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Development and validation of COVID-19 mitigation measures instrument: Application of Hierarchical Principal Components Analysis and Building Shiny app

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Introduction

On March 11, 2020, the World Health Organization (WHO) declared a pandemic state caused by the SARS-CoV2 virus [1].

Two years after, the study of each mitigation measures adopted is important, in order to understand the effectiveness of their application on the infection incidence, on the response of health services and on the disease prognosis.

However, many of the mitigation measures were applied aggregated in time and within countries therefore a development of mitigation measures instrument that identifies the major patterns of this measures is the extreme importance [2].

This work aims to develop a COVID-19 mitigation measures instrument, obtained through Hierarchical Principal Components Analysis, that allows tracking the mitigation measures application and that can lead to improve the responses by the governments of the European Union (EU) countries. This work also intends to compare the proposed instrument with the Stringency Oxford Index given by Oxford University [3]. The Stringency Index was developed by a panel of experts from the University of Oxford, with the aim of understanding the effect of mitigation measures on the incidence of the virus. In this work we develop an instrument with same purpose, but using a data driven approach, and the objective was to compare both to understand which one explain better the effect on incidence number of cases of SARS-CoV2 infection at 14 days per 100 000 inhabitants.

Methods

This study included the information from the 27 countries of the EU, provided by the European Center for Disease Control and Prevention (ECDC) [4]. Data were collected on the implementation of 66 mitigation measures, as well as their start and end dates, by country and by week, from February 2020 to March 2022. In order to simplify the data, and considering that several measures were only different levels from same measure, a variables restructuring was carried out, resulting in 31 mitigation measures with Likert scale (ranged from 0: no measure applied to 3: maximum level implemented).

Taking into account that many of the mitigation measures were applied simultaneously, a principal component analysis was performed, with Oblimin rotation, applied to the correlation matrix to identify how the measures were aggregated. Considering the scree plot, two different solutions were selected with 1 and 7 subdimensions (components).

The principal components analysis was again applied to the 7 scores extracted from to obtain a general dimension. This method is called Hierarchical principal components analysis and it is more advantageous than the traditional because it allows to determine the existence of a general dimension. The existence of this general dimension is one of the main objectives of this work. To obtain reparameterization of the general dimension, a Schmid-Leiman rotation was applied. To evaluate the internal consistency the alpha and the omega T and H values were determined.

Three separated (not nested) linear regressions models were estimated, stratified by country, between the cumulative incidence number of cases of SARS-CoV2 infection at 14 days per 100 000 inhabitants (dependent variable) and the general score (model 1), the Stringency Index (model 2) and the 7 subdimensions Scores (model 3).

The comparison of the variance explained (R^2) and information criteria (AIC and BIC) of the 3 models was performed considering that the models were not nested.

At the end it was developed a Shiny app https://inesviseu.shinyapps.io/Covid-19/# .

All analyses were performed using the software R (version 4.0.2).

Keywords:
COVID-19, Principal Components Analysis, Mitigation Measures, Hierarchical Factor Analysis, Shiny

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Results

A total of 31 mitigation measures has different proportions of applications in each country. The 7 components explained 55% of total variance. Considering the measures with highest correlations and that contribute most to the formation of each subdimension, the following components were identified: 1st represented Closure of educational institutions, 2nd represented Indoor/Outdoor interventions, 3rd represented Closure of non-essential shops, 4th represented Ban on all events, 5th represented Closure of hotels/accommodation services, 6th represented Masks Mandatory and 7th represented Stay Home Order. The Cronbach's alpha value was approximately or higher 0.7 for all subdimensions (except component 7).

Hierarchical principal components analyses were performed to obtain the general dimension. This factor explained 22% of total variance and omega H 0.54.

The R^2, AIC and BIC values showed that the general factor is similar to the Stringency Index and none of them explains the incidence with R^2 ranging from 0.0 to 0.22. The model 3 has higher R^2 values, ranging from 0.16 to 0.88. All AIC and the majority of BIC values of model 3 are lower compared to model 1 and 2. For example, for Germany the R^2 values for model 1 was 0.03, for model 2 was 0.11 and for model 3 was 0.60. And to Belgium the R^2 values for model 1 was 0.07, for model 2 was 0.04 and for model 3 was 0.59.

Discussion

The study showed that was possible to identify an aggregation of mitigation measures in time, with existence of strong general factor. The use of 7 subdimensions to evaluate the effect of mitigation measures in incidence showed more explanatory capacity. Country differences were identified on the explanatory capacity, this could be explained by differences of the population adherence to these measures, also to the implementation program of the vaccination.

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