International Journal of Disaster Risk Reduction 68 (2022) 102720

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Statistical indicators of compliance with anti-COVID-19 public health measures at European airports

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A R T I C L E I N F O

Keywords:
COVID-19
Infectious disease
Import cases
Public health interventions
Mitigation measures
Travel-related infection

A B S T R A C T

International travel and the infrastructures involved are key elements in controlling and predicting the number of infections by an infectious disease (specifically COVID-19 cases). This research presents the rates or percentages of compliance with COVID-19 mitigation measures at several international airports in Europe (Madrid, Dublin, Paris-Charles de Gaulle, Zurich, Barcelona, and Bilbao). A structured survey called the COVID-19 Measures Implementation Rate at Airports (MIRA) was developed. First, the validity and reliability of the measurements obtained by MIRA were analyzed. A total of 1239 volunteers (passengers, cabin crew, and ground crew) participated in the study and answered the MIRA questionnaire. Second, once the validity and reliability of the measurements were assured, the rates or percentages of cases that observed compliance with the mitigation measures were calculated. The results indicated that participants perceived a low degree of compliance with sanitary measures in their international travel (the proportions ranged from 52.6% to 59%). The airports with the highest compliance with mitigation measures were the Dublin (with a rate of 70%) and Zurich airports (with a rate of 69.1%). In conclusion, the percentages could be low due to the ineffective implementation of some of the mitigation measures. The low percentages are not related to the health measures themselves. The implications of mitigation measures for containing the transmission of infectious diseases such as COVID-19 are discussed.

1. Introduction

During the COVID-19 pandemic, widespread restrictions and preventive measures were implemented in most countries to contain the spread of the coronavirus [1,2]. These measures were characterized by (1) the use of mouth masks, (2) the utilization of disinfection products, (3) the physical distancing of people from each other, (4) the closure of certain types of establishments, (5) the implementation of curfews, (6) the social quarantining of the population in their homes, and (7) the widespread limitation of travel [3–5]. Although these measures were present in most activities and countries, analysis of how they impacted coronavirus transmission and people's perception of safety is still under investigation [6–8].

One of the sectors and human activities that influence pathogen transmission is international travel [9]. There is sufficient evidence in the scientific literature demonstrating the importance of airports and air travel during the spread of coronavirus [10,11]. This evidence considers the interactions between travelers and the infrastructures involved in air travel as an essential factor in predicting the spread and estimating the containment of a virus such as SARS-CoV-2 [12]. Of the seven measures highlighted above in most

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https://doi.org/10.1016/j.ijdrr.2021.102720
Received 27 August 2021; Received in revised form 10 November 2021; Accepted 5 December 2021

Available online 11 December 2021
2212-4209/

international and western airports, at least six were implemented (the "curfew" was not implemented at airports) [13]. Therefore, analyzing the impact of these measures on passengers, crew members, and ground workers at international airports is essential to optimizing future decisions and verifying which prevention measures were the most consistently used in this context [14,15].

The research that examined the impact of prevention measures implemented in international travel was based on epidemiological survey studies [8,16]. These surveys analyzed passengers' attitudes regarding their travel experience during the COVID-19 pandemic but did not inquire about which measures were not implemented at airports [17]. Other studies used geo-localization analyses of the COVID-19 incident cases in areas near airports to relate them to the measures enforced at the nearby airport in each of those residential areas [18,19]. Along these lines, most investigations concluded that COVID-19 cases were more frequent in cities with an associated airport [20,21]. In fact, in China, international airports generated an increase in incidence rates of 21.2% [22]. Similarly, measures applied at airports could explain changes in the incidence rates of nearby populations [23].

One of the handicaps was that there was no research on which COVID-19 mitigation measures were most prevalent at airports and how they affected passengers, cabin crew members, and ground workers. It is also unknown what the impact of these mitigation measures was on the stress levels of airport workers. Most studies focused on the impact of facemask use, but there are more mitigation measures that conditioned travelers and workers [24,25]. Analyzing the relationship between the most prevalent mitigation measures at airports and the travelers' perception of compliance with them could provide useful data to determine the most effective prevention measures to reduce COVID-19 incidence rates in populations near airports [26].

