

Hajj a Biomechanical Journey

By Dr. Taqi Hashmi, Consultant Family Medicine
King Faisal Specialist Hospital & Research Center - Jeddah



Dr. Taqi Hashmi,
Consultant Family Medicine
King Faisal Specialist
Hospital & Research
Center - Jeddah

Introduction:

Hajj unlike the other pillars of Islam is the most physical form of worship in Islam. The physical nature of Hajj is further emphasized by the fact that the very essence of Hajj lies not in a particular prayer or supplication but in the physical presence of a person on the plain of Arafat. The journeying and camping from site to site resemble that of a short trip undertaken by military cadets. The process of travel and hardship endured all combine to make the most rigorous and demanding pillar of Islam.

The physical demands placed on the human body are wide and varied. Every bodily system ranging from the musculoskeletal to the immunological is required to play its role in the performance of this unique form of worship. A whole body worship in its truest sense.

Research into the physiology of the pilgrim is limited and sparse. Most research on the physiological effects of stress has been done on healthy, young volunteers in a non-pilgrimage setting. From a medical perspective it would be interesting to gain a perspective of the various physical demands and physiological adaptations that occur at this time of stress. With increasing numbers of pilgrims from abroad performing the Hajj (fig 1) it is most likely that there is an over representation of the elderly within this group as they have access to increased free time and are more likely to have financial capital required towards the end of their working lives. This poses a challenge for the provision of medical services as in general the elderly require more health interventions than the young. For instance the majority of admissions to intensive care units are by the elderly with myocardial infarctions and pneumonia being the most common admitting diagnoses¹. It is important for health professionals to be aware of the changing demographics and the true extent and nature of the demands being placed on the pilgrim. This will help them give better advice and health education to pilgrims who are undertaking this holy journey.

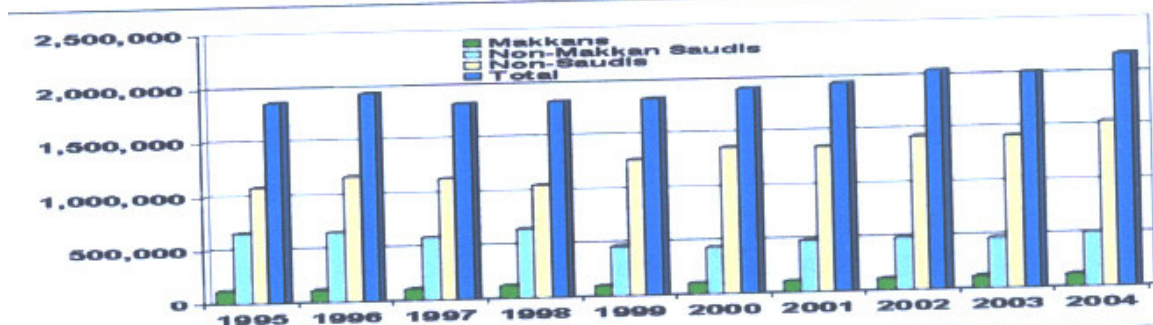


Figure 1— Ministry of Hajj Statistics

¹ Madani et al. , *Ann Saudi Med.* 2007 Mar-Apr;27(2):101-5

Covering the entire range of stressors is beyond the scope of this article. What would be interesting given that one of the leading causes of morbidity is myocardial infarction would be to assess the degree of biomechanical stress in the form of walking that is undertaken during the pilgrimage.

Types of Hajj and their effect on walking:

To understand the degree of walking necessitated during the Hajj a brief look at the process of the pilgrimage is required. The Hajj can be combined with the lesser pilgrimage, Umra. Most people who arrive from distant lands tend to use this opportunity to perform both together. The most commonly performed type is with a complete break between Hajj and Umra. For the purposes of this article it is assumed that the pilgrim performs the combined version known as *Tamattu Hajj*.

Distance Travelled Method

The Tamattu Hajj can be split into various distinct phases. The phases are naturally divided by the dates in the twelfth lunar month of the Islamic lunar calendar. These can be divided into the rites prior to the 9th and then the rites over the next successive five days followed by the final rite of leaving Makkah which occurs on any day after this, usually in close succession as well.

Distances have been calculated utilizing a mix of satellite images and aerial photography provided by Google Earth Browser². The path calculating tools within the programme were used to calculate distances. The tools do not take into account undulation in topography or variation in path distance due to changes in crowd density.

