The influence of environmental conditions and human congregation on the immune system response: systematic review article

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Abstract

The immune system protects the human body from disease through several lines of defense, each with its own specificity. Physical barriers, such as the skin, prevent pathogens such as bacteria, viruses and parasites from entering the body. If a pathogen breaches these barriers, the innate immune system responds immediately, but in a non-specific manner. When a pathogen successfully evades the innate immune response, vertebrates have a second line of defense: the adaptive immune system (specific), activated by the innate immune response, the immune system adapts its response during infection to improve pathogen recognition.

Human immune responses can change depending on environmental conditions, so many environmental factors influence the Arbaeen march (the focus of our study), which is the fortieth day after the martyrdom of Imam Hussein (peace be upon him). Arbaeen is considered one of the largest gatherings of human beings in the world. It is a great, authentic, and deeply rooted movement, bringing together millions of Muslims from all over the world annually, regardless of their nationalities, colors and languages.

Therefore, the scarcity of rest areas, the varying outdoor air quality, and the varying temperatures coincide with the visiting season. However, not all visitors are affected by most environmental factors, as the feeling of comfort in performing these religious rituals supports the immune system, and thus supports better health for the individual (visitor). This study aims to comprehend the influence of environmental agents and interpret the immune responses of visitors of both genders and different ages.

Key word:Immune system, arbaeen march , Human Gatherings, Environmental Conditions.

Introduction

The immune system consists of a complex and integrated network of tissues, organs and molecules that act together to protect the body from pathogens such as bacteria, viruses, parasites and cancer cells. So, the main components of the immune system are the physical barriers, which include the skin, mucous membranes, and body fluids. The other part includes immune cells (white blood cells), which are produced in the bone marrow (Wang et al., 2024). These include lymphocytes (T and B cells), killer cells and phagocytes (including neutrophils, monocytes, macrophages and dendritic cells), among others. All of these components work in coordination with each other to ensure an effective immune response against various threats. The human body consists of about 2 trillion lymphocytes, which constitute between 20% and 40% of white blood cells (Vaillant et al., 2024).

B cells and T cells arise from the same multipotent hematopoietic stem cells, which remain indistinguishable from each other until activated. B cells play a major role in the humoral immune response, while T cells primarily influence cell-mediated immune responses. Adaptive immunity relies on the ability of immune cells to distinguish between the body's own cells and any unwanted foreign bodies or organisms that invade the immune system (Elena et al., 2013).

External environmental conditions are a set of factors and forces that exist in the external environment, they are a set of physical, chemical, and biological factors that surround individuals and influence their interaction with each other and with the environment (Vantourout and Hayday., 2013). These factors determine the nature of any ecosystem and affect the behavior and performance of the individuals who can live in it. Environmental conditions greatly affect the human immune system, either by strengthening or weakening it. This complex interaction determines the body's susceptibility to diseases and injuries and how it responds to them (Sundas et al., 2024).

Types of environmental Elements

The concept of the environment refers to its natural components and the conditions and factors in which living organisms live. It is the science that studies the relationship between living organisms and the environment in which they live. This science is concerned with living organisms, their nutrition, their ways of life, and their presence in the study of non-living factors such as communities, population centers, or peoples (Andersen et al., 2021). It also includes the characteristics of climate (temperature, humidity, radiation, water and air gases), and the physical and chemical properties of the soil, water and air (Abdul Kari., 2025).The environment element can be divided into three components: (Gupta., 2025).

- First:The natural environment: This is the atmosphere, which consists of four closely interconnected systems: the hydrosphere, the terrestrial environment, and the atmosphere. These systems include water, air, soil, minerals, and energy sources, in addition to plants and animals. These all represent the resources that God Almighty has provided for humans to obtain the necessities of life, including food, clothing, medicine, and shelter.
- Second:The biological environment: This includes the individual human being, his family, and his community, as well as the living organisms in the biosphere. The biological environment is considered part of the natural environment.
- Third:The social environment: The social environment refers to the framework of relationships that determines the relationship between humans and others. This framework of relationships is the basis for organizing any group, whether among its individuals in a given environment, or among diverse groups and civilizations in distant environments. The patterns of these relationships constitute what are known as social systems (Ofremu et al., 2025).

