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What Is The Prevalence of Acute Cardiovascular Events among Elderly Hajj Pilgrims (≥60 Years), and What are The Associated Risk Factors? : A Systematic Review

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ABSTRACT

Introduction: The Hajj pilgrimage, attracting millions of Muslims annually, involves elderly participants (≥60 years) who face significant cardiovascular risks due to advanced age, comorbidities, and extreme environmental conditions. Despite cardiovascular disease being the leading cause of Hajj-related mortality, the precise prevalence of acute cardiovascular events among elderly pilgrims and their associated risk factors remain poorly quantified. This systematic review aimed to determine the prevalence of acute cardiovascular events among elderly Hajj pilgrims (≥60 years) and identify associated risk factors.

Methods: A systematic review of 58 observational studies, systematic reviews, and meta-analyses was conducted. Studies were included if they involved Hajj pilgrims aged ≥60 years,

reported cardiovascular outcomes during the Hajj period, and provided quantifiable data. Data extraction focused on study characteristics, elderly pilgrim demographics, cardiovascular event definitions, prevalence rates, and risk factor associations. Data sources included SISKOHATKES (Indonesian Hajj health information system), hospital records, and mortality registries.

Results: Mortality data showed that 81% of Hajj deaths occurred in pilgrims ≥60 years (3), with cardiovascular causes accounting for 38-42% of all deaths (1,2). Cardiovascular risk factor prevalence among elderly pilgrims was extremely high: hypertension (71.34%), hyperglycemia (43.76%), and hypercholesterolemia (59.46%) (8). Age ≥60 years was the dominant risk factor for mortality (adjusted OR range: 3.1–8.1) (3,10,11). Diabetes mellitus showed the strongest association with mortality in some cohorts (RRa=18.7) (3), while hypertension (OR=2.03–3.7) (3,10,13), dyslipidemia (OR=1.82) (13), and male gender (OR=1.87) (10) were consistently significant. Hajj-specific factors, including heat stress (independent predictor of MACE, p=0.001) and dehydration (independent predictor of mortality, p=0.009) (15), emerged as critical triggers. High-risk health status (risti) classification demonstrated strong associations with mortality (OR=7.83) (27) and morbidity (Exp(B)=19.745) (40).

Discussion: The cardiovascular burden in elderly Hajj pilgrims results from a convergence of high comorbidity prevalence, age-related physiological vulnerability, and extreme environmental stressors. The absence of direct prevalence estimates reflects methodological limitations in current surveillance systems. The interaction between traditional risk factors and Hajj-specific triggers—particularly heat exposure during the physically demanding Armuzna (Arafah, Muzdalifah, Mina) phase—provides

a mechanistic framework explaining both elevated baseline risk and annual mortality variability. The paradoxical finding that AMI pilgrims had worse outcomes despite fewer traditional risk factors (19) underscores the importance of environmental triggers. The extreme diabetes-related mortality risk in 2023 likely reflects synergistic effects of heat stress and operational failures. Integrated risk stratification using functional capacity (6MWT) and composite high-risk classification offers the most evidence-based screening approach.

Conclusion: Elderly Hajj pilgrims face a 3- to 8-fold increased mortality risk compared to younger pilgrims, driven primarily by cardiovascular disease in the context of near-universal risk factor burden. Pre-departure screening should prioritize integrated risk assessment incorporating age, comorbidities, and functional capacity, while during-Hajj interventions must focus on heat exposure mitigation and early recognition of cardiovascular events in this vulnerable population.

Keywords: Hajj, elderly pilgrims, cardiovascular disease, mortality, risk factors, hypertension, diabetes mellitus, heat stress

INTRODUCTION

Background

The Hajj pilgrimage, one of the largest annual mass gatherings globally, attracts approximately 2.5 million Muslims from over 180 countries to the holy sites in Mecca, Saudi Arabia (20). Among these pilgrims, the proportion of elderly participants (aged ≥60 years) has steadily increased due to longer life expectancies and extended waiting periods for pilgrimage quotas in many Muslim-majority countries. In Indonesia, the world's largest Hajj sending country, pilgrims may wait up to 12 years between registration and departure, resulting in substantial aging during the waiting period (57). This demographic shift has significant implications for pilgrimage medicine, as aging is associated with increased prevalence of chronic diseases and reduced physiological reserve to withstand extreme environmental conditions.

Cardiovascular disease (CVD) has consistently been identified as the leading cause of morbidity and mortality during Hajj (1,20,21). The pilgrimage involves physically demanding rituals performed in crowded conditions, often under extreme heat, with limited access to immediate healthcare during critical phases. These conditions create a "perfect storm" for acute cardiovascular events, particularly among vulnerable elderly participants with underlying cardiovascular risk factors.

Problem Statement and Research Gap

Despite the recognized importance of cardiovascular health in Hajj pilgrims, significant knowledge gaps persist regarding the precise burden of acute cardiovascular events specifically among elderly pilgrims (≥60 years). Existing literature has several limitations: (1) most studies report overall mortality or hospitalization rates without age stratification; (2) cardiovascular event definitions vary widely across studies; (3) the majority of research originates from single countries (predominantly Indonesia), limiting generalizability; and (4) few studies have systematically examined the interaction between traditional cardiovascular risk factors and Hajj-specific environmental triggers in elderly populations.

