RESEARCH ARTICLE

Are mega-events super spreaders of infectious diseases similar to COVID-19? A look into Tokyo 2020 Olympics and Paralympics to improve preparedness of next international events

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Abstract

Tokyo Summer Olympics and Paralympics have raised social issues regarding the potential rise in COVID-19 cases in Japan and risks associated with the safe organization of mega sporting events during the pandemic, such as the FIFA World Cup Qatar 2022. This study investigates the Tokyo Summer Olympics as a unique case study to clarify the drivers of infectivity and provide guidelines to host countries for the safe organization of subsequent international sporting events. The result here reveals that Tokyo and Japan did not experience a rise in confirmed cases of COVID-19 due to the hosting of the Summer Olympics. Still, transmission dynamics seems to be mainly driven by the high density of population (about 1.2%, p-value <0.001) like other larger cities in Japan (result confirmed with Mann-Whitney U test, significance at 0.05). Our study provided evidence that hosting mega sporting events during this COVID-19 pandemic is safe if strictly maintained the precautions with non-pharmaceutical (and pharmaceutical) measures of control of infections. The Tokyo Summer Olympics hosting will be exemplary for next international events due to the successful implementation of preventive measures during COVID-19 pandemic crisis.

Keywords COVID-19 · Response policy · Japan · Sporting events · Crisis management · Pandemic preparedness

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Introduction

Currently, the world health care system is facing overwhelming challenges due to the emergence of the Coronavirus Disease 2019 (COVID-19) pandemic crisis (Coccia 2021a; Coccia, 2022c, e; Núñez-Delgado et al., 2021; Bontempi and Coccia 2021). Countries, such as Brazil, the USA, India, the UK, and Italy, have struggled to prevent the widespread transmission of this highly contagious coronavirus with manifold mitigation and containment policies (Coccia 2022a, b). Countries have introduced different response policies (e.g., wearing face masks, social distancing, travel restrictions, lockdown, isolation and quarantine, vaccination and immunity passport) to prevent the rapid transmission of COVID-19 but still struggling to control the pandemic diffusion that is driven by new variants of SARS-Cov-2, such as Omicron (Ardito et al., 2021; Wilf-Miron et al. 2021; Coccia 2021b, 2021c, 2022a). Similar to other respiratory infections, the widespread transmission of COVID-19 may be influenced by manifold atmospheric factors since the higher probability of infection can depend on weather conditions (wind speed, humidity, temperature), air pollution, density of people, trade, etc. (Bontempi 2020; Bontempi et al. 2021;

Coccia, 2021a; Hoang and Tran 2021; Lim et al. 2021). Several factors, such as population size, economy, human behavior, and immunity, may severely confuse the influence of environmental variables on COVID-19 (Bontempi et al. 2020; Bontempi and Coccia, 2021). Gaisie et al. (2022) analyzed the geographies of COVID-19 in Melbourne and identified that several build environment attributes such as density, distance to transit, diversity, and destination accessibility are responsible for the rise of COVID-19 infection cases (Gaisie et al. 2022). Liu and Fu have developed a novel study to address and identify the public attention towards major events and their relationship with sustainable development (Liu and Fu 2022). This study reported that people attention changes with the severity of events. Similarly, Park and colleagues using text mining method investigated the main drivers of user perceptions and policy compliance in airports and reported that building design has a large impact on policy compliance and the vulnerability of health crisis (Park et al. 2022). Lak and colleagues identified the correlation between neighborhood resilience and the cases of COVID-19 and stated that they have a negative relationship (Lak et al. 2021). Aral and Bakir performed spatiotemporal analysis for Turkey to investigate the spread of COVID-19 cases and found that it is related to the population density and elderly dependency ratio (Aral and Bakir 2022). Spatiotemporal effects of COVID-19 in the USA were also explored by Maiti et al. (2021). This study observed that migration factors, crime rate, income, and ethnicity have strong relationship with the spread and deaths of COVID-19. Pal and Masum (2021) investigated the impact of monthly rainfall, temperature, relative humidity, and wind speed on the spread of COVID-19 in Bangladesh and found that positive correlations exist among relative humidity, rainfall, wind speed, and COVID cases (Pal and Masum 2021). Pani et al. (2020) analyzed Singapore's meteorological parameters and COVID-19 and found a strong association among absolute humidity, temperature, dew points, and COVID cases (Pani et al. 2020). Zhu et al. (2020) found a significant correlation between absolute humidity and COVID infection rates for South American regions (Zhu et al. 2020). Hossain et al. (2021) applied autoregressive integrated moving average (ARIMAX) model to determine the influence of weather on COVID cases for five South Asian countries and found that the impact of meteorological variables on COVID varied region wise (Hossain et al. 2021). The study determined that $PM_{2.5}$, temperature, wind speed, and rainfall can strongly impact the spread of this novel coronavirus. Some researchers have also highlighted that social interaction is one of the main sources of contagious spread, considering different provinces of the same country, or regions of different areas, and all over the world (Bontempi et al. 2021; Bontempi 2022). In this context of the COVID-19 pandemic crisis, human society has organized and is organizing international events for a recovery to normal socioeconomic activities, such as Tokyo 2020 Summer Olympics and Paralympic Games celebrated in July–September