Within Makkah

A path was drawn to reflect the movement of a pilgrim during the Tawaf or circambulation. Three measurements have been taken. The first one at an initial distance of 7 meters from the start point of the Tawaf, black stone. The path then traces the border of the maximum crowd density around the Ka'ba. The photograph taken by Google Earth is dated 2nd Sep, 2006 which corresponds to the 9th of Shaban 1427 at 1 pm local time. The significance of the timing is that the month and time of day both corresponds to a time when crowd density is likely to be relatively low compared to other times. This measurement gives a reading of approximately 120 meters. The second reading traces a route closer to the periphery of the open courtyard which measures 200 meters. This reflects the upper range of distance during non-peak hours. Taking these two ranges the average distance is 160 meters, this is likely to be a better reflection of the distance traversed. A third measurement measures the distance traversed on the roof of the masjid. This measures at around 600 meters. The roof and first floor is heavily used especially during the circambulation of the Ka'ba during the peak days on the 10th and final circambulation on the 12th or 13th of the month. The average pilgrim will make a total of 21 circuits of the Ka'ba. Seven of these are likely to be in the courtyard and the remaining fourteen are likely to be on the roof.

The other ritual performed within Makkah during the Hajj is the Sae'e. This is a seven circuit walk between two hills called Safa and Marwah. Like the Tawaf, the Sae'e can be performed at different levels, but unlike the Tawaf the distance involved

² <http://earth.google.com/index.html>

is constant as there is no requirement for an open area surrounding the path traveled. The distance from Safa to Marwa is 370 meters. This is undertaken 7 times during the initial Umra and then a further 7 lengths are performed as part of the Hajj. Thus the total distance traversed is 5180 meters.

Outside Makkah

Prior to the 9th of the Dhul Hijjah the pilgrims will make their way to the near by area known as Mina. This lies at a distance of 7.58 km, if measured tracing a route through the pedestrian tunnels to a point mid way inside Mina. Here they will stay until the morning of the ninth when they will journey to Arafat at a distance of 11.79 km measured from a mid point in Mina to a mid-point in Arafat. Later after sunset they return to Mina via Muzdalifah where they will camp for the night. The return journey to Mina essentially retraces the route taken to Arafat giving a similar distance of 11.79 km.

On arriving on the 10th in Mina they will begin four important rituals for the day, one which will take them back to Makkah to perform the second Tawaf and Sae'e. By the evening they will return to the Mina. Excluding the distances traversed during the Tawaf and Sae'e they will have crossed 15.16 km by the evening. Over the next three days they will be required to symbolically stone the three pillars known as the Jamarat. This is a physical expressing of their obedience in following the commands of the Prophet Muhammad (S) and a rejection of Satan's temptations. Each time they will walk from their camps based in Mina to the Jamarat or pillars which lie at the periphery of Mina. The distance as measured from a midpoint in Mina to the furthest Jamarat and back measures as the crow flies is 4.96 km. This is very likely to be an under estimate as the journey has now been directed through specific feeder walkways which elongate the distance traveled but streamline the crowds as they approach a single point within Mina. This can be done for two or three successive days giving a potential total of 14.88 Km traveled over three days. The final journey back to Makkah measures at 7.58 km. The final Tawaf done prior to leaving Makkah, as a farewell to the Holy House is not included in this sum.

Pilgrims can be sub-divided into two groups based on their use of transportation for the inter-area journeys. Group A are those pilgrims who do take transport for inter-ritual areas. Group B are pilgrims who perform the entire pilgrimage rituals on foot without access to transport during the Hajj period. Table 1 summarizes the total distance traveled by these two groups. These figures do not take into account the average walked per day. A total figure based upon the average walking distance per day has been added to take this into account.

Distance Walked in Hajj for rituals

	Unit length/circuit distance(m)	Circuits/length	Sub-total distance (m)	Group A	Group B
Tawaf (courtyard average)	160	7	1120	1120	1120
Tawaf (roof)	600	14	8400	8400	8400
Safa & Marwah	370	14	5180	5180	5180

Makkah to Mid Mina	7580	4	30320	0	30320
Mid Mina to Mid Arafat	11790	2	23580	0	23580
Mid Mina to Mid Jamarat	2480	6	14880	14880	14880
Average non-rital walking (8days)	816	8	6528	6528	6528
Total (m)				36108	90008

Discussion:

The total distance walked by Group A is around 36 km while it reaches 90 km by Group B. The medical impact of this degree of walking depends on the background average distance walked by pilgrims outside Hajj. The greater the ratio of Hajj-to-non-Hajj walking the more likely that physical problems as a result of walking are to occur. Figures on the normal walking habits of such an internationally diverse population are not readily available. What data does exist mainly comes from industrialized nations. In a recent survey of walking habits in the United Kingdom³ the average distance walked on a daily amount was 816 meters per day. Though the figure is imperfect it provides some data to compare the normal daily walking habits of pilgrims when compared to the requirements during the Hajj.