The objectives of this research consisted of the analysis and mathematical measurement of the degree of compliance perception of travelers with COVID-19 transmission preventive measures during the entire air travel, including passenger interactions from the moment they enter the departure airport until they leave the destination airport. The purpose of these analyses was to determine which mitigation measures were more and/or less complied with. Airport users' perception of anti-COVID-19 measures provides crucial information: although we know that effective preventive measures (e.g., social distancing) exist, these measures have no value if people do not abide by them. Therefore, we should consult the degree to which each user applies COVID-19 mitigation measures to reinforce the use of those less used. The perception of compliance with mitigation measures was surveyed with three different types of populations: (1) travelers or passengers, (2) cabin crew members, and (3) ground crew members. The *COVID-19 Measures Implementation Rate at Airports* (MIRA) metric was developed and mathematically validated. Fig. 1 illustrates the logic behind this study.

Fig. 1 summarizes the main objectives of this research. Although the information source was self-reported in all cases, it was considered a multisource because it came from three different populations. Some researchers also use the term multilevel; however, in this study, each population cannot be considered a "level" because they do not form independent clusters [27]. In this way, if only passengers' statements were considered, the measurement would not be complete or exhaustive. Thus, the purpose is to obtain a valid and reliable measure for each of the evaluation contexts' mitigation measure applications.

2. Methods

2.1. Participants

A total of 1239 adult volunteers over 21 years of age participated ($Mean_{age} = 36.55$; $SD_{age} = 7.495$); 592 participants (47.8%) were men, and 646 (52.1%) were women. Volunteers came from 4 departure airports: (1) Charles de Gaulle International Airport (n = 333, 26.9%); (2) Bilbao Airport (n = 278, 22.4); (3) Dublin International Airport (n = 327, 26.4%); and (4) Zurich International Airport (n = 301; 24.3%). Likewise, participants from two arrival airports responded to this study: (1) El Prat International Airport, Barcelona (n = 628, 50.7%) and (2) Adolfo Suarez Madrid-Barajas International Airport (n = 611, 49.3%). Participants included passengers (n = 463; 37.4%), cabin crew members (n = 399; 32.2%), or ground persons (n = 377; 30.4%). This allowed the study to be conducted from a multisource perspective. Finally, participants could choose whether to answer the MIRA test using the Spanish or English version. A total of 619 chose the Spanish version, and 620 preferred to respond to the English version.

All participants collaborated in this research on a voluntary and completely anonymous basis. Finally, they signed an informed consent form in which all the information and purposes of this research were explained. For more information on the access to the sample and the data collection procedure, see section 2.2.2 "Procedures related to data collection".

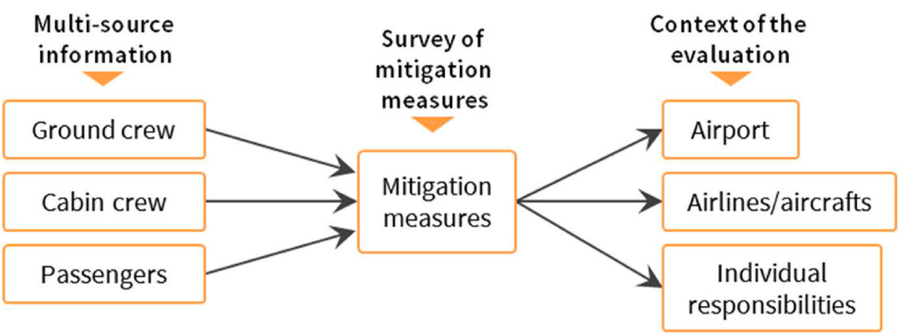

Fig. 1. Flow chart explaining the logic and summarizing the research objective. For each evaluation context, there will be an index reporting the frequency or presence of mitigation measures.

2.2. Procedures

The development of this research was based on structural equation modeling. Specifically, it has a nonexperimental psychometric survey design [28,29].

2.2.1. Procedures for the creation of the MIRA rate

The construction of the MIRA index was based on multiple published evidence regarding mitigation measures and COVID-19 health restrictions [20–23]. 23 items were written in sentence form. All MIRA items were the same for passengers, cabin crew, and ground staff. Similarly, the content of the items did not change qualitatively and was the same for the English and Spanish versions.