2021, Beach Volleyball World Championships Rome in June 2022, and FIFA World Cup Qatar in November–December 2022. Literatures reported the possibility of this Olympics in Japan being a global super spreading event (Mahase 2021), such that vaccination would be the more suitable control measure to lower the risk of COVID-19 spread (Coccia, 2022c). In Japan, the first case of COVID-19 was reported on January 16, 2020 (Yao et al. 2020). Several cases were confirmed on a cruise ship in early February of 2020. The newly confirmed cases rose high in the first week of August 2020 (Hatakeyama et al. 2021). Among forty-seven prefectures of the country, three prefectures (Tokyo, Osaka, and Kanagawa) have more confirmed cases than others. Tokyo has been severely affected by the novel coronavirus, with more than 0.38 million confirmed cases (CSSEGIS and Data, 2021a). Because of the increasing trend of COVID-19 cases, to protect athletes, the Tokyo 2020 Summer Olympics and Paralympic Games have been rescheduled in 2021. Amid concerns of cancelling both events due to the COVID-19 pandemic, Tokyo and Japan successfully hosted the 2020 Summer Olympics from July 23 to August 8, 2021, and Paralympic Games from August 24 to September 5, 2021. However, the confirmed cases of COVID-19 have seen enormous growth, hitting new infection records during this period. It is also important to highlight that on July 1, 2021, in Japan, only 14.63% of the population was fully vaccinated against COVID-19 (Our World in Data, 2021).

As many international sporting mega-events are forthcoming, such as FINA World Swimming Championships in Fukuoka (Japan) 2022 and FIFA 2022 World Cup in Qatar, the goal of this study is to analyze the critical and unique case study of Tokyo Summer Olympics and Paralympic Games in 2021 to clarify the determinants that can play a major role in the elementary propagation of the novel coronavirus to design and endeavor, for the first time, to show best practices to host cities and countries that can protect not only public health but also surrounding environment for safe organization of next international events and support economic and social activities at domestic and global level during COVID-19 era. The severity of COVID-19 pandemic crisis has encouraged researchers and scientists worldwide to analyze every aspect related to the propagation of the new coronavirus. However, the impact of organizing a mass gathering event on the transmission dynamics in host cities is yet to be evaluated. Using Japanese prefectural data, we analyze the associations among different variables, such as population density, vaccination status, environmental parameters, international trade, and COVID cases during hosting of Tokyo Olympics and Paralympics. Besides, this study also shows how hosting cities can recover their economic loss due to the pandemic through a resiliency scale. Results here can be attractive to policymakers, academics, and citizens to really understand the main factors affecting the pandemic diffusion, verify if the restriction measures adopted for Olympics were properly considered, and prepare better response policies for eventual future similar situations.

Materials and methods

Research setting and sample

Our study has collected data from different databases for N=42 prefectures in Japan, including the 2020 Summer Olympics and Paralympics organizer Tokyo. This study aims to analyze and assess if the organization of these international events could have increased the confirmed cases of COVID-19 in Tokyo compared to other similar Japanese cities with a larger population and higher population density.

Measures

– Daily confirmed cases of COVID-19 from July to September 2021 per Japanese prefecture were collected. The study design considers total confirmed cases because it indicates the impact of COVID-19 in society in the presence of a certain level of population and socioeconomic activity (Coronavirus | NHK WORLD-JAPAN News, 2021c, Development of Coronavirus cases: Japan, 2021d).

– Total import and export, total value in US dollar ($) in the year 2020 is a complex indicator including various factors given by the density of population, economic dynamism, and people mobility of countries. In fact, a suitable measure must indicate human-to-human interactions, but it must also be correlated with the people mobility associated with socioeconomic interactions (Ferretti et al. 2020). Notably, commercial relationships, related to the globalization of companies' value chains and markets, are based on persistent mobility patterns across different countries, and differently from travel for vacation, almost always need close social interaction among individuals. Then, they can be considered the synthetic expression of socioeconomic relationships created by economic activities, requiring human contacts associated with business collaboration. In fact, globalization has been accompanied by a growing share of international trade. The high level of imports of resources indicates increasing living standards (Rodrigue et al. 2016). In particular, the economic value of imports and exports of international trade (in money) of different regions in a country is a main indicator of people's living standard, economic activities, and globalization dynamics (Oster 2012). Hence, the indicator of the sum of the total amount of import and export in international trade can be accounted for considering the last reported available data (2020 year) for each prefecture in Japan (OEC - The Observatory of Economic Complexity https://oec.world/).

– Population and density of population per km^2 of all prefectures (Japan: Prefectures and Major Cities http://www.citypopulation.de/en/japan/cities/).

– COVID-19 vaccination data over the period under study (Japan Vaccine Rate Progress https://ncovtrack.com/vaccine/japan).

– Air quality data (PM$_{2.5}$, PM$_{10}$, NO$_2$, SO$_2$, CO, O$_3$, temperature, humidity, wind speed) (timeanddate.com https://www.timeanddate.com/, Historical Weather Data & Weather Forecast Data | Visual Crossing https://www.visualcrossing.com/weather-data, Air Quality Historical Data Platform https://aqicn.org/data-platform/register/.)

Data analysis procedure

First, this study has considered the cities having the largest population and the higher density of people per km^2 for a comparative analysis with Tokyo that has organized the Summer Olympics and Paralympic Games. COVID-19 new cases per 100,000 people in July, August, and September 2021 of Tokyo have been compared to Osaka (the second largest city in Japan with about 9 million people) and the group of five largest prefectures (Fukuoka, Hyogo, Chiba, Aichi, and Osaka). In addition, it has been calculated the percent growth of new cases of the month t (e.g., August) on the previous month t-1 (e.g., July) of Tokyo, Osaka, and the group of the five largest prefectures.

