

# The use of the time-to-event index (Tevent) to compare the negative impact of COVID-19 on public health among continents/regions in 2020 and 2021

## An observational study

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### Abstract

**Background:** During the COVID-19 pandemic, how to measure the negative impact caused by COVID-19 on public health (ImpactCOV) is an important issue. However, few studies have applied the bibliometric index, taking both infected days (quantity) and impact (damage) into account for evaluating ImpactCOV thus far. This study aims to verify the proposed time-to-event index (Tevent) that is viable and applicable in comparison with 11 other indicators, apply the Tevent to compare the ImpactCOVs among groups in continents/countries in 2020 and 2021, and develop an online algorithm to compute the Tevent-index and draw the survival analysis.

**Methods:** We downloaded COVID-19 outbreak data of daily confirmed cases (DCCs) for all countries/regions. The Tevent-index was computed for each country and region. The impactCOVs among continents/countries were compared using the Tevent indices for groups in 2020 and 2021. Three visualizations (i.e., choropleth maps, forest plot, and time-to-event, a.k.a. survival analysis) were performed. Online algorithms of Tevent as a composite score to denote the ImpactCOV and comparisons of Tevents for groups on Google Maps were programmed.

**Results:** We observed that the top 3 countries affected by COVID-19 in 2020 and 2021 were (India, Brazil, Russia) and (Brazil, India, and the UK), respectively; statistically significant differences in ImpactCOV were found among continents; and an online time-event analysis showed Hubei Province (China) with a Tevent of 100.88 and 6.93, respectively, in 2020 and 2021.

**Conclusion:** The Tevent-index is viable and applicable to evaluate ImpactCOV. The time-to-event analysis as a branch of statistics for analyzing the expected duration of time until 1 event occurs is recommended to compare the difference in Tevent between groups in future research, not merely limited to ImpactCOV.

**Abbreviations:** AUC = area under the curve, DCC = daily confirmed case, ImpactCOV = the negative impact caused by COVID-19 on public health, IP = inflection point, SMD = standardized mean difference, Tevent = the time-to-event index.

**Keywords:** choropleth map, COVID-19, forest plot, log-rank test, survival analysis, time-to-event index

## 1. Introduction

The COVID-19 pandemic has led to more than 0.44 billion confirmed cases and 6 million deaths as of April 1, 2022.<sup>[1]</sup> There were 6007,315 deaths up to 2022, which substantially exceeded the death toll of Middle East respiratory syndrome in 2012 (final death toll at 858) and severe acute respiratory syndrome in 2003 (final death toll at 774).<sup>[2–4]</sup>

### 1.1. Overall composite scores are required to measure the impact on public health

A composite score is required when a new disease (e.g., COVID-19) is spread to measure the negative impact on public health caused by the new disease (ImpactCOV).<sup>[4,5]</sup> However, a single indicator, such as the cumulative number of infected cases or the death toll, the case fatality rate,<sup>[5]</sup> or the inflection point (IP),

The datasets generated during and/or analyzed during the current study are publicly available.

Supplemental Digital Content is available for this article.

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## Highlights

1. Our study used the Tevent-index as a composite score to examine the impact of COVID-19 on public health, a concept rarely discussed during the COVID-19 epidemic.
2. The online time-to-event analysis was programmed to measure the struggle with COVID-19 between groups in countries or continents using the Tevent-index.
3. The Tevent-index has been demonstrated online for displaying the visual representation in comparison of Tevent-indices between groups, which makes it easier to understand how to calculate Tevent that is feasible in use in public health and how to draw the visual representation in comparison of Tevent between groups.

cannot adequately indicate the extent of the fight against COVID-19.<sup>[6-8]</sup> ImpactCOV is calculated by combining the daily confirmed cases (DCC) with the infected days as in bibliometric studies,<sup>[9-17]</sup> which take into account both publications (quantity) and citations (impact) shown on horizontal and vertical axes, respectively.

### 1.2. A composite score is required to represent the ImpactCOV

As one of the most popular indicators to evaluate individual research accomplishments, the h-index<sup>[18]</sup> has 2 disadvantages: its integer nature makes it difficult to differentiate between entities,<sup>[9,10]</sup> and DCCs are significantly higher than citations (e.g., over 10,000 vs 100 and less), which limits the h-index used to estimate ImpactCOV (i.e., *the h-index is defined as the maximum value of h such that the given author/journal has published at least h papers that have each been cited at least h times.*<sup>[18]</sup> The h-index is therefore redirected to a point where both publications and citations are equal).

While the IPcase index has been proposed as a measure of ImpactCOV (by multiplying the inflection point, IP, with the corresponding cumulative number of infected cases, CNICs<sup>[19]</sup>), the approach differs substantially from the bibliometric indices based on citations (or DCCs in this study) instead of CNICs. Therefore, IPcase is defined by the formula ( $= \sqrt{IP_i \times c_i}$ , where  $c_i$  denotes the corresponding DCCs). Due to its non-integer nature, the IPcase index can overcome the 2 major disadvantages of the h-index, described in the previous section. IPcase has one drawback, however, which is the difficulty of determining the number of IP days by the algorithm.<sup>[7,8]</sup>

### 1.3. Tevent-index as a composite score to represent ImpactCOV

Time-to-event analysis (also known as survival analysis) is a statistical technique used to estimate the duration of time until an event occurs and has been applied to compare ImpactCOVs for countries and regions.<sup>[6]</sup> In this study, the time-to-event (Tevent)-index ( $= \sqrt{D_i \times c_i}$ , where  $C_i$  is the descending DCCs on the corresponding i-th day based on the probability at  $D_i \geq 0.50$ , is conceived and proposed. As a result, we are motivated to investigate whether the Tevent is more closely related to the IPcase when compared to bibliometric indices and to determine whether the Tevent is suitable for measuring the ImpactCOV for countries/regions.