The immune system

The immune system is a system specialized in defending the body against foreign agents or dangerous invading agents, the immune system, such as any other system in the body, consists of organs and cells (Zhou et al., 2025).The organs of the immune system are divided into two main groups: primary lymphoid organs, whose function is to produce different immune cells, represented by the bone marrow, or to educate immune cells after they are produced to distinguish between self and non-self-cells, appeared by the thymus gland (Delves et al., 2024). There are secondary lymphoid organs, which include the spleen and lymph nodes. As for the cells of the immune system, they are divided into two main groups: granular cells, which include neutrophils, eosinophil's and basophils, and a group of non-granular cells, which includes types of T cells, B cells, killer cells, monocytes, and macrophages, lymphocytes are considered the most important and are the backbone of the immune system (Patel ., 2025).

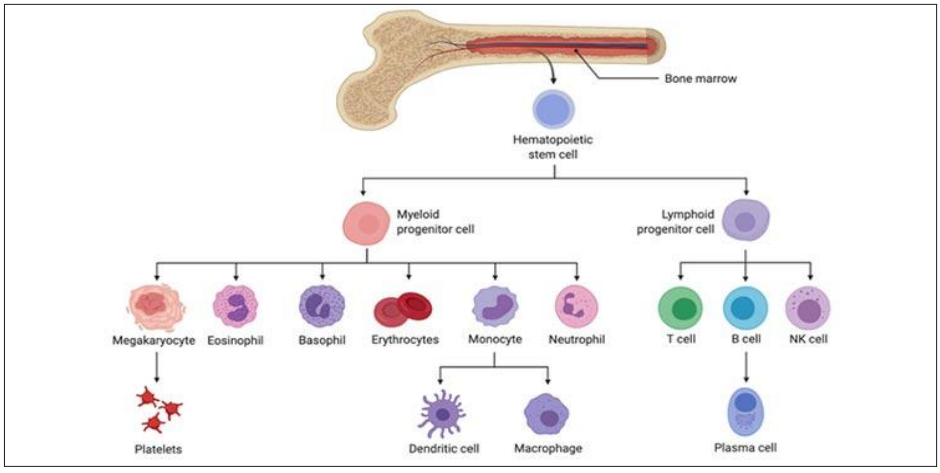

Figure (1) the source of blood cells production

Components of the Immune System

1. Antigens: An antigen refers to a foreign substance that enters the body. It can be a protein, glycoprotein, virus, bacteria, parasite, or other substance. These substances are chemically distinct and have the ability to stimulate the body's immune system to produce antibodies that trigger a specific immune response (Chaplin., 2010). These antigens are called immunogens because the body responds to them upon recognition with an immune reaction, which is the formation of antibodies, antigens have certain distinctive properties that give them immunogenicity, antigens are molecules that interact with antibodies, while immunogens are molecules that stimulate an immune response (Humphrey and Perdue., 2025).

2. Epitope: or antigenic determinants, which is a small, specific part of the antigen, which usually consists of 4-6 amino acids or sugar groups, that determines the immune reaction, i.e. it is the site of binding of the antigen to its antibody (Kringelum et al., 2012).

3. Antibodies: Chemically, antibodies are glycoproteins dissolved in blood plasma called immunoglobulins. They are produced by plasma cells, which originally from B lymphocytes, and are secreted by the body as a specific response to the presence of antigens (humoral immunity) (Patel et al., 2023).These immunoglobulins contain components capable of reacting specifically with the specific antigens that led to their formation. Antibodies are divided into five main categories (immunoglobulins): G, M, A, D, and E, with IgG representing the largest group (Vaschetto., 2025).

The Arbaeen march

The Arbaeen march : It is a sacred ritual through which individuals (visitors) visit the grave of Imam Hussein, peace be upon him, from all parts of the country and even from remote countries and distant regions. Since the martyrdom of Imam Hussein, peace be upon him, the visitors have been keen to make the connection vibrant, alive and continuous btween them and Karbala. It is a procession during which millions of Muslims set out towards Karbala to visit Hussein bin Ali bin Abi Talib on the twentieth of Safar every year, 40 days after the Karbala incident in which Hussein bin Ali was killed (Aboud., 2024).

