Preparedness for the Rio 2016 Olympic Games: hospital treatment capacity in georeferenced areas

Preparação para os Jogos Olímpicos Rio 2016: capacidade de tratamento hospitalar em áreas georreferenciadas

La preparación para los Juegos Olímpicos de Río 2016: capacidad de tratamiento hospitalario en áreas georreferenciadas

Carolina Figueiredo Freitas [1]
Claudia Garcia Serpa Osorio-de-Castro [2]
Kimberley Irene Shoaf [3]
Raulino Sabino da Silva [2]
Elaine Silva Miranda [1]

Abstract

Recently, Brazil has hosted mass events with recognized international relevance. The 2014 FIFA World Cup was held in 12 Brazilian state capitals and health sector preparedness drew on the history of other World Cups and Brazil's own experience with the 2013 FIFA Confederations Cup. The current article aims to analyze the treatment capacity of hospital facilities in georeferenced areas for sports events in the 2016 Olympic Games in the city of Rio de Janeiro, based on a model built drawing on references from the literature. Source of data were Brazilian health databases and the Rio 2016 website. Sports venues for the Olympic Games and surrounding hospitals in a 10km radius were located by geoprocessing and designated a "health area" referring to the probable inflow of persons to be treated in case of hospital referral. Six different factors were used to calculate needs for surge and one was used to calculate needs in case of disasters (20/1,000). Hospital treatment capacity is defined by the coincidence of beds and life support equipment, namely the number of cardiac monitors (electrocardiographs) and ventilators in each hospital unit. Maracanã followed by the Olympic Stadium (Engenhão) and the Sambódromo would have the highest single demand for hospitalizations (1,572, 1,200 and 600, respectively). Hospital treatment capacity proved capable of accommodating surges, but insufficient in cases of mass casualties. In mass events most treatments involve easy clinical management, it is expected that the current capacity will not have negative consequences for participants.

Mass Casualty Incidents; Delivery of Health Care; Hospitals; Geographic Locations

[1] Faculdade de Farmácia, Universidade Federal Fluminense, Niterói, Brasil.
[2] Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brasil.
[3] Department of Family and Preventive Medicine, University of Utah, Salt Lake City, U.S.A.

Correspondence
E. S. Miranda
Faculdade de Farmácia, Universidade Federal Fluminense.
Rua Dr. Mário Viana 523, Niterói, RJ 24241-000, Brasil.
elainemiranda@id.uff.br

Introduction

In Brazil, events that involve mass gatherings are held every year, and the country has recently hosted major international events. The 2014 FIFA World Cup was held in 12 Brazilian state capitals. In some World Cup host cities, operational plans were produced that included health and health surveillance preparedness [1,2,3]. Health sector preparedness drew on the history of other World Cups and Brazil's own experience with the 2013 FIFA Confederations Cup. Planning was based on the prevailing health system's structure.

Health sector preparedness measures for mass events pointed to improvement in services capacity and quality. For the 2014 FIFA World Cup, improvements were proposed in access to services, activation of deactivated hospital beds, and the construction of new Emergency Care Units to increase the installed capacity [1,2,3].

Probable causes of disease, injury, and death in major events have been reported in the literature and are generally context-related. The health threats depend on climatic factors, participants' profile, and type of event [4]. Intrinsic factors in mass gatherings further influence the health outcomes. The agglomeration of people with diverse origins and health conditions favors transmissible diseases, which become real threats [5]. The physical structure of the venues where events take place, such as problems with access routes and emergency exits and/or lack of public safety measures can also lead to incidents [6]. Health problems related to the events can also overload health services [7].

According to studies on the causes of demand for medical care and severity according to type of event, in most events the incidents are minor and do not require medical evacuation [1]. During preparedness for the 2014 FIFA World Cup, it was estimated that 1% to 2% of the public at the match venues might need some medical care, and of these, 0.2% to 0.5% would require high complexity care and consequently evacuation to a hospital facility [3].

In the international literature, studies on previous World Cups report estimates on the demand for hospital care ranging from 0.002% a 0.05%, and from 0.5% to 2% for the need of hospitalization in case of a disaster [8,9,10,11].

In addition to the equipment needed for medical evacuation, cases of hospital care require provision of basic equipment and physical infrastructure for diagnosis and treatment. Takahashi et al. [12] estimated hospital treatment capacity in different situations, based on coinciding availability of beds and essential life support equipment, such as ventilators and electrocardiographs.

The current article aims to analyze the treatment capacity of hospital facilities in georeferenced areas for sports events in the 2016 Olympic Games in the city of Rio de Janeiro, based on a model built drawing on references from the literature.

Method

Study scenario

The municipality of Rio de Janeiro is located at longitude 43º12'W and latitude 22º54'S in the Southeast region of Brazil. Arenas, parks, and stadiums were built or organized, forming complexes for the competitions, distributed in four regions determined by the event's organization: Barra da Tijuca, Maracanã, Copacabana, and Deodoro.