### 1.4. Aims of this study

The purpose of this study is to verify the validity of the Tevent-index in comparison with 11 other indicators, apply the Tevent-index to compare ImpactCOVs among continents/countries in

2020 and 2021, and develop an online algorithm for computing this index and draw the survival analysis for comparing the difference in Tevent between groups.

## 2. Methods

### 2.1. Data source

The COVID-19 data for 299 countries/regions were downloaded from GitHub.<sup>[20]</sup> The events were calculated using a series of DCCs collected in 2020 and 2021.

All downloaded data are publicly available on the website.<sup>[20]</sup> Following the guidance of the Welfare Department of the Taiwanese government, ethical approval was waived.

### 2.2. How to compute the Tevent

A Tevent is computed by relating the maximum  $D_t$  to the minimum  $St \geq 0.5$  using Equations 1 to 3.

$$\text{Survival rate } (St) = p_t \times p_{t-1}, \quad (1)$$

$$p_t = \frac{n_t - \text{Event}_t}{n_t}, \quad (2)$$

$$\text{Tevent} = \sqrt{D_t \times c_t}, \text{ where } t \text{ at } \min_{St} \geq 0.5, \quad (3)$$

where survival rate ( $St$ ) is defined as the conditional probability of survival at a given time point  $t$ . The remaining number of counts in survival analysis is  $nt$ . The inflection point is set at  $St \geq 0.5$ . Thus, the corresponding day (denoted by  $D_t$ , and expressed by publications or infected days) and the  $c_t$  standing for the DCCs (or citations in bibliometric analysis) are known and shown on the horizontal and vertical axes, respectively. A comparison is made between the computation of Tevent and the traditional survival analysis in Table 1. It is important to note that the citations (or DCCs) are sorted in descending order.

### 2.3. Approaches to achieving the study goals

The results of the study are comprised of 3 parts:

#### 2.3.1. Comparison of indices related to the Tevent-index.

**2.3.1.1. Study indices used for comparison.** This study provides a list of the most important variants of the h-index that have been discussed in greater detail in the literature (see Table 2).

**2.3.1.2. Differences and similarities between indices using simulation data.** For the bibliometric study, citations were generated based on the Collatz sequence,<sup>[23,24]</sup> defined as an iterative method over the set of positive integers  $N$  within a range (e.g., 1–500).

It is concerned with sequences of integers in which the next term is half of the previous term if the previous term ( $v$ ) is even (i.e.,  $\frac{1}{2} \times v$ ). The next term is 3 times the previous term plus one if the previous term was odd (i.e.,  $3v + 1$ ). Regardless of what positive integer is chosen to begin the sequence, these sequences will always reach 1.

Collatz sequence data are represented by citations (or DCCs) generated by initial integers (i.e., 1 through  $n$ , where  $n$  represents the number of articles, or DCCs, on the horizontal axis). Table 2 contains the values of these indices, which were converted into standardized scores following  $\sim N(0,1)$ , and a forest plot<sup>[24]</sup> was used to compare the standardized mean difference (SMD) between the indices.

Pearson correlation coefficients are used to measure the similarity between indices. Thus, the study's first goal (to verify the

**Table 1**  
**Comparison of the Tevent and traditional survival analysis:citations={6,4,2,2,1}.**

Type	Citation	Event	Censored (Ct)	nt	Survival rate (St)	Pt	Description
<b>A, Traditional survival analysis</b>							
Dt	0	0	0	5	1	0	
1	1	1	0	5	0.8	0.8	St = 1*0.8 = 0.8; Pt = (5-1)/5 = 0.8
2	2	1	0	4	0.6	0.75	St = 0.8*0.75 = 0.6; Pt = (4-1)/4 = 0.75
3	4	2	0	3	0.2	0.333	St = 0.6*0.333 = 0.2; Pt = (3-2)/3 = 0.333
4	6	1	0	1	0	0	St = 0.2*0; Pt = (1-1)/1 = 0
<b>B. Tevent</b>							
Dt	0	0	0	5	1	0	
1	6	1	0	5	0.8	0.8	St = 1*0.8 = 0.8; Pt = (5-1)/5 = 0.8
2	4	2	0	3	0.264	0.33	Stop due to 0.264 < 0.5
3	2	1	0	2	0.132	0.5	
4	1	1	0	1	0	0	

Tevent= $\sqrt{D_t \times c_t} = \sqrt{1 \times 6} = 2.45$  based on the conditional probability  $>= 0.5$ .  
 Tevent = the time-to-event index.

