between 9 and 10. Notably, the question "Did the declaration of a pandemic by the World Health Organization have an impact on you?" has been removed. Additionally, the specific items included have fluctuated, and the designations of the factors are often quite similar, making it challenging to distinguish between them. It is important to note that these studies did not make significant adaptations to the initial items, limiting changes only to those related to the name of infectious disease and the location of its spread. In contrast, our version of the instrument incorporated substantial modifications aimed at ensuring the relevance, accuracy, and applicability of the scale in the context of the COVID-19 pandemic and lockdowns in Portugal. Critically, our approach went beyond mere terminological updates (e.g., replacing "swine flu" with "COVID-19"). While the scale was adapted for COVID-19 as the current infectious disease under focus, its structure and item content were intentionally designed as a template for future infectious disease outbreaks. The use of italicized and underlined placeholders (e.g., [disease name], [country/region]) serves as a blank space to be filled and adjusted according to the specific pandemic context, mirroring the adaptability of widely used transdiagnostic measures. This template-based approach allows researchers to quickly modify the scale while maintaining its psychometric properties—a flexibility particularly valuable for screening health anxiety across evolving public health crises. Therefore, the results from these previous studies do not provide a suitable foundation for our analysis.

Measurement invariance is crucial in scientific research (Vandenberg & Lance, 2000), especially during pandemic waves, where the consistency of measurements over time may be affected. Recent studies highlight the need to assess measurement invariance at different times during the pandemic (Bonzini et al., 2021; Cao et al., 2021; Smith et al., 2023; Yang et al., 2022; Zhang et al., 2021). This is essential to ensure accurate comparisons between population groups and over time, providing valuable insights into the psychological

impacts of the pandemic and guiding effective interventions. However, the dynamics of the COVID-19 pandemic may challenge measurement invariance in assessment scales due to variations in pandemic conditions, such as infection rates and public health policies. These changes can influence people's responses over time and in different geographic regions, resulting in inconsistency in psychological measurements. Notwithstanding, an adaptation for assessing COVID-19-related anxiety has become necessary due to its prior development and validation base in a similar pandemic context during the spread of the H1N1 virus. The hypothesis is that the "Swine Flu Inventory" could provide a solid and well-founded framework for assessing specific anxiety related to COVID-19, considering that both contexts involve similar concerns about contagion, disease severity, and preventive measures. Thus, adapting this instrument for COVID-19 may offer a consistent anxiety assessment during this pandemic.

The Current Study

The present study has the following main objectives: (a) to adapt and validate the IDOAS for use with adults, ensuring relevance and applicability for future pandemics (as a flexible tool for future public health crisis); and (b) to investigate the invariance of the IDOAS among Portuguese adults during the three phases of the COVID-19 pandemic (first, second waves and post-pandemic scenario).

To achieve these goals, two studies were conducted. Study 1 aims primarily to validate the IDOAS and study the psychometric properties of the IDOAS in terms of factorial structure. For this, a Portuguese version of the IDOAS was adapted for the COVID-19 pandemic, and its questions adjusted across the three phases of the pandemic (three time points). Study 2 aims to investigate the measurement invariance of the IDOAS at the three time points of data collection. Taken together, the two studies will provide a comprehensive understanding of the validity and consistency of the IDOAS as an assessment tool for health anxiety in future public health crisis due to infectious disease outbreaks.

Study 1

This study evaluates the underlying factorial structure of the IDOAS, through Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) to assess its psychometric properties.

Materials and Method

Participants

The present sample comprised 200 participants of Portuguese nationality, including 177 females (85%) and 23 males (15%). Participants' ages ranged from 18 to 72 years, with a mean age of 37.74 years (SD = 12.27). Regarding university qualifications, 36% of participants had a bachelor's degree ($n = 71$), 18% had a master's degree ($n = 37$), and 2.5% had completed a doctorate ($n = 5$). 19.5% of participants completed secondary education (high school diploma; $n = 39$) and 15.5% ($n = 31$) had an equivalent qualification. Finally, 4% had completed the second cycle ($n = 8$) and 4.5% the third cycle ($n = 9$).

Measures

Infectious Disease Outbreak Anxiety Scale (IDOAS) The IDOAS consists of 10 items *(e.g., "How quickly do you believe contamination from COVID-19 is spreading in Portugal?")* assessing perceptions, anxiety, and behavioral changes related to COVID-19 and the impact that the lockdown had on participants' lives. Each item is rated on a 5-point Likert scale ranging from 0 = *Very Little* to 4 = *Very Much*. The original scale, "Swine Flu Inventory" (Wheaton et al., 2011), was developed in the United Kingdom during the H1N1 flu outbreak. It was adapted to assess perceptions and behaviors related to COVID-19 during the COVID-19 pandemic in Portugal. The main modifications included replacing items to reflect specific concerns related to COVID-19, such as personal risk perception, likelihood of infection, and disease spread in Portugal. Exposure to information was expanded to encompass various media sources due to the rapid dissemination of digital information. Items regarding social interaction decisions and travel plans were adjusted to consider the impact of confinement on daily routines and work practices, reflecting changes in safety behaviors and adaptation to public health guidelines. These adaptations aimed to ensure the relevance, accuracy, and applicability of the scale in the context of the COVID-19 pandemic in Portugal.