During the development of the items, some concepts were clarified in parentheses to avoid confusion among participants. Specifically, the minor contents in parentheses were the only expressions that changed according to whether the participant was a passenger, cabin crew or ground crew. Thus, it was specified in each item whether the content or mitigation measure referred to the departure, arrival or work airport (the latter category was for ground crew). The instructions for answering the test were as follows:

Below you will find a series of statements that relate to your travel experience and COVID-19 mitigation measures. Each statement may refer to your behaviors or the COVID-19 measures implemented both at airports and on aircraft. We ask you to rate the degree of compliance with each of the COVID-19 mitigation measures. Please indicate your response on a scale from 0 to 4. Please note what each numerical value means:

- *0 = Compliance with this measure was ZERO.*
- *1 = Compliance with this measure was NOT REGULAR.*
- *2 = Compliance with this measure was SUFFICIENT.*
- *3 = Compliance with this measure was REGULAR.*
- *4 = Compliance with this measure was COMPLETE.*

There are no right or wrong answers. Be honest with your answers. There is no time limit on this test. If you understand these instructions, you may begin.

The 23 items were qualitatively reviewed by several experts in aviation psychology and several epidemiologists. Based on experts' recommendations, it was decided to discard items 5, 10, and 17 for having content that did not explicitly state COVID-19 mitigation measures. All MIRA items can be found in Table 1.

Once the respective items were discarded, the test was applied gradually and progressively. The application of this instrument

Table 1
MIRA items grouped according to each factor analyzed (people, airports, and airlines factor). The version used in this research was in Spanish and English (The contents in parentheses specific to passengers are provided as an example).

Mitigation measures based on individual responsibility.	
16	Permanent use of approved face mask.
11	Use of 2 or more approved face masks.
20	Replacing or exchanging the face mask for a new, unused one during your stay in airports and aircrafts.
2	Cleaning and disinfecting hands when entering and leaving the aircraft.
22	Cleaning and disinfecting your hands during your stay at the departure and destination airports.
12	Maintain a safe distance from other people during your stay at the airport of departure and/or destination.
6	Avoid physical contact with other workers at airports and aircrafts.
Mitigation measures implemented by airports.	
18	Prohibition of entry into the airport of any outsider other than passengers, cabin crew and airport workers (only for the airport of departure).
15	Closure of V·I.P. lounges (at departure airports).
7	Implementation of health checkpoints for medical screening and disease inspection (departure airport only).
21	Systematic supervision of passenger COVID-19 travel authorizations (departure airport only).
13	Implementation of signs indicating the safety distance to be maintained during queues, including check-in, police control and boarding-disembarkation queues (for departure airport only).
1	Implementation of signage indicating where passengers may and may not sit (departure airport only).
8	Implementation of body temperature control stations (departure airport only).
Mitigation measures implemented by airlines.	
9	Special prevention protocols during boarding and disembarkation processes (apply only for the airline you flew with on your last flight during the COVID-19 crisis).
14	Implementation of safety distance in the aircraft, specifically from seat to seat (apply only for the airline you flew with on your last flight during the COVID-19 crisis).
3	Distribution of free disposable sanitary wipes to the passenger when entering or exiting the aircraft (apply only for the airline with which he/she flew on his/her last flight during the COVID-19 crisis).
23	Distribution of individual bags for waste or garbage when entering or leaving the aircraft and during the flight (apply only for the airline you flew with on your last flight during the COVID-19 crisis).
4	Cleanliness and hygienic conditions of the aircraft; this includes the seat you were seated in, adjacent seats, and the lavatory of the aircraft (apply only for the airline you flew with on your last flight during the COVID-19 crisis).
19	Explanation of COVID-19 hygiene measures prior to your flight (either by email, in writing on paper or over the aircraft loudspeaker).
General COVID-19 Pandemic-Related Occurrences.	
10	The flight schedule was included within the limits of curfews implemented during COVID-19 (according to the regulations in force in each country).
5	Take-off and landing delays due to COVID-19 related problems.
17	Making nonfood purchases at the airport and/or on the aircraft.

lasted 5 months (from January 2021 to May) and was carried out online.

2.2.2. Procedures related to data collection

For the collection of data, we collaborated with six workers who acted as intermediaries to facilitate the application of the MIRA. The collaboration with airport workers was completely anonymous and voluntary. Concretely, in the case of the cabin crew, data relating to the airlines were also not recorded to avoid any conflict of interest. Any ground staff data related to their jobs were not recorded to prevent conflicts of interest. Data collection was ensured using the double-blind technique. This means that the researcher did not know the respondents (participants) and had no prior contact. The respondents also did not know the researcher.