Among the most important rituals and ceremonies of the Arbaeen march practiced by visitors are walking long distances to Karbala, holding mourning gatherings, offering food and drinks to visitors, reciting prayers, and making special visits to Imam Hussein and his family. One of the most prominent rituals is the walk to Karbala. So, walking to Karbala is considered one of the most prominent aspects of the march , as millions of visitors from various cities and countries head on foot to the shrines of Imam Hussein and his brother Abbas. Among the etiquettes of the Arbaeen visit are speaking to people in a good way and refraining from idle talk and foul language. Avoiding eating while walking, but rather sitting, and not wasting food. Walking with calmness and dignity. Engaging in verbal supplications such as seeking forgiveness, saying “There is no god but Allah,” and sending blessings upon Muhammad and his family.

So the most important etiquette can be summarized of visiting Imam Husein (peace be upon him) are the following: First: Consideration attention to purity, a good appearance, tranquility and dignity. Second: Show a sense of sadness and melancholy. Third: Consolation in times of hunger and thirst. Fourth: Visit Imam Hussein (peace be upon him) out of longing for him and love for the Prophet and his family (peace be upon them). Fifth: Visit Imam Hussein (peace be upon him) with true knowledge of his religion.

Statistics the total number visitors of Arbaeen march and pilgrims

”The Arbaeen march is the largest human gathering in the world, regardless of color ,race ,or language ,as they see in Hussein) peace be upon him (the entire universe ,a symbol of freedom and great sacrifice“. This historical miracle that occurs every year leaves behind a global astonishment at the scene that is not repeated at other times of the year. What is even more amazing is that people from different European and American countries head to the city of Karbala to experience the scene up close .It is an amazing thing ,as adults ,children ,and even people with special needs who cannot walk flock to this city ,indifferent to the security conditions and other things .What is important to them is reaching Imam Hussein) peace be upon him .(Several foreign newspapers wrote about how a small city like Karbala can accommodate all these numbers of people in such conditions “,stressing at the same time” :It is truly a miracle because approximately (20) million people enter this city in a few days ,and food is provided to them in such abundance and variety ,along with the rest of the requirements such as housing ,transportation ,and the like .All of this requires money ,and Iraq is going through an economic crisis .It is truly a miracle ,so it was included “.The visit is in the encyclopedia of world records and in several categories ,including :the largest human gathering, the longest dining table in the world ,the largest number of volunteers at a single event ,etc .There are some statistics related to the human gatherings during the Arbaeen visitors as follow:

Table (1) demonstrated total number of Arbaeen visitors and the pilgrims

No.	Year	Total number of Arbaeen visitors	Total number of pilgrims
1	2016	30 million	1, 862, 909
2	2017	13.8 million	2, 352, 122
3	2018	20 million	2, 371, 675
4	2019	< 15 million	2, 489, 406
5	2020	few	10000
6	2021	few	60000
7	2022	21,198,640 milion	899, 353
8	2023	< 22 million	1,845, 045
6	2024	< 22 million	1, 833, 164

The number of visitors (in table 1) to the Arbaeen march has reached millions over the years alone, although the number decreased in 2020 and 2021 due to the Corona pandemic. It is considered the largest human gathering in history compared to other human gatherings that include Hajj. This may be due to the facilities provided by visitors in all details, or it may also be due to the influx of visitors from several other countries to revive these sacred religious rituals. So, these numbers are evidence of the religious and spiritual significance of the Arbaeen march and its significant impact on the region.

The differences of immune responses between different age groups and the gender

The immune response varies across age groups depending on several factors, including the age group (months to 1 year). Their immunity is weak due to the incomplete development of the immune system before the age of one year. The body relies on antibodies received from the mother (passive immunity). Therefore, they are highly susceptible to bacterial, parasitic, or viral infections, especially in crowded areas, including the Arbaeen pilgrimage. Therefore, it is recommended not to bring children of this age with them (Simon et al., 2025). (1 - 18 year) , their immune systems may be more developed, as B and T cells are better formed and they acquire immunological memory due to their exposure to diseases and vaccinations, which enable the body to develop strong immunity against many diseases common in these communities, such as measles, mumps, and influenza (Pollard and Bijker., 2021).

As for those aged (18 - 65), these age groups possess strong and effective immune systems and have extensive immunological memory from previous exposure to diseases. However, their immune system may be affected by certain lifestyle factors, depending on the nature of their work and social activities. These factors, such as stress, poor nutrition, lack of sleep, and smoking, can affect the strength of the immune system. However, this does not occur when performing religious rituals, as they perform them with comfort and reassurance (Nguyen et al.,2025).