**Table 2**  
**Definitions of the h-index and its variants used to compare the Tevent.**

No	Index	Description	Reference	Citations={6,4,2,2,1}
1	h	=max{ci>=i}	[18]	3.00
2	g	$\leq \sum_{i=1}^g c_i$	[15]	4.00
3	x	$= \sqrt{\text{Max}(i \times c_i)}$	[14]	3.46
4	hT	See <sup>[16,17]</sup>	[16,17]	4.03
5	AIF	$= \frac{\sum_{i=1}^N c_i}{N}$	[11]	3.40
6	hb	$= h + \sqrt{\sum_{i=1}^N c_i - h^2}$	[19]	5.83
7	A	$= \frac{1}{h} \sum_{i=1}^h c_i$	[21]	2.00
8	R	$= \sqrt{\sum_{i=1}^h c_i}$	[21]	1.41
9	hg	$= \sqrt{h \times g}$	[22]	3.72
10	hx	$= h + (\frac{e}{t} \div (1 + \frac{e}{t}))$	[10]	3.57
11	IP	$= \sqrt{P_i \times c_i}$	[6-8]	2.41
12	Tevent	$= \sqrt{D_i \times c_i}$	This study	2.45

Note. i = the i-th article; ci = citation at the i-th article; i ∈ N; e = excess part in citation; t = tail part in citations.  
 Tevent = the time-to-event index.

Tevent as viable and applicable in comparison with the other 11 indicators) will be achieved.

**2.3.2. Using the Tevent to compare the ImpactCOVs in 2020 and 2021** To measure the ImpactCOVs for each country/region, the Tevent-index was applied to survival analysis with Kaplan–Meier<sup>[25]</sup> in 8 groups representing 6 continents and the United States and China. The data input format is defined in 3 columns as Equation 4, where Tevet for each country/regions, event label with 1 for all countries/regions, and labels of 8 groups, respectively. Details are described in Supplemental Digital Content 1, <http://links.lww.com/MD/H771>. The copy & paste approach is required to fill data on the website.<sup>[26]</sup> Notes that this study does not contain any censored data.

$$\begin{array}{ccc}
 \text{Column 1} & \text{Column 2} & \text{Column 3} \\
 \text{Tevent} & \text{Event} = 1 & \text{Group} \{ \text{continets, the US, China} \} \\
 \dots & | 1 & | \dots \\
 \dots & 1 & \dots
 \end{array} \tag{4}$$

The area under the curve (AUC) was calculated based on the trapezoid area according to Equation 5 and the 95% confidence intervals (CIs = AUC ± 1.96×SE) in Equation 6.<sup>[6]</sup>

$$AUC = \sum_{i=1}^n (P_{i+1} + P_i) \times h_{pi} \div 2, \tag{5}$$

$$\text{Standard Error} = SE = \sqrt{(AUC) \times (1 - AUC) \div n}, \tag{6}$$

$P_i$  represents the conditional probability for a given continent or country and  $h_{p_i}$  represents the distance between  $P_i$  and  $P_i + 1$  (i.e.,  $ct$  and  $ct + 1$ , on the vertical axis, corresponding to both  $Dt$  and  $Dt + 1$ , on the horizontal axis, in Eq. 3 and Table 1).  $n$  represents the sample size (i.e., the number of time points on the horizontal axis for a specific group).

The ImpactCOV of all Tevents in counties/regions was compared using a choropleth map<sup>[27]</sup>; darker colors indicate a higher ImpactCOV. In this study, 2 types of comparisons were performed between continents/countries using the parameter SMD with the Q-index<sup>[28]</sup> and a time-to-event analysis using a log-rank test.<sup>[25]</sup> The study's second goal (i.e., the comparison of ImpactCOVs between continents/countries in 2020 and 2021) will be accomplished.

### 2.4. Develop an online algorithm to compute the Tevent

The algorithm for calculating the Tevent was programmed. Two visualizations of Hubei Province in China in 2020 and 2021 were presented to demonstrate the Tevent in computation. The online survival analysis for comparing the difference in Tevent between groups was also programmed for readers to practice them on their own. The third goal of the study (i.e., the development of algorithms for Tevent computation and online survival analysis for readers) will be achieved.

