App-based tracking of self-reported COVID-19 symptoms

Martin Zens, Arne Brammertz, Juliane Herpich, Norbert P Suedkamp, Martin Hinterseer

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Abstract

Background: COVID-19 is an infection characterized by various different clinical presentations. Knowledge of possible symptoms and their distribution allows an early identification of infected patients.

Objective: To determine the distribution pattern and possible unreported symptoms an app-based self-reporting tool was created.

Methods: The COVID-19 Symptom Tracker study is an app-based daily self-reporting study. Between 08 April and 15 May 2020, a total of 22,327 individuals installed the smartphone app (COVID-19 Symptom Tracker) on their mobile device. An initial questionnaire asks for demographic information (age, gender, post code) and a past medical history with relevant chronic diseases. The participants are notified daily to report whether they are suffering from current symptoms and have been tested for SARS-CoV-2. When seeking healthcare advice additional questions regarding diagnostics and therapy are asked. Participation is open for every adult (minimum age 18 years). The study is completely anonymous.

Results: 11,829 (52.98%) participants completed the symptom questionnaire at least once. 291 of these participants stated that a RT-PCR test for SARS-CoV-2 was performed. 65 reported a positive and 226 a negative test result. The mean average number of reported symptoms in the group of untested participants was 0.81 (SD: 1.85). Participants with a positive test showed a mean average of 5.63 symptoms (SD: 2.82). Most significant risk factors are diabetes (OR: 8.95; CI: 3.30-22.37) and chronic heart disease (OR: 2.85; CI: 1.43-5.69). We identified chills, fever, loss of smell, nausea and vomiting and shortness of breath as the top five of the strongest predictors for a COVID-19 infection. The odds ratio (with 95% confidence interval) for loss of smell was 3.13 (1.76-5.58). Nausea and vomiting (OR: 2.84; CI: 1.61-5.00) has been reported as an uncommon symptom however our data suggest a significant predictive value.

Conclusions: Self-reported symptom tracking helps to identify novel symptoms of the COVID-19 disease and estimate the predictive value of certain symptoms. This helps to develop reliable screening tools. A clinical screening with a high pre-test probability allows the rapid identification of infections and a cost-effective use of testing resources. Our data stress the necessity for an awareness of loss of smell and taste as a cardinal symptom and suggest that diabetes is a risk factor for a highly symptomatic course of a COVID-19 infection. Clinical Trial: DNA

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Short Paper

App-based tracking of self-reported COVID-19 symptoms

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Short Paper

App-based tracking of self-reported COVID-19 symptoms

Abstract

Background: COVID-19 is an infection characterized by various different clinical presentations. Knowledge of possible symptoms and their distribution allows an early identification of infected patients.
Objective: To determine the distribution pattern and possible unreported symptoms an app-based self-reporting tool was created.
Methods: The COVID-19 Symptom Tracker study is an app-based daily self-reporting study. Between 08 April and 15 May 2020, a total of 22,327 individuals installed the smartphone app (COVID-19 Symptom Tracker) on their mobile device. An initial questionnaire asks for demographic information (age, gender, post code) and a past medical history with relevant chronic diseases. The participants are notified daily to report whether they are suffering from current symptoms and have been tested for SARS-CoV-2. When seeking healthcare advice additional questions regarding diagnostics and therapy are asked. Participation is open for every adult (minimum age 18 years). The study is completely anonymous.
Results: 11,829 (52.98%) participants completed the symptom questionnaire at least once. 291 of these participants stated that a RT-PCR test for SARS-CoV-2 was performed. 65 reported a positive and 226 a negative test result. The mean average number of reported symptoms in the group of untested participants was 0.81 (SD: 1.85). Participants with a positive test showed a mean average of 5.63 symptoms (SD: 2.82). Most significant risk factors are diabetes (OR: 8.95; CI: 3.30-22.37) and chronic heart disease (OR: 2.85; CI: 1.43-5.69). We identified chills, fever, loss of smell, nausea and vomiting and shortness of breath as the top five of the strongest predictors for a COVID-19 infection. The odds ratio (with 95% confidence interval) for loss of smell was 3.13 (1.76-5.58). Nausea and vomiting (OR: 2.84; CI: 1.61-5.00) has been reported as an uncommon symptom however our data suggest a significant predictive value.
Conclusions and Relevance: Self-reported symptom tracking helps to identify novel symptoms of the COVID-19 disease and estimate the predictive value of certain symptoms. This helps to develop reliable screening tools. A clinical screening with a high pre-test probability allows the rapid identification of infections and a cost-effective use of testing resources. Our data stress the necessity for an awareness of loss of smell and taste as a cardinal symptom and suggest that diabetes is a risk factor for a highly symptomatic course of a COVID-19 infection.