The applicators were responsible for disseminating the MIRA survey online. The participants' responses were automatically recorded on a platform that the researcher would later download and analyze.

2.3. Materials: the COVID-19 Measures Implementation Rate at airports (MIRA)

The MIRA survey is a psychometric test developed by Dr. Álex Escolà-Gascón. It measures the degree of compliance with COVID-19 mitigation measures classified in three dimensions: (1) individual responsibility, (2) mitigation applied to airports, and (3) mitigation applied to aircraft. This questionnaire is specialized in international travel and was constructed to measuring how travelers, cabin crews, and ground staff perceive coronavirus mitigation measures. In the MIRA, the participant must mark the degree to which such mitigation measures were or are were met on a Likert scale from 0 to 4 points. The validity and reliability of the test were analyzed in this research. Table 1 shows the 23 items of the MIRA survey. However, the final version of the MIRA survey should be applied with only 20 items, as described in the procedures section.

2.4. Statistical analysis

Data were processed with SPSS and the AMOS structural equation modeling package. The R programming language was used to perform specific calculations of the reliability of the measurements with the PSYCH library [30].

The validity assessment of the measurements was based on the confirmatory factor analysis technique (CFA). The purpose of this procedure is to check whether different groupings of items or questions in a questionnaire can be predicted by an unobservable variable called a factor. The factors represent a linear combination of observable variables (items) and enable a score to be obtained from the sum of the responses. Factor techniques such as the CFA make it possible to know whether the scores obtained from the factors measure what they purport to measure (this logic is called measurement validity) [28,29]. The maximum likelihood method was used to estimate the parameters of the structural equation models. The assumptions of normality and multivariate normality were met to use this method. Several fit indices were used to check the validity and are shown in the results section.

The analysis of the reliability of the measurements was estimated using two types of coefficients based on the internal consistency

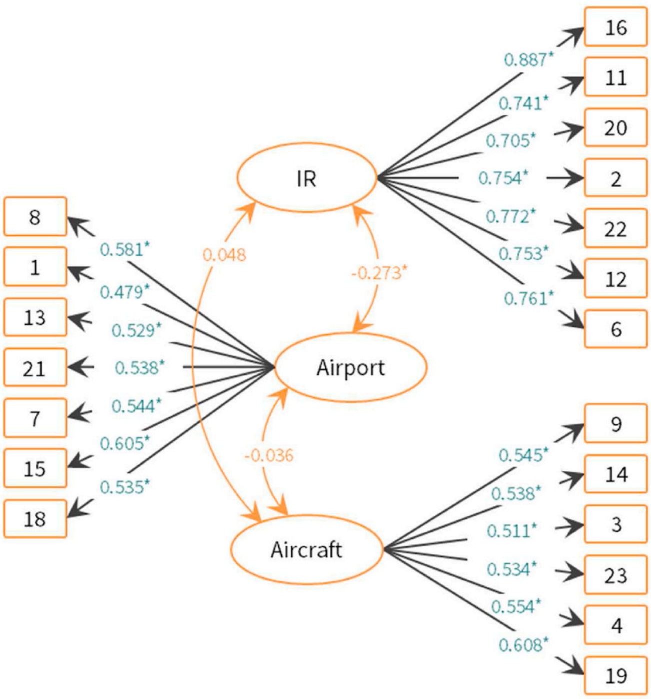

Fig. 2. Structural equation modeling of the Spanish version of the MIRA indices. Regression coefficients and standardized covariances are shown in the graph. The asterisk indicates that the values differed from "0" and were significant at $p < 0.01$. Note: IR = Individual Responsibility; Airport = mitigations applied at airports; and Aircraft = mitigations applied on aircraft.

of the scores. In contrast to validity, reliability informs about the precision of the measures. On the one hand, the l*evel 2 Guttman lambda coefficient* (hereafter λ_2) was used. Guttman coefficients are interpreted as the minimum lower limit that the accuracy of a prediction can have. According to the Guttman model, reliability bounds can be estimated at up to 6 different levels. One of the most robust levels is the λ2 coefficient, close to the classical *Cronbach's alpha* coefficient [29]. On the other hand, to provide a more robust estimate of reliability than the previous coefficient, the *Greatest Lower Bound* (henceforth GLB) was calculated. This index is based on the above logic but analyzes the consistency of the scores from the error covariance matrix. Mathematically it is calculated as follows:

$$GLB = 1 - \frac{tr(Ce)}{\sigma_x^2}$$

where.

