Google Trends analysis of keywords related to smoking and smoking cessation during the COVID-19 pandemic in four European countries

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Abstract

Background: Smoking is a modifiable risk factor for Coronavirus SARS-CoV-2 infection. Evidence of smoking behavior during the pandemic is ambiguous. Most investigations report an increase in smoking. In this context, Google Trends data monitors real-time public information-seeking behavior and is therefore useful to characterize smoking-related interest over the trajectory of the pandemic.

Objective: Google Trends data was used to evaluate the transition into the pandemic on public interest regarding smoking and cessation. Special attention was paid to the influence of lockdowns, vaccinations, and incidence. Intensification of cessation aid might be crucial in times of pandemic to improve public health.

Methods: The weekly relative search volume was retrieved from Google Trends for England, Germany, Italy, and Spain during the period from 31-12-2017 to 18-4-2021. Data was collected for keywords concerning cessation, treatment, and consumption. Trend curves were generated, and the relative search volume of keywords before and during the pandemic was compared. To address short-term changes linked to lockdowns or vaccination campaigns flexible scan statistics were used to identify clusters. Subsequently, the numbers of clusters after the onset of the pandemic were compared.

Results: Country-wise minor differences were observed while overarching tendencies prevailed. Overall trend curves and statistical comparison revealed a decline in interest in cessation. Also, e-cigarettes and most consumption-related keywords showed decreased relative search volume during the pandemic. Substantial clusters of increased interest were sparsely linked to lockdowns, vaccination campaigns, or incidence. Generally, fewer clusters for cessation were present during the pandemic.

Conclusions: This study reports a substantial decline in overall relative search volume and clusters for cessation interest. These results underline the importance of intensifying cessation aid during times of crisis. Lockdowns, vaccination, and incidence had less impact on information-seeking behavior. Other public measures that positively affect smoking behavior remain to be determined. Clinical Trial: n.a.

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Abstract

Background:
Smoking is a modifiable risk factor for Coronavirus SARS-CoV-2 infection. Evidence of smoking behavior during the pandemic is ambiguous. Most investigations report an increase in smoking. In this context, Google Trends data monitors real-time public information-seeking behavior and is therefore useful to characterize smoking-related interest over the trajectory of the pandemic.

Objective:
Google Trends data was used to evaluate the effect of the pandemic on public interest in smoking-related topics with a focus on lockdowns, vaccination campaigns, and incidence.

Methods:
The weekly relative search volume was retrieved from Google Trends for England, Germany, Italy, and Spain from 31-12-2017 to 18-4-2021. Data was collected for keywords concerning consumption, cessation, and treatment. The relative search volume before and during the pandemic was compared. General trends were evaluated using Wilcoxon Rank-Sum Test. Short-term changes and hereby temporal clusters linked to lockdowns or vaccination campaigns were addressed by flexible spatial scan statistics proposed by Tango and Takahashi. Subsequently, the numbers of clusters after the onset of the pandemic were compared by Chi-squared test.

Results:
Country-wise minor differences were observed while four overarching trends prevailed. First, regarding cessation, the statistical comparison revealed a significant decline in interest for 58% of related keywords and fewer clusters were present during the pandemic. Second, concerning consumption significantly reduced relative search volume was observed for 58% of keywords, while treatment-related keywords exhibited heterogeneous trends. Third, substantial clusters of increased interest were sparsely linked to lockdowns, vaccination campaigns, or incidence.

Conclusions:
This study reports a substantial decline in overall relative search volume and clusters for cessation interest. These results underline the importance of intensifying cessation aid during times of crisis. Lockdowns, vaccination, and incidence had less impact on information-seeking behavior. Other public measures that positively affect smoking behavior remain to be determined.

Keywords: Internet, Coronavirus, COVID-19, SARS-CoV-2, Pandemics, Public Health, Smoking Cessation, Tobacco Products

Introduction

COVID-19 pandemic in Europe

The Coronavirus SARS-CoV-2 pandemic (COVID-19) posed unprecedented challenges to global healthcare and public health. Severe acute respiratory syndrome coronavirus type 2 the virus responsible for COVID-19, initially surfaced in Wuhan, China, in December 2019 and quickly

spread worldwide [1]. The first cases in Europe were reported in January 2020, shortly after it was declared a global pandemic by the World Health Organisation [2].

Smoking is a COVID-19 risk factor

European countries exhibited disparate patterns of incidence and mortality rates during the pandemic which triggered national governments to pass varying public restrictions e.g. shut-down of public institutions, curfews, quarantine, and use of face masks in public spaces [3,4]. The predominant manifestation of COVID-19 infections is characterized by the clinical triad of cough, fever, and symptoms resembling those of influenza [5]. In the initial stages of the pandemic, there ensued a discourse regarding putative protective attributes associated with smoking as a study showed a lower incidence of COVID-19 among smokers [6]. These studies received a lot of media attention. However, as cumulative data have been assimilated, smoking is presently discerned as a substantial risk factor for potentially life-threatening consequences following infection [5,7–11]. Also, the authors of the mentioned studies had severe non-declared conflicts of interest with the tobacco industry [12]. Hence, in light of the ongoing coronavirus pandemic, smoking as a modifiable risk factor has re-emerged as a focal point within public health concerns.