Descriptive statistics (standard deviation, arithmetic mean, kurtosis, and skewness coefficient) have been applied to variables under consideration to evaluate the normality of distribution. Since some variables under study do not have a normal distribution, they are transformed in a logarithmic scale to have normality and a more consistent parametric analysis. Bivariate Pearson correlations were employed to establish associations between variables, with the correlation coefficient determining the degree of association. We computed one-tailed significance tests for correlation to study the associations between variables. In particular, the association investigated is between the variables of import-export and COVID-19 confirmed cases over July–September period in Japanese cities with a density < or > than 300 people per km^2.

Regression analysis using a *log-log* model to analyze the relationships between COVID-19 confirmed cases and density of population is given by:

$$\log y_{i,t} = a + b \log y_{i,t} + u_{i,t} \qquad (1)$$

a is a constant; *log* has base e= 2.7182818; u_t is the error term.

y is COVID-19 confirmed cases over July–September period 2021.

x is the density of population per km^2 in 2020.

The relationships under study are investigated using the ordinary least squares (OLS) method to estimate the unknown parameters in regression models.

Finally, this study considers the largest cities in Japan, categorized in two sets: cities having a population density in the range of 1,000–2,000 people per km^2 and cities having a density of population (inhabitants per km^2) >2,000 (i.e., Osaka and Tokyo). The arithmetic means and standard error of the mean of COVID-19 confirmed cases over July–September 2021 in these two largest cities are calculated. After that, as the sample is of small size, the confirmed cases of COVID-19 in these two sets are analyzed with the Mann-Whitney U test: a non-parametric test that is useful for determining if the mean of two groups is different from each other. The hypotheses under study are:

$$H_0: \ \mu_{\text{cities having} > 2,000 \text{ people per km}^2}$$
$$- \ \mu_{\text{cities having} 1,000–2,000 \text{ people per km}^2} = 0$$

("the difference of the means is equal to zero")

$$H_1: \ \mu_{\text{cities having} > 2,000 \text{ people per km}^2}$$
$$- \ \mu_{\text{cities having} 1,000–2,000 \text{ people per km}^2} \neq 0$$

("the difference of the means is *not equal* to zero")

To decide whether to reject (null hypothesis) H_0, we will use the exact p-value. Suppose the exact p-value is smaller than the specified level (0.05). In that case, we reject H_0 that the difference of the means is equal to zero: Mann-Whitney U test shows that there is a significant difference between sets, i.e., confirmed cases in largest cities having a density of people >2,000 inhabitants per km^2 is higher than the group of cities having a lower density of people. If we retain the null hypothesis, these two sets do not have a significant difference; consequently, cities having a higher density of people, such as Tokyo during Summer Olympics and Paralympic Games in 2021, have a similar mean of COVID-19 confirmed cases of cities with a lower density (1,000–2,000 people per km^2). Hence, the behavior of transmission dynamics of COVID-19 in Tokyo during the Olympics is like other larger cities and associated mainly with other factors, such as density of people if just mentioned statistical analyses support it. Statistical analyses are performed with the IBM SPSS Statistics 26 ®.

Results

In Table 1, we present the five largest prefectures (except Tokyo) in Japan based on population and density of people per km^2 to explain, with a comparative analysis, the recent infection dynamics of COVID-19 during Tokyo 2020 Summer Olympics. Figure 1 shows new cases of COVID-19 per 100,000 people in Tokyo, Osaka, and the five largest

Table 1 Five largest prefectures based on population and density of people

N	Prefecture	Population	Density (per km^2)
1	Fukuoka	5,138,891	1,030.0
2	Hyogo	5,469,184	651.0
3	Chiba	6,287,034	1,219.0
4	Aichi	7,546,192	1,459.0
5	Osaka	8,842,523	4,642.0
6	Tokyo	14,064,696	6,411.0

prefectures of Japan in July, August, and September 2021. Results show that confirmed cases peaked in August, followed by a sharp fall out in September 2021. Figure 2 reveals that COVID cases have a negative growth rate for Tokyo and other prefectures in August and September (only for Tokyo).

Table 2 shows the estimated relationship (*log-log* model) of COVID-19 confirmed cases in Japan with population density. The regression coefficient suggests that a 1% increase in the population density increases the expected confirmed cases of COVID-19 by 1.2% (p-value <0.001). The R^2 value indicates that more than 79% of the variation in COVID-19 confirmed cases can be attributed linearly to the density of people. This relationship is illustrated in Fig. 3 that shows how Tokyo is in the top-right section characterized by high population density and a high level of COVID-19 confirmed cases similar to the second-largest Japanese city of Osaka (cf., Table 1A in supplementary file).

If we consider average confirmed cases of COVID-19 in Japanese cities having a density of population 1,000–2,000 people per km^2 and >2,000 people per km^2 from July to September 2021 (Table 2A in the supplementary information), as the sample has a small size (five cities), these two sets are analyzed with the Mann-Whitney U test: a non-parametric test that is useful for determining if the mean of two groups are different from each other.

Results in Table 3 show that we retain the null hypothesis; these two sets do not have a significant difference. Therefore, cities having a higher density of people, such as Tokyo during the period of Summer Olympics in 2021, have a similar behavior of COVID-19 confirmed cases of cities with a lower density (1,000–2,000 people per km^2). Hence, the behavior of transmission dynamics of COVID-19 in Tokyo during the Olympic game is like other larger cities in Japan and associated mainly with the density of people rather than the organization of the international event (Table 2). In short, the organization of the mega international event, such as the summer Olympics in Tokyo, has not increased COVID-19 confirmed cases that are driven mainly by the high density of people in cities.