Keywords: COVID-19, self-reporting, symptom tracking

Introduction

COVID-19 was initially characterized as an acute respiratory infection with a significant virulence and mortality. Following reports of the first cases in Wuhan, China in December 2019, the virus spread around the world with currently 9,738,374 confirmed cases (as of 26 June 2020; http://www.worldometers.info/coronavirus). Research studies have revealed that SARS-CoV-2 has to be considered a systemic disease rather than an isolated acute respiratory illness [1,2]. Most diverse symptoms are the result of the coronavirus 2 attacking various organs.

The aim of this study was to identify further symptoms and to investigate whether certain symptoms may be used as a screening tool to differentiate COVID-19 infections from other diseases. A powerful and reliable clinical screening tool may help to identify and isolate SARS-CoV-2 infected individuals and hereby slow down the spreading of the disease.

Methods

Study setting and participants

The COVID-19 Symptom Tracker was developed by DESIGN-IT GmbH, in collaboration with University Medical Center Freiburg and Kliniken Ostallgaeu-Kaufbeuren, Fuessen Hospital. The first version was released for Apple iOS on 08 April 2020 and for Google Android on 20 April 2020. Within five weeks, 22,327 downloads were registered. The app was released in German, English, French and Spanish. An initial questionnaire asks for demographic information (age, gender, post code) and a past medical history with relevant chronic diseases. The participants are notified daily to report whether they are suffering from current symptoms and have been tested for SARS-CoV-2. When seeking healthcare advice additional questions regarding diagnostics and therapy are asked. Participation is open for every adult (minimum age 18 years). The study is completely anonymous.

Statistical analysis

Data were downloaded from the database server. Only datasets of individuals that live in Germany and had at least once completed the entire symptom questionnaire were included in a further analysis. Participants are presented as number, age is displayed as mean and standard deviation derived from an age span. Items are presented as percentage. For each risk factor and symptom odd ratios were calculated.

Results

Between 08 April and 15 May 2020, a total of 22,327 individuals installed the daily self-reporting smartphone app (COVID-19 Symptom Tracker) on their mobile device. 11,829 (52.98%) participants completed the symptom questionnaire at least once. Furthermore, 291 of these participants stated that a RT-PCR test for SARS-CoV-2 was performed. 65 reported a positive and 226 a negative test result. The mean average number of reported symptoms in the group of untested participants was 0.81 (SD: 1.85). Negative tested individuals reported 4.26 symptoms (SD: 2.52) and participants with a

positive test result a mean average of 5.63 symptoms (SD: 2.82). All participants were asked an initial questionnaire assessing an intrinsic risk and demographic data. The self-reported prevalence of risk factors, e.g. diabetes (7.95%), hypertension (25.19%) and smoking (31.89%) show a significant correlation with data provided regularly by the German Federal Office of Statistics (https://www.destatis.de) and Ministry of Health (https://www.rki.de) suggesting a representative dataset for the German population (age group 18-65). Elderly individuals are underrepresented due to the method of this study.