Changes in smoking behavior during the pandemic

Many studies addressed smoking behavior during COVID-19 in different locations during diverging periods using varying methods [13–19]. A large meta-analysis points to an increase in smoking [15]. Still, no general conclusion can be drawn from the presented evidence regarding changes in consumption and cessation. Smoking cessation can be categorized into two groups. One is commercially available substitutes like nicotine patches and e-cigarettes. The latter are advertised as less harmful cessation aids. Nevertheless, current evidence is ambiguous and their role during the COVID-19 pandemic is understudied [17]. Besides, there is professionally guided smoking cessation. Yet during the pandemic and due to associated restrictions regarding mobility and face-to-face meetings, availability might have been a challenge for patients [20]. In a previous study, our group shed light on the quitting behavior of smokers and ex-smokers in England, Germany, Spain, and Italy during the pandemic [21]. Despite psychological distress about the severe outcomes of COVID-19 infection, no higher rates of smoking cessation attempts were observed. Individuals may react both ways and augment their consumption patterns as a mechanism for stress mitigation, or demonstrate an increased interest in cessation programs or the adoption of alternative nicotine-replacement products due to fear of severe outcomes [21–24].

Methodological introduction to Google Trends data

The present follow-up study further investigates the aforementioned countries. Google Trends data was retrieved to monitor public interest in smoking, cessation, and treatment. Google Trends data reflects interest for keywords on a scale from 0-100 (= relative search volume (RSV)) relative to all search inquiries in a given period and location. Google Trends data has been proven a valid tool in medical research and has been applied throughout various fields in medicine for example evaluating effects of interventions or forecasting future trends to prepare healthcare providers [25,26]. In smoking-related research, different tobacco control measures have been evaluated using RSV [27–30]. Further, a study by Cavazos-Rehg linked the information-seeking behavior on Google with real-life use of tobacco products [31]. Google Trends data has the advantage of being easily accessible, objective, and always up-to-date. These properties are especially useful in the dynamic event of a pandemic [32,33]. Furthermore, during the COVID-19 pandemic, people turned to the Internet for guidance on health-related topics [34]. Previous publications displayed an increase in RSV for selected mental health-related keywords [32,35]. As cited above psychological distress also seems to play a major role in motivation for cessation [21–23]. In line, studies at the intersection of Google

Trends data and smoking research during the pandemic are limited but showed stable or decreased interest in cessation [16,19,36].

Hypothesis, study design, and implications

Based on previous research we hypothesized that major events during the pandemic caused substantial changes in public interest for smoking-related topics concerning consumption, cessation, and treatment [15,16,36]. Among these major events, it was assumed that lockdowns, vaccination campaigns, and rising incidence would induce the greatest echo in Google Trends data [33]. From the results of available survey studies, we expected the RSV to mirror the trend of increased interest in consumption and a decrease in cessation and treatment [15].

For investigation, a reasonable period was selected from 31-12-2017 to 18-04-2021, capturing the dynamics of the transition into the pandemic state and comprising multiple waves of infection. Changes in RSV were evaluated in three separate ways. First, the overall RSV for the above-mentioned domains after the start of the pandemic were compared. Second, short-term changes in RSV were addressed. Cluster analysis was conducted to discern the lockdown measures, the start of vaccination, and changing incidence rates that evoked the greatest levels of interest, in terms of RSV. Third, the general occurrence of clusters was compared between the pre- and pandemic state.

Identification of optimal timing and kind of intervention is essential to protect vulnerable groups during a public health crisis. Currently, evidence in the field of smoking cessation during the pandemic is mainly reliant on survey-generated data and is heterogeneous. RSV data is a cost-effective and instantaneous tool to monitor public interest and might effectively supplement survey data. By screening various keywords appropriate interventions might be determined. These insights could guide policymakers and health care providers, first if intensification of public campaigns for cessation aid and/or information about treatment is necessary in times of pandemics and second to follow up on possible detrimental effects on smoking behavior due to political measurements such as lockdowns.

Methods

Data collection

Google Trends query was carried out based on methodological suggestions by Nuti et al. [25]. The weekly RSV was retrieved from Google Trends on 01-07-2023 for each country during the period from 31-12-2017 to 18-4-2021 to investigate a reasonable time preceding the pandemic to identify changes [37]. The preceding period had to be long enough to serve as a comparison mirroring long-term trends and patterns. The observed period after the onset of the pandemic spanned approximately the first three waves of infections according to the Robert Koch Institute and hereby sufficiently reflects dynamics at the beginning of the pandemic [38]. Data was collected for the indicated keywords as listed in Table 1. All query categories were searched, no quotation marks were used, and locations were set according to the four countries. To examine alterations in the search behavior surrounding smoking-related keywords, our study targeted three specific domains: *cessation*, *treatment*, and *consumption*. A comprehensive translation of the relevant keywords into all four designated languages was conducted. Word selection was carried out based on expert consensus and literature review. Most common tobacco products and treatment options were filtered [39–44]. For terms regarding cessation previous research concerning RSV data in the context of cessation was searched [16,28–30,36]. However, choices were restricted by the overlapping availability of Google Trends data for each country. Otherwise, keywords were chosen to display a broad spectrum of each above-mentioned domain. Noteworthy Champix (trade name for varenicline) was chosen over

varenicline as varenicline showed higher variability in RSV over time, increasing the susceptibility of this keyword to outliers. In the following, the English term is used for cases of subsumption.