Procedure

We obtained authorizations from the Ethics Committee of the University of Maia (Portugal) as well as informed consent from all participants (approval references 1/2020 and 80/2023). All participants completed an online questionnaire distributed through social media platforms (Facebook, Instagram, and LinkedIn) and by the Portuguese Psychologists Association through its mailing list. The online questionnaire was shared in various online groups covering topics related to COVID-19, mental health, and regional issues, resulting in participation from individuals across all regions of Portugal. The average response time was approximately 15 min.

Data Analysis

Initially, an EFA was conducted to identify the underlying structure of the data matrix and the number and nature of factors that best represent the observed variables (Brown, 2006). First, the adequacy of the data to the statistical procedure was verified, considering the sample size and the relationship between the items. Following Nunnally's (1978) recommendation of a ratio of ten participants to each item of the scale, it was concluded that the sample used met this assumption ($N = 200$). Next, Bartlett's Test of Sphericity and the Kaiser–Meyer–Olkin (KMO) sampling adequacy measure were utilized. To determine the number of factors to be extracted, three criteria were considered: the parallel analysis method, Kaiser-Guttman criterion, and Scree Plot. Subsequently, the quality of items was analyzed, considering that communalities with values below 0.40 would be excluded, as it suggests that these items may not be related to the others (Costello & Osborne, 2005).

Following this, the initial model was confirmed using a CFA. Within this framework, chi-square values, GFI (Goodness of Fit Index), CFI (Comparative Fit Index), and RMSEA (Root Mean Square Error of Approximation) were considered to assess the overall fit of the factorial model. Reference values followed Hu and Bentler (1999) proposal, where values lower than 0.06 for RMSEA, greater than 0.95 for CFI and TLI, and lower than 0.08 for SRMR indicate good model fit (Hu & Bentler, 1999). If necessary, modification indices would be used to improve the fit. All the analysis were conducted in JASP (version 18.3.0).

Results

To assess the factorial structure of the IDOAS we conducted an EFA with factor extraction using the Maximum Likelihood estimation method, followed by oblique rotation. To assess the suitability of the dataset for factor analysis, we used the KMO measure and Bartlett's Test of Sphericity (Hu & Bentler, 1999). The KMO measure indicated a good sample adequacy for analysis (KMO = 0.75), and Bartlett's Test of Sphericity [χ^2(45) = 4427.300, $p < 0.001$] suggested that the association matrix is not an identity matrix.

To aid in determining the number of factors to be extracted, three criteria were considered: the parallel analysis method, Kaiser-Guttman criterion, and Scree Plot. The results obtained in the EFA pointed to a final solution composed of three factors. The first factor, named "Disease outbreak concerns", explains 30.5% of the total variance, composed of items 1, 2, and 3. The second factor, named "Impact on routines and safety behaviors", explains 13.2% of the total variance, composed of items 4, 5, and 6. The last factor, named "Contamination concerns", explains 11.2% of the total variance, composed of items 7, 8, 9, and 10.

As Table 1 shows, communalities values were high and the factor loadings (all above 0.40) suggest a good relation between the items and the identified factors.

Next, to confirm the factor solution derived from the EFA, we conducted a CFA. Results confirmed the three-factors solution with the corresponding items found in the EFA (see Fig. 1). All items showed adequate standardized factor loadings, ranging from 0.67 to 0.74. This measurement model provided adequate fit to the data (χ2 (45) = 386.64,

Table 1 EFA of the IDOAS with varimax rotation and communalities

Items	Factors			Commonalities
	1	2	3	
1. To what extent are you concerned about *[COVID-19*]*?	.808	.241	,043	.713
2. Did the declaration of a pandemic by the World Health Organization have an impact on you?	,743	,310	-,031	.649
3. How quickly do you believe contamination from *[COVID-19*]* is spreading in *[Portugal*]*?	.653	-.081	,258	.500
4. How likely is it that you could become infected with *[COVID-19*]*?	,277	,098	,813	.748
5. How likely is it that someone you know could become infected with *[COVID-19*]*?	,230	,097	,816	.727
6. If you did become infected with *[COVID-19*]*, to what extent are you concerned that you will be seriously ill?	,186	-,043	,488	.487
7. How much exposure have you had to information about *[COVID-19*]* (e.g. news, social media)?	.382	,454	-,002	.402
8. To what extent has the threat of *[COVID-19*]* influenced your routines?	,177	,809	,097	.695
9. To what extent has the threat of *[COVID-19*]* influenced your work?	,076	,788	,149	.649
10. To what extent has the threat of *[COVID-19*]* influenced the use of safety behaviors? (e.g. disinfect hands)	,400	,511	,033	.422

*Through adjusting the underlined expressions, the IDOAS can be adapted to other future infectious disease outbreaks besides COVID-19