The distances in Table 1 can be traversed over a minimum period of between 6-8 days, depending on the precise timing of various rituals at the beginning and end of the Hajj period. It is likely that the time taken to perform all the rituals averages around 10 ten days. The average non- pilgrim over ten days would thus walk around 8 km compared to Group A who are expected to walk over 36 km and Group B over 90 km. As shown in Table 2 when expressed as a ratio is a 44 fold increase in the amount walked for Group A and a 110 fold increase for Group B. The percentage increase for Group B is likely to be an over estimate as it is likely that pilgrims in Group B will come from socio-economic backgrounds which will necessitate a greater average daily distance being walked outside the Hajj period. National surveys have shown that households which do not have a car walk longer distances than households with cars. It is logical for this difference to be amplified in groups which show a greater separation in terms of socio-economic variables. Conversely the estimate fro Group A is probably an under estimate. It is likely that Group A have pilgrims for a more economically well off background and are thus more likely to use automobiles rather than walk. Evidence supporting this comes from the UK national survey data which showed that the people who walked the least were males who had company owned cars.

³ National Travel Survey, Department for Transport, United Kingdom

Day	Group A	Percentage*	Group B	Percentage*
7	1936	237%	1936	237%
8	816	100%	8396	1029%
9	816	100%	22038	2701%
10	7606	932%	25124	3079%
11	5776	708%	5776	708%
12	5776	708%	5776	708%
13	5776	708%	13356	1637%
14	7606	932%	7606	932%
Total	36108	4425%	90008	11030%

* Daily distance / Average daily distance as a percentage

The distances traveled during the Hajj are not uniformly spread. Figure 2 shows the data for Group A as a pie chart, day 10 and 14 represent the day when the majority of walking is done for Group A. Figure 3 shows that for Group B days make up the bulk of the walking done at 54% of the total walked.

