



ORIGINAL ARTICLES

Global Public Health Implications of a Mass Gathering in Mecca, Saudi Arabia During the Midst of an Influenza Pandemic

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Background. Every year millions of pilgrims from around the world gather under extremely crowded conditions in Mecca, Saudi Arabia to perform the Hajj. In 2009, the Hajj coincided with influenza season during the midst of an influenza A (H1N1) pandemic. After the Hajj, resource-limited countries with large numbers of traveling pilgrims could be vulnerable, given their limited ability to purchase H1N1 vaccine and capacity to respond to a possible wave of H1N1 introduced via returning pilgrims.

Methods. We studied the worldwide migration of pilgrims traveling to Mecca to perform the Hajj in 2008 using data from the Saudi Ministry of Health and international air traffic departing Saudi Arabia after the 2008 Hajj using worldwide airline ticket sales data. We used gross national income (GNI) per capita as a surrogate marker of a country's ability to mobilize an effective response to H1N1.

Results. In 2008, 2.5 million pilgrims from 140 countries performed the Hajj. Pilgrims (1.7 million) were of international (non-Saudi) origin, of which 91.0% traveled to Saudi Arabia via commercial flights. International pilgrims (11.3%) originated from low-income countries, with the greatest numbers traveling from Bangladesh (50,419), Afghanistan (32,621), and Yemen (28,018).

Conclusions. Nearly 200,000 pilgrims that performed the Hajj in 2008 originated from the world's most resource-limited countries, where access to H1N1 vaccine and capacity to detect and respond to H1N1 in returning pilgrims are extremely limited. International efforts may be needed to assist resource-limited countries that are vulnerable to the impact of H1N1 during the 2009 to 2010 influenza season.

The Muslim ritual of pilgrimage to Mecca, known as the Hajj, has been occurring every year for more than 14 centuries and is an obligation of all

Muslims who are physically able to perform at least once in their lifetime.¹ In June 2009, the host nation of Saudi Arabia, in partnership with national and international public health agencies such as the World Health Organization (WHO), the US Centers for Disease Control and Prevention, and the European Centre for Disease Prevention and Control convened a special meeting to consider the most effective measures available to mitigate the impact of pandemic influenza

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A (H1N1) on the health and well being of pilgrims performing the Hajj as well as the countries from which they originate.² The potential for importation of H1N1 into Mecca during the 2009 Hajj was deemed considerable given that (1) most of the world's Muslims reside in the Northern hemisphere, which would be in the midst of influenza season at the onset of the 2009 Hajj and (2) because a significant proportion of traveling pilgrims was expected to originate from resource-limited countries that would not have access to H1N1 vaccine prior to the onset of the Hajj. Furthermore, this mass gathering of millions, which occurs under extremely crowded conditions, is known to be conducive to the in situ spread of respiratory-borne infectious diseases such as influenza.^{3–12} If pilgrims were to become exposed and infected with H1N1 during the Hajj, then they could potentially transport it back to their home countries. The possibility of a wave of H1N1 in pilgrims returning to the world's most resource-limited countries was of particular concern because such countries would lack the resources needed to detect and mobilize an effective public health response to H1N1. Furthermore, because resource-limited countries do not have highly developed airline transportation networks, they have been among the last places on earth to receive imported cases of H1N1.¹³ This is significant because H1N1 epidemics in many resource-limited countries outside of the Americas are considerably less evolved than in their industrialized-world counterparts, and hence they could potentially become overwhelmed by a sudden influx of imported H1N1 in returning pilgrims.