Geoprocessing

The study obtained the addresses of the competition venues from the official website of the Rio de Janeiro Olympic and Paralympic Games (Rio 2016; http://www.brasil2016.gov.br/pt-br/olimpiadas/instalacoes). The hospital addresses were obtained from the National Registry of Health Establishments – CNES [Cadastro Nacional de Estabelecimentos de Saúde]. Healthcare establishments pertaining to hierarchical levels 5,6,7, and 8 were selected, since these levels are classified as hospital care units. All the addresses were then geocoded to obtain the geographic coordinates (latitude and longitude), allowing the geoprocessing, performed in ArcGIS, version 10.1.1 (Environmental Systems Research Institute, Redlands, USA. http://www.esri.com/software/arcgis/index.html).

A 10-kilometer radius was drawn around each competition venue [13], illustrated with a colored circle, referring to the probable inflow of persons to be treated in case of hospital referral. This allowed identifying large areas that would concentrate health care. The hospitals were identified individually on a map, within each large area.

Model

- **Calculation of needs**

In case of an increase in the demand for medical evacuation and/or hospitalizations due to a surge, calculation of needs is based on the maximum estimate of the public in attendance at the event venues. In the current study the information on the venues' capacity was obtained from the official Rio 2016 website. Each area's maximum demand was obtained as the sum of the individual maximum capacities of the competition venues on the days or periods in which the sports contests were scheduled to take place, according to the official calendar published by the Olympic Games organization (https://www.rio2016.com/sites/default/files/users/rio2016_files/guia_ingressoport_2015_diario.pdf, accessed on 20/Mar/2016).

Six different factors were used to calculate needs. The surge categories were: 0.05/1,000, adopted in Japan for the 2002 FIFA World Cup [11]; 0.07/1,000, based on a historical series of mass gatherings in Australia [10]; 0.5/1,000, based on planning for the 2010 FIFA World Cup in South Africa [8]; and calculations based on the Brazilian Ministry of Health's report on the 2013 FIFA Confederations Cup, which pointed to several possibilities, namely 0.02/1,000, 0.04/1,000, 0.05/1,000,and 0.1/1,000, all for high complexity care and assuming that 1% to 2% of the public will need some medical care [3].

To calculate the demand for medical evacuation and/or hospitalizations due to a surge with mass casualties, the calculation was based on the maximum capacity of each competition venue, as a function of the assumption that the incident would be locally restricted, namely that it would not involve all the venues in a given area. Another possibility would be the calculation for the sum of the local capacities, according to the definition of worst-case scenario (maximum credible event). The calculation factor was that used for disasters (20/1,000), based on Yancey et al. [8].

All the hospital units belonging to a given area were included. Some hospitals adjoined more than one area, but the model did not take into account the juxtaposition of more than one coverage area per hospital unit.

- **Calculation of supply**

The hospital bed occupancy rate was calculated based on the year 2015 for the months of August and September, according to the Datasus database (for the Brazilian Unified National Health System – SUS). This rate was applied to the total supply of public and private hospital beds and provided the number of operational beds by area. Data on ventilators and electrocardiographs in each hospital unit were also obtained from the CNES database.

Hospital treatment capacity is defined by the coincidence of beds and life support equipment, namely the number of cardiac monitors (electrocardiographs) and ventilators in each hospital unit [12]. The sum by area was obtained from the results for each hospital.

Ethical considerations

The current project is nested in the *Pharmaceutical Care Preparedness Project* for mass events in Brazil (Prepare Brazil Project), approved by the Ethics Research Committee of Escola Nacional de Saúde Pública Sergio Arouca/Fundação Oswaldo Cruz (CAAE 177965.13.6.0000.5240).

Results

Figure 1 shows nine areas: red, blue, green, black, pink, orange, yellow, white, and gray. In a 10-kilometer radius around all the competition venues, a total of 338 hospital units were identified, both public and private, with and without emergency care. The majority of the hospital units are located in the green, black, yellow, white and gray areas.

Except for the red area, all the areas had hospitals that could be georeferenced to more than one event venue. The choice was made to analyze each area alone.

Table 1 shows the areas, competition venues with their maximum capacities, and number of corresponding hospitals. Note that three areas, pink, orange, and blue, have fewer hospitals. Among the areas with more than 50 units (green, black, yellow, white, and gray) the yellow area has the most hospitals.