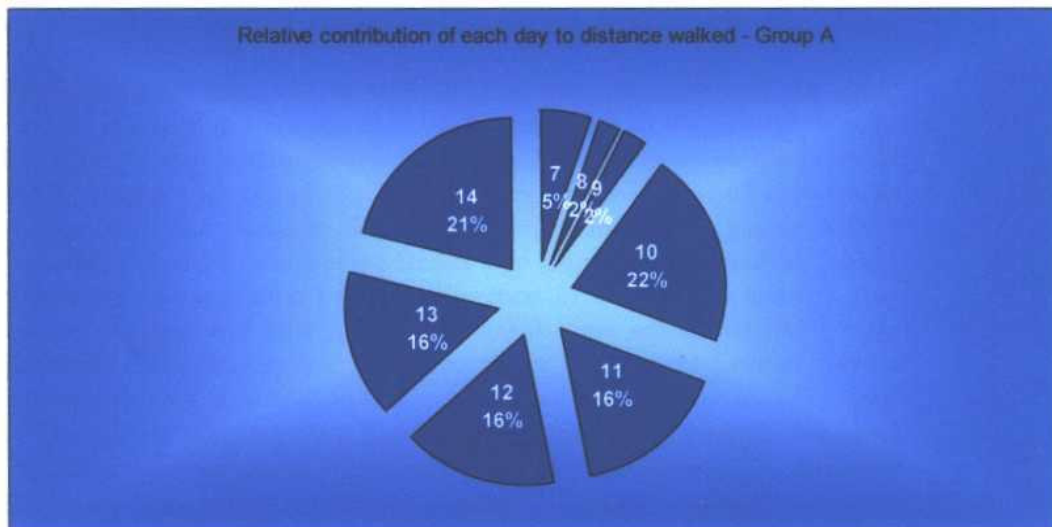


Figure 2

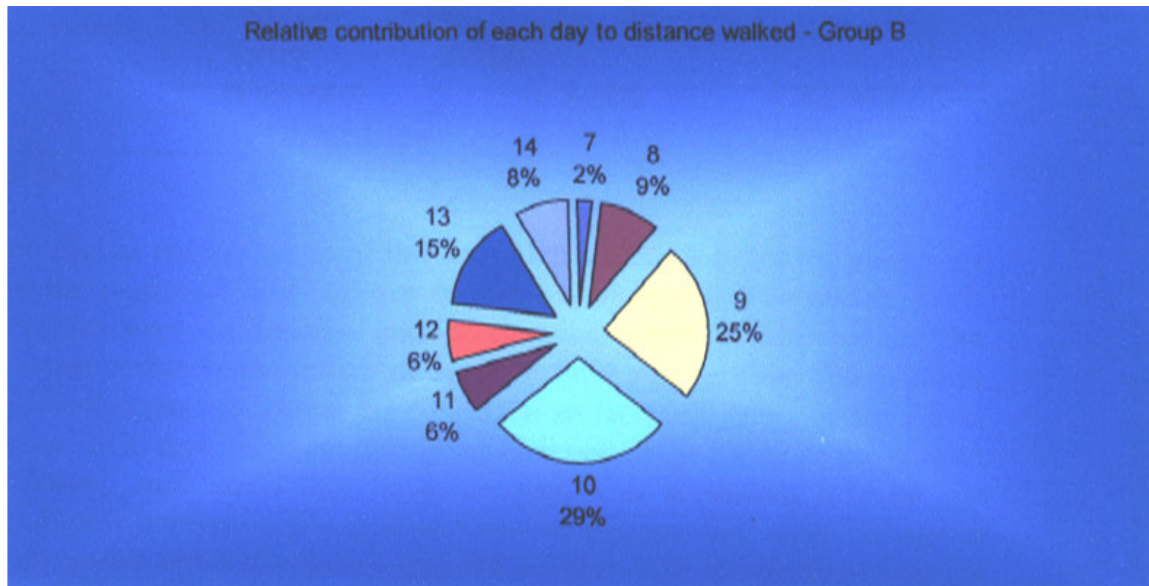


Figure 3

This initial analysis of the distance walked provides an insight into the considerably increased biomechanical stress that is placed on the human body during the Hajj. Patients who have cardiovascular disease or are at risk of such disease may find that this degree of stress precipitates significant morbidity. There are currently no studies examining the longer term effects of such stress. It would be both interesting from an academic point of view and of clinical benefit to be able to evaluate whether there are longer term sequelae of such stress in the weeks to months after Hajj.

Biomechanically men and women differ in they way they walk. In stride analysis studies⁴ the average man when compared to the average women has a longer step length. Step length is the distance between the point of initial contact with the ground of one foot and the point of subsequent contact with the opposite foot. The average male step length is 0.79 meters compared to the average female step length of 0.66 meters. Table 3 shows the consequence of this difference in step length namely that female pilgrims will take 9,000 and 22,000 steps more than their male counterparts in Groups A and B respectively. Perhaps the increased stress and burden that is placed on a female pilgrim compared to a male is part of the reason why the Hajj has been described as a 'struggle' or Jihad specifically for women as opposed to men by the Prophet Muhammad (peace be upon him) and hence a cause for greater reward for female pilgrims.

Stride Analysis Table

	Group A	Group B
Total Distance	36,108	90,008

⁴<http://moon.ouhsc.edu/dthompsogait/knmarics/stride.hrm>

Travelled (m)			
Steps Taken	Male	45,706	113,934
	Female	54,709	136,376
	Extra Steps (Female)	9,003	22,442
	% Difference	20%	20%

Table 3

The clinical consequences of this are unknown but it raises the possibility that the degree of wear and tear on joints in women will be greater. Each step involves acceleration and deceleration which is buffeted by the pressure redistributive *effect* of synovial fluid and cartilage compression and decompression. But in the context of an increased stress on the joints, poorer fluid replenishment during the Hajj period the ability of the joint to withstand such stress may be diminished. This is unlikely to pose any significant burden on young fit and healthy pilgrims but where old age or arthropathy alters the joints capacity to deal with stress there may be important clinical effects.

If a clinical worsening was proven to be the case it would allow for interventional studies and a more accurate prediction of the likelihood of mechanical injury due to walking. This raises a whole of host of possible interventional strategies from interventions at the individual level looking at rehydration, nutrition and footwear to the public level and examination of road surface and foundation materials designed to increase walking efficiency.

In this biomechanical analysis of the Hajj recourse to estimations and various assumptions have been made which have been discussed above. But it shows that there is a great deal of research that can be further conducted to collect data on the effect of the Hajj on pilgrims. This would provide valuable data for the authorities in the provisioning and commissioning of medical and emergency services which are provided free of charge through the auspices of the Custodian of the two Holy Mosques.

Dr. Taqi Hashmi,
 Consultant Family Medicine
 King Faisal Specialist Hospital & Research Center - Jeddah