Under ideal circumstances, pilgrims performing the 2009 Hajj would have been vaccinated against H1N1 with sufficient time to develop protective immunity before embarking upon their pilgrimage.^{14,15} However, intrinsic delays in the vaccine manufacturing process resulted in an extremely limited supply of H1N1 vaccine at the onset of the 2009 Hajj in late November. Consequently, only a handful of economically prosperous countries were able to vaccinate their pilgrims with sufficient lead-time for them to develop protective immunity before starting the Hajj.^{16,17} The WHO has strongly encouraged wealthier countries with pre-ordered contracts for H1N1 vaccine to share a portion of their stock with the developing world, particularly now that one dose appears sufficient to produce an effective immune response under most circumstances.^{14,15} At the time of writing, nine countries including Australia, Brazil, France, Italy, New Zealand, Norway, Switzerland, the UK, and the USA have pledged to do so.¹⁸ Understanding the mass gathering and dispersion of millions of people from nearly every country in the world during the 2008 Hajj could provide important insights into which populations may be most imminently vulnerable to the effects of H1N1 during the 2009 to 2010 influenza season, and hence how limited supplies of internationally donated H1N1 vaccine could best be utilized to maximize public health benefits.

Methods

We analyzed data from the Saudi Ministry of Health on all domestic (ie, Saudi) and international (ie, non-Saudi) pilgrims that performed the Hajj in 2008. Data on international pilgrims were analyzed to identify their country of origin, mode of travel to Saudi Arabia, and point of entry into the Kingdom. We used data from the World Bank¹⁹ to determine the 2008 gross national income (GNI) per capita of countries using the Atlas method,²⁰ and categorized them as low, lower middle, upper middle, or high income. We assumed that GNI per capita was reflective of a country's ability to purchase H1N1 vaccine and mobilize an effective public health response to H1N1. We used WHO definitions to categorize countries into world regions.²¹

As the vast majority of international pilgrims performing the Hajj in 2008 traveled to Saudi Arabia via commercial flights, we performed analyses of air-traffic data at King Abdulaziz International Airport in Jeddah (referred to hereafter as Jeddah IAP) and Prince Mohammad Bin Abdulaziz International Airport in Medina (referred to hereafter as Medina IAP). Jeddah IAP, which has a new standalone terminal dedicated specifically for pilgrims performing the Hajj, is the leading point of entry for pilgrims traveling by air, whereas Medina IAP operates as an important secondary point of entry.

We first performed an analysis of the monthly flows of commercial air traffic, measured as international passenger arrivals plus departures, at Jeddah IAP between January 2000 and October 2007 to identify important seasonal and annual trends. Data after October 2007 were not available at the time of our analysis. These data were obtained from Airports Council International²² and the Saudi General Authority of Civil Aviation.²³ We then analyzed data on worldwide airline ticket sales from the International Air Transport Association (IATA)²⁴ to identify the destination cities of all passengers departing either Jeddah or Medina IAP in December 2008—the month during which the Hajj occurred that year. While these data capture passenger flight itineraries on commercial flights worldwide, they do not include information on passengers traveling via unscheduled, chartered flights into the standalone Hajj terminal at Jeddah IAP, and do not distinguish passengers performing the Hajj from other international passengers. All statistical, network, and spatial analyses were performed using SAS version 9.2, whereas maps were created using ESRI ArcGIS version 9.3 and Adobe Photoshop.

Results

Pilgrims (2.5 million) from 140 countries traveled to Mecca to perform the Hajj in 2008. Pilgrims (1.7 million) were of international (ie, non-Saudi) origin, with 91.0% traveling to Saudi Arabia by air, 7.7% traveling by land—almost exclusively from

Table 1 Leading countries with international pilgrims performing the Hajj in 2008 by income status*

World ranking	Country name	Number of pilgrims	Percentage of total pilgrims	Cumulative percentage of total pilgrims	Country income status
1	Indonesia	214,159	12.4	12.4	Lower middle income
2	India	173,265	10.0	22.4	Lower middle income
3	Pakistan	170,573	9.8	32.2	Lower middle income
4	Turkey	134,693	7.8	40.0	Upper middle income
5	Iran	111,511	6.4	46.4	Lower middle income
6	Nigeria	97,396	5.6	52.0	Lower middle income
7	Egypt	94,015	5.4	57.5	Lower middle income
8	Bangladesh	50,419	2.9	60.4	Low income
9	Morocco	48,483	2.8	63.2	Lower middle income
10	Algeria	44,484	2.6	65.8	Upper middle income
11	Sudan	38,562	2.2	68.0	Lower middle income
12	Malaysia	36,877	2.1	70.1	Upper middle income
13	Iraq	35,326	2.0	72.1	Lower middle income
14	Afghanistan	32,621	1.9	74.0	Low income
15	Syria	30,556	1.8	75.8	Lower middle income
16	Yemen	28,018	1.6	77.4	Low income
17	Russia	25,749	1.5	78.9	Upper middle income
18	Jordan	22,373	1.3	80.2	Lower middle income
19	Oman	21,587	1.2	81.4	High income
20	Lebanon	19,945	1.2	82.6	Upper middle income
—	Others	301,634	17.4	100.0	—