RSV serves as a temporally resolved representation of search behavior concerning a designated keyword. The term "relative" refers to the quantitative assessment of search queries associated with the keyword relative to the total search query volume prevalent at a given point in time in a specified location. To facilitate meaningful comparisons and emphasize variations in search term popularity over time, the time point at which this ratio reaches its maximum is conventionally designated as having a RSV of 100. All other values within the examined period are subsequently expressed regarding this maximum.

Data concerning the COVID-19 incidence was retrieved from *coronavirus.data.gov.uk* for England [45] and from *Our World in Data COVID-19 Dataset* for Germany, Italy, and Spain [4]. Lockdown measurements and the start of vaccination were selected and gathered from the media.

Table 1: Keywords by country and domain.

	England	Germany	Italy	Spain
Consumption	*Cigarette* *Cigar* *Tobacco*	*Zigarette* *Zigarre* *Tabak*	*Sigaretta* *Sigaro* *Tabacco*	*Cigarrillo* *Cigaro* *Tabaco*
Cessation	*Smoking cessation* *Smoke free* *Stop smoking*	*Rauchentwöhnung* *Rauchfrei* *Rauchen aufhören*	*Smettere di fumare* *Anti fumo* *Non fumatore*	*Deshabituatión tabaquita* *Libre de humo* *Dejar de fumar*
Treatment	*Nicotine patch* *e-cigarette* *Champix*	*Nikotinpflaster* *E-Zigarette* *Champix*	*Cerotti alla nicotina* *Sigaretta electtronica* *Champix*	*Parche de nicotina* *Cigarillo electrónico* *Champix*

Statistical analysis

For statistical analysis of time series, three different approaches were employed. First, for overall trends, Wilcoxon Rank-Sum Test was applied to compare the entire RSV by keywords before and during the pandemic. A similar approach was previously presented by Cunningham et. al [36]. The onset was defined as 24-01-2020 with the first reported cases in Europe [2]. To verify that the date chosen for the division of the time series, was appropriate, we confirmed by checking the RSV of common search terms linked to the pandemic (exemplary for Germany *COVID-19, Coronavirus, Pandemie*). The week of the first reported case in Europe coincided with the emerging interest in the indicated terms as RSV started to rise (suppl. Figure 1). These dynamics were also presented by Effenberger et al. [46]. P-Values were adjusted using the Benjamini-Hochberg Procedure to control for False Discovery Rate [47]. This approach only compares RSV before and during the pandemic, therefore fluctuations within the pandemic are beyond the scope of this kind of analysis. A higher temporal resolution is necessary to reveal changes in RSV within the time of the pandemic.

Hence for short-term changes in RSV possibly linked to COVID-19-related events, a cluster detection test was used. This flexible scan statistics was introduced by Takahashi et al. and is a common approach in epidemiologic research and has been previously employed in the context of RSV data [27,48]. For events evoking the greatest interest in a population, we anticipated lockdown measurements, vaccination campaigns, and steep rises in incidence, based on expert consensus and previous research [33]. R programming language was used to apply the FleXScan package [49]. The settings for the algorithm were adapted from Tabuchi et al. as follows [27]: pre-specified significance level for the restriction $\alpha 1 = 0.2$, significance level of the test $\alpha = 0.05$, replications of the Monte Carlo hypothesis testing 999, maximum length of a cluster 17 weeks, minimum length of

a cluster 2 weeks. For the baseline of expected RSV at an indicated date the median RSV of the period 26 weeks flanking the corresponding date was used. This ensured that temporal clusters could be identified irrespective of long-term trends.

Third, Chi-squared test was performed to compare the number of weeks that were part of clusters before and during the pandemic. Clusters were aggregated by domains. This was done to verify if the accumulation of periods with heightened interest was randomly distributed before and after the onset of the pandemic. P-values less than 0.05 were considered statistically significant. Tabular data was handled in .xlsx format. R Studio and R programming language were used for all calculations and generation of plots [50,51].

Votum of the ethics committee

The utilization of publicly available data and non-personally identifiable information within this research obviates the necessity for an ethics review process.