In addition, Fig. 4 reports the weekly confirmed COVID-19 cases per million people from March 12, 2021 to October 29, 2021 in Japan and surrounding Asian countries (https://github.com/CSSEGISandData). Japan has the behavior of infections

Fig. 1 New cases of COVID-19 (per 100,000 people) in Tokyo, Osaka, and five largest prefectures of Japan in July, August, and September 2021
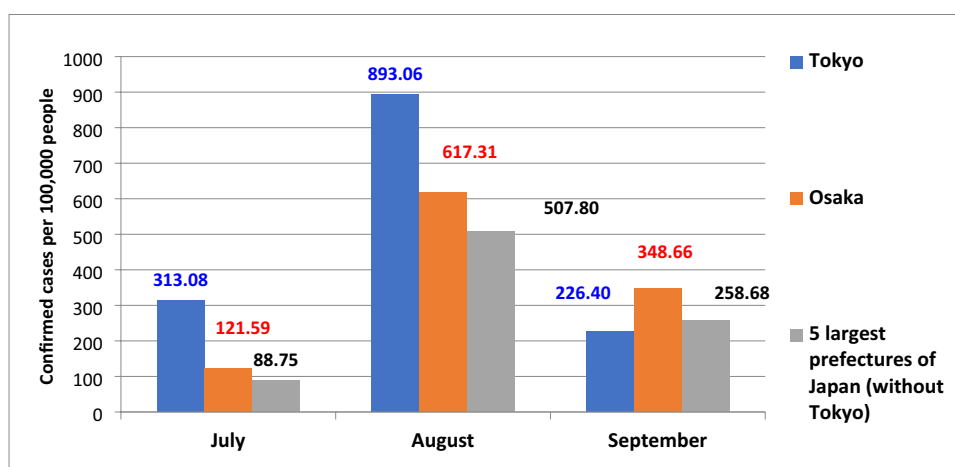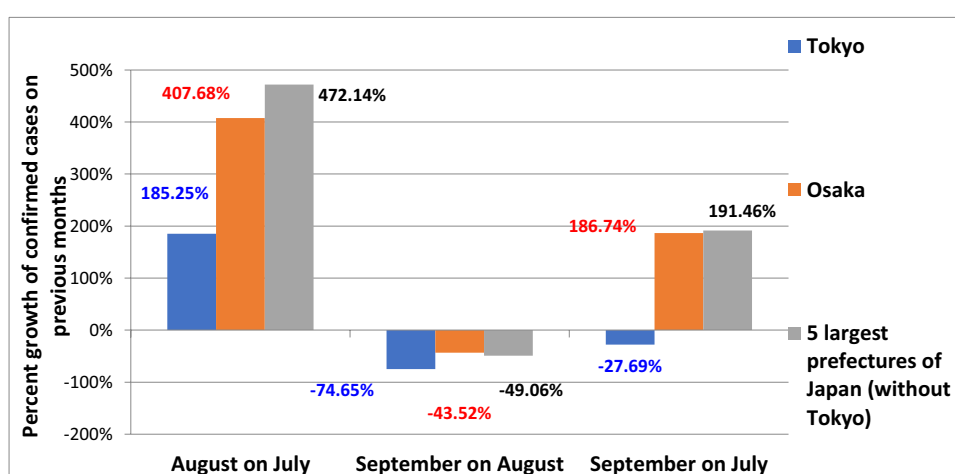

Fig. 2 Monthly growth of new COVID-19 cases in Tokyo, Osaka, and five largest prefectures of Japan over August–September 2021 period

like other Asian countries, suggesting that the diffusion of COVID-19 is also associated with the pandemic wave in Asia rather than specific factors related to Olympics. In particular, an increase of the contagious wave of COVID-19, with a corresponding maximum occurring before that of Japan, is evident for Malaysia, Indonesia, and Thailand, where the Olympics does not occur. This study also analyzed various environmental pollution and weather variables such as $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3, temperature (maximum, minimum and average value), humidity (maximum, minimum, and average value), and wind speed to understand the diffusion of COVID-19 parameters for 42 prefectures. Results suggest that these factors did not significantly impact the rise of COVID-19 cases during the Tokyo Olympics and Paralympics (see supplementary file).

Discussions

Recent Tokyo Summer Olympics and Paralympic Games have raised social issues of the potential increase of COVID-19 cases in Japan and questions about organizing mega

international events during the COVID-19 pandemic (Yashio et al. 2021; Murakami et al. 2021). In the problematic context of the COVID-19 pandemic crisis, containment policy in Tokyo was based on protocols established during the Summer Olympics, making it primarily fan-free. In addition, extra precautions and continuous testing for athletes and staff were applied (Table 4 and supplemental information).

However, at the Summer Olympics closing, Japan recorded more than 12,000 new COVID-19 infection cases, corresponding to a tripled value compared to the opening day (about 4,200 cases). This, coupled with a vaccination hesitancy in Japan (Poon 2021), alimented the idea that the Olympics also contributed to the spread of the novel coronavirus in Japan (Fig. 5).