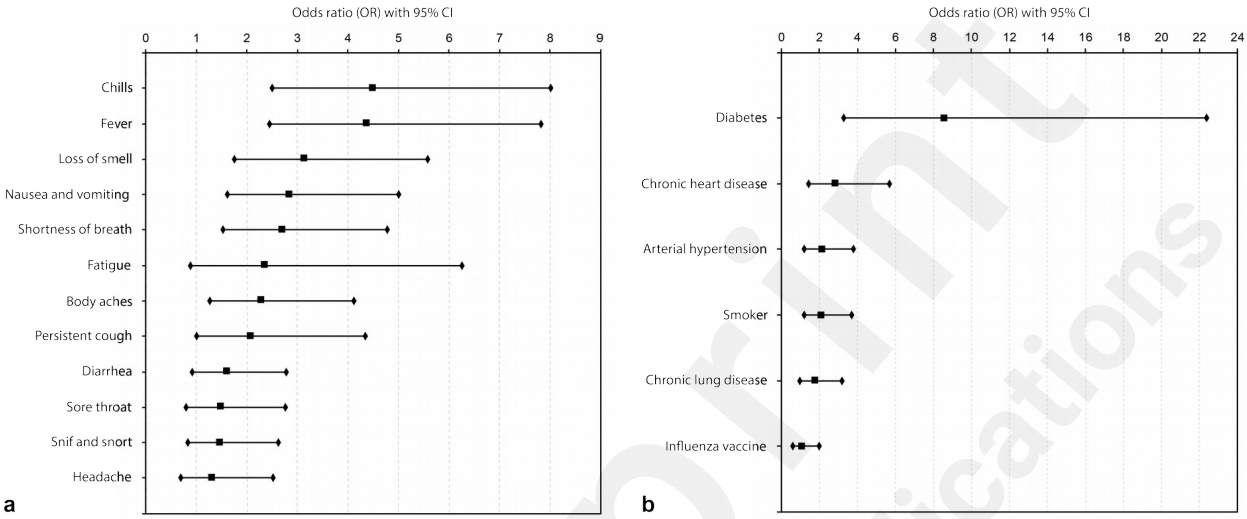
Table 1: Characteristics of the German cohort

	Tested for SARS-CoV-2		Not tested for SARS-CoV-2
	Tested positive	Tested negative	
Number	65	226	11,538
Female (%)	50.77	48.23	37.79
Age (years)	42.65 (13.33)	41.04 (12.88)	44.47 (15.41)
Smoker (%)	50.77	32.74	31.89
Diabetes (%)	21.54	3.10	7.95
Aterial hypertension (%)	40.00	23.89	25.19
Influenza vaccine (%)	32.31	30.53	28.32
Chronic lung disease (%)	33.85	22.57	11.72
Chronic heart disease (%)	26.15	11.06	8.84
Loss of smell (%)	47.69	22.57	2.82
Fatigue (%)	92.31	83.63	13.52
Shortness of breath (%)	61.54	37.17	4.80
Fever (%)	55.38	22.12	2.57
Persistent cough (%)	84.62	72.57	11.18
Diarrhea (%)	52.31	40.71	5.81
Chills (%)	58.46	23.89	3.41
Headache (%)	76.92	71.68	12.03
Snif and snort (%)	66.15	57.08	11.61
Nausea and vomitting (%)	52.31	27.88	3.71
Body aches (%)	69.23	49.56	12.03
Sore throat (%)	73.85	65.49	10.27

The daily symptom questionnaire asked for known or suggested symptoms as of 01 April 2020 [3-6] and allowed entering additional possible symptoms as free text. Odds ratios were calculated for all risk factors and reported symptoms. According to this data the most significant risk factors are diabetes 8.95 (3.30-22.37) and chronic heart disease 2.85 (1.43-5.69) (Fig. 1b). We identified chills, fever, loss of smell, nausea and vomiting and shortness of breath as the top five of the strongest predictors for a COVID-19 infection (Fig. 1a). The odds ratio (with 95% confidence interval) for loss of smell was 3.13 (1.76-5.58), of comparable significance were chills (OR: 4.48; CI: 2.51-8.01) and fever (OR: 4.37; CI: 2.44-7.81). Chills, fever and shortness of breath have been identified and communicated as common symptoms in mainstream media. Nausea and vomiting (OR: 2.84; CI:

1.61-5.00) has been reported as an uncommon symptom however our data suggest a significant predictive value.