Note: Saudi Arabia had 0.8 million pilgrims perform the Hajj in 2008 and had gross national income per capita in 2008 of \$15,500 US dollars, thereby defining it as a high-income country.

*As defined by the World Bank.

countries sharing a land border with Saudi Arabia—and 1.3% traveling by sea—largely from Egypt and Sudan—into the Saudi seaports of Jeddah and Yanbo. Twenty countries accounted for more than 80% of all international pilgrims worldwide (see Table 1). The largest numbers of international pilgrims performing the Hajj in 2008 originated from the WHO's Eastern Mediterranean Region (733,417), followed by the South-East Asia Region (463,316), the European Region (243,351), the African Region (217,972), the Western Pacific Region (60,877), and finally the Region of the Americas (13,311). Of these international pilgrims, 11.3, 64.1, 16.6, and 8.0% originated from low, lower middle, upper middle, and high income countries, respectively.

A total of 195,501 pilgrims from 40 low-income countries performed the Hajj in 2008, although just 3 of these countries accounted for 57% of such pilgrims—Bangladesh (50,419), Afghanistan (32,621), and Yemen (28,018). The next 18 low-income countries were the source of between 1,000 and 10,000 pilgrims totaling 79,101 people. These countries included Niger (8,231), Senegal (8,043), Tajikistan (6,883), Mali (6,526), Somalia (6,463), Guinea (5,792), Uzbekistan (5,559), Chad (5,251), Ethiopia (3,926), Benin (3,674), Myanmar (3,342), Mauritania (3,189), Ghana (2,550), Kenya (2,451), Burkina Faso (2,350), Tanzania (1,976), Gambia (1,848), and Togo (1,381). An additional 19 countries were the source of less than 1,000 pilgrims totaling 5,342 people. Furthermore, 10 lower

middle-income countries sent more than 25,000 pilgrims each to the Hajj, which included Indonesia (214,159), India (173,265), Pakistan (170,573), Iran (111,511), Nigeria (97,396), Egypt (94,015), Morocco (48,483), Sudan (38,652), Iraq (35,326), and Syria (30,556). A scatterplot of the number of pilgrims performing the Hajj by country and the economic status of the country (see Figure 1) measured as GNI per capita depicts which countries may be most vulnerable to H1N1 after the Hajj (ie, those with the highest number of pilgrims and the lowest financial resources).

Our analysis of international passenger traffic at Jeddah IAP revealed three annual surges in travel associated with: (1) a summer tourism festival located in Jeddah; (2) the month of Ramadan when many Muslims travel to Mecca to take part in a lesser pilgrimage known as the *Umrah*; and (3) the Hajj. At the time of the Hajj, approximately three million international passenger trips are regularly made via Jeddah or Medina IAP—the two main commercial airports used by pilgrims traveling to and from Mecca (see Figure 2; data from Medina IAP not shown).

With the notable exception of Indonesia, we found that a substantial majority of the world's pilgrims originated from the Northern hemisphere in 2008, which was in the midst of influenza season when the Hajj began in late November. Our analysis of the flight itineraries of international passengers departing Jeddah or Medina IAP in December 2008 (ie, excluding non-scheduled chartered flights) identified a high volume of