Then, literature and newspapers developed different theories about the pandemic spread, often introducing competitive conclusions. Results here show that pandemic diffusion in Tokyo is mainly associated with its high population density within a general dynamics of the diffusion of Delta variant of SARS-CoV-2 that also invested the surrounding Asian countries, rather than other factors and the organization of this international event. This study suggests that Tokyo during

Table 2 Estimated relationships (*log-log* model) of COVID-19 detected cases as a function of the density of population in Japanese cities from July to September 2021

Dependent variables					
	COVID-19 detected cases till July 5, 2021	COVID-19 detected cases till August 9, 2021	COVID-19 detected cases from July 6 to August 9, 2021	COVID-19 detected cases till September 5, 2021	COVID-19 detected cases from August 9 to September 5, 2021
Coefficient b	1.241***	1.242***	1.262***	1.232***	1.217***
Constant a	1.493*	1.700**	-0.147	2.212***	1.273**
F-test	151.35***	171.98***	140.73***	176.07***	159.045***
R^2	0.896	0.823	0.792	0.826	0.811

Note. Explanatory variable is density of population per km². F is the ratio of the variance explained by the model to the unexplained variance; R^2 is the coefficient of determination adj.

***Significant at 1‰; **significant at 1%; *significant at 5%

Summer Olympics in 2021 has a transmission dynamics of confirmed cases like other Japanese cities with a high population density, regardless of the organization of the Summer Olympics. The containment of COVID-19 diffusion in Tokyo during the Summer Olympics can be associated with factors such as Japanese culture and accurate organization of mega-events from the arrival of athletes in the airport to sporting and extra sporting activities (see supplemental information). Hence, our statistical evidence seems, in general, to support, for the first time, that the hosting of both the Tokyo Olympics and Paralympics was not responsible for COVID surges in Japan. About 71,000 international participants joined both in the Olympics and Paralympic Game, and several safety protocols such as frequent testing schemes and bubble schemes were introduced and strictly maintained by the organizing committee. In the bubble scheme, athletes were not allowed to be in contact with general people. International participants had to go through 3 days of compulsory quarantine after arrival in Japan. Participants and officials had to take quantitative saliva antigen tests and subsequent saliva real-time polymerase chain reaction (RT-PCR) test daily during these events. All individuals were needed to wear face masks, and vaccination was also encouraged even though it was not mandatory. It was found that 80% of the total staff and participants were vaccinated during this event. No foreign visitors were allowed to travel in Japan, and a state of emergency was imposed during the event to discourage spectators from Tokyo and nearby prefectures such as Chiba, Saitama, and Kanagawa to enter the game. Many fans were allowed in several prefectures such as Miyagi, Fukushima, and Shizuoka,
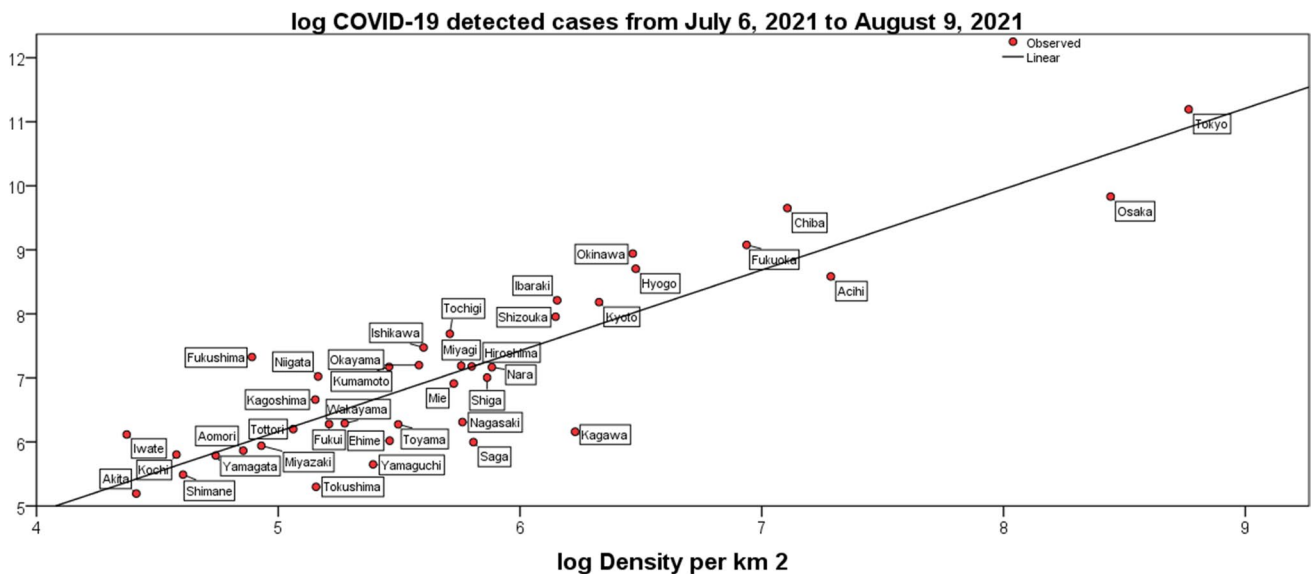

Fig. 3 Regression line of detected cases on density per km² over the period of Tokyo 2020 Summer Games from July 23, 2021 to August 8, 2021 (*log-log* model)

Table 3 Non-parametric test (independent-samples Mann-Whitney U test of COVID-19 detected cases in Japanese cities having a density of population 1,000–2,000 people per km^2 *versus* cities having >2,000 people per km^2 (Tokyo and Osaka) from July to September 2021