Figure 1: a, Association between reported symptoms and the odds ratio for a positive SARS-CoV-2 test result in the population of 291 participants who tested via RT-PCR. Error bars represent the 95% confidence interval. **b**, Association between reported risk factors and the odds ratio for a positive SARS-CoV-2 test result in the population of 291 participants who tested via RT-PCR. Error bars represent the 95% confidence interval.



Discussion

The COVID-19 pandemic induced numerous research endeavours focussing on a better understanding of the disease caused by a novel coronavirus (SARS-CoV-2). Agile and dynamic projects led to contemporaneous approaches with similar and comparable study designs. Menni et al. [7] report of real-time symptom tracking to predict COVID-19 infections. The approach is based on a smartphone app available in the United Kingdom and United States. 2,618,862 participants were included and analysed in order to design a prediction model. Simultaneously, a total of 22,327 participants reported potential COVID-19 symptoms on a smartphone-based app in Germany. However, in comparison the cohort discussed in this work, the British cohort does not represent the general British population (e.g. overrepresentation of female participants).

Menni et al. [7] suggest that loss of sense of smell and taste could be included in routine screening for COVID-19. We strongly agree with this opinion as our data also suggest a strong predictive value. Although chills and fever are found in COVID-19 patients with a higher probability, in a clinical setting a loss of smell and taste is more unique and allows a better differentiation from other infectious diseases, as many are accompanied by chills and fever. In the current situation of a worldwide pandemic, we suggest that loss of smell and taste, especially in combination with other symptoms, ought to be considered a red flag and should result in an immediate testing for SARS-CoV-2 as well as isolation of the patient until the test result is obtained.

Furthermore, our work suggests that an increased awareness is needed for gastrointestinal symptoms, namely nausea and vomiting, as these have a stronger predictive value for a COVID-19 infection than symptoms such as sore throat or persistent cough which are commonly considered as typical.

Manual screening of the answers to the open question asking for additional symptoms revealed an accumulation of the following symptoms: vertigo, painful ears or eyes, burning sensation of the tongue and thoracic pain. A static analysis of these reported symptoms is not yet possible due to insufficient data but corresponding questions have been added to the questionnaire in an updated version of the smartphone app.

Regarding risk factors for a symptomatic course of a COVID-19 infection diabetes could be identified as a major contributor. Other studies reported an increased risk, rapid progression and worse prognosis in patients with diabetes mellitus [8-9]. The mechanism remain unclear and require further investigation.

Limitations

The limitations of this study are mainly due to the self-reporting nature of the study. The design does not allow a verification of the reported symptoms or test results. Apart from that, the participants are not invited or preselected and may not represent the general population. A possible bias is the necessity of a smartphone device which may result in an underrepresentation of the elderly. Another possible limitation is the small number of participants that has been tested for SARS-CoV-2.

Conclusions

Self-reported symptom tracking may help to identify novel symptoms of the COVID-19 disease and estimate the predictive value of certain symptoms. [10] This may help to develop reliable screening tools. A clinical screening with a high pre-test probability allows the rapid identification of infections and a cost-effective use of testing resources. Our data stress the necessity for an awareness of loss of smell and taste as a cardinal symptom.

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Conflicts of Interest

The authors declare the following competing interests: A.B. is CEO of DESIGN-IT GmbH.

Ethics

Approval of the study design was obtained by the Ethics Committee at the University Medical Center Freiburg (EK 337/20). The committee was very supportive of the project.

Data availability

The anonymous data collected by the COVID-19 Symptom Tracker app is shared with researchers on request presenting a research protocol, question of public interest and positive vote by the responsible ethics committee. Requests can be sent to the corresponding author. The Laravel PHP script for SQL data extraction is publicly available at https://github.com/martinzens/covid-19-st.

Code availability

The app code is available on request. Requests can be sent directly to the corresponding author. The Laravel PHP script for SQL data extraction is publicly available at https://github.com/martinzens/covid-19-st.

Author contributions

A.B. designed the app and database. M.Z., J.H. and M.H. developed the study questionnaires. M.Z. and N.P.S. analysed the data and plotted the results of the statistical analysis. M.Z. and J.H. wrote the manuscript. All authors revised the manuscript.

Additional information

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