Results

Visual inspection

RSV for keywords of smoking *consumption*, *cessation*, and *treatment* from 31-12-2017 to 18-04-2021 are depicted in Figure 1. Visual inspection revealed three aspects. First, there are large differences in the variability of the RSV for the keywords examined. High variability is characterized by trends on the x-axis and isolated spikes with high RSV. Keywords in the *consumption* group appeared to be less variable, while terms in the *cessation* and *treatment* groups showed higher variability, especially in Italy and Spain (Figure 1). Second, overarching trend lines seem to decline within all domains and countries, with few exceptions that are later presented. Third, there seems to be no accumulation of substantial clusters after the start of the pandemic, again with few exceptions (Figure 1).

Consumption

For general effects of the pandemic comparison of the entire RSV was conducted before and after the start. Hereafter short-term relationship between lockdown measures and the start of vaccination and RSV data was established. Observations were made to ascertain whether clusters initiate or exhibit an abrupt termination with the commencement of lockdown measures.
For consumption, we saw an overarching trend of decline in RSV after the start of the pandemic. For 7 out of 12 (58%) consumption-related keywords, a significantly reduced RSV was observed. However, there were exceptions. *Cigar* had more RSV during the pandemic than before in England ($P = .035$). Besides in Germany and Spain, we saw an increase in informational demand for *tobacco* ($P < .001$ and $P = .031$) (Error: Reference source not found). In short-term dynamics, long-lasting clusters for *tobacco* at the beginning of the pandemic for the aforementioned countries were observed. A second *tabaco* cluster emerged in Spain at the beginning of the second wave. Around the time of the start of the vaccination campaign short-lasting clusters for *cigar* were observed in all countries except Spain (Figure 1). Overall, clusters regarding *consumption* during the pandemic only occurred significantly more frequently in Germany ($P = .008$), otherwise, numbers remained stable (Error: Reference source not found).

Cessation

As for *consumption*, a decrease in interest in *cessation* was noticeable across all countries for nearly

all keywords, with 7 out of 12 (58%) keywords showing a significant decline. Keywords with non-significant changes were frequently victim to high variability in RSV, e.g. *libre de humo* (P = .52) or *non fumatore* (P = .18). No keyword showed significantly increased RSV during the pandemic (Error: Reference source not found). In temporal evaluation, no relation between the occurrence of clusters and incidence, lockdowns, or vaccination could be established. Interestingly England, Italy, and Spain showed an accumulation of clusters around New Year before the pandemic. Such clusters were missed in these countries during the pandemic (Figure 1). Generally, clusters for *cessation* were less frequent during the pandemic in all countries, especially in England and Italy significant differences were observed (P = .037 and P < .001) (Error: Reference source not found).

Treatment

Treatment showed a heterogeneous picture. The comparison of the RSV did not yield uniform results. The only consistent finding across all countries was a decline in interest in *e-cigarette (*England P < .004, Germany, Italy, and Spain P <.001*)*. Interest in *Champix* has risen in Spain (P < .001), whereas it has fallen in Italy (P < .014) (Error: Reference source not found). The cluster analysis revealed a long cluster for *Champix* in Spain, which began prior to the pandemic. Otherwise, there was a longer cluster for Italy concerning *sigaretta elettronica*, occurring between the second and third waves and ending with the start of the third lockdown. No other temporal correlations could be established (Figure 1). During the pandemic, only Germany showed a significantly shorter duration of clusters for *treatment* (P = .009). Here similar to the effects noticed for *cessation*, before the pandemic clusters of *treatment* around the turn of the year were present. These were absent during the pandemic (Error: Reference source not found).
Generally, across all countries, the collected data points to less interest in the domain *cessation* during the COVID-19 pandemic. But also the domain *consumption* was overall of less interest while the amount of clusters remained mostly the same. *Treatment*-related keywords behaved less uniformly. Here only *e-cigarette* showed a country-spanning decline.

Figure 1: RSV data and new cases per million over time. Dashed lines illustrate long-term trends in RSV calculated as linear regression. The vertical dotted line indicates the defined start of the pandemic in Europe with the first confirmed case on 24-01-2020. The vertical solid lines mark the start of lockdowns. The grey dashed lines mark the start of the vaccination campaigns. The color-coded solid lines below the x-axis mark the clusters. Countries are separated by quadrants: upper-left England (ENG), upper-right quadrant Germany (DEU), lower-left Italy (ITA), and lower-right Spain (ESP).