### 2.5. Statistics and tools

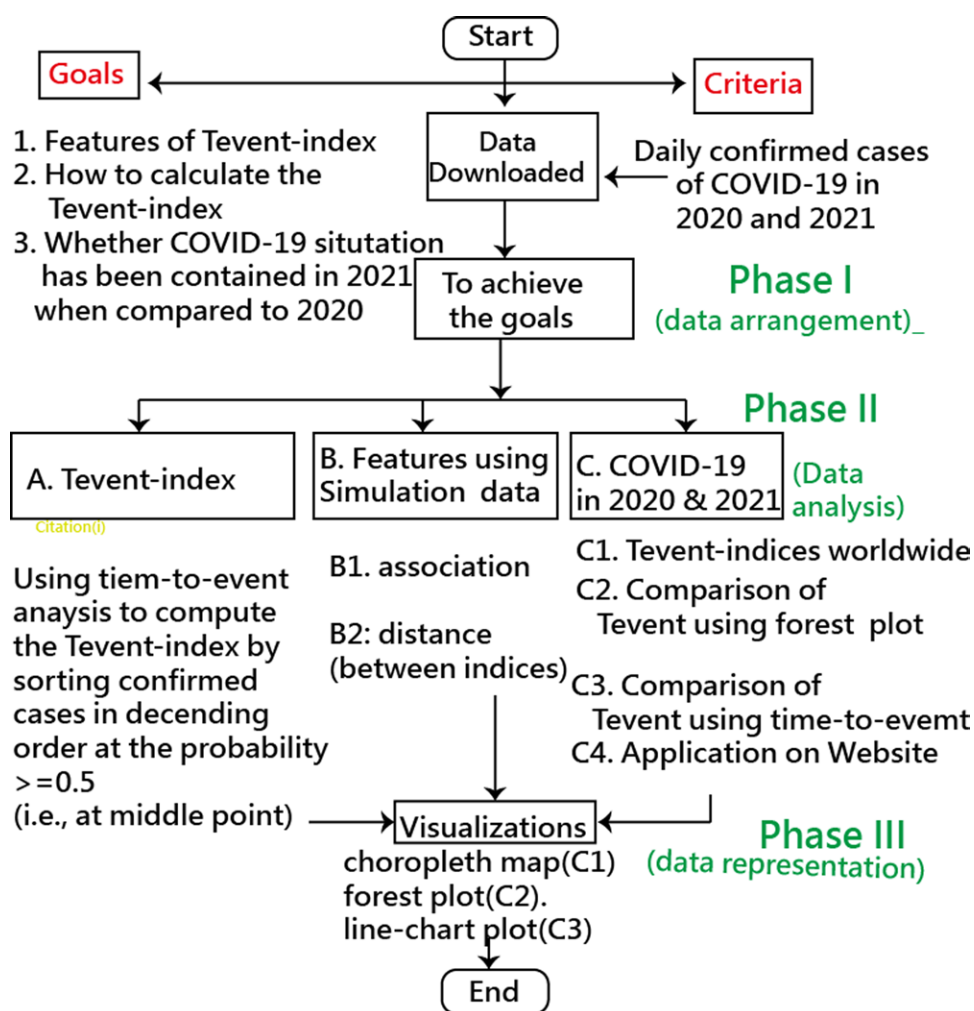
A forest plot was used to compare the SMD values. We set a significance level of 0.05 for type I errors. We determined the 95% CIs based on the pooled standard deviations (SD<sub>p</sub>) of the indices between 2-time points (i.e.,  $SD_p = \sqrt{s_1 \times s_1 + s_2 \times s_2}$ , where  $s_1$  and  $s_2$  are the SDs of the Tevent scores in 2020 and 2021).<sup>[28]</sup> Figure 1 illustrates the study flowchart.

On Google Maps, all visual representations were displayed, including the choropleth map, the line-chart plot, and the forest plotted.

## 3. Results

### 3.1. Verify that the Tevent is viable and applicable

Using the simulation data of Collatz sequences in Table 3, the Pearson correlation coefficients between Tevent and the contrast indices are high ( $\geq 0.87$ ). According to Figure 2, the Tevent has similar standardized scores to the IPcase (-0.29) and is associated with higher hT, hb, r-index, and IP-index scores ( $\geq 0.98$ ). Thus, the Tevent is a viable and applicable tool for evaluating ImpactCOV in accordance with the first study objective.



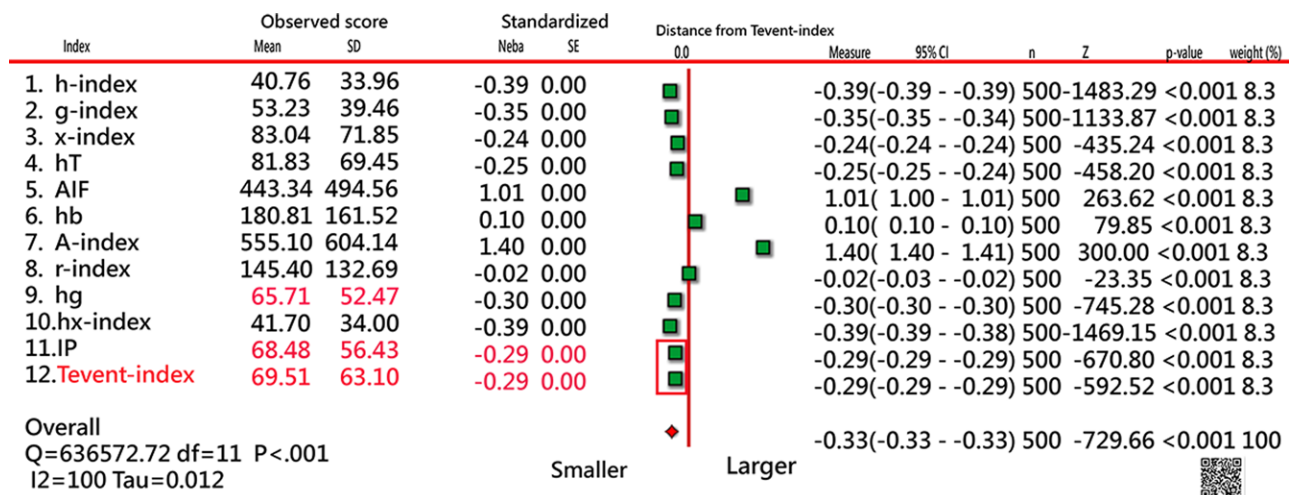
COVID-19 data at <https://github.com/CSSEGISandData/COVID-19>  
 Tevent-index at <http://www.healthup.org.tw/kpiall/htindexurlsurva.asp>

Figure 1. Study flowchart.