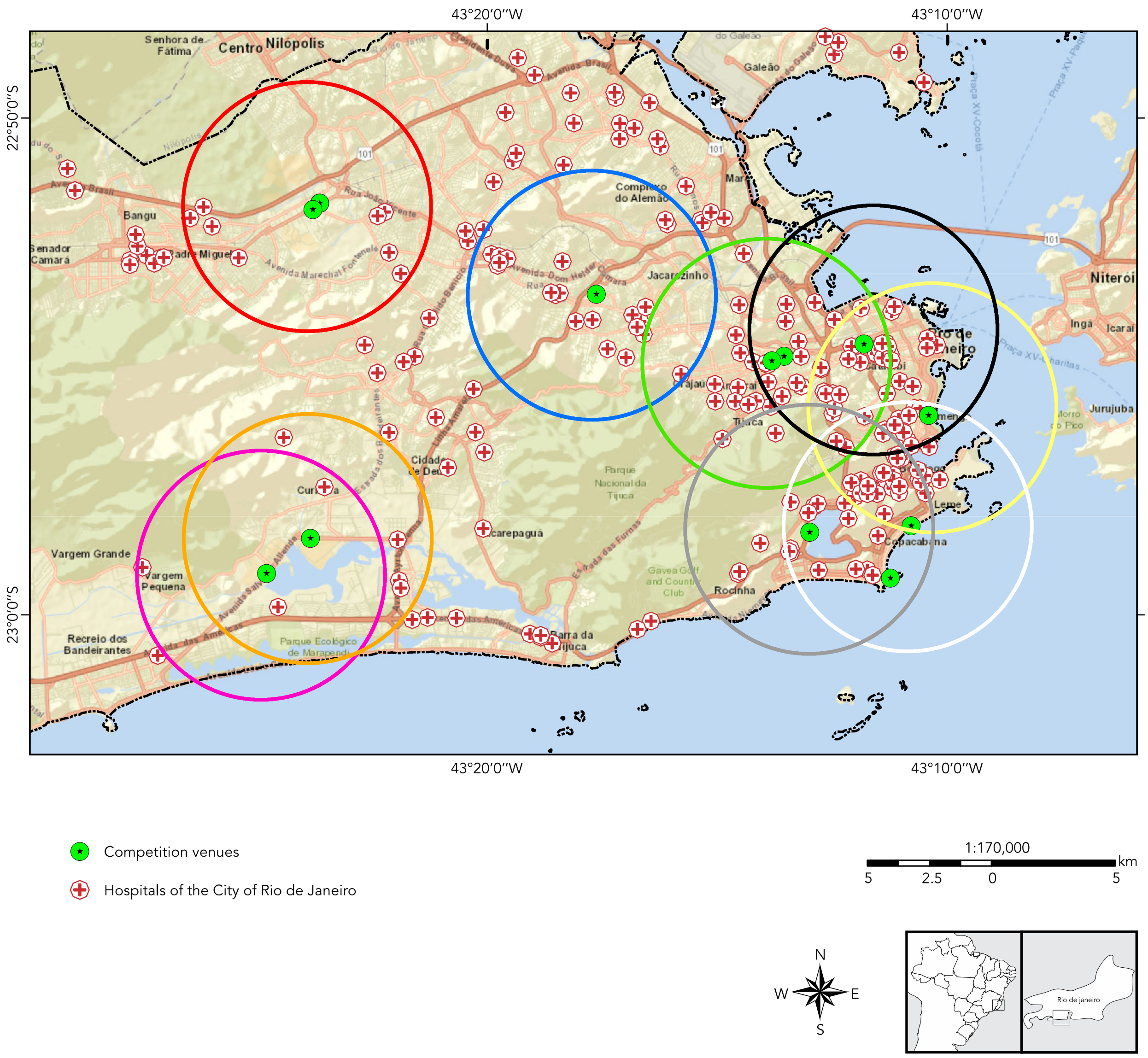
The green area has the largest population and includes Maracanã, the venue for the opening and closing ceremonies of the Olympic Games. This area's profile has the potential for an incident with mass casualties.

Table 2 shows the demand for medical evacuation and/or hospitalizations in case of surge, for each day of the Games, in relation to calculation factors identified in the literature and others defined by the Ministry of Health. Note that the blue, green, and orange areas will concentrate the largest public and thus the heaviest potential demand for hospitalizations, highlighted in gray. On August 11 and 12 the orange area will draw the largest attendance of the Games (123,300) if the capacity is reached, meaning the greatest potential for hospitalizations.

The factor proposed by Yancey et al. [8] for the 2010 FIFA World Cup in South Africa (c) assumes the highest demands, while one of the factors identified by the Brazilian Ministry of Health for high complexity treatment (d) denotes the lowest. The total demand for all the areas, for each factor, varies from 1.2 (2 hospitalizations)

Figure 1

Geoprocessed and georeferenced hospital units and competition venues for the Rio 2016 Olympic Games.



on August 3 and 4 to 162.2 (163 hospitalizations) on August 19.

Table 3 shows the numbers on the demand for hospitalizations in case of a surge (by area) and in case of mass casualties (by venue and area), plus the results for hospital treatment capacity, by area. The lowest treatment capacity is in the red area (27 patients) and the highest in the green area (194 patients).

Next, the demand was analyzed per surge and per event resulting in mass casualties, in relation to treatment capacity.

Surge

According to the factor proposed by Yancey et al. [8], the orange area, with the capacity for 44 treatments, would have a peak demand of 62 treatments. The green area would demand up

Table 1

Georeferenced areas, maximum capacity, and total hospital units in a 10-kilometer radius from the competition venues of the Rio 2016 Olympic Games.