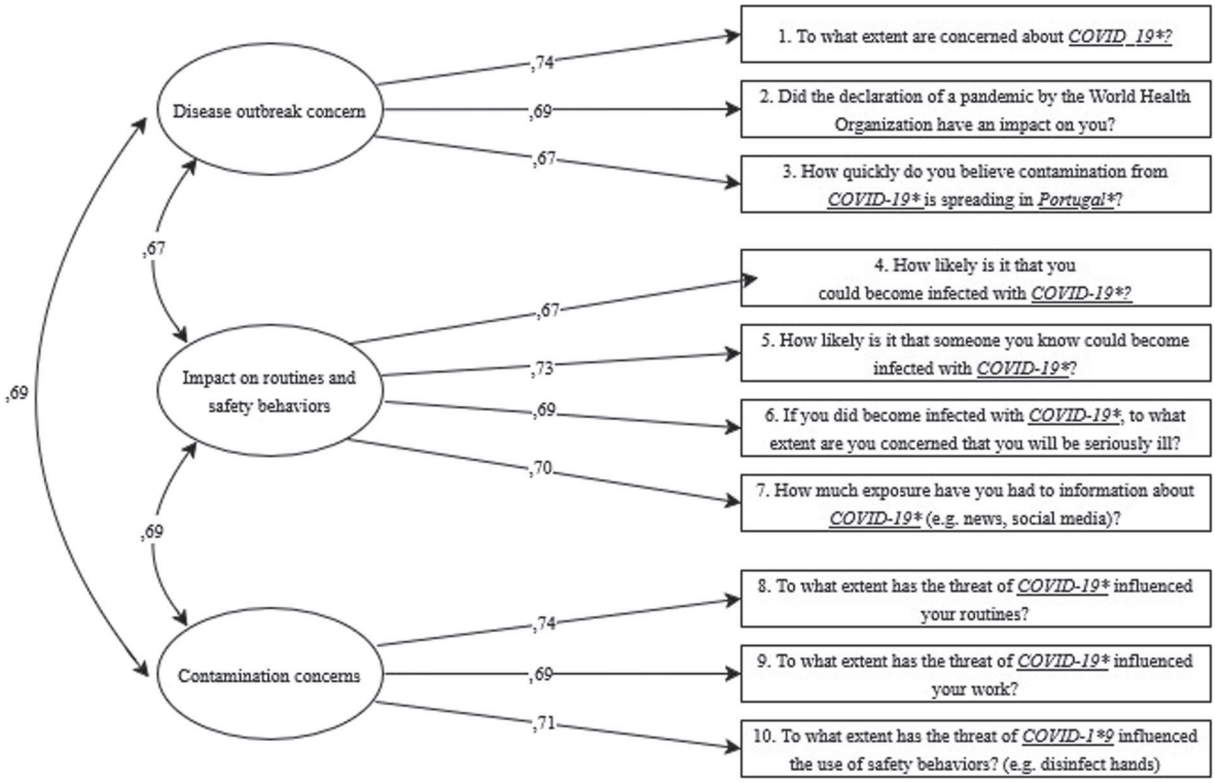

Fig. 1 CFA of the IDOAS

$p < 0.001$, CFI = 0.94, TLI = 0.91, RMSEA = 0.06, and SRMR = 0.05). The 10 items composing the IDOAS, organized into a three-factor structure, demonstrated adequate overall internal consistency (α = 0.73). The internal consistency for each factor was as follows: (1) Disease Outbreak concerns (α = 0.68), (2) Impact on routines and safety behaviors (α = 0.45), and (3) Contamination concerns (α = 0.60).

Discussion

The "Swine Flu Inventory," originally developed by Wheaton and colleagues (2011) to assess health anxiety, perceptions, and behaviors related to the H1N1 infectious disease, was adapted to address specific aspects of the COVID-19 pandemic outbreak, resulting in the IDOAS. This adaptation aimed to provide a more comprehensive and accurate assessment of the psychological distress associated with the COVID-19 pandemic. The current study focused on adapting and validating the IDOAS for use with adults in the Portuguese population, ensuring its cultural and linguistic sensitivity and applicability for future pandemics. This validated tool emerges as a practical and evidence-based tool for assessing, screening, and monitoring health anxiety in public health crisis contexts.

The study of the psychometric characteristics of the IDOAS scale suggests that it is a valid and reliable measure for assessing health anxiety, perceptions, and behaviors related to COVID-19. The analysis of the factorial structure of the instrument provided valuable insights into the multidimensional nature of anxiety related to COVID-19. Thus, Exploratory Factor Analysis (EFA) indicated the presence of three factors: 1) Disease Outbreak concerns, 2) Impact on routines and safety behaviors, and 3) Contamination concerns. The identified factors reflect the different aspects of concern and stress induced by the pandemic, providing a solid basis for clinical understanding and intervention.