**Table 3**  
Correlations between 12 bibliometric indicators on 500 Collatz sequences.

	h-index	g-index	x-index	hT	AIF	hb	A-index	r-index	hg	hx-index	IP	Tevent
h-index												
g-index	1.00											
x-index	0.88	0.87										
hT	0.99	0.99	0.97									
AIF	0.81	0.80	0.88	0.86								
hb	0.97	0.96	0.92	0.99	0.92							
A-index	0.78	0.77	0.84	0.84	0.99	0.90						
r-index	0.95	0.95	0.89	0.98	0.94	0.99	0.93	1.00				
hg	0.98	0.98	0.96	1.00	0.88	0.99	0.84	0.96				
hx-index	1.00	1.00	0.88	0.99	0.81	0.97	0.78	0.95	0.98			
IP	0.93	0.93	0.91	0.96	0.95	0.99	0.94	0.99	0.96	0.93		
Tevent	0.94	0.93	0.87	<b>0.98</b>	0.94	<b>0.99</b>	0.92	<b>0.99</b>	0.95	0.94	<b>0.98</b>	1

Tevent is associated more with the 4 indicators of hT, hb, r-index, and IP-index.  
Tevent = the time-to-event index.



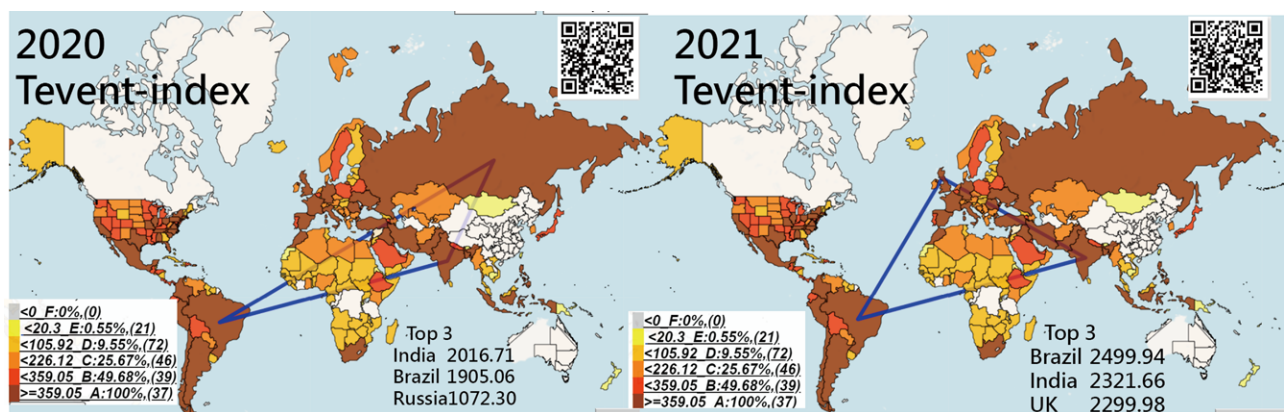
**Figure 2.** Differences in distances between 12 bibliometric indicators (note. Tevent is closer to the IP index due to approximately identical points on IP and St). IP = inflection point, Tevent = the time-to-event index.

**3.2. Apply the Tevent to compare the ImpactCOVs**

The top 3 countries most affected by COVID-19 in 2020 and 2021 were India, Brazil, Russia and Brazil, India, and the UK, respectively (Fig. 3). A statistically significant difference in ImpactCOV between continents was found using the Q-index ( $P = .02$ ) and log-rank test ( $P < .001$ ), as shown in Figures 4, 5, and Table 4. The study’s second goal (i.e., the comparison of ImpactCOVs between continents/countries in 2020 and 2021) was achieved.

**3.3. Develop an onlinealgorithm to compute the Tevent-index**

An online time-event result was shown to present the Tevent for Hubei Province (China) in 2020 and 2021 with 100.88 and 6.93, respectively, via the link<sup>[29]</sup> shown in Figure 6. Red dots indicate the locations of h-indices (=42 and 6), indicating that the containment effect on COVID-19 in Hubei Province (China) was substantial. A third study objective



**Figure 3.** Geographical distribution of COVID-19 impacts around the world in both years.

Indicator	2020		2021		SMD	Measure	95% CI	n	Z	p-value	weight (%)
	Mean	SD	Mean	SD							
1. AFRICA	84.19	96.40	117.69	144.10		-0.27(-0.66 - 0.12)	51	-1.37	0.171	17.3	
2. ASIA	241.04	333.52	466.22	487.24		-0.53(-0.97 - -0.10)	41	-2.40	0.016	13.6	
3. China	14.96	16.99	9.34	7.53		0.42(-0.05 - 0.90)	34	1.74	0.082	11.5	
4. EUROPE	216.20	225.57	506.72	475.19		-0.77(-1.18 - -0.37)	49	-3.73	<0.001	15.6	
5. N. AMERICA	100.65	161.72	148.10	199.67		-0.26(-0.72 - 0.20)	36	-1.10	0.271	12.3	
6. OCEANIA	19.02	28.38	19.00	21.69		0.00(-0.64 - 0.64)	18	0.00	1.000	6.4	
7. S. AMERICA	474.34	529.95	637.61	650.60		-0.27(-1.01 - 0.48)	13	-0.70	0.484	4.6	
8. US	269.59	180.12	362.71	239.44		-0.44(-0.81 - -0.06)	56	-2.30	0.021	18.7	
Overall						-0.32(-0.48 - -0.16)		-3.87	<0.001	100.0	

Q=16.595 df=7 P=0.02  
I<sup>2</sup>=57.82 Tau=0.076

● Significance

Larger in 2021      Larger in 2020

Figure 4. Comparison of the Tevent indices among the participants/countries between 2020 and 2021 (note. Significance in Asia and Europe with a larger impact on public health in 2021). Tevent = the time-to-event index.