Area	Competition venue	Maximum capacity	Hospital units
Red	Youth Arena	5,000	9
	Deodoro Stadium	15,000	
	Whitewater Stadium	8,000	
	Mountain Bike Centre	27,500	
	Olympic Equestrian Centre	35,200	
	Olympic Shooting Centre	7,577	
Blue	Olympic Stadium (Engenhão)	60,000	19
Green	Maracanã	78,600	50
	Maracanãzinho	11,800	
Black	Sambódromo	30,000	55
Pink	Riocentro - Pavilion 2	6,500	5
	Riocentro - Pavilion 3	6,500	
	Riocentro - Pavilion 4	6,500	
	Riocentro - Pavilion 6	9,000	
Orange	Rio Olympic Velodrome	5,000	7
	Carioca Arena 3	10,000	
	Rio Olympic Arena	12,000	
	Olympic Golf Course	25,000	
	Future Arena	12,000	
	Carioca Arena 2	10,000	
	Maria Lenk Aquatics Centre	5,300	
	Olympic Aquatics Stadium	18,000	
	Carioca Arena 1	16,000	
	Olympic Tennis Centre	10,000	
Yellow	Marina da Glória	10,000	76
White	Fort Copacabana	5,000	64
	Beach Volleyball Arena	12,000	
Gray	Lagoa Stadium	10,000	53

Source: Brazilian Olympic Committee (COB; http://www.cob.org.br/); National Registry of Health Establishments (CNES; http://cnes2.datasus.gov.br/Lista_Es_Nome.asp?VTipo=0).

to 46 hospitalizations, thus below its capacity (194), as would the blue area, with capacity for 86 hospitalizations and a peak demand of 30 hospitalizations.

Mass casualties

Two possibilities were considered: (i) that a harmful event would occur in only one venue alone, or (ii) simultaneous occurrences, resulting in a "maximum credible event", such that the demand would represent a maximum number of casualties, calculated as the sum of demands from each venue.

Maracanã (green area) would have the largest single demand for hospitalizations (1,572), followed by the Olympic Stadium (Engenhão) (1,200) and the Sambódromo (600). The orange area would have the largest demand (2,466), while the yellow and gray areas would have the lowest demands for hospitalizations (200).

In case of hospitalizations of mass casualties, none of the areas would have sufficient treatment capacity. In addition to the orange area; both the red and green areas would have a high demand (1,966 and 1,808, respectively). All the areas show deficits in treatment capacity for mass casualties.

Table 2

Demand for medical evacuation and/or hospitalizations per surge, by day and by area, during the Rio 2016 Olympic Game

Area	Surge	Days of August																		
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Maximum attendance/ day *		0.0	0.0	0.0	62.8	70.8	70.8	70.8	70.8	70.8	47.8	47.8	47.8	40.2	40.2	40.2	55.2	55.2	47.5	32.5
Red	a	0.0	0.0	0.0	3.1	3.5	3.5	3.5	3.5	3.5	2.4	2.4	2.4	2.0	2.0	2.0	2.8	2.8	2.4	1.6
	b	0.0	0.0	0.0	4.4	5.0	5.0	5.0	5.0	5.0	3.3	3.3	3.3	2.8	2.8	2.8	3.9	3.9	3.3	2.3
	c	0.0	0.0	0.0	31.4	35.4	35.4	35.4	35.4	35.4	23.9	23.9	23.9	20.1	20.1	20.1	27.6	27.6	23.8	16.3
	d	0.0	0.0	0.0	1.3	1.4	1.4	1.4	1.4	1.4	1.0	1.0	1.0	0.8	0.8	0.8	1.1	1.1	1.0	0.7
	e	0.0	0.0	0.0	2.5	2.8	2.8	2.8	2.8	2.8	1.9	1.9	1.9	1.6	1.6	1.6	2.2	2.2	1.9	1.3
	f	0.0	0.0	0.0	6.3	7.1	7.1	7.1	7.1	7.1	4.8	4.8	4.8	4.0	4.0	4.0	5.5	5.5	4.8	3.3
Maximum attendance/ day *		60.0	60.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	0.0
Blue	a	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0
	b	4.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.0
	c	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0
	d	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	0.0
	e	2.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	0.0
	f	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0
Maximum attendance/ day *		0.0	0.0	78.6	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	90.4	90.4	11.8	90.4	90.4	90.4
Green	a	0.0	0.0	3.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	4.5	4.5	0.6	4.5	4.5	4.5
	b	0.0	0.0	5.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	6.3	6.3	0.8	6.3	6.3	6.3
	c	0.0	0.0	39.3	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	45.2	45.2	5.9	45.2	45.2	45.2
	d	0.0	0.0	1.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.8	1.8	0.2	1.8	1.8	1.8
	e	0.0	0.0	3.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.6	3.6	0.5	3.6	3.6	3.6
	f	0.0	0.0	7.9	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	9.0	9.0	1.2	9.0	9.0	9.0
Maximum attendance/ day *		0.0	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black	a	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	c	0.0	0.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	d	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	e	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	f	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum attendance/ day *		0.0	0.0	0.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	15.5	15.5	15.5	9.0
Pink	a	0.0	0.0	0.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.8	0.8	0.8	0.5
	b	0.0	0.0	0.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.1	1.1	1.1	0.6
	c	0.0	0.0	0.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	7.8	7.8	7.8	4.5
	d	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2
	e	0.0	0.0	0.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6	0.6	0.4
	f	0.0	0.0	0.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.6	1.6	1.6	0.9
Maximum attendance/ day *		0.0	0.0	0.0	93.3	93.3	93.3	93.3	93.3	118.0	123.3	95.3	105.3	60.3	60.3	78.3	78.3	93.3	93.3	50.0

(continues)

Table 2 (continued)