The subsequent Confirmatory Factor Analysis (CFA) served to corroborate the validity of the three-factor structure identified in the EFA. The results of this analysis indicated that the IDOAS is a reliable tool for assessing health anxiety about the disease in public health and crisis contexts, such as the COVID-19 pandemic. The internal consistency of the items in the IDOAS was also considered satisfactory, suggesting that the instrument is capable of consistently measuring the constructs under study.

The practical implications of this study are significant for clinical practice, public health policies, and psychosocial screening during the COVID-19 pandemic. The validation of the IDOAS offers a valuable tool for assessing and screening pandemic-related health anxiety. However, several limitations should be noted: The sample was limited to adults in the Portuguese population, which may affect

the generalizability of the results to other cultural or demographic groups. The IDOAS is subject to common biases in self-report instruments, such as social desirability and response distortion. Although validated for the Portuguese population, further research is needed to confirm its applicability and reliability in different cultural and linguistic contexts.

Study 2

The second study aims to verify the measurement invariance (MI) of the IDOAS scores from three independent samples, measured during distinct epidemiological stages: the first wave of COVID-19, the second wave of COVID-19, and the post-pandemic phase.

Materials and Method

Participants

We collected data from three independent samples at three time points, namely during the first wave of the pandemic ($n_{(sample\ 1)} = 2000$), during the second wave of the pandemic ($n_{(sample\ 2)} = 2396$), and in the post-pandemic scenario ($n_{(sample\ 3)} = 1815$), totaling a combined sample of 6211 participants. Table 2 details the origin of the data.

Measures and Procedure

As in Study 1, we used the IDOAS in Study 2 to evaluate health anxiety. Based on the results from the prior EFA and CFA, we adopted a factorial structure with three factors: (1) Disease outbreak concerns, (2) Impact on routines and safety behaviors (3) Contamination concerns. The data collection procedure used in this study is the same as used in Study 1.

Data Analysis

The MI was tested through conducting a Multigroup CFA analysis. All analyses were conducted in JASP (version 18.3.0) (JASP Team, 2022). The MI analysis aims to examine the hypothesis about the similarity of the covariance structure between the scores of the IDOAS collected at the three time points. For running MI, we considered and compared three nested models: (a) Configural invariance model, where all model parameters are allowed to vary across groups, but the overall model structure is kept the same; (b) Metric invariance model, keeping factor loadings invariant across groups; (c) Scalar invariance model, also requiring invariant intercepts across groups (Van de Schoot et al., 2012). Because the hypothesis about the similarity of the covariance structure between the three data collection time points was not confirmed, we

Table 2 Sociodemographic characteristics of participants during the first wave (Sample 1), second wave (Sample 2), and post-pandemic (Sample 3)

	Sample 1		Sample 2		Sample 3	
	N	%	N	%	N	%
Sex						
Female	1701	85	1827	76	1094	61
Male	299	15	568	24	721	39
Educational qualifications						
Reading and writing skills	9	0.5	5	0.1	3	0.2
First cycle	5	0.3	14	0.5	34	1.9
Second cycle	24	1.4	25	1	32	1.7
Third Cycle	96	5.5	109	4	44	2.5
9th grade equivalency	19	1	13	0.4	22	1.2
12th grade equivalency	154	8.8	213	9	162	9
Secondary Education	363	20.8	584	25	362	20
Bachelor's degree	760	43.6	953	40	674	37
Master's Degree	276	15.8	375	16	457	25
Doctorate	39	2.2	100	4	25	1.5
	Min and max	M(SD)	Min and max	M(SD)	Min and max	M(SD)
Age	18 to 88 years	39.84 (12.20)	18 to 90 years	38.33 (13.86)	18—90 years	35.60 (14.70)

inspected partial invariance to identify which parameters differed across groups and understand further the nature and extent of these differences. Reference values following Chen's (2007) proposal indicate that the criteria for metric invariance and scalar invariance are $\Delta CFI \leq -0.010$ or $\Delta RMSEA \leq 0.01$.

Results

The alfas, means, standard deviations, and correlations of the variables, separately for each of the samples, are presented in Table 3.

In the first step, the best model found in Study 1 (three-factor model) was tested separately for the data from the three samples. The model showed adequate fit indices for all three samples, as can be seen in Table 4. The factor loadings were all significantly different from zero. Next, we evaluated whether the model met the criteria for configural invariance. This was done by estimating the hypothesized model simultaneously across the different samples, without including equality constraints for model parameters. Configural invariance criteria were met, as indicated by good model fit indices across the different samples (see Table 4). Regarding metric invariance, the scale could not be considered metrically invariant across samples, since the change in CFI exceeded the recommended thresholds ($\Delta CFI = -0.034$), although the change in RMSEA remained below the recommended threshold ($\Delta RMSEA = -0.001$). Therefore, we analyzed whether partial metric invariance could be achieved. After inspecting parameters for the three samples equality constraints for the sample 3 loadings were removed, they were largely different than the loadings from sample 1 and 2. The results showed that the hypothesized model was invariant between sample 1 and sample 2, thus establishing partial metric invariance ($\Delta CFI = 0.004$; $\Delta RMSEA = 0.000$).