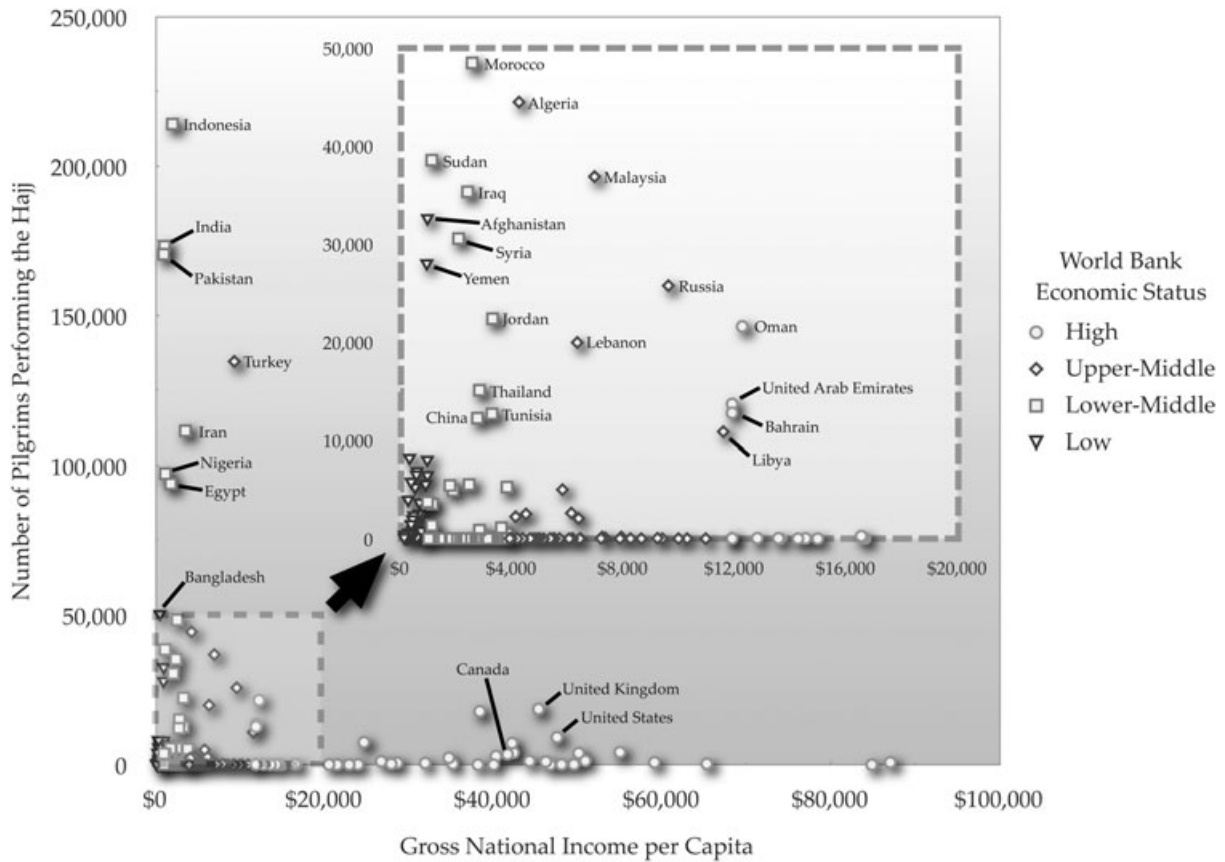


Figure 1 Number of international pilgrims performing the Hajj in 2008 by income status (shown as gross national income per capita in US dollars in 2008). Income categories are defined by the World Bank). No countries are hidden by the inset in this figure. Saudi Arabia had 0.8 million pilgrims perform the Hajj in 2008 and had gross national income per capita in 2008 of \$15,500 US dollars, thereby defining it as a high-income country.