As for the elderly (over 65 years old), their immune system may suf fer from a gradual decline with age, known as immunosenescence. This is due to a decline in innate and adaptive immunity, as the number and function of various immune cells (such as neutrophils, monocytes, macro phages, T cells, and B cells) change. This makes them more susceptible to

infection, and diseases are more severe, leading to serious complications. Furthermore, most of these people have chronic diseases such as diabetes, heart disease, and kidney disease, which further weaken their immune systems and make them more susceptible to complications in such human populations (Goyani et al., 2024). In the conclusion, these populations pose different immune challenges to each age group, necessitating preventive strategies and health interventions tailored to each group.

As for gender, several studies have shown clear differences in the im mune responses between males and females. These are represented by some the factors:

1. Sex hormones: Females have two hormones (estrogen and progesterone), which make them exhibit stronger immunity, whether at the level of in nate or adaptive (cellular and humoral) immunity. Estrogen is believed to enhance immune responses, which in turn leads to faster clearance of pathogens. However, it also increases susceptibility to autoimmune diseases and infections. It is estimated that more than 80% of those with autoimmune diseases are women(Sciarra et al., 2023).

While for the males, testosterone generally acts as an immunosup pressant. Testosterone can also reduce the production of pro-inflamma tory cytokines and affect the differentiation of helper T cells, the pro duction of immunoglobulins (antibodies), and the activity of killer cells. This inhibition explains the reason for the increase. Males are more sus ceptible to certain infections and disease severity than females, which may increase in such large populations, with lower rates of autoimmune diseases (Batalla et al., 2020).

2. Sex chromosomes: Females carry the XX chromosome, while males carry the XY chromosome. Females have an extra X chromosome, which carries a number of immunity-related genes, unlike males, thet carry Y chromo some, which contains fewer immunity-related genes (Roman et al., 2024).

3. Differences in innate and adaptive immune responses: Females gener ally exhibit higher activity in innate immune cells, such as monocytes, macrophages, and dendritic cells, and their antigen-presenting cells are more efficient. Conversely, females may have lower activity in natural killer cells compared to males. As for adaptive immunity, females pro duce higher levels of antibodies that protect against antigens, along with increased lymphocyte proliferation and activation and production of pro-inflammatory cytokines. Males, on the other hand, possess a more expanded subset of regulatory cells than females (Dash et al., 2024).

4. The final factor is age. Sexual immunological differences change with age. Males may exhibit more severe immune changes with aging, lead ing to an increased risk of certain diseases (Calabrò et al., 2023).

Furthermore, these immunological differences explain the disparity in in fection rates and disease severity between males and females, which rquires more specific treatments in such populations based on biological sex.

The relationship between environmental conditions and the immune system

The immune system is a complex network that protects the body from harmful pathogens, such as viruses, bacteria and fungi from various internal and external factors, including seasonal changes, strengthen or weaken our immune defenses. External environmental conditions significantly in flence the Arbaeen visitors, including climate, terrain and disease prevalence, as well as social and economic factors that impact visitor flow and safety (Marshall et al., 2018). Environmental impacts include: Climate: The Arbaeen march often experiences high temperatures and humidity, which can lead to sunstroke and heat exhaustion among visitors, especially the elderly and children. Terrain: Some trails may be rough and unpaved, increasing the risk of falls and injuries, especially with large numbers of pedestrians. Diseases: The spread of infectious diseases, such as influenza and diarrhea, may pose a risk to visitors' health, especially with crowding and large gatherings. While the social and economic factors involve population Influx: significantly increasing visitor numbers may place pressure on infrastructure and available resources, such as water and sanitation. Pollution: Increased waste and environmental pollution may negatively impact air and water quality, threatening visitors' health. Security: Security threats may pose a challenge to the visitors, especially with large numbers of persons, requiring enhanced security measures (Li and Wu ., 2021).

Whilst the impacts on the visitors: as harms and diseases: Harsh environmental conditions may lead to increased rates of injury and illness among visitors, which may hinder their enjoyment of the march and logistical difficulties, so, organizing agencies may face difficulty providing basic services, such as water, food and first aid, due to the large number of visitors and environmental conditions, as well as, psychological Impacts:

some visitors may feel anxious and stressed due to the difficult conditions, which may affect their spiritual experience (Najafi et al., 2022). Therefore, the proposed solutions: include awareness: visitors must be made aware of the dangers of environmental conditions and the need to take necessary precautions and provide Infrastructure, sanitation facilities, potable water, and appropriate shelters must be provided for visitors. as well as provide medical services, emergency the services must be provided along visitor routes and coordination with security authorities, coordination with security authorities must be undertaken to provide a safe environment for visitors , and last pollution reduction, measures must be taken to reduce environmental pollution and maintain a clean environment (Keng et al., 2013).