Next, we analyzed whether the IDOAS met the criteria for scalar invariance between sample 1 and 2. We did not consider scalar invariance for sample 3, given that

Table 3 Alfa, means, standard deviations and correlations of the three data collection variables

	α	M (SD)	1. Disease outbreak concerns	2. Impact on routines and safety behaviors	3. Contamination concerns
Sample 1 (first wave)					
1. Disease Outbreak concerns	.68	21.87 (2.65)	—		
2. Impact on routines and safety behaviors	.56	29.08 (3.02)	.468***	—	
3. Contamination concerns	.59	17.01 (2.34)	.396***	.371***	—
Sample 2 (second wave)					
1. Disease Outbreak concerns	.58	22.03 (2.10)	—		
2. Impact on routines and safety behaviors	.70	27.24 (2.90)	.611***	—	
3. Contamination concerns	.42	17.84 (1.53)	.491**	.351**	—
Sample 3 (post-pandemic)					
1. Disease Outbreak concerns	.83	15.52 (3.49)	—		
2. Impact on routines and safety behaviors	.75	16.63 (4.09)	.350**	—	
3. Contamination concerns	.58	13.35 (3.17)	.514***	.617***	—

*$p < .05$, ** $p < .01$, *** $p < .001$

Table 4 Results of the invariance analysis for model 1 across sample 1, sample 2 and sample 3

Model	x^2	df	p	CFI	RMSEA	ΔCFI	ΔRMSEA
Sample 1 ($N = 2000$)	328.18	32	< .001	.923	.068	-	-
Sample 2 ($N = 2396$)	148.78	32	< .001	.973	.039	-	-
Sample 3 ($N = 1815$)	197.25	32	< .001	.966	.053	-	-
Configural invariance	674.21	87	< .001	.955	.057	-	-
Metric invariance	1564.03	101	< .001	.921	.071	.034	-.001
Partial metric invariance [a]	750.38	94	< .001	.951	.057	.004	.000
Partial scalar invariance [a]	2097.02	114	< .001	.953	.051	-.002	.006

$\chi 2$ = Chi squared; CFI = comparative fit index; RSMEA = root-mean-square error of approximation; ΔCFI = change in comparative fit index; ΔRMSEA = change in root-mean-square error of approximation

[a]the equality restrictions imposed between sample 3 loadings were removed

metric invariance was not met. The results showed that the hypothesized model is invariant between sample 1 and 2. The criteria for scalar invariance between the scores from these two samples were thus met ($\Delta CFI = -0.002$; $\Delta RMSEA = 0.006$).

Discussion

The present cross-sectional study aimed to assess the MI of the IDOAS at three distinct time points: during the first and second waves of the COVID-19 pandemic and in the post-pandemic scenario. We found that invariance was not observed across the three data collection time points, particularly during the post-pandemic phase.

The lack of invariance in the third data collection time point (post-pandemic phase) of the IDOAS, suggests a complex dynamic in the experience of COVID-19-related anxiety over time. Several explanations may be considered for this intriguing finding. The analysis of the factor loadings of items comprising the COVID-19-related anxiety factor in the IDOAS revealed significant variations specifically at the third data collection point. These differences suggest a shift in how health anxiety is measured over time, potentially assigning greater or lesser importance to certain items at the expense of others. During the post-pandemic phase, the item "How quickly do you believe contamination from COVID-19 is spreading in Portugal?" demonstrated a more pronounced factor loading. This change can be attributed to shifts in public perception regarding virus spread, influenced by the implementation of mitigation strategies such as mass vaccination campaigns and more effective public health protocols. The introduction of these initiatives may have improved the overall perception of safety and control over the spread of the virus, leading people to perceive that the spread may be being contained more efficiently than during the early stages of the pandemic. Previous studies suggest that infection risk perception is directly related to the adoption of preventive behaviors and ongoing vigilance over virus spread (Bavel et al., 2020; Harapan et al., 2020). Conversely, items such as "How likely is it that someone you know could become infected with COVID-19?" and "If you did become infected with COVID-19, to what extent are you concerned that you will be seriously ill?" showed decreases in factor loadings during the third data collection point. This reduction may indicate a shift in the importance attributed to these items as indicators of anxiety, rather than a general decrease in anxiety levels. Van Kersen et al. (2024) highlighted that individual risk perception and perceived disease severity tend to decrease as populations adapt to new conditions and emerging scientific information. This suggests that as people became more familiar with the actual risks of COVID-19 and adopted adaptation strategies, the intensity of concerns regarding the risk of infection and the severity of the disease may have decreased, reflecting a psychological adaptation to the post-pandemic context.