	Independent-samples Mann-Whitney U test summary		
	Null hypothesis: The distribution of confirmed cases is the same across categories of Japanese cities having a density of population 1,000–2,000 people per km^2 *and* cities having >2,000 people per km^2 (Tokyo and Osaka)	Sig.	Decision
1	COVID-19 detected cases till July 5	0.200[a]	Retain the null hypothesis
2	COVID-19 detected cases till August 9	0.200[a]	Retain the null hypothesis
3	COVID-19 detected cases from July 6 to August 9	0.200[a]	Retain the null hypothesis
4	COVID-19 detected cases till September 5	0.200[a]	Retain the null hypothesis
5	COVID-19 detected cases from August 9 to September 5	0.200[a]	Retain the null hypothesis

Note. Asymptotic significances are displayed. Test significance is 0.05. [a]Exact significance (2-sided test) is displayed for this test

Fig. 4 Weekly confirmed COVID-19 cases per million people from March 12 to October 29, 2021 Olympics and Paralympic period are highlighted with yellow rectangles. Maxima of the reported cases are indicated for the Japan surrounding countries that showed an increase of the detected cases curve (and maxima) before Japan (sources of data: https://github.com/CSSEGISandData).
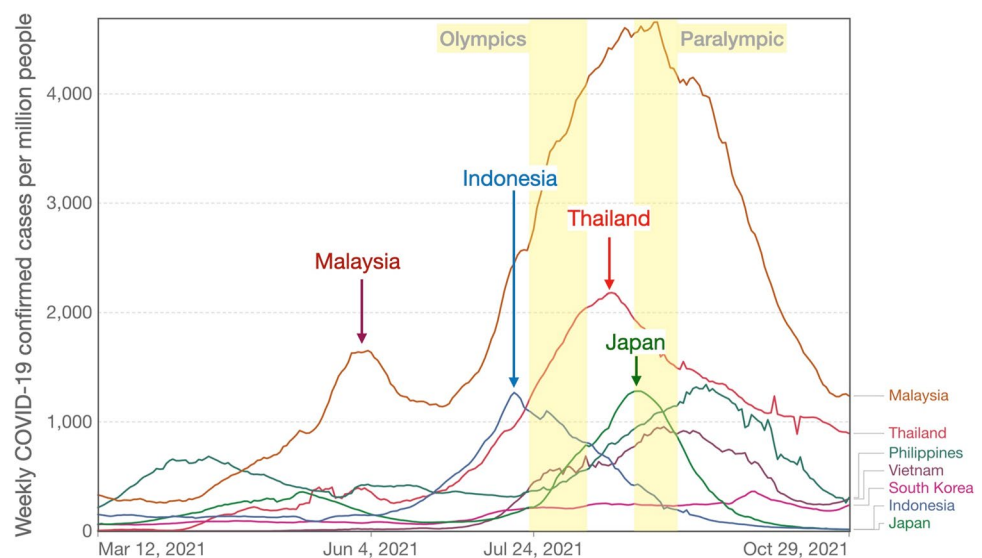
Table 4 Control measures during Tokyo Summer Olympics in 2021 (Tokyo 2020 Playbooks https://olympics.com/ioc/tokyo-2020-playbooks)

| Measures control	Persons involved	Place of measures	Activity (sporting/extra/nonsporting)
Daily temperature monitoring for 14 days	Athletes, official, press, broadcaster	Before arrival and during staying in Japan	Non-sporting
Submission of COVID negative test	Athletes, official, press, broadcaster	Before arrival	Non-sporting
Quarantine for 3 days	Athletes, official, press, broadcaster	After arrival	Sporting and non-sporting
Official Accommodation	Athletes, official, press, broadcaster	During staying in Japan	non-sporting
Using of game designated transportation	Athletes, official, press, broadcaster	On arrival, during staying in Japan	Non-sporting
PPE and hygiene	Athletes, official, press, broadcaster	Before, on arrival, and during staying in Japan	Sporting and non-sporting
Limited social interaction	Athletes, official, press, broadcaster	On arrival and during staying in Japan	Sporting and non-sporting
Daily antigen COVID test	Athletes and officials	During stay in Japan	Nonsporting
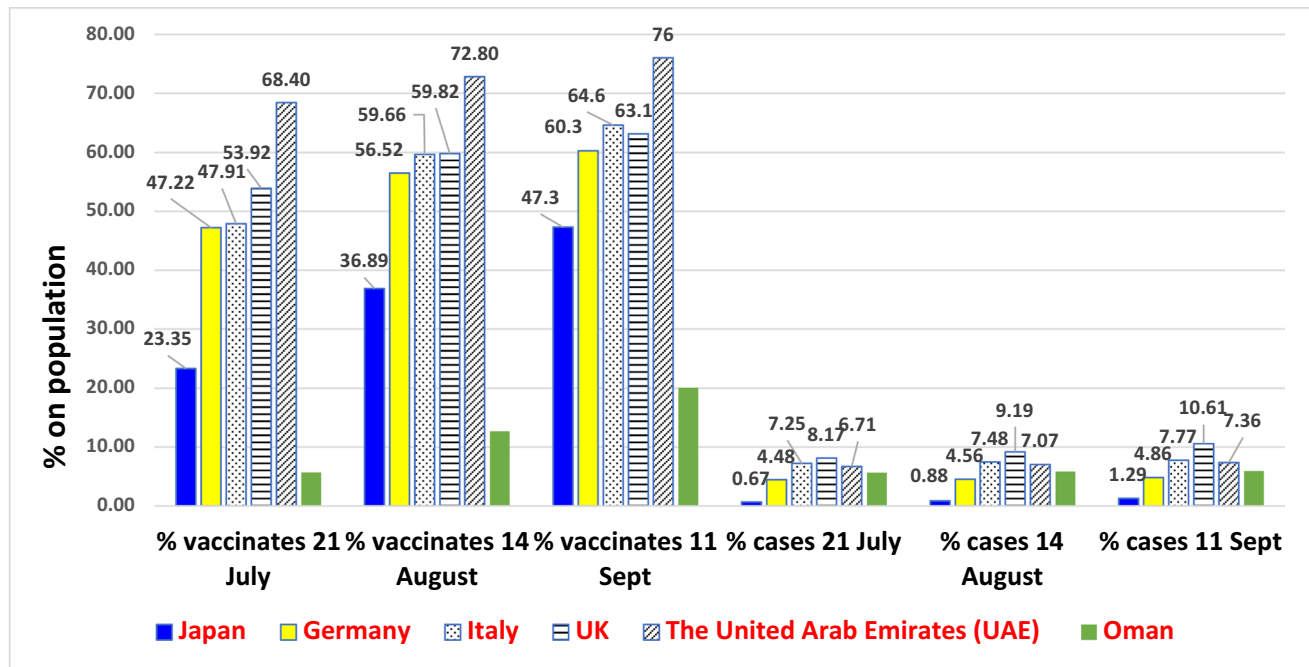
Fig. 5 Comparative analysis of people fully vaccinated against COVID-19 and confirmed cases across countries organizing sporting events (except Germany)