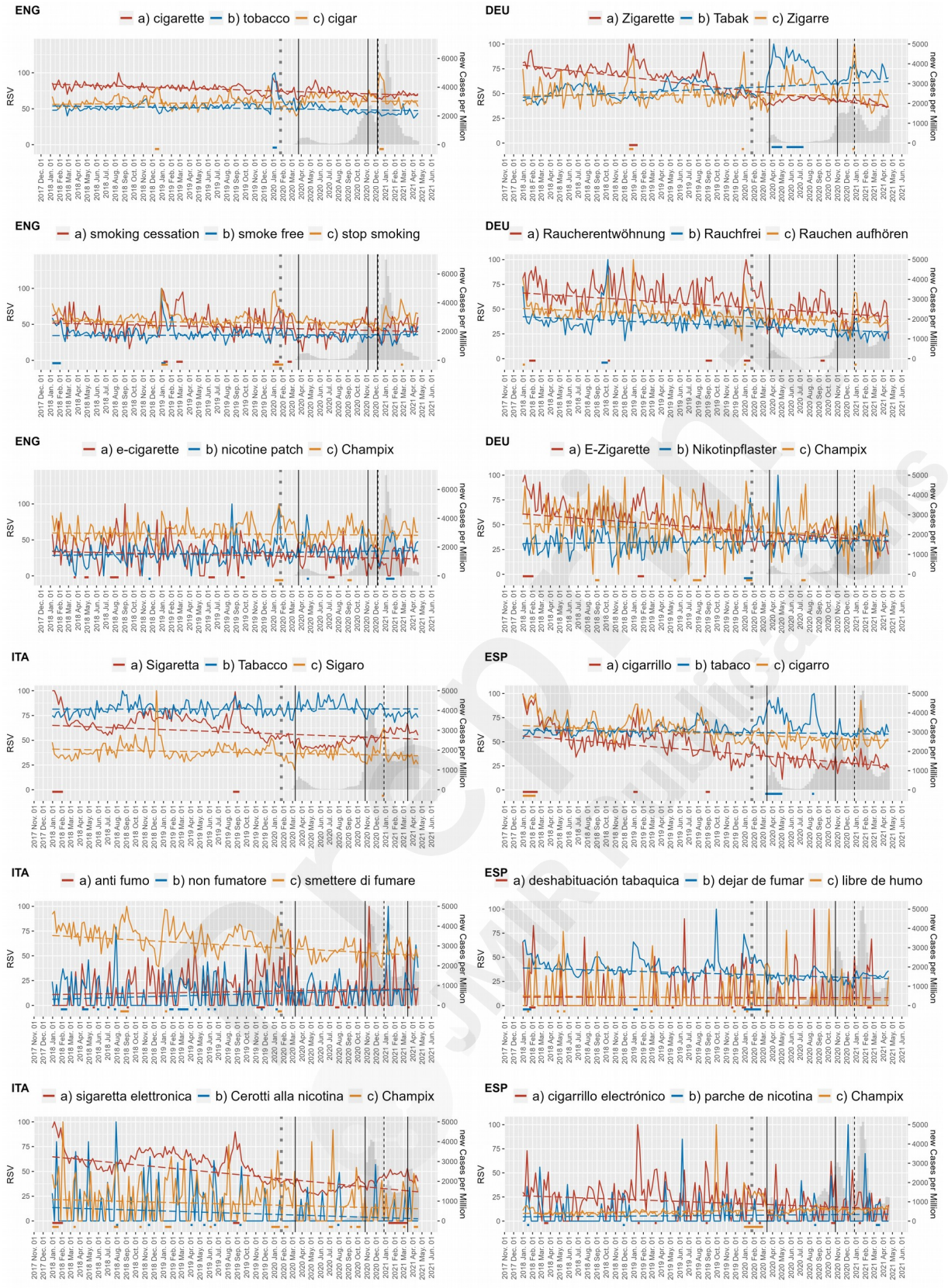

Table 2: Since the high heterogeneity of lockdown measures between the investigated countries listing of specific bans was omitted. However shared characteristics of lockdowns were the closure of public cultural facilities, curfew, ban on assembly, and restriction of mobility.

	England	Germany	Italy	Spain
Start of Lockdowns	23-03-2020 05-11-2020 06-12-2020	22-03-2020 01-11-2020	10-03-2020 26-10-2020 15-03-2021	14-03-2020 25-10-2020
Start of Vaccacination	08-12-2020	27-12-2020	27-12-2020	27-12-2020

Table 3: Comparison of RSV before and during the COVID-19 pandemic using Wilcoxon Rank-Sum Test. P-values were adjusted using the Benjamini-Hochberg Procedure.

	Median before COVID	Median during COVID	Trend during pandemic	Adj. *P*
England				
Cigarette	80	71	↓	<.001
tobacco	52	47	↓	<.001
cigar	59	63	↑	.035
smoking cessation	51	45	↓	<.001
smoke free	37	35	↓	.027
stop smoking	57	55	=	.16
e-cigarette	36	28	↓	.004
nicotine patch	31	38	↑	.009
Champix	61	60	=	.62
Germany				
Zigarette	70	43	↓	<.001
Tabak	51	72	↑	<.001
Zigarre	48	50	=	.40
Raucherentwöhnung	66.5	48	↓	<.001
Rauchfrei	38	27	↓	<.001
Rauchen aufhören	46	39	↓	<.001
E-Zigarette	59	36	↓	<.001
Nikotinpflaster	33	34	=	.15
Champix	51.5	47	=	.07
Italy				
Sigaretta	67	51	↓	<.001
Tabacco	81	81	=	.95
Sigaro	38	35	↓	.003
anti fumo	18	12	=	.31
non fumatore	0	14	=	.18
smettere di fumare	71.5	53	↓	<.001
sigaretta elettronica	61.5	38	↓	<.001
Cerotti alla nicotina	0	0	=	.08
Champix	25	13	↓	.014
Spain				
cigarrillo	52.5	29	↓	<.001
tabaco	61.5	64	↑	.031
cigarro	67	52	↓	<.001
deshabituación tabaquica	0	0	=	.65
dejar de fumar	39	31	↓	<.001
libre de humo	0	0	=	.52
cigarrillo electrónico	25.5	15	↓	<.001
parche de nicotina	0	0	=	.63
Champix	8	12	↑	<.001

Table 4: Comparison of cluster weeks before and during the COVID-19 pandemic by Chi-squared test.