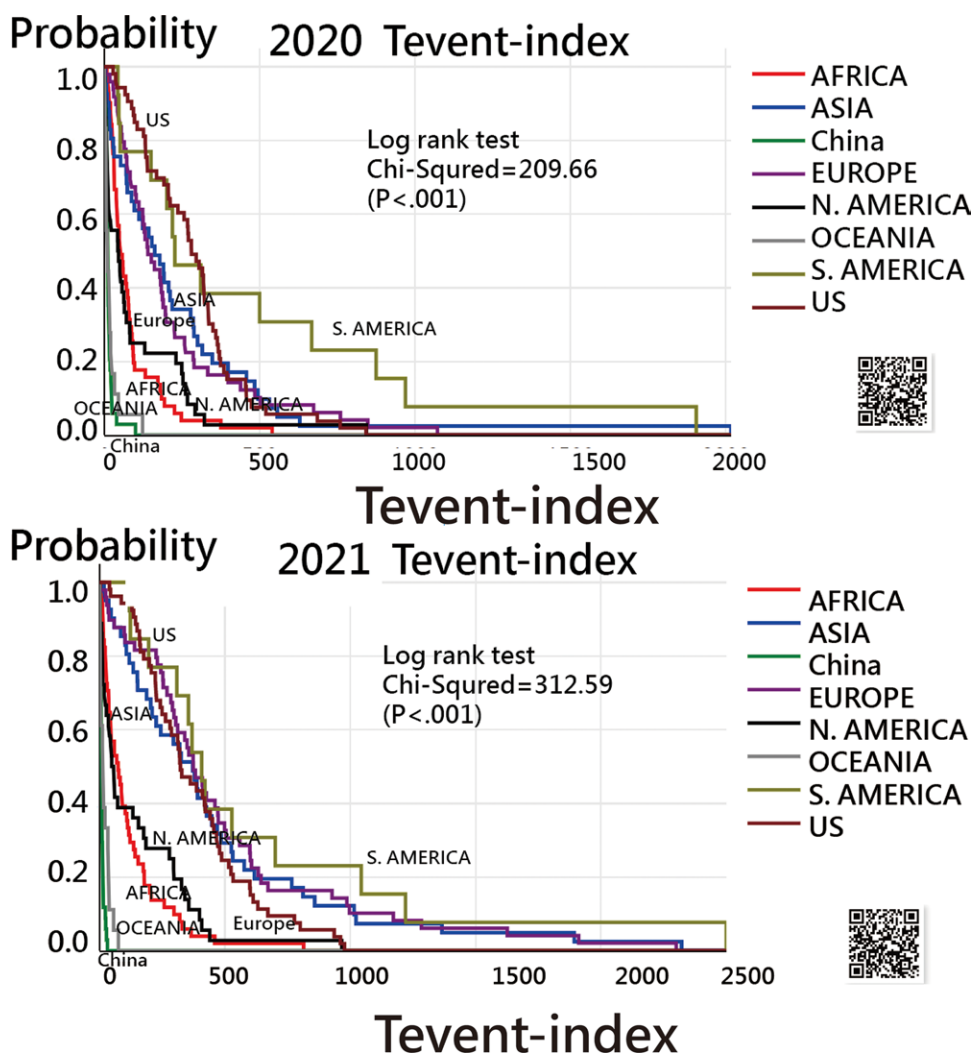


Figure 5. Time-to-event analysis of the Tevent indices among continents/countries in 2020 and 2021. Tevent = the time-to-event index.

was accomplished, which was the development of an online algorithm for computing the Tevent-index and generating a survival analysis to compare the difference in Tevent between groups.