following appropriate social distancing and personal protective equipment (PPE). Athletes were instructed to follow the rules regarding PPE, social distancing, hygiene, catering, transportation, and accommodation in the games bubble. COVID-19-positive athletes were immediately placed in isolation and quarantine to stop the diffusion of the novel coronavirus. Both athletes, broadcasters, and press officials were also subjected to restrictions as mentioned above (Table 4 and supplemental information). The result shows the determination of Japanese authorities in performing Summer Olympics, coupled with the capacity to identify and apply the more suitable control measures to manage and stop a possible COVID-19 "super-spreading" event. In short, organizers were triumphant to prevent widespread diffusion by successfully implementing these restrictions. The success of the Tokyo Olympics suggests that with appropriate control measures, as indicated in Table 4 (and supplemental information), it is possible to organize safe international mega-events also in the presence of a pandemic threat. Then, the Summer Olympics provided a valuable case study and demonstrated that large-scale events can also be organized also in future, with a great attention to the upcoming FIFA World Cup Qatar 2022 and Beijing 2022 Winter Olympics. The model adopted by the Tokyo Olympics committee can be followed to prevent widespread transmission during next international sporting events. However, banning spectators and international travelers can pose a massive financial loss to the organizer, and this aspect raises a social and economic issue of the COVID-19 crisis that generates a

trade-off between higher safety or support of the economic activity. It is estimated that Tokyo Olympic may have lost around $800 million from ticket sales (Why banning fans at the Olympics isn't a total loss https://finance.yahoo.com/news/why-banning-fans-at-the-olympics-isnt-a-total-loss-145120586.html). In addition to control measures, a vital role is played by COVID-19 vaccines that can partially solve the problem of just mentioned trade-off and support a balance between biosafety of these international events and economic aspects. Fully vaccinated persons may be allowed following the international championship of Twenty20 cricket (ICC Men's T20 World Cup), hosted by the United Arab Emirates (UAE) and Oman during October and November 2021 (Key measures taken to ensure safe Men's T20 World Cup https://www.icc-cricket.com/news/2285200). During this event, both the host country Oman and UAE had a higher percentage of vaccinated population. The UAE had 96% of people receiving at least one dose of vaccine (COVID-19 FAQs at the T20 World Cup 10-Day Isolation for Positive Tests Fans to Wear Masks, n.d.). Allowing fully vaccinated crowds and international travelers, and maintaining proper safety guidelines will allow host countries to minimize financial and economic loss. These results conclude that the organization of large events can be obtained by also considering a suitable balance of safety and socioeconomic activities (see Fig. 6) when the organization considers some parameters (Coccia, 2021e). The suggested resilience indicator in Fig. 6 shows that large events can be organized, maintaining a balance between
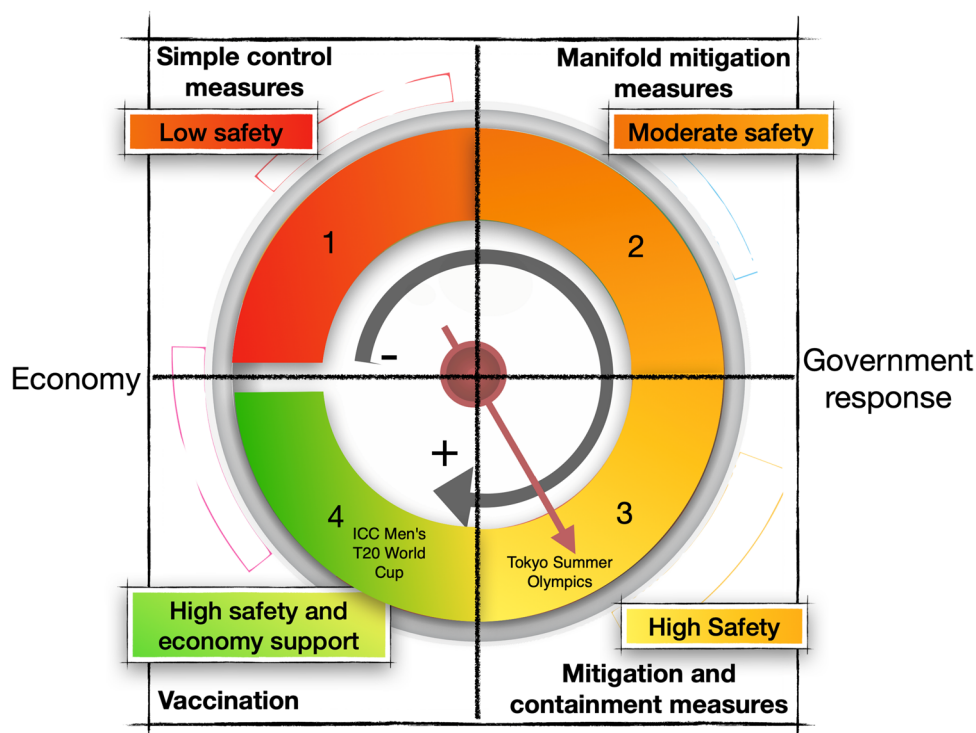
Fig. 6 Resilience scale for safe organization of mega international events during COVID-19 pandemic crisis. It is based on two dimensions (safety and economic benefits) that generate a *trade-off*: 1 is the lowest value of safety; 4 is the highest value for safety and economic benefits. In particular, 1—simple control measures, LOW SAFETY/ red section; 2—manifold mitigation measures, MODERATE SAFETY/orange section, here host city cannot organize events; 3—based on mitigation and containment measures/yellow section, HIGH SAFETY/LOW ECONOMIC RETURN, this area assures a high safety but generates low economic return from mega international events; 4—control measures associated with higher vaccination/green section HIGH SAFETY/HIGH ECONOMIC RETURN, this area can support a safe organization of mega international events with positive economic returns. Safe organization of mega international events can be organized from the level 3 onwards. For instance, Tokyo Summer Olympics has a level of about 3, whereas international championship of Twenty20 cricket (ICC Men's T20 World Cup), hosted by the United Arab Emirates (UAE) and Oman, can be placed at level 4 (able to balance safety and economic benefits).