Area	Surge	Days of August																		
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Orange	a	0.0	0.0	0.0	4.7	4.7	4.7	4.7	4.7	5.9	6.2	4.8	5.3	3.0	3.0	3.9	3.9	4.7	4.7	2.5
	b	0.0	0.0	0.0	6.5	6.5	6.5	6.5	6.5	8.3	8.6	6.7	7.4	4.2	4.2	5.5	5.5	6.5	6.5	3.5
	c	0.0	0.0	0.0	46.7	46.7	46.7	46.7	46.7	59.0	61.7	47.7	52.7	30.2	30.2	39.2	39.2	46.7	46.7	25.0
	d	0.0	0.0	0.0	1.9	1.9	1.9	1.9	1.9	2.4	2.5	1.9	2.1	1.2	1.2	1.6	1.6	1.9	1.9	1.0
	e	0.0	0.0	0.0	3.7	3.7	3.7	3.7	3.7	4.7	4.9	3.8	4.2	2.4	2.4	3.1	3.1	3.7	3.7	2.0
	f	0.0	0.0	0.0	9.3	9.3	9.3	9.3	9.3	11.8	12.3	9.5	10.5	6.0	6.0	7.8	7.8	9.3	9.3	5.0
Maximum attendance/ day *		0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
Yellow	a	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0
	b	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0
	c	0.0	0.0	0.0	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0
	d	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
	e	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0
	f	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Maximum attendance/ day *		0.0	0.0	0.0	17.0	17.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	17.0	17.0	12.0	17.0	0.0	5.0	0.0
White	a	0.0	0.0	0.0	0.9	0.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.9	0.9	0.6	0.9	0.0	0.3	0.0
	b	0.0	0.0	0.0	1.2	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.2	1.2	0.8	1.2	0.0	0.4	0.0
	c	0.0	0.0	0.0	8.5	8.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	8.5	8.5	6.0	8.5	0.0	2.5	0.0
	d	0.0	0.0	0.0	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.0	0.1	0.0
	e	0.0	0.0	0.0	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.5	0.7	0.0	0.2	0.0
	f	0.0	0.0	0.0	1.7	1.7	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.7	1.7	1.2	1.7	0.0	0.5	0.0
Maximum attendance/ day *		0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0
Grey	a	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.0
	b	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.0
	c	0.0	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0	5.0	5.0	5.0	5.0	5.0	5.0	0.0
	d	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.0
	e	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.0
	f	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0

Surge: (a) 0.05/1,000 [Japan – 2002 FIFA World Cup (Morimura et al. [11]) and Brazil – Planning of 2014 FIFA World Cup [3]]; (b) 0.07/1,000 [Australia – Historical Series of Mass Events (Zeitz et al. [10]]; (c) 0.5/1,000 [South Africa – 2010 FIFA World Cup (Yancey et al. [8]]; (d) 0.02/1,000 [Brazil – Planning of 2013 FIFA Confederations Cup [3]]; (e) 0.04/1,000 [Brazil – Planning of 2013 FIFA Confederations Cup [3]]; (f) 0,1/1,000 [Brazil – Planning of 2013 FIFA Confederations Cup[3]]. Note: the boxes in gray highlight the days with the highest demand for hospitalizations, considering all the calculation factors.
* Maximum attendance/day x 1,000.

Discussion

Geographic Information System (GIS), or geoprocessing, is a useful tool for planning health actions and services, since it allows visualizing the current situation and proposing the reallocation of human and structural resources. GIS is widely used in developed countries and also increasingly in less developed countries [14].

The current study proposed a model to identify the hospital treatment capacity in georeferenced areas for Olympic Games venues in Rio de Janeiro. The model predicts the maximum capacity and demand for health services given the competitions' attendance and also in cases of mass casualties. Considering the demand for hospitalizations (surge), the results point to insufficient capacity in two areas (red and orange) and surplus capacity in the other areas.

However, the hospital capacity proved short of necessary when considering the demand for hospitalization of mass casualties, whether

Table 3

Demand for medical evacuation and/or hospitalizations of mass casualties, by area, during the Rio 2016 Olympic Games.

Area	Venues	Maximum capacity	Maximum number of hospitalizations per surge *	Hospitalizations of mass casualties **	Maximum credible event	Hospital treatment capacity ***
Red	Youth Arena	5,000	36	100	1,966	27
	Deodoro Stadium	15,000		300		
	Whitewater Stadium	8,000		160		
	Mountain Bike Centre	27,500		550		
	Olympic Equestrian Centre	35,200		704		
	Olympic Shooting Centre	7,577		152		
Blue	Olympic Stadium (Engenhão)	60,000	30	1,200	1,200	86
Green	Maracanãzinho	11,800	46	236	1,808	194
	Maracanã	78,600		1,572		
Black	Sambódromo	30,000	15	600	600	176
Pink	Riocentro - Pavilion 2	6,500	11	130	570	31
	Riocentro - Pavilion 3	6,500		130		
	Riocentro - Pavilion 4	6,500		130		
	Riocentro - Pavilion 6	9,000		180		
Orange	Rio Olympic Velodrome	5,000	62	100	2,466	44
	Carioca Arena 3	10,000		200		
	Rio Olympic Arena	12,000		240		
	Olympic Golf Course	25,000		500		
	Future Arena	12,000		240		
	Carioca Arena 2	10,000		200		
	Maria Lenk Aquatics Centre	5,300		106		
	Olympic Aquatics Stadium	18,000		360		
	Carioca Arena 1	16,000		320		
	Olympic Tennis Centre	10,000		200		
Yellow	Marina da Glória	10,000	5	200	200	186
White	Fort Copacabana	5,000	9	100	340	182
	Beach Volleyball Arena	12,000		240		
Gray	Lagoa Stadium	10,000	5	200	200	156

* 0.5/1,000 (Yancey et al. [8]);
** 20/1,000 (Yancey et al. [8]);
*** Takahashi et al. [12].

limited to a single venue, or more acutely in the occurrence of simultaneous events that could increase the number of casualties exponentially (maximum credible event).