	Consumption		**Cessation**		**Treatment**	
	Cluster	**No Cluster**	**Cluster**	**No Cluster**	**Cluster**	**No Cluster**
England						
before COVID	6	321	29	298	24	303
during COVID	3	189	7	185	16	176
P	1		.037		.81	

Germany						
before COVID	10	317	22	305	29	298
during COVID	17	175	5	187	5	187
P	.008		.07		.009	
Italy						
before COVID	10	317	53	274	44	283
during COVID	2	190	10	182	28	164
P	.24		< .001		.82	
Spain						
before COVID	24	303	36	291	19	308
during COVID	11	181	14	178	20	172
P	.6		.22		.08	

Discussion

In this study, the effect of the COVID-19 pandemic on internet search query data concerning smoking-related keywords was investigated. Despite some differences in country-specific manner, overarching trends are displayed. Our study comprises three main findings. First, via analysis of overall RSV before and during the pandemic a substantial drop in interest in the domains of *cessation* and secondly *consumption* was observed. *Treatment* showed heterogeneous trends in a country-dependent manner.

Third, in short-term analysis, a sparse relationship of substantial clusters to lockdown measurements or the start of vaccination campaigns could be established as discussed later. These events seem to have little influence on search queries. Clusters are preferably evoked by other incidents. However, as seen in the overall RSV comparison a trend towards lower interest in *cessation* during the pandemic was presented with fewer cluster weeks. For *consumption* number of cluster weeks remained stable during the pandemic despite a decrease in overall RSV for this domain, possibly pointing to events beyond the scope of this study triggering spikes of interest despite a decline in overall interest.

Research on the interplay between the COVID-19 pandemic and smoking exhibits multifaceted outcomes. Initially, smokers may have perceived smoking cessation as unnecessary due to emerging reports suggesting nicotine's potential protective role against severe COVID-19 infection [6,13,52]. Nevertheless, in the short term, mounting evidence underscored the deleterious impact of smoking on the disease trajectory [7–9,11]. Intuitively, one might hypothesize that this phenomenon prompted numerous smokers to limit their smoking habits, albeit temporarily [53]. However, diverging from this expectation, the majority of empirical studies conducted during the pandemic across diverse global regions present contradictory findings. The meta-analysis conducted by Bakaloudi et al. elucidates a prevailing pattern of escalated or sustained smoking behavior across most studies [15]. A plausible explanation for the observed phenomenon is the characterization of the COVID-19 pandemic as a stressor, rendering smoking cessation more challenging [54]. Noteworthy are studies where heightened stress levels correlated with increased smoking behavior [14,22,55,56]. Smoking is construed as a coping mechanism to manage psychosocial stressors associated with lockdown scenarios [23,24,57–59].

Consumption

As opposed to the study by Bakaloudi et al. mentioned in the Error: Reference source not found that investigated worldwide trends, our investigation revealed a decline in consumption-associated RSV

[15]. Two possible explanations might be presented. First, there is a plethora of studies that account for regional differences. Some also report a decline in smoking during the pandemic [23,53]. In Spain, smokers decreasing their consumption seem to outnumber users with increased consumption [60]. Interestingly the same study reports a decline in sales for cigarettes and cigars during the pandemic with a substantial rise in tobacco sales which resamples our findings from RSV analysis. Besides, before the onset of the pandemic, a discernible trend emerged across the European Union marked by a general decrease in smokers [61]. England for example implemented the campaign "Smokefree 2030" in 2019 so interest might have been exhausted [45]. Perhaps as a consequence of the campaign or the pandemic, England saw a diminishing number of smokers in 2020 [62]. Further, less social interaction and heightened awareness of severe health risks, might have resulted in the coincidence of fewer new smokers during the pandemic. Notably, studies regarding the initiation of smoking habits during the pandemic are missing. Regular users even with increased consumption might not significantly contribute to search volume because of satisfied informational demand. Matching this hypothesis a study from Italy presents decrease in smoking prevalence while overall cigarette consumption increased attributed to regular users [63].