Additionally, the level of exposure to COVID-19 information, as measured by the item "How much exposure have you had to information about COVID-19 (e.g., news, social media)?" also showed a decrease in factor loading. This suggests a potential adaptation of the public to pandemic information saturation, as media attention and societal priorities evolved over time (Lee et al., 2022). As the pandemic continues, people may adjust their information consumption to focus on other areas of daily life or emerging issues beyond the pandemic. In the occupational context, items such as "To what extent has the threat of COVID-19 influenced your work?" and "To what extent has the threat of COVID-19 influenced the use of safety behaviors? (e.g., disinfecting hands)" exhibited increases in factor loadings, indicating persistent concerns about safety and adaptation of work practices during and after the critical phase of the pandemic. This increase may be attributed to the complexity of organizational changes and individual practices in response to public health guidelines and post-pandemic workplace demands (Bavel et al., 2020). These analyses of variations in the factor loadings of items in the IDOAS provide detailed insights into the evolution in how COVID-19-related anxiety is measured. The observed changes illustrate shifts in the importance attributed to different items as indicators of anxiety, highlighting how these shifts reflect broader macro-level factors affecting individuals' lives. This underscores the need for dynamic approaches in public mental health assessment and intervention that account for evolving societal influences and their impact on individual well-being.

Strengths, Limitations, and Future Directions

The findings of this study highlight several significant practical implications for mental health interventions and public health policies in response to the dynamics of COVID-19-related anxiety over time. The analysis of variations in factor loadings of the IDOAS items reveal the need for dynamic and adaptable intervention strategies. It is essential to tailor therapeutic approaches to reflect changes in the perception and experience of anxiety throughout different phases of the pandemic, ensuring an effective response to individual and collective needs. However, some important limitations should be noted. The data collection method, relying on online surveys distributed through social media and professional networks, resulted in samples with significant gender imbalances (e.g., 85% women in the first wave), which may affect the generalizability of findings to more diverse populations. Additionally, this sampling approach likely excluded certain demographic groups with limited digital access or mastery of digital skills, such as the elderly individuals or people in rural communities. The absence of a

consistent measure for assessing COVID-19-related anxiety across pandemic and post-pandemic phases complicates direct comparisons of anxiety levels. Anxiety dynamics shift with evolving circumstances; during the pandemic, concerns were driven by virus uncertainty, infection fears, and socioeconomic impacts. In the post-pandemic phase, as mitigation measures and vaccinations were implemented, these concerns may have lessened or changed. This lack of invariance reflects shifts in public perception of infection risk and the effectiveness of health interventions, affecting how anxiety is experienced and prioritized throughout different stages of the crisis. As well as the continuous adaptation of the measure to capture the specific temporal and contextual nuances of each phase of the pandemic and post-pandemic, longitudinal studies are essential for tracking the evolution of anxiety over time, allowing for a more robust analysis of changes in individual and collective perceptions and experiences of anxiety.

Furthermore, to enhance the IDOAS's applicability in future infectious disease outbreaks, several key steps are necessary. First, the scale's template-based design—featuring placeholders such as *"[disease name]"* and *"[country/region]"*—ensures rapid adaptation to novel pathogens and infectious outbreaks. However, future empirical validation during emerging outbreaks will remain necessary to confirm its psychometric robustness across diverse contexts. Proactive validation studies conducted during inter-pandemic periods could establish baseline properties, enabling faster and more reliable deployment during crises. Second, partnerships with public health agencies and global mental health networks are vital to integrate the IDOAS into future outbreak response frameworks. Such collaborations would facilitate real-time anxiety monitoring, guiding tailored interventions. Cross-cultural validation studies must also be prioritized to ensure linguistic and socio-cultural relevance, particularly in low-resource regions disproportionately affected by infectious disease outbreaks. Another crucial aspect would be to explore how contextual factors, such as public health policies, media influence, and organizational adaptation, shape the perception and experience of health anxiety over time. These studies could provide fundamental insights to guide public policies and clinical practices, contributing to the refinement of this assessment tool for more effective screening and monitoring during public health crises.

Conclusion

The present studies on the IDOAS evidence its validity and reliability in assessing anxiety during the pandemic (Study 1). Factor analysis identified three main dimensions of concern: virus spread, changes in routines and safety behaviors, and perception of infection likelihood and severity, highlighting the multifaceted complexity of anxiety during pandemics and global emergencies. The lack of invariance across pandemic phases (Study 2), particularly in the post-pandemic phase, suggests a complex dynamic in the experience of COVID-19-related anxiety over time. This variation in IDOAS item factor loadings indicate changes in the importance attributed to different aspects of anxiety, reflecting adaptations in public perception of infection risk and the effectiveness of public health interventions.

The true contribution of this study is the development of a tool for assessing health anxiety, specifically related to infectious diseases and the fear of contagion during future outbreaks. This advancement represents a significant contribution to future discussions on improving the management of health anxiety associated with infectious diseases and better preparing responses to public health emergencies.

Authors Contributions Maria Moutinho https://orcid.org/0000-0002-5563-4241, contribution on conceptualization formal analysis and writing – original draft.

Tiago Ferreira https://orcid.org/0000-0002-2884-2547, contribution on methodology and writing – review & editing.

Carla Cunha https://orcid.org/0000-0001-7369-5075, contribution on conceptualization and writing – review & editing.