σ_x^2 is the variance of the questionnaire/protocol; and.

$tr(Ce)$ is the trace of the error covariance matrix.

Both λ_2 and GLB fluctuate between 0 and 1. The closer they are to 1, the better the reliability of the measurements. A value of 0.6 is usually used as the minimum threshold [31].

3. Results

3.1. Analysis of the validity and reliability of the measurements

Before obtaining descriptive statistics for each of the MIRA indices, it is necessary to ensure the validity of the measurements. This was checked by running two CFAs (CFAs were applied for each version of MIRA). Figs. 2 and 3 illustrate the structural equation models.

To test the hypothesis of the validity of the model, goodness-of-fit indices were used. These indicators and their cutoff points are presented in Table 2.

The regression coefficients in Figs. 2 and 3 were significant. The goodness-of-fit indices supported the statistical validity of the model according to the thresholds in Table 2. The only goodness-of-fit index that did not support validity was the chi square statistic, which yielded a significant critical level. However, statistical evidence warns that this index is highly sensitive to sample size. Along these lines, the result of the chi square statistic can be explained as a type 1 error considering that the sample size is greater than 500 cases. Since the other fit indices scored satisfactorily, the validity of the measurement model is accepted. Table 3 shows the descriptive statistics for each index, the minimum and maximum expected scores and the reliability coefficients.

Table 3 shows that the reliability of the measurements was acceptable and satisfactory for all the MIRA protocol indices (all values exceed the threshold of 0.7) [31]. The cutoff points were obtained according to the median of the scores. In the following section, these

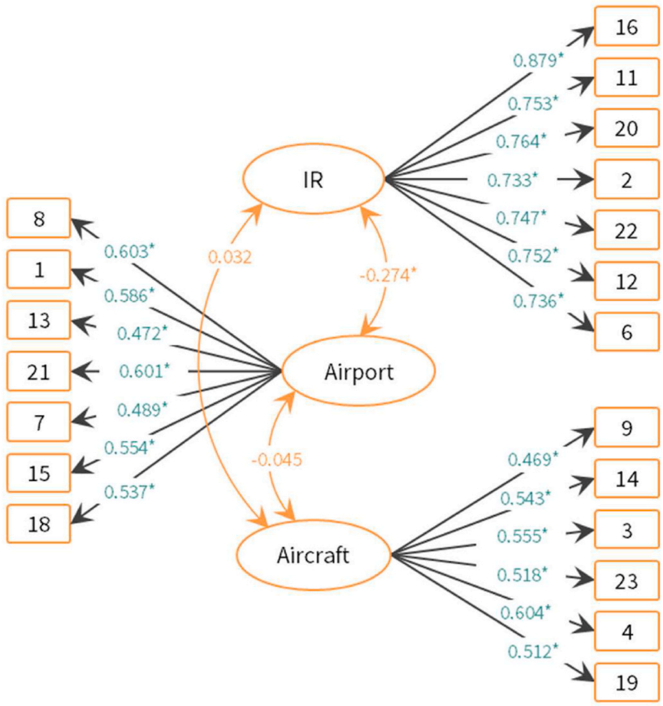

Fig. 3. Structural equation modeling of the English version of the MIRA indices. Regression coefficients and standardized covariances are shown in the graph. The asterisk indicates that the values differed from "0" and were significant at $p < 0.01$. Note: IR = Individual Responsibility; Airport = mitigations applied at airports; and Aircraft = mitigations applied on aircraft.

Table 2
Goodness-of-fit indices to test the validity of the measures made with the Spanish and English versions of the MIRA.

Indices	Thresholds according to Kline (2013) [29]	MIRA Spanish version		MIRA English version	
		Independence model	Proposed measurement model	Independence model	Proposed measurement model
$\chi 2$	–	3972.270	**267.586**	3889.857	**233.243**
p	–	~0	**<0.001**	~0	**0.001**
$\chi 2/df$	–	20.907	**1.602**	20.473	**1.397**
GFI	>0.95	0.464	**0.959**	0.468	**0.965**
AGFI	>0.9	0.407	**0.948**	0.412	**0.955**
CFI	>0.95	~0	**0.973**	~0	**0.982**
PCFI	>0.8	~0	**0.856**	~0	**0.863**
TLI	>0.95	~0	**0.970**	~0	**0.980**
IFI	>0.95	~0	**0.974**	~0	**0.982**
RMSEA	<0.05	0.179 (0.175–0.184)	**0.031 (0.024–0.038)**	0.177 (0.173–0.182)	**0.025 (0.07–0.033)**
AIC	–	4012.270	**353.586**	3929.857	**319.243**
BIC	–	4100.832	**543.995**	4018.452	**509.721**
CAIC	–	4120.832	**586.995**	4038.452	**552.721**