3.4. Online dashboards shown on google maps

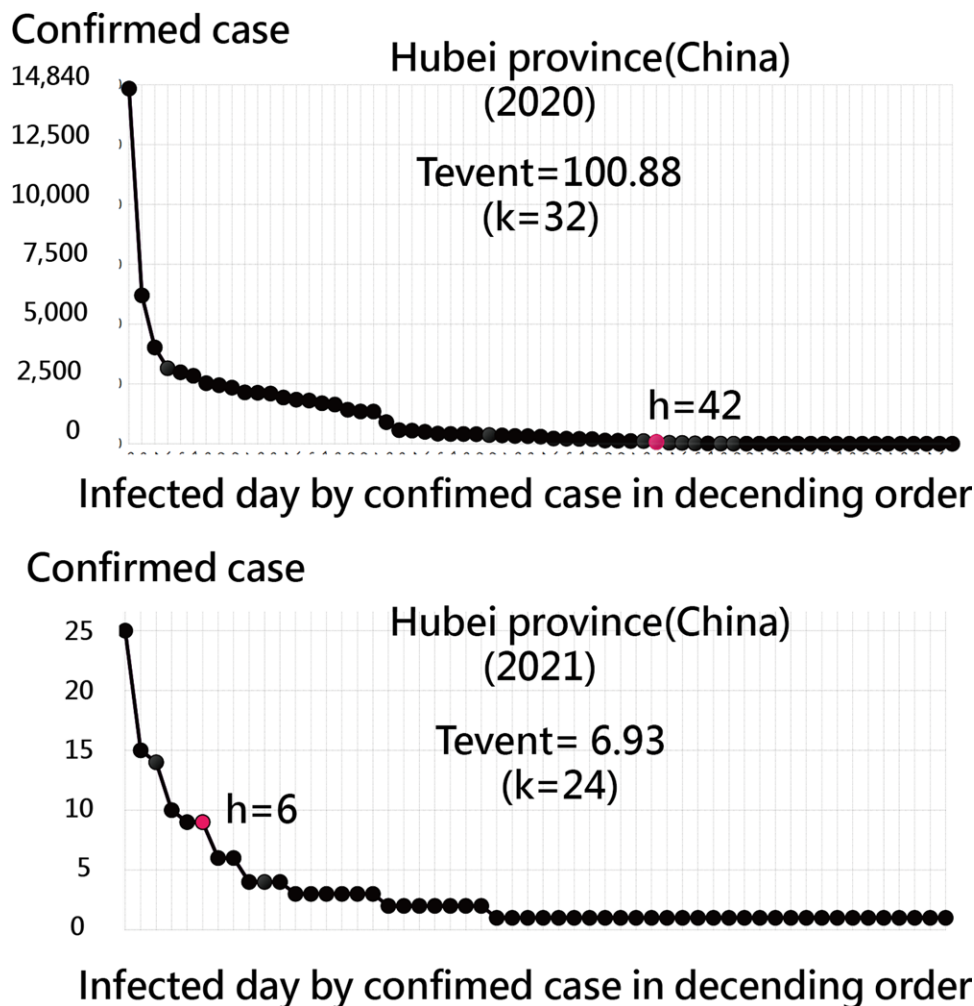
Once the QR code is scanned, all dashboards in Figures are displayed. The reader is advised to examine the details of the information for each entity.

**Table 4**

**Comparisons of the area under the curve in Figure 5.**

No.	Area	2020	Between	2021	Between	Between
			Areas		Areas	2 years
1	AFRICA	0.06(0.04–0.08)	(7)(8)	0.06(0.04–0.08)	(2)(4)(7)(8)	
2	ASIA	0.09(0.08–0.10)	(3)(5)(6)	0.13(0.12–0.14)	(1)(3)(5)–(7)	Sig.
3	China	0.02(0.00–0.05)	(2)(4)(7)(8)	0.02(0.03–0.07)	(2)(4)(7)(8)	
4	EUROPE	0.09(0.07–0.11)	(3)(5)(6)	0.13(0.12–0.14)	(1)(3)(5)–(7)	Sig.
5	N. AMERICA	0.05(0.04–0.06)	(2)(4)(7)(8)	0.05(0.04–0.06)	(2)(4)(6)–(8)	
6	OCEANIA	0.02(0.00–0.04)	(2)(4)(7)(8)	0.01(0.00–0.03)	(1)(2)(4)(5)(7)(8)	
7	S. AMERICA	0.14(0.12–0.16)	(1)–(6)	0.16(0.15–0.17)	(1)–(6)(8)	
8	US	0.12(0.10–0.14)	(1)(3)(5)(6)	0.12(0.10–0.14)	(1)(3)(5)(6)(7)	

Sig. = significance, Tevent = the time-to-event index.



**Figure 6.** Tevent-index of Hubei Province (China) based on confirmed cases in 2020 and 2021. Tevent = the time-to-event index.

**4. Discussion**

**4.1. Principal findings**

We observed that the Tevent is closer to and associated with the IPcase index when using simulation data of Collatz sequences; India, Brazil, and Russia were the top 3 countries to be severely affected by COVID-19 in 2020 and 2021, respectively; there were statistically significant differences in ImpactCOV among continents using the Q-index ( $P = .02$ ) and log-rank test ( $P < .001$ ); and an online time-event result was shown to present the Tevent for Hubei Province (China) in 2020 and 2021 with 100.88 and 6.93, respectively, indicating that the impact of COVID-19 on public health in 2020

was substantially more significant than that in 2021 in Hubei Province (China).

**4.2. Additional information**

In 2020 and 2021, India and Brazil used the Tevent index to measure ImpactCOV, similar to India (= 379,308 cases per day in 2020) and Brazil (= 79,726 cases per day in 2020).<sup>[30–33]</sup>

In 2020, the US ranked first (19,899,082), India (10,266,674), Brazil (10,266,674), and Russia (7,675,973) in DCC, and the US (54,533,878), India (34,861,579), Brazil (22,291,839), and the UK (13,010,849) in 2021. Based on the results of this study, the Tevent-index was found to be

viable, feasible, and applicable as a composite score but is more meaningful due to both infected days and DCCs that were considered.

As shown in Figure 4, all ImpactCOVs, except for China and OCEANIA, are higher in 2021 than in 2020, consistent with the data: 19,075 (2021) compared to 95,967 (2020) in China, but different from 84,263 (2020) and 606,434 (2021) in OCEANIA since some excessive DCCs, such as in Kosovo, New South Wales (Australia), and Victoria (Australia), were excluded. For this reason, AIF (=citations/publications) has been criticized in bibliometrics. As such, the DCCs alone are not sufficient to determine the ImpactCOV.