All authors approved the final version of the article.

Funding Open access funding provided by FCT|FCCN (b-on). This article was supported by the Portuguese Foundation for Science and Technology (FCT) under the Pluriannual Funding Programme for Research Units 2020–2023 UIDP/00050/2020 and through the Ph.D. Grant 2021.09368.BD and https://doi.org/10.54499/2021.09368. BD, and MCTES, FSE, and UE.

Data Availability Data are available upon request from the Authors.

Declarations

Publication Ethics All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study. We obtained authorizations from the institutional Ethics Committee of the authors as well as informed consent from all participants (approval references 1/2020 and 80/2023).

Open Data Open Data: The information needed to reproduce all of the reported results is not openly accessible. Further information can be requested from the authors.

Open Materials: The information needed to reproduce all of the reported methodology is not openly accessible. Further information can be requested from the authors.
Open Analytic Code: The code is not openly accessible.

Conflict of interest Maria Moutinho, Tiago Ferreira and Carla Cunha declare that they have no conflict of interests.

References

Abramowitz, J. S., & Braddock, A. E. (2008). *Psychological treatment of hypochondriasis and health anxiety: A biopsycho-social approach*. Hogrefe & Huber.

Asmundson, G. J. G., & Taylor, S. (2003). *Health anxiety: Clinical and research perspectives onhypochondriasis and related conditions*. John Wiley & Sons.

Asmundson, G. J., & Taylor, S. (2020). How health anxiety influences responses to viraloutbreaks like COVID-19: What all decision-makers, health authorities, and health care professionals need to know. *Journal of Anxiety Disorders, 71*, 102211.

Bavel, J. J. V., Malhotra, N., & Van Boven, L. (2020). using social and behavioral science to support COVID-19 pandemic response. *Nature Human Behaviour, 4*(5), 460–471. https://doi.org/10.1038/s41562-020-0884-z

Bonzini, M., et al. (2021). Psychometric properties of the Fear of COVID-19 Scale: A replication study and cross-validation. *Journal of Psychosomatic Research, 141*, 110334. https://doi.org/10.1016/j.jpsychores.2020.110334

Bösch, V. D., & Inauen, J. (2022). Older adults' physical activity after lockdown: Testing the health action process approach and the moderating role of fear of Covid-19. *Applied Psychology: Health and Well-Being, 15*, 369–389. https://doi.org/10.1111/aphw.12384

Brown, T. A. (2006). *Confirmatory factor analysis for applied research*. The Guilford Press.

Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., Dong, J., & Zheng, J. (2021). The measurement invariance of the fear of COVID-19 scale among people in quarantine in China. *Journal of Psychiatric Research, 135*, 1–7. https://doi.org/10.1016/j.jpsychires.2020.12.020

Chen, F. F. (2007). Sensitivity of goodness of fit indices to lack of measurement invariance. *Structural Equation Modeling, 14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chen, L., Wang, L., & Zhang, J. (2023). Psychological impact of the COVID-19 pandemic on global populations: A systematic review and meta-analysis. *Journal of Affective Disorders, 297*, 88–96.

Costello, B., & Osborne, W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10*(7), 1–9.

Gallagher, M. W., Zvolensky, M. J., Long, L. J., Rogers, A. H., & Garey, L. (2020). The impact of Covid-19 experiences and associated stress on anxiety, depression, and functional impairment in American adults. *Cognitive Therapy and Research, 44*(6), 1043–1051.

Harapan, H., Itoh, N., Yufika, A., Winardi, W., Keam, S., Te, H., & Mudatsir, M. (2020). Coronavirus disease 2019 (COVID-19): A literature review. *Journal of Infection and Public Health, 13*(5), 667–673.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55. https://doi.org/10.1080/10705519909540118

JASP Team. (2022). JASP (Version 0.16.1) [Computer Software]. Retrieved March 3, 2024, from https://jasp-stats.org

Kelly, B., Raphael, B., Judd, F., & Perdices, M. (1998). Psychological responses to HIV/AIDS: Perceived stigma and the role of coping. *International Journal of Mental Health and Addiction, 2*(1), 15–27.

Lee, Y., Jeon, Y. J., Kang, S., Shin, J. I., Jung, Y. C., & Jung, S. J. (2022). Social media use and mental health during the COVID-19 pandemic in young adults: A meta-analysis of 14 cross-sectional studies. *BMC Public Health, 22*(1), 995. https://doi.org/10.1186/s12889-022-13409-0

Liu, H., Zhang, E., Wong, F., Hyun, S., & Hahm, C. (2020). Factors associated with depression, anxiety, and PTSD symptomatology during the COVID-19 pandemic: Clinical implications for U.S. young adult mental health. *Psychiatry Research, 290*, 113172.

Mahoney, J., & McEvoy, M. (2012). A transdiagnostic examination of intolerance of uncertainty across anxiety and depressive disorders. *Cognitive Behaviour Therapy, 41*(3), 212–222.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). McGraw-Hill.