Mapping the competition venues and hospitals located within a 10-kilometer radius of these locations revealed unequal distribution of resources, since in places with large gatherings, the treatment supply might not meet the estimated demand.

The distance travelled to an emergency health service can be a determining factor in increasing patients' risk of death. According to a study in the United Kingdom, every 10km added to this distance was associated with a 1% increase in absolute mortality [15]. According to another study, in Chicago (USA), this distance between the event and treatment facilities was even smaller, 5 kilometers, for evacuating patients with gunshot wounds to a specialized trauma center [13].

To minimize or mitigate the health problems resulting from the increase in distances travelled, logistics solutions are important for defining preferred routes in order to optimize prehospital treatment or even the victim's evacuation to a hospital unit. For the Rio 2016 Olympic Games, the hospital treatment capacity in case of a surge could be planned to serve areas with deficient capacity, and establishing logistics solutions would suffice. The proposed solutions should consider redistribution of staff and resources and/or transportation of patients.

Assessment of the best route begins with the dispatch call for treatment, since reaching the venue where the incident took place requires defining the best, quickest, and safest route [16]. In addition to GIS, which allow visualizing the resources and routes, the combination of these programs with vehicle routing and programming systems gave rise to so-called Decision Support Systems (DSS) [17], computerized platforms that provide users with more mathematical and graphic resources and better integration. Large-scale use via the internet allows proposing real and online mobility situations, lending greater precision to vehicle localization and predicted arrival times [17]. The Brazilian Ministry of Health issued a ruling on the availability of financial resources for emergency medical resources for the Rio 2016 Olympic and Paralympic Games [18]. However, no information was identified on planning of routes for transporting possible patients or mass casualties.

Many urban works have been ongoing in Rio de Janeiro in preparation for the Olympic Games, the so-called "Olympic legacy". New developments include expressways, tunnels and mass transportation options (Bus Rapid Transit – BRT and Rio de Janeiro Light Rail – VLT), and temporary strategies such as preferential one-way traffic aisles in many of the city's thoroughfares. In spite of this Rio de Janeiro suffers from permanent difficulties in urban mobility that may present a burden during the Games. This is due to two main reasons. First is the city's peculiar geography – a sequence of narrow bits of land pressed in between mountains and the sea. Second is the preference for individual means of transportation, historically favored by city planners. Not surprisingly, Rio de Janeiro is esteemed to have the third worse traffic in the world, after Istanbul (Turkey) and Mexico City (Mexico) [19]. As a way to mitigate the pressure of intense traffic during the Games, the City has declared three holidays spaced on event-peak days and has postponed school holidays for the month of August. Nevertheless, the superior surge in traffic may well be over the expected limits. Moreover, certain areas of the city which already suffer from daily congested traffic, such as Maracanã and Barra da Tijuca, will concentrate sports events and will bear a bigger burden. Mobility in these areas, especially in case of emergency medical services, may pose a challenge.

The model estimated the hospital treatment capacity by area, for each sports day independently. It also applied the heaviest demand among all the factors identified in the literature [8] as the most appropriate for the Brazilian context, among other estimates of the kind in the literature [9,10,11] and because it refers to the demand for general hospital treatment rather than high-complexity treatment, as referred by the Ministry of Health [3].

In addition, as known, the treatment demand normally results from medical problems involving easy clinical management [5]. However, the Olympics will last consecutive 19 days. Thus, even if the hospital treatment capacity is sufficient for surge in the majority of the areas, with or without patient transit, the possibility exists that the same patient will remain hospitalized for more than one day, depending on the severity of the medical problem. Length of hospital stay will have an impact on treatment availability on the subsequent days, so the apparent surplus capacity in most of the areas may not be confirmed in practice.

In Brazil, data on events in 2013 like the FIFA Confederations Cup and World Youth Day were used to estimate the possible treatment demand [20]. Importantly, however, these data are not from the same types of events or with the same scope. In the 2014 FIFA World Cup website, preparedness only addressed health problems related to preexisting or age-related diseases, assuming that the public would mainly consist of healthy individuals 25 to 49 years of age who would not require specialized health care [3]. Notwithstanding this characterization of the World Cup spectators, the calculation failed to consider the possibility of a disaster or the need for large-scale treatment.

Preparation for the London 2012 Olympic Games analyzed a series of surge risks, highlighting the possibilities of environmental risks such as extreme temperatures, food poisoning, and infectious diseases. Any of these risks could entail mass casualties. An additional possibility that would involve mass casualties is terrorism [21,22,23].