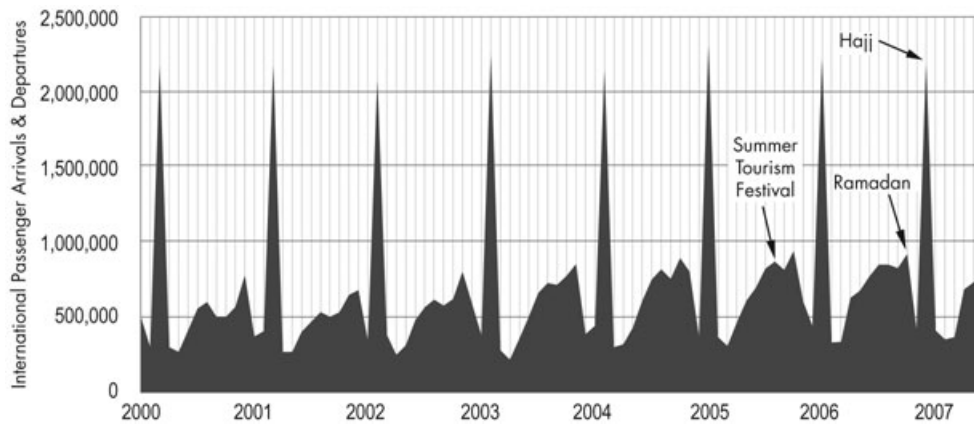


Figure 2 Trends in international passenger traffic at Jeddah International Airport, 2000–2007. During an average year, approximately 800,000 additional pilgrims travel to Mecca to perform the Hajj via Medina International Airport. The three main travel peaks shown here correspond to the Jeddah Summer Tourism festival (which follows the Gregorian calendar) and Ramadan and Hajj (which follow the shorter Muslim calendar).

passengers traveling to Cairo (150,343), Beirut (42,837), Sana’a (28,225), Dubai (19,752), Kozhikode (15,211), Karachi (14,987), Amman (14,044), Alexandria (13,119), Jakarta (12,476), Dhaka (11,592), Kuwait (11,382), and

Mumbai (11,258). Within Western Europe and the Americas, the highest volume of passengers traveled to London (10,608), followed distantly by Toronto (1,626), New York City (1,606), Paris (1,535), Manchester

(1,439), Frankfurt (1,135), and Washington, DC (1,036).

Conclusions

We present a detailed description of the global migration of 2.5 million pilgrims that traveled to and from Mecca, Saudi Arabia in 2008 to offer insights into how the 2009 gathering for the Hajj might have interacted with the H1N1 influenza pandemic. We direct our attention to the world's most resource-limited countries because they will undoubtedly face significant challenges securing adequate supplies of H1N1 vaccine for their populations and have difficulties detecting and responding to cases of H1N1 introduced via returning pilgrims. By studying the origins and volume of pilgrims traveling to Mecca from around the world in 2008, we identify countries that could be imminently vulnerable to H1N1 after the 2009 Hajj.

We found that close to 200,000 pilgrims performing the Hajj in 2008 originated from the world's most resource-limited countries. In light of existing commitments made by a number of countries to share part of their H1N1 vaccine stock with the developing world, our analysis could be useful in guiding decisions about where and when supplies of internationally donated vaccine might best be utilized during the 2009 to 2010 influenza season. A strategy of pre-departure vaccination of pilgrims would have been ideal, in that it would have offered protection to those performing the 2009 Hajj, reduced potential for the importation of H1N1 in returning pilgrims, and consequently slowed the evolution of epidemics in countries where large numbers of pilgrims returned to after the Hajj. However, for many countries a pre-departure vaccination strategy was not feasible given their inability to either purchase H1N1 vaccine or secure supplies of internationally donated H1N1 vaccine before the Hajj began. Consequently, international efforts to help vaccinate high-risk populations in resource-limited countries where a large numbers of pilgrims are expected to return to after the 2009 Hajj may be needed to mitigate the domestic effects of a potential wave of imported H1N1.

For pilgrims traveling to Saudi Arabia by air, a detailed screening protocol was implemented at the Hajj terminal at Jeddah IAP. All pilgrims were screened for fever using non-contact infrared thermography.²⁵ A medical team stationed at the Hajj terminal assessed febrile pilgrims. If a pilgrim's signs and symptoms were deemed to be compatible with influenza, the pilgrim was immediately transported to a dedicated isolation hospital where a nasopharyngeal specimen was collected and tested for H1N1 by polymerase chain reaction (PCR). Oseltamivir was empirically initiated and discontinued if PCR results were negative 6 hours later. If PCR testing was positive for H1N1, the pilgrim was then admitted to hospital and treated until clinically well and afebrile for period of at least 24 hours before

being able to participate in the Hajj. The Kingdom of Saudi Arabia requested that countries screen their pilgrims for fever and signs of illness before they departed for and after they returned from the Hajj.