Despite all the conditions and factors mentioned above, which most Arbaeen visitors may encounter, many of them are not affected by them. This is because when a person is pleased, reassured, or proud of the work they are doing, their immune system can respond positively by increasing its activity and strengthening its defenses against disease. Relaxation contributes to the secretion of chemicals in the body that enhance the functions of the immune system, such as dopamine, which plays a role in enhancing feelings of happiness and strengthening the functions of the immune system, performing these rituals also leads to reducing stress and anxiety, which reduces the secretion of stress hormones that can weaken the immune system (Agahtani et al., 2022). Some studies indicate that a positive psychological state can enhance the immune system's ability to fight diseases and infections. Levels of stress hormones such as cortisol and adrenaline are reduced, allowing the immune system to function efficiently. There is a definite link between the activity and health of the immune system and a person's psychological state and mood (George ., 2024). There are several ways for the immune and nervous systems to communicate. One of

these is through the release of cytokines, a type of protein secreted by the immune system in cases of illness, infection, anxiety, or any stimuli that stimulate an immune response (Al-Marsomy et al., 2020). The relationship between the two systems lies in the transport of cytokines to the brain and their impact on the neurotransmitters that control mood and mental health. This leads to disruptions in serotonin, dopamine, oxytocin and glutamate levels, thereby increasing the risk of developing mental illnesses such as depression, anxiety (Coffey et al., 2021).

One of the most important components that strengthens the immune system and thus helps it withstand adverse conditions is eating a healthy, varied, and balanced diet, including vegetables, fruits, proteins, starches, legumes, and good fats. This diet is available throughout the Arbaeen march , ensuring the body receives all the vitamins, minerals, and other beneficial elements it needs (Tardy et al., 2020).Another factor is exercising, which in turn stimulates blood circulation, helping immune system cells move more quickly throughout the body. Visitors who walk to visit the Imam can do this, which can take two weeks or more for some visitors from provinces far from Karbala. Another factor is drinking sufficient amounts of water, which is a key factor in the immune system's activity. This is because lymph, the fluid that transports immune system cells throughout the body, contains a large amount of water. Walking long distances makes people thirsty and dehydrated, so drinking sufficient amounts of water strengthens the immune system for both sexes and all various ages (Watso and Farquhar., 2019). Another factor is avoiding prohibited substances such as analgesic and smoking, which can increase stress and tension due to their nicotine content, that weakens the immune system, which all visitors stay away from, especially on visiting days, staying evade them strengthens people's immunity. The most important and final factor is that helping

others and providing services to all visitors enhances positive energy and reduces psychological stress (Chang et al., 2024). Therefore, all of these factors, lead to enhanced immune system activity and resistance to all environmental factors that may affect when exposed it in other conditions.

Conclusion

The conclusion from the presented study that there are many common environmental factors affecting visitors are harsh climatic conditions such as heat and dust. So, The Arbaeen visit in the summer season may coincide with high temperatures, which can lead to sunstroke and dehydration. There is a risk of disease spreading, as crowding and congested conditions are ideal circumstanceses for the spread of infectious diseases. Physical and psychological stress also increases by the long distances that visitors walk, along with lack of sleep and fatigue, all weaken the immune system. However, in addition to all the environmental factors that affect visitors, the immune system may resist these factors due to: enhance the function and activity of the immune system, because the feeling of comfort and reassurance when performing the holy ritual (the Arbaeen march), and the high level of hormones of satisfaction and cheerfulness, in addition to eating various healthy foods and walking long distances, all of which support the immune system to resist the most external environmental conditions that visitors are exposed to in the various seasons that coincide with the date of this holy ritual, for both sexes and all different ages, with slight variations between one age group and another.

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المصادر العربية :

1. مقالة لدار الخليج (للصحافة والطباعة والنشر) / اعداد الحجاج خلال السنوات العشر الماضية في 2/7/2025.

2. مقالة للموسوعة الحرة / اكبر تجمعات بشرية في العالم في 2024/7/19