In the current study, application of the factor proposed by Yancey et al. [8] revealed an important deficit in hospital treatment capacity for dealing with mass casualties (deficit 8,268). In such cases, a palliative solution would be to rely on strategies for evacuating patients to hospital facilities outside the areas adjoining the competition venues. The U.S. National Disaster Medical System (NDMS) was developed to provide emergency expansion in capacity in an area with casualties, including the availability of transport for patients that require transfer to hospital facilities farther removed from the disaster scene, thereby relieving the hospitals closer to the event. Another possibility offered by the NDMS is medical evacuation to field hospitals for clinical and surgical treatment.

Brazil has used field hospitals in disasters and public health emergencies [14], equipped by the Armed Forces. Field hospitals are mobile and flexible to need. They can be employed to service outpatient clinics and/or supply inpatient care (usually up to 50 beds) and are built in modules for greater adaptability [24]. In cases when demand exceeds local response capacity, the National Health Force will provide support in three response levels, in terms of personnel, equipment and deployment of field hospitals, according to the severity of the health emergency or disaster [25]. Although there is a pledge for this support, information is lacking as to number of available field facilities to attend to a determined number of victims during the Games.

Since the 2014 World Cup was a mass event, the strategy deployed by the Ministry of Health was to designate four referral hospitals in the city of Rio de Janeiro. It is possible that these same hospitals (Albert Schweitzer State Hospital, Souza Aguiar Municipal Hospital, Miguel Couto Municipal Hospital, and Pedro II Municipal Hospital) [26] will be maintained as references for the Rio 2016 Olympic Games. Three of these hospitals are situated inside the georeferenced areas. The Pedro II Municipal Hospital is located approximately 32 kilometers from the closest competition venue, far from the majority of the events, and has treatment capacity for 20 patients (CNES; http://cnes2.datasus.gov.br/Lista_Es_Nome.asp?VTipo=0). At least two facilities have already been recognized as referral hospitals. In May 2016 the Rio de Janeiro Municipal Health Secretariat announced investments to be directed to health services for the Games. In Souza Aguiar Municipal Hospital (in downtown Rio de Janeiro), 40 ICU beds will be made available and Miguel Couto Municipal Hospital (in the southern part of the city) will be provided with a new trauma center and three isolation beds. Moreover, patient transportation may be eased by 146 ambulances donated by the Brazilian Federal Government [27]. However, the link between actual needs and these palliative measures remains unclear.

The relationship between the number of hospitals and the treatment capacity denotes the extreme situation under which the hospitals operate in the city of Rio de Janeiro. The lack of preparedness related to patient examination and treatment areas, isolation, and quarantine was already reported by Shoaf et al. [28] in relation to the host cities for the 2014 FIFA World Cup. The current study's data corroborate this information. An analysis of the hospital units corresponding to the competition venues shows insufficient hospital treatment capacity in case of a maximum credible event. Given the potential risks in mass events, the situation becomes even more critical considering the lack of plans for expanding the treatment capacity or hospital beds. We call special attention to the risk posed by the recent Zika virus epidemic in Brazil [29]. Although acute manifestations of Zika virus infection are uncommon [29], there is little evidence on the effects in populations without previous immunity, as may be the case of many visitors. Visitors exposed to this virus and other infectious agents such as influenza A (H1N1) may present acute symptoms while still within the August 2016 Olympic Games calendar.

Most of the areas demarcated by a 10-kilometer radius contain some common hospital units. An important limitation to the model proposed in the current study is the impossibility of predicting the circulation of patients and equipment between hospitals, which could mitigate the low hospital treatment capacity. Another limitation is the lack of a time parameter in the integration model that resulted in the estimated hospital treatment capacity. This means that both for surges and mass casualties, it is not possible to estimate the time each patient will use the hospital equipment.

The estimate defined maximum credible event as harmful occurrences, in all areas, at the same time. In case of events executed to reach the larger possible number of persons, like terrorist attacks, the areas could be hit simultaneously. When dealing with preparedness for disasters, the worst-cases scenario should be considered by the event's organization [5].

The study used data from the CNES and Datasus databases for 2015 to estimate the situation in the Olympic Games timeframe. These systems are fed by the hospitals, and the information may vary from one year to the next. Since the Olympic and Paralympic Games will take place in August 2016, there may be structural and physical changes by then that alter the hospital treatment capacity.

Two major happenings have added to the challenges faced by Rio de Janeiro as host city to the Olympic Games. Both occurrences may compromise the city's response capacity to health emergencies and disasters that may ensue from mass gatherings. Since late 2015 the State of Rio de Janeiro has been suffering from a health services crisis, with temporary closure of emergency rooms, strikes by health workers and reduction in treatment capacity. Less than two months before the Olympics, the State has declared a "state of emergency" due to insolvency and debt [30]. With this declaration the State can adopt strict measures to curb spending and reallocate funding. Even if the Municipality has more abundant resources, the State's difficult financial situation has prompted the Municipality to absorb the upkeep of several State health facilities located in the city of Rio de Janeiro, undermining surplus resources that could be directed elsewhere.