According to Figure 5, the time-to-event analysis used in ImpactCOV to differentiate groups is suitable<sup>[6]</sup> when the data are not distributed normally, such as those used in the bootstrapping method<sup>[34–36]</sup> for the comparison of the differences in h-indices between groups.

Among the many existing bibliometric indices, such as the journal impact factor (=citations/publications),<sup>[11]</sup> the x-index,<sup>[14]</sup> the g-index,<sup>[15]</sup> and the hT-index,<sup>[16,17]</sup> Tevent is novel, modern, and meaningful when applied to measure ImpactCOV mainly when  $C_i$  (citations or DCCs) is substantially greater than  $D_i$  (publications or events). The 3 scenarios with identical x-indices (=10)<sup>[14]</sup> are unfair and doubtful: 1 publication with 100 citations, 10 publications with 10 citations each, and 100 publications with 1 citation each. There are h-indices<sup>[18]</sup> of 1, 10, and 1, corresponding to hT-indices of 3.28, 10, and 3.28 and Tevents of 10, 10, and 10, respectively. In contrast, they have g-indices of 1, 10, and 1, which correspond to AIFs of 100, 10, and 1.

#### 4.3. Implications and changes

The Tevent index is used as a composite score for measuring ImpactCOV to take both DCCs and infected days into account, as opposed to only taking the DCCs or CNICs into account traditionally. This study has several distinctive features. The first thing to note is that each country or region has its own daily epidemic score that the Tevent-index indicates. In comparison to the IPcase index, which makes it difficult to determine the number of IP days, the Tevent index can be used to measure both the length of infected days and the impact of COVID-19,<sup>[7,8]</sup> as shown in equation. A correlation exists between the Tevent-index and hT, hb, r-index, and IP index ( $\geq 0.98$ ), as shown in Table 3. The Tevent is therefore viable and applicable to the evaluation of ImpactCOV.

The second feature of this study is the use of time-to-event analysis to compare differences in Tevenets among continents/countries, instead of the traditional parameter statistics, which assumes that data follow a normal distribution (e.g., using the forest plot in Fig. 4). The online survival analysis is available at the following links<sup>[26,37]</sup> (see the instruction tutorial material in Supplemental Digital Content 1, <http://links.lww.com/MD/H771>).

As a third feature, Figure 4 provides readers with an easy way to compare the findings of pair comparison in 2 panels (i.e., 2020 and 2021).

Aside from the 3 aforementioned features, the visual representations displayed on Google Maps are the feature of this study (see Figs. 3–5). A demonstration of the algorithm for computing the Tevent can be found at the link.<sup>[29]</sup> For practice, readers can enter a series of integer numbers separated by commas (e.g., 6,4,2,2,1) to see the results (e.g., Tevent = 3.46), as shown in Figure 6.

#### 4.4. Limitations and suggestions

Further studies should examine several issues in depth. The first concern is the calculation of the Tevent index. While the concept is somewhat different from the traditional survival analysis

(e.g., backward computation of survival rates as described in Table 1), it is nonetheless similar to the traditional survival analysis (see the codes at the link<sup>[28]</sup>). The Tevent-index may be applied to other epidemics, not only the COVID-19 pandemic, particularly if significant differences exist between  $c_i$  (citations or DCCs on the vertical axis) and  $D_i$  (publications or infected days on the horizontal axis), referring to Equation 3.

As a second point, the survival rates presented on Google Maps appear to be extremely inflated. In particular, algorithms adjust the curves to map probabilities onto earth coordinates. By observing the area of their coordinates on Google Maps, the AUC and its 95% CI can be calculated. Accordingly, a post hoc test can be conducted after the log-rank test appears in the survival analysis.<sup>[26,37]</sup>

The Tevent-index determined by the time-to-event analysis has some major concerns that might be confusing to readers in data design; for example, the length of a Tevent is deemed as time, contrary to the traditional days taken into consideration in survival analysis. It is easy to read the 20-line program code.<sup>[29]</sup> The codes provided facilitate the use of the Tevent-index in other fields in the future, such as awards, funding proposals, and the results of competitions in groups (e.g., Olympic Games).

The fourth problem is that we have not provided a more detailed interpretation of the meanings in the figures. Nonetheless, readers can easily understand the contents of dashboards due to visual representations.

Last, although the Tevent-index is considered useful and applicable in nature, the comparison of the difference between groups should be made with caution, since the Tevent-index does not always follow a normal distribution. In comparing ImpactCOVs among groups, readers are advised to use the bootstrapping method.<sup>[34–36]</sup>

## 5. Conclusion

The Tevent-index was applied to differentiate the ImpactCOV for countries/regions in 2020 and 2021 based on both impactful DCCs and infectious days. To break the boundaries of descriptive statistics alone in traditional epidemic studies, quantitative and inferential statistics were provided in this study. Based on advanced computer science, the Tevent indices and plots used to assess ImpactCOVs are recommended for use in future epidemic studies, not only for COVID-19 research.

## Author contributions

TW and HY provided the concept and designed this study. HM and WC interpreted the data. SHC monitored the process and the manuscript. HY and TW drafted the manuscript. All authors read the manuscript and approved the final manuscript.

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