Note: GFI = goodness of fit index; AGFI = adjusted goodness of fit index; CFI = comparative fit index; PCFI = parsimony adjustment to the CFI; TLI = Tucker-Lewis coefficient; IFI = incremental fit index; RMSEA = Root Mean Square Error Approximation; AIC = Akaike information criterion; BIC= Bayes information criterion; CAIC = consistent AIC.

Table 3
Descriptive statistics for each MIRA index and reliability estimates of the measurements.

	MIRA indices	Minimums and maximums	Cutoff point according to median	M	SD	Greatest Lower Bound	Guttman's λ_2
MIRA Spanish Version	Individual Responsibility	0–28	**14**	13.93	5.94	**0.920**	**0.908**
	Airport Mitigations	0–28	**16**	16.07	5.378	**0.747**	**0.793**
	Aircraft Mitigations	0–18	**12**	12	4.088	**0.722**	**0.767**
	Total	0–100	**42**	42	8.311	**0.830**	**0.710**
MIRA English Version	Individual Responsibility	0–28	**14**	13.92	5.887	**0.918**	**0.907**
	Airport Mitigations	0–28	**16**	15.94	5.288	**0.791**	**0.752**
	Aircraft Mitigations	0–18	**12**	12.05	4.157	**0.735**	**0.705**
	Total	0–100	**42**	41.9	7.93	0.842	0.730

Note: M = mean; SD= Standard deviation.

cutoff points were used to analyze the effectiveness of the implementation of the COVID-19 mitigation measures.

3.2. Compliance analysis of mitigation measures

Participants with scores above the cutoff points in Table 2 can also be interpreted as observations regarding whether mitigation measures are met for international travel. Then, it is possible to know the raw counts of participants with scores higher than the cutoff points. Using the raw counts, the percentages or sample rates can be calculated. These rates will indicate the proportion of observations regarding the frequency of application of the COVID-19 mitigation measures. This information is shown in Tables 4 and 5.

The percentages in Tables 4 and 5 were low considering the health risks of the coronavirus crisis. However, the rates of Tables 4 and 5 are indirect estimations of the performance of the mitigation measures. This means that they should be taken as orientation values according to the experience and observations of the participants of this research. Similarly, these percentages cannot be analyzed as efficiency indices because they should be related to an external and direct criterion variable. This criterion variable should reflect the

Table 4
Analysis of the implementation of COVID-19 mitigation measures according to the cutoff points of the MIRA indices.

	MIRA indices	Passengers	Cabin crew	Ground crew
The two versions of MIRA: Spanish and English	Individual Responsibility	66.3% (307)	63.9% (255)	66.8% (252)
	Airport Mitigations	70.2% (325)	65.2% (260)	69.2% (261)
	Aircraft Mitigations	66.3% (307)	66.4% (265)	67.1% (253)
	Total	59% (273)	52.6% (210)	56.8% (214)

Table 5
Analysis of the implementation of COVID-19 mitigation measures at European airports.

	European airports	Individual Responsibility	Airport Mitigations	Aircraft Mitigations	Total
Departure airports	Paris-Charles de Gaulle	66.1% (220)	65.8% (219)	63.4% (211)	54.7% (182)
	Bilbao Airport	61.2% (170)	68.3% (190)	69.1% (192)	57.2% (159)
	Dublin Airport	71.9% (235)	70% (229)	67% (219)	57.8% (189)
	Zurich Airport	62.8% (189)	69.1 (208)	67.4% (203)	55.5% (167)
Arrival airports	El-Prat Airport (Barcelona)	67.4% (423)	–	66.2% (416)	–
	Madrid-Barajas	64% (391)	–	66.9% (409)	–

Warning: Rates for arrival airport mitigations were not included. In the survey, the questions on this category referred only to mitigation measures at departing or working airports. The same is true for the total MIRA scores.

number of direct applications of mitigation measures. This point is discussed in the discussion.