Conclusion

Based on an empirical model drawing on the literature and fed with data on the crowd capacity of the competition venues, georeferencing the hospitals and competition venues, the Olympic Games calendar, and the available hospital infrastructure, the hospital treatment capacity was calculated in relation to the possible demand during the 2016 Olympic Games in Rio de Janeiro.

Although the proposed model has some limitations involving the difficulty in predicting the response dynamics, we believe that the model will be useful in hospital treatment preparedness for mass events. As the basis for calculation, this model uses readily accessible information that can be applied to orient preparedness both for surges and disasters.

For the Rio 2016 Olympic Games, the hospital treatment capacity proved capable of accommodating surges, but insufficient in cases involving mass casualties. Based on the principle proposed in the literature, that in mass events most treatments involve easy clinical management and can be resolved at the event venue itself, it is expected that the current capacity will not have negative consequences for participants.

Measures of preparedness for the sports events involving the Municipality's health sector have taken place. Although recognizing this fact, the State's overflowing economic crisis and emerging disease threats may pose a great challenge for Rio de Janeiro as a host city for the 2016 Olympic Games, in light of the demands for response in case of health emergencies.

Contributors

C. F. Freitas contributed to the data collection and analysis and writting of the paper. C. G. S. Osorio-de-Castro and E. S. Miranda contributed to the study design, methodological development, data analysis, and writing and review of the paper. K. I. Shoaf contributed to the methodological development, data analysis, and review of the paper. R. S. Silva contributed to the data collection and analysis and review of the paper.

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Resumo

Recentemente, o Brasil sediou eventos de massa com relevância internacional reconhecida. A Copa do Mundo FIFA de 2014 foi realizada em 12 capitais estaduais e a preparação do setor da saúde contou com a história de outras Copas do Mundo e com a própria experiência do Brasil com a Copa das Confederações FIFA de 2013. O presente artigo objetivou analisar a capacidade de tratamento de instalações hospitalares em áreas georeferenciadas para eventos esportivos, nos Jogos Olímpicos de 2016, na cidade do Rio de Janeiro, com base em um modelo construído a partir da literatura. Os dados foram coletados nas bases de dados de saúde do Brasil e da página de Internet da Rio 2016. As instalações esportivas para os Jogos Olímpicos e os hospitais circundantes em um raio de 10km foram localizados por geoprocessamento; foi designada uma "área de saúde", referindo-se ao afluxo provável de pessoas a serem tratadas em caso de necessidade hospitalar. Seis fatores foram utilizados para calcular necessidades para surtos e um fator de cálculo foi usado para as desastres (20/1.000). Capacidade de tratamento hospitalar é definida pela coincidência de leitos e equipamentos de suporte de vida, ou seja, o número de monitores cardíacos (eletrocardiógrafos) e respiradores em cada unidade hospitalar. O Maracanã, seguido do Estádio Olímpico (Engenhão) e o Sambódromo, teria a maior demanda para internações (1.572, 1.200 e 600, respectivamente). A capacidade de tratamento hospitalar mostrou-se capaz de acomodar surtos, mas insuficiente em casos de vítimas em massa. Em eventos de massa, a maioria dos tratamentos envolve uma fácil gestão clínica. Espera-se que a capacidade atual não terá consequências negativas para os participantes.

Incidentes com Feridos em Massa; Assistência à Saúde; Hospitais; Localizações Geográficas

Resumen

URecientemente, Brasil fue sede de eventos de masa con relevancia internacional reconocida. La Copa Mundial de la FIFA 2014 se llevó a cabo en 12 capitales de los estados y la preparación del sector de la salud tenía la historia de otras copas mundiales y con la experiencia de Brasil en la Copa Confederaciones de la FIFA 2013. Este artículo tiene como objetivo analizar la capacidad de tratamiento de las instalaciones hospitalarias en zonas georreferenciados para los eventos deportivos, en los Juegos Olímpicos de 2016, en la ciudad de Río de Janeiro, basado en un modelo construido a partir de la literatura. Los datos fueron recogidos en las bases de datos de salud en Brasil y en el sitio web del Río 2016. Las instalaciones deportivas para los Juegos Olímpicos y los hospitales circundantes dentro de un radio de 10km fueron localizados por el geoprocesamiento; un "área de la salud" fue designado, en referencia a la posible afluencia de personas que van a tratarse en el caso de una emergencia hospitalaria. Seis factores se utilizaron para calcular las necesidades a los brotes y un factor de cálculo se utilizó para los desastres (20/1.000). Capacidad de tratamiento hospitalario se define por la coincidencia de camas y equipos de soporte vital, o el número de monitores cardíacos (electrocardiógrafos) y respiradores en cada hospital. El Maracanã, seguido por el Estadio Olímpico (Engenhão) y el Sambódromo, tendría la mayor demanda de hospitalizaciones (1.572, 1.200 y 600, respectivamente). La capacidad de tratamiento hospitalario ha demostrado ser capaz de adaptarse a los brotes, pero insuficiente en casos de víctimas en masa. En los eventos masivos, la mayoría de los tratamientos implican un manejo clínico fácil. Se espera que la capacidad actual no tendrá consecuencias negativas para los participantes.

Incidentes con Víctimas en Masa; Prestación de Atención de Salud; Hospitales; Ubicaciones Geográficas

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