As cases of H1N1 increased worldwide, the consumption of the neuraminidase inhibitors increased in parallel, raising concerns about the emergence of antiviral resistant strains. If resistant H1N1 virus were introduced into Mecca during the Hajj, it could have been spread to pilgrims from other parts of the world, consequently amplifying its global geographic distribution. Prior to the onset of the Hajj, cases of oseltamivir resistance to H1N1 were only sporadically reported in a handful of cities around the world.²⁶⁻²⁹ Furthermore, clusters involving person-to-person transmission of oseltamivir-resistant H1N1 virus were rare and limited in scale.^{27,30} Fortunately, no cases of oseltamivir-resistant H1N1 infections were identified during the Hajj, and at the time of writing no cases have been reported in pilgrims after returning to their home countries.

Despite the potential for a much larger epidemic, two mass gatherings in Saudi Arabia resulted in less than 100 confirmed H1N1 cases. Just prior to the Hajj, an estimated one to two million pilgrims gathered in the month of Ramadan (ie, August 22 to September 20, 2009) to perform a lesser pilgrimage known as the *Umrab*. During this period, only 26 cases of H1N1 were confirmed among pilgrims, with no deaths occurring.³¹ Given that a second wave of H1N1 was widely anticipated across the Northern hemisphere during the fall,³² efforts to mitigate potential health risks associated with the Hajj continued. Subsequently, during the Hajj, a total of 73 H1N1 cases were identified resulting in five deaths.³³ Incidentally, the number of H1N1 cases observed during the 2009 Hajj reflects a pilgrim population of which an estimated 10% received H1N1 vaccine and 40% received seasonal influenza vaccine.

Our study has a number of important limitations. Foremost, we are unable to identify precisely how many pilgrims opted to forgo the 2009 Hajj in light of the H1N1 pandemic. Although pilgrims at high risk of complications from H1N1 have been discouraged from performing the 2009 Hajj,² to our knowledge, only Tunisia prohibited its citizens from participating.³⁴ Anecdotal information from travel agents organizing pilgrimages for this year's Hajj suggests that there may have been a modest decline in participation.³⁵ Nonetheless, we presume that any decrease in the number of pilgrims would apply to all countries equally, and that the rank order of pilgrims participating by country in 2008 was largely preserved in 2009. Incidentally, the rank order of pilgrims participating by country varies minimally from year to year given that the number of pilgrims allowed to perform the Hajj is determined by national quotas produced by the government of Saudi Arabia. These quotas are fairly consistent because they are calculated based upon the

estimated size of the Muslim population in a given country. Thus, we presumed that global movements of pilgrims during the 2009 Hajj would not be dramatically different from those observed in 2008.

Our analysis of the worldwide destinations of passengers departing Saudi Arabia was limited by a lack of data on the flight itineraries of persons specifically traveling on unscheduled chartered flights via the standalone Hajj terminal in Jeddah. Thus in some countries, where large numbers of pilgrims performed the Hajj in 2008, a surprisingly low volume of international passenger arrivals were noted (eg, cities in Indonesia and Nigeria). In these instances, non-scheduled chartered flights likely play a major role in the transportation of pilgrims to and from Saudi Arabia. Nonetheless, we performed this analysis to identify which cities within a given country appear to be most strongly connected to Jeddah and Medina via commercial air travel at the time of the Hajj.

For more than a millennium, Muslims from around the world have been drawn to Mecca to fulfill a spiritual obligation. In 2009, the health and welfare of pilgrims and the countries from which they originate could have been adversely affected by the H1N1 pandemic. Fortunately, the low numbers of H1N1 cases actually observed during the Hajj suggest that the local and global public health implications of this mass gathering were far more limited than their potential.

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Declaration of Interests

The authors state they have no conflicts of interest to declare.

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