Second, there is a methodological shortcoming of RSV data. This data is a relative indicator of interest compared to general interest in all searched keywords. As other keywords rise, the shares of interest for the investigated keywords decline, even if the absolute number of search queries remains stable. Especially during the COVID-19 pandemic, this might introduce a bias as COVID-19-related keywords rose exponentially [46]. To account for this shortcoming, we employed a moving median approach in our analysis as laid out in the Error: Reference source not found section. This way clusters were evaluated relative to a period of one year and long-term trends were less influential on cluster evaluation. Accordingly, when looking into cluster accumulation during COVID-19 stable numbers were observed as opposed to the comparison of plain RSV.

In the context of cluster detection, attribution to events beyond the scope of this study must be considered. Here two clusters are striking. In Germany, interest in *Tabak* peaked from April 2020 to July 2020 which is most likely caused by COVID-19-related import restrictions. Cheap imported cigarettes were not available, so customers shifted their consumption behavior [41]. Also, the pattern of repetitive short-lasting interest in *cigar* at the time of the start of the vaccination campaign should be carefully interpreted as this might coincide with behavior during festivities. Still, it sticks out that during the pandemic these clusters were absent. We hypothesize that due to reduced social gatherings around the holidays, people shifted their interest, and especially occasional cigar consumption was thus limited.

Cessation

Interest for cessation leveled during the pandemic across all countries, seen in overall RSV and number of clusters. Specific keywords where significance was missed should be interpreted with caution due to high variability in search volume. Regarding cessation during the pandemic, most identified survey studies point towards increased interest in cessation, mainly due to fear of disease [20,21,24,64]. However, these studies are frequently victim to effects like social desirability [65]. Also, cohort selections mark a large confounder.

Studies on RSV data are in line with our findings and indicate constant or decline in cessation interest [16,19,36]. However, two of these investigations solely entailed a visual assessment of the Google search data without employing statistical methodologies. Few keywords were analyzed, and the scope was limited to either a single country or the global RSV data. This approach, given the globally diverse trajectory of the pandemic, appears lacking in specificity. Contrarily, the presented approach provides more objective data analysis. Further recent publications indicate that increased level of stress hinders smokers from abstinence and cessation programs switched to disadvantageous remote settings or were discontinued [20,22,56,57,63].

Treatment

For *treatment*, we saw diverse developments. Throughout there was a decline in *e-cigarettes*. This trend was evident in other studies, especially in a young population and at the beginning of the pandemic [66–68]. However, a cross-sectional study by Gallus et al. reveals that the effect is probably cohort-dependent. Mostly adolescents decreased consumption, attributed to harder access because of fewer social gatherings [69,70]. In line with this, we observed a lasting cluster for *sigaretta elettronica* in Italy from January 2021 to March 2021, during this time incidence declined and restrictions were less harsh, implying an increase in social gatherings. The cluster showed an abrupt end with the start of the third lockdown [71]. RSV data is anonymized, no conclusion about subgroups can be drawn. Previous studies elaborated on the disparities of internet use for health-related topics in different age groups [72,73]. As this is a limitation of the method which might account for further differences between the presented results and results from cohort studies. Hence, studies investigating internet use for cessation-related topics among different age groups are needed.
The categorization of e-cigarettes within the category of treatment is debatable. In some instances, e-cigarettes solely serve recreational purposes, particularly among the younger demographic [74,75]. The analysis of RSV revealed a notable similarity between *e-cigarettes* and keywords of *consumption*, with a decline in both cases. The classification of *e-cigarettes* within the *treatment* category stems from comprehensive meta-analyses, demonstrating their efficacy as treatment products [39]. Further, the National Health Service recommendations explicitly advise against the utilization of e-cigarettes by non-smokers [76]. Motivational factors influencing e-cigarette usage have been investigated, with prevailing evidence suggesting a large proportion of users employ e-cigarettes as aids for smoking cessation or reduction [74,77,78]. Especially these goal-oriented users continued consumption [79]. Consequently, the categorization of e-cigarettes within treatment aligns with the observed patterns described in previous studies.
Temporal analysis revealed a peaking interest in *Champix* in Spain starting before the pandemic. This is most likely confounded by the coverage of Champix cost by the Spanish health insurance beginning of 2020 [80]. Another season-depending effect was seen in England, Italy, and Spain with repetitive clusters for *treatment* around New Year before the pandemic but not during the pandemic. We argue that people shifted their New Year's resolutions during the health crisis.

Limitations of the study

Alongside the previously mentioned shortcomings of RSV data, further limitations shall be discussed. First, changes in lockdown policies were passed by the day and hence any cluster detected during the pandemic could have been attributed to one of these changes or diverse non-COVID-19 related occurrences. However, to ensure compatibility across countries we had to limit the investigated events to major lockdowns, rises in incidence, and vaccinations as we anticipated these would create drastic changes in RSV.
Second, keyword selection poses a bottleneck for Google Trends studies as the selection is mostly reliant on expert consensus, and literature review and is limited by the data provided by Google Trends. Here relevant terms might be missed or might be searched in a divergent context. By choosing the reference terms based on criteria described in the Methods section with only minor changes between countries introduced by translation or availability of keywords provided by Google Trends, we aimed to be as objective as possible. Further three groups of *consumption*, *cessation*, and *treatment* display various aspects of smoking behavior and three reference terms per group should suffice to mirror products and word usage prevalent in society.
Third, only one search engine and hereby online source was used for data acquisition. Although Google dominates the market concerning search engines, further research might encompass other valuable online resources such as social media platforms and news forums to estimate population response to public health crises [81–83,83].