health security and economic activity if the level is 4 (four). Hence, Qatar, host countries of next international events given by FIFA 2022 World Cup, should focus on these directions and best practices using, whenever possible, control measures for COVID_19 as indicated in Table 4 and reinforced vaccination campaign with boosters and new vaccines to achieve a level of human and economic security higher than three points as indicated in Fig. 6 also in the presence of new variants of SARS-CoV-2 (Coccia, 2022d).

Conclusions

Overall, results here show that COVID-19 confirmed cases in Japan and Tokyo are mainly associated with population density and general dynamics of pandemic waves in Asia, rather than other factors, as confirmed with new variants of SARS-CoV-2 driven by Omicron BA.5 that generates re-infections also in vaccinated people (Khandia et al., 2022). Weather parameters and environmental factors related to

air pollution did not play a significant role in spreading the COVID-19 cases during Tokyo Olympic. Regression analyses were performed using density of population as explanatory variable and COVID cases in different periods as response variable. Results reveal that high density of population was mainly responsible for the transmission of COVID-19 (about 1.2%, *p*-value <0.001). Our study provided evidence that hosting mega sporting events during this COVID-19 pandemic is safe if strictly maintained the precautions with non-pharmaceutical (and pharmaceutical) measures of control of transmission dynamics. This result is significant for the international scientific community because it can help policymakers to design satisfying goals to cope with current infectious disease with effective strategies to prevent future outbreaks of new variants of COVID-19 and similar infectious diseases in future.

Although this study has provided some interesting results that are of course tentative, it has several limitations. First, a limitation of the study is the lack and or underreport of data that may be present in the database

under study here. Second, not all the possible confounding factors are taken into consideration (such as health expenditures and contact tracing systems) and in the future, they deserve to be controlled for reinforcing results here. Third, the lack of integration of data with the age of people may have influenced the results of infected individuals and deaths. Fourth, new variants of COVID-19 may increase the diffusion and these aspects have to be considered in future development of this study. Despite these limitations, the results presented here clearly illustrate that the introduction of different safety tiers in hosting cities can also help to prevent the spread of the novel viral agent (i.e., SARS-CoV-2). These findings can better support the strategies for prevention and/or reduction of negative effects of the COVID-19 pandemic crisis in the presence of main sporting international events (Coccia, 2021c, 2021d, 2022a, 2022b). In fact, Benati and Coccia (2022) suggest the positive effects of good governance of countries in supporting the prompt implementation of policy responses to cope with pandemic impact, mitigating diffusion of new infections and reinfections, and fatality rates.

To conclude, there is a need for much more detailed research into the relations between transmission dynamics of new viral agents, sporting events, vaccinations, and other control measures to balance the trade-off between safety and economy aspects of countries especially in the presence of new variants of the novel coronavirus, such as Omicron BA.5, that change scenarios and maintain a continuous state of alert worldwide.

Author contribution TC and HC: conceptualization, data collection, interpretation of data, writing. EB and MC: writing, data analysis, method, interpretation of data, editing, proofreading, supervision. HM, SMS, TS: writing, proofreading, editing.

Data Availability The data that support the findings of this study are available from the corresponding author, Hemal Chowdhury, upon reasonable request.

Declarations

Ethics approval and consent to participate The facts and views in the manuscript are solely ours, and we are responsible for authenticity, validity, and originality. We also declare that this manuscript is our original work, and we have not copied it from anywhere else. No plagiarism is detected in this manuscript.

Consent for publication We undertake and agree that the manuscript submitted to your journal has not been published elsewhere and has not been simultaneously submitted to other journals.

Competing interests The authors declare no competing interests.

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