Salkovskis, M., Rimes, K. A., Warwick, H. M., & Clark, D. M. (2002). The health anxiety inventory: Development and validation of scales for the measurement of health anxiety and hypochondriasis. *Psychological Medicine, 32*(5), 843–853.

Shabani, J., Mohsenabadi, H., Gharraee, B., Shayanfar, F., Corcoran, V. P., & McKay, D. (2023). Psychological correlates of health anxiety in response to the coronavirus (COVID-19) pandemic: A cross-sectional online study in Iran. *International Journal of Cognitive Therapy, 16*(1), 103–122. https://doi.org/10.1007/s41811-022-00152-y

Smith, K., & Jones, M. (2018). The social and economic impacts of infectious disease outbreaks on communities: The case of Ebola. *International Journal of Mental Health and Addiction, 20*(4), 589–601.

Smith, J., & Jones, A. (2021). Impact of the COVID-19 pandemic on mental health: A global cross-sectional study. *Journal of Mental Health, 45*(3), 123–135.

Smith, J. K., et al. (2023). Geographical variability in the measurement invariance of COVID-19 assessment scales: A multi-region study. *Journal of Public Health, 45*(2), 201–214.

Steere, C., Drouin, E., & Glickstein, J. (2003). Relationship between immunity to Borrelia burgdorferi outer-surface protein A (OspA) and Lyme arthritis. *Clinical Infectious Diseases, 37*(Suppl 1), S111–S115. https://doi.org/10.1086/375010

Taylor, S., & Asmundson, G. J. G. (2004). Treating health anxiety: A cognitive-behavioral approach. *International Journal of Mental Health and Addiction, 2*(1), 5–16. https://doi.org/10.1007/s11469-004-3261-y

Tyrer, P., Cooper, S., Tyrer, H., & Salkovskis, P. (2016). Health anxiety in medical clinics: A systematic review and meta-analysis of diagnostic aid. *Journal of Psychosomatic Research, 91*, 17–25.

Van De Schoot, R., Lugtig, P., & Hox, J. (2012). A checklist for testing measurement invariance. *European Journal of Developmental Psychology, 9*, 486–492. https://doi.org/10.1080/17405629.2012.686740

Van Kersen, W., de Rooij, M. M. T., Portengen, L., et al. (2024). Impact of COVID-19 containment measures on perceived health and health-protective behavior: A longitudinal study. *Science and Reports, 14*, 419. https://doi.org/10.1038/s41598-023-50542-1

Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods, 3*(1), 4–70.

Warwick, C., & Salkovskis, W. (1989). The worry illness questionnaire: A measure of health anxiety. *Behaviour Research and Therapy, 27*(6), 589–595. https://doi.org/10.1016/0005-7967(89)90020-5

Wheaton, M. G., Berman, N. C., Franklin, J. C., & Abramowitz, J. S. (2010). Health anxiety: Latent structure and associations with anxiety-related psychological processes. *Journal of Psychopathology and Behavioral Assessment, 32*, 565–574.

Wheaton, G., Abramowitz, S., Berman, C., Fabricant, E., & Olatunji, O. (2011). Psychological predictors of anxiety in response to the H1N1 (Swine Flu) pandemic. *Cognitive Therapy and Research, 36*(3), 210–218. https://doi.org/10.1007/s10608-011-9353-3

WHO. (2020). Mental health and psychosocial considerations during the COVID-19 outbreak (WHO/2019-nCoV/MentalHealth/2020.1). Retrieved June 19, 2024, from: https://www.who.int/docs/default source/coronaviruse/mentalhealthconsiderations.pdf

WHO. (2021). COVID-19 weekly epidemiological update. Retrieved June 19, 2024, from:https://www.who.int/publications/m/item/weekly-epidemiological-update

Wijnant, A., Jacobs, M., van Rijn, L., et al. (2020). Persistence of Ebola virus in semen among Ebola virus disease survivors in Sierra Leone: A cohort study of frequency, duration, and risk factors. *The Lancet Global Health, 8*(2), e239–e246. https://doi.org/10.1016/S2214-109X(19)30546-7

Wu, P., Fang, Y., Guan, Z., et al. (2009). The psychological impact of the SARS epidemic on hospital employees in China: Exposure, risk perception, and altruistic acceptance of risk. *Canadian Journal of Psychiatry, 54*(5), 302–311. https://doi.org/10.1177/070674370905400504

Yang, X., et al. (2022). Investigating the measurement invariance of COVID-19 assessment scales across pandemic phases: A Multi-Country Study. *Journal of Health Psychology, 27*(3), 543–556.

Zhang, W., et al. (2021). Investigating Measurement Invariance of the Fear of COVID-19 Scale Across Different Pandemic Phases and Groups in China. *Frontiers in Psychology, 12*, 629792. https://doi.org/10.3389/fpsyg.2021.629792

Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH (“Springer Nature”).

Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users (“Users”), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use (“Terms”). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.

These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.

We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.

While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval , sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.

These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.

To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.

Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.

If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com