Furthermore, Google Trends data retrieved for an entire country is low in regional resolution, especially under consideration of disparate incidence rates in national regions information might be lost.

Implications of the presented results

For optimal allocation of resources, it is crucial to evaluate the impact of a health crisis on a vulnerable population. During the COVID-19 pandemic, smokers were among this population [7]. The optimal timing of public health intervention often remains elusive. Survey studies in this setting are disadvantageous. Google Trends studies in contrast mirror real-time effects, investigate a large share of the population, and are cost effective. By screening a plethora of keywords appropriate interventions might be determined. Here Ayers et al. demonstrated an interesting approach to identify search terms and behavioral shifts upon tax increases on cigarettes [84].
In the presented study the decline in cessation interest could have justified policymakers' efforts to intensify campaigns informing about cessation programs during the pandemic. A more detailed analysis of terms associated with cessation like quit lines and local support groups would be required in further studies to filter optimal interventions. Besides interest in treatment options seemed to stagnate. Here health care providers could have increased their efforts to educate people about therapy strategies.
Finally, RSV data has provided useful insights for various research in medicine [16,26,28–30,32,36]. Future studies in the context of smoking and health crises could use this data to predict smoking trends early to expand cessation programs and also to monitor the potentially unexpected detrimental effects of other public health measures on smokers. However, there is a need for following studies to develop methods to deal with shortcomings in keyword selection, regional resolution, and subgroup analysis.

Conclusion

Trends were comparable across all countries with minor differences. A decline in interest in *consumption* and *cessation* was observed. Besides, *treatment* terms showed heterogeneous dynamics, while specifically, *e-cigarettes* displayed a marked decreased RSV. Temporal clusters of peaked RSV were only sparsely linked to lockdown measures and changes in incidence. The flexible scan statistics proved as a valid tool for cluster detection. The resulting clusters corresponded with visual inspection and could partially be linked to events other than lockdown measures or vaccination campaigns. Our study underlines the importance of intensifying cessation aid considering decreased interest during the pandemic. Measures that positively affect smoking behavior in times of health crisis remain to be determined.

Acknowledgements

Conflicts of Interest

none declared

Abbreviations

COVID-19	*Coronavirus SARS-CoV-2*
RSV	*relative search volume*

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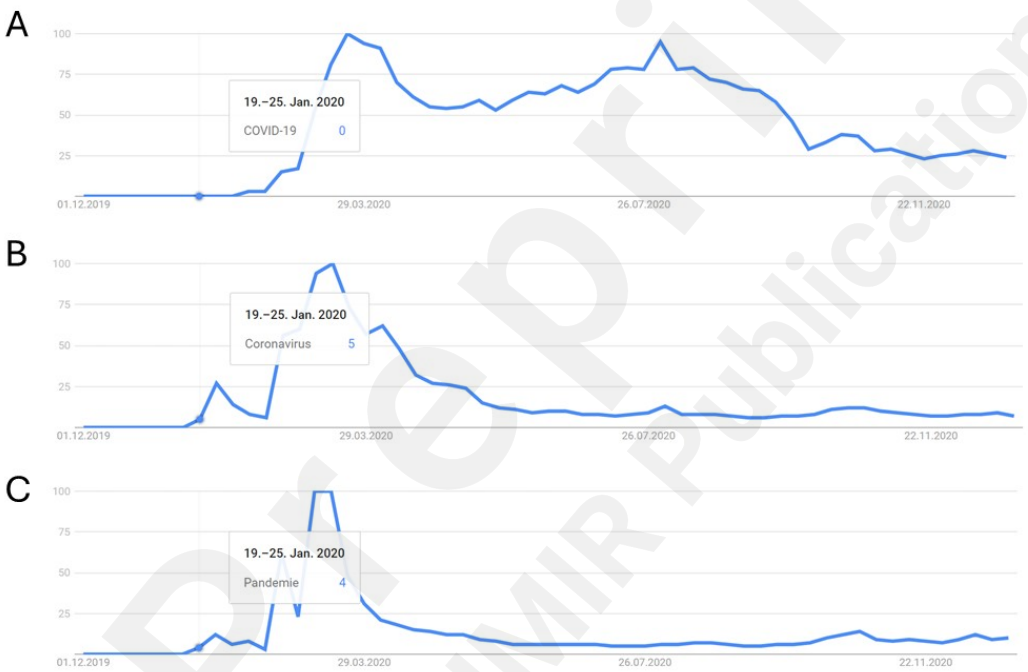
Supplementary Materials



suppl. Figure 1: Exemplary screenshots of RSV data from Google Trends for German search terms commonly linked to the pandemic. Starting in the week of the first reported case in Europe there is an emerging interest in the indicated terms.