4. Discussion

The objectives of this research were to explore and measure the perceptions of compliance with COVID-19 mitigation measures of travelers, cabin crew, and ground workers in a valid and reliable way. The mitigation measures that were officially implemented in general and specifically in most European countries were considered following the contributions of Escolà-Gascón et al. [3–5]. The MIRA assessment protocol specialized in measuring the degree of compliance with mitigation measures was developed. The validity and reliability of the measurements obtained with MIRA were analyzed. In the same way, cutoff points were set based on the median of the scores that allowed the calculation of the percentages reporting the degree of compliance with the mitigations.

The results indicated that MIRA provides valid and reliable measures. Therefore, the counts and percentages in Tables 4 and 5 are interpretable. Overall, considering the total MIRA scores, the proportions obtained were low in all cases and ranged from 52.6% to 59%. More specifically, the airports where people (passengers and workers) had applied mitigation measures with the most significant individual responsibility were the Dublin, Barcelona-El-Prat and Paris-Charles de Gaulle airports. However, this does not mean that the mitigation measures used by airports are equivalent to the responsible behaviors of individuals inside airports and airplanes. Therefore, according to the "Airport mitigation" index rate, the Dublin and Zurich airports implemented the most mitigation measures. In this line, the participants perceived better compliance with the mitigation measures implemented in the airplanes associated with the Dublin, Zurich, and Bilbao airports.

The cabin crew scores suggest that this group of workers is the least likely to perceive compliance with COVID-19 mitigation measures. This seems to have a certain logic, given that the amount of air travel performed by cabin crews is greater than the amount of ordinary travel that a conventional passenger might perform. Therefore, cabin crews are more exposed to and at greater risk of coronavirus illness. This would justify why their scores appear slightly lower than the values and proportions of passengers and ground crew. However, we are discussing subtle and nonsignificant differences, so this interpretation should be considered purely speculative.

In this regard, certain theories of social cognition and perception could explain why the rates obtained were low. In terms of behavior, it has been shown that an individual's sense of loss of control leads to an increase in stress levels and an irrational search for resources to recover the perceived lack of safety. This idea is important because stress and the irrational search for control can generate causal illusions [32] and states of paranoia [5], which ultimately triggers the so-called herd behaviors [3]. This was very common during the early months of the COVID-19 pandemic [33]. Given evidence from another research [34], it is plausible that a sense of lack of control may have increased baseline stress and paranoia levels in the general population. Consequently, these increases could have altered the perception of compliance with mitigation measures, promoting a feeling of non-compliance with mitigation measures when in fact the measures are correctly implemented. This is one of the risks of survey-based assessments and introduces an important limitation of this study: we are assessing perceptions and not direct observation regarding whether anti-COVID-19 measures are being complied with. Therefore, rates based on medians are not incorrect, but should be interpreted with great caution.

Noticeably, in all cases, there remains a weight between 29% and 42% to maximize and increase the degree of compliance with mitigation measures. Considering the pandemic situation in Europe during the months between January and May 2021, the perception of compliance with mitigation measures by passengers, cabin crew, and ground staff should have been higher. This seems to indicate in medical and public health terms, that theoretically, very adequate mitigation protocols could have been designed, but the execution and implementation of these protocols are what might have failed in international travel. If the COVID-19 safety measures had been strictly and absolutely enforced, the scores of the participants in this research would have been much higher.

A crucial result is found in the negative correlation between individual responsibility (IR) and mitigations applied at airports (see Figs. 2 and 3). As mitigation measures at airports increase, individual compliance with prevention measures tends to decrease significantly. This could warn of something very important; the solution should not be to just load airports with maximum efficiency protocols to prevent contagions and infections. According to the results obtained, if this were the case, passengers and workers would relax and would not apply mitigation measures with high levels of responsibility. Therefore, it is necessary to investigate and mathematically find the optimal set point that allows airports to maintain adequate prevention protocols without encouraging carelessness on the part of passengers for individual adherence to mitigation measures.

Concerning the limitations of this study, 3 observations stand out [1]: as we have mentioned in the previous paragraphs, this study is based on surveys and, therefore, does not allow direct measurements of the applicability of mitigation measures in international travel. As a result, it was not possible to estimate the effectiveness of anti-COVID-19 measures implemented at airports and on airplanes. Therefore, as mentioned in the results section, the ratios obtained should only be interpreted as a guideline based on the observations and experience of the participants (passengers and workers) [2]. Some scholars and statisticians consider the Guttman lambda coefficients less effective and efficient than the classical Cronbach's alpha reliability coefficient. This is not entirely correct [29]. In this case, the level 2 lambda estimates the internal consistency of the test and tends to approximate Crobach's alpha (since the level 3 lambda is a statistic equivalent to Cronbach's alpha itself). Thus, for the reader who prefers Cronbach's model, the alpha coefficient will be either the same or similar to L2. This fact should not impair the reliability of the measurements [3]. the data for this research were collected for 5 months (from January to May 2021). During these five months, mitigation measures could have varied at individual airports and aircraft/airlines. This variability was not estimated in this research and was not considered. However, at least in Spain, the national state of alarm lasted until May; specifically, it was not until the last week of May that mitigation measures began to change since the state of alarm began in October 2020. Therefore, it is expected that the scores will not change excessively or that this variability will not generate problems in the validity and reliability of the measurements.

Considering that this research was based on surveys with valid and reliable mathematical measurements, future research should analyze the relationship between the perceived degree of compliance with COVID-19 mitigation measures and direct epidemiological indicators of the pandemic. For example, whether the implementation rate of the mitigation measures and the total number of confirmed cases in airports are positively correlated or not. This means that a higher implementation rate of the mitigation measures could cause a lower number of confirmed cases in airports.

The positive cases found at the airports are non-public data. However, certain US airports made these figures public [35]. This information could be used with similar survey studies that may have been conducted in the United States. In addition, the comparison of survey results with direct and empirical measurements of reality would also give predictive validity to the MIRA protocol and allow generalization of the results beyond individual perceptions of compliance with COVID-19 health regulations. This should be tested in future studies. These lines are only guidelines to advance the understanding of how to act in future pandemic crises to encourage abidance with the mitigation measures attributed with the least sense of compliance by people.

5. Conclusions

In conclusion, four contributions of this research to the analysis of the impact of coronavirus mitigation measures can be highlighted:

(1) The COVID-19 Measures Implementation Rate at Airports (MIRA) survey is an assessment protocol that provides valid and reliable measures to examine the degree of compliance and implementation of COVID-19 mitigation measures in international travel. Unlike other survey-based studies, MIRA classifies the degree of compliance with mitigations into three categories according to the context of air travel: mitigations based on individual responsibility, mitigations implemented at airports, and mitigations implemented by airlines on their aircraft.

(2) The proportions or rates of compliance with the mitigation measures were low considering the total MIRA values (between 52.6% and 59%). According to each MIRA category, the percentages relative to the degree of compliance were higher, reaching compliance rates of 69 and 70% in the cases of the Dublin and Bilbao airports. Further indications and optimization of current protocols related to mitigation measures and their implementation in international travel are required. In this regard, the airports scoring lower rates in MIRA assessment may be those with higher COVID-19 cases in their surrounding populations. This hypothesis should be tested with empirical data and not with information based exclusively on self-reporting sources. As already highlighted above, it is necessary to consider the confirmed positive cases at each airport where the evaluation is carried out.

(3) Of the airports recorded in this research, Dublin International Airport had the highest levels of perceived compliance with COVID mitigation measures. The Zurich and Bilbao airports came in second place. Consideration should be given to the type of protocols used at Dublin airport so that their implementation can be exported to other airports with the most substantial difficulties.

(4) The cabin crew scores were lower in the MIRA survey, suggesting that this group might feel more exposed to coronavirus infection and, therefore, would be more demanding to implement mitigation measures. For this hypothetical reason, they could have scored lower. However, these results were not significant and should be considered as a guideline.

(5) As airports implement mitigation measures more frequently, passengers' and workers' levels of individual responsibility decrease. This means that the solution should not be based solely on how to increase the implementation of anti-COVID-19 measures; an economical and optimal setpoint must be found that ensures infectious disease preventive safety at airports but at the same time does not encourage certain individual oversights for compliance with mitigation measures.

Finally, the perception of compliance was lower on airplanes than at airport facilities, suggesting priority reinforcement of anti-COVID-19 mitigation measures applied inside airplanes (e.g., several passengers reported that there was no safety distance between seats on several domestic flights). These perceptions could also justify why rates were low in the perception of compliance with in-flight mitigation measures. The differences and criteria of these public health regulations need to be reviewed so that in future epidemic crises, it will be easier to prevent contagions related to international travel.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

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