The central research questions—"What is the prevalence of acute cardiovascular events among elderly Hajj pilgrims (≥60 years), and what are the associated risk factors?"—remain inadequately answered. While individual studies have reported mortality rates, cardiovascular comorbidity prevalence, and risk factor associations, no comprehensive synthesis has integrated these findings to provide a coherent picture of cardiovascular risk in this vulnerable population.

Research Objectives

This systematic review aimed to:

1. Determine the prevalence of acute cardiovascular events among Hajj pilgrims aged ≥60 years
2. Identify and quantify risk factors associated with cardiovascular events in this population
3. Examine the interaction between traditional cardiovascular risk factors and Hajj-specific environmental triggers
4. Evaluate the evidence for current screening and risk stratification approaches in elderly pilgrims

Hypotheses

We hypothesized that: (1) acute cardiovascular events constitute the predominant cause of morbidity and mortality among elderly Hajj pilgrims; (2) age ≥60 years is the dominant independent risk factor for adverse cardiovascular outcomes; (3) traditional cardiovascular risk factors (hypertension, diabetes, dyslipidemia) maintain significant associations even after adjustment; and (4) Hajj-specific factors (heat stress, physical exertion, crowding) act as critical triggers interacting with underlying vulnerability.

Novelty and Significance

This review provides the first comprehensive synthesis of cardiovascular outcomes specifically focused on elderly Hajj pilgrims, integrating evidence from 58 studies across multiple countries and healthcare settings. Its novelty lies in: (1) explicit focus on the ≥60 years age group; (2) systematic examination of both traditional and pilgrimage-specific risk factors; (3) triangulation

of mortality, morbidity, and risk factor prevalence data to estimate cardiovascular burden despite the absence of direct prevalence estimates; and (4) identification of mechanistic pathways linking age-related vulnerability with environmental triggers.

The findings have direct implications for pre-departure screening protocols, during-Hajj healthcare resource allocation, and development of targeted interventions for this growing vulnerable population.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate What Is The Prevalence of Acute Cardiovascular Events among Elderly Hajj Pilgrims (≥60 Years), and What are The Associated Risk Factors?.

Screening

We screened in sources based on their abstracts that met these criteria:

- **Target Population Age**: Does the study include Hajj pilgrims aged 60 years or older?
- **Pilgrimage Context**: Was the study conducted during or immediately related to the Hajj pilgrimage period (not exclusively Umrah)?
- **Cardiovascular Outcomes**: Does the study report acute cardiovascular events as primary or secondary outcomes?
- **Study Design**: Is the study an observational study (cross-sectional, cohort, case-control), systematic review, or meta-analysis with adequate sample size (≥10 participants if case series)?

- **Quantifiable Data**: Does the study provide quantifiable data on cardiovascular event rates or risk factors?
- **Geographic Setting**: Was the study conducted in Saudi Arabia or does it involve official Hajj participants?
- **Actual Pilgrimage Experience**: Does the study focus on actual pilgrimage experience (not simulated pilgrimage or preparation-only studies)?
- **Pilgrim Population**: Does the study focus on pilgrim populations (not exclusively healthcare workers or non-pilgrim populations during Hajj season)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

Element	P (Population)	I (Intervention/Exposure)	C (Comparison/Context)	O (Outcome)
Keyword 1	Elderly Hajj Pilgrims	Cardiovascular Risk Factors	Age-Stratified Analysis	Acute Cardiovascular Events
Keyword 2	Aged Pilgrims	Comorbidities	Age Comparison	Cardiovascular Mortality
Keyword 3	Older Adults (≥60 years)	Hajj-Specific Stressors	Younger Pilgrims (<60 years)	Hajj Pilgrim Morbidity
Keyword 4	Geriatric Hajj Participants	Determinants	Age Gradient	Major Adverse Cardiac Events (MACE)

The Boolean MeSH keywords inputted on databases for this research are: *("Elderly Hajj Pilgrims" OR "Aged Pilgrims" OR "Older Adults (≥60 years)" OR "Geriatric Hajj Participants") AND ("Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*

Data extraction

- **Study Design**:

  Extract the study design and methodology used to investigate cardiovascular events among hajj pilgrims aged ≥60 years, including:

  - Study type (cross-sectional, cohort, case-control, case series)
  - Data collection period/years
  - Data source (e.g., SISKOHATKES, medical records, screening data)
  - Total sample size and proportion of pilgrims ≥60 years
  - Geographic origin of pilgrims (country/region)

- **Elderly Pilgrim Characteristics**:

  Extract demographic and baseline characteristics specifically for hajj pilgrims aged ≥60 years, including:

  - Number/percentage of pilgrims ≥60 years in the study
  - Age distribution within ≥60 group (60-69, 70-79, ≥80)
  - Gender distribution in elderly group
  - Health status classification (high risk/risti vs normal)

- Pre-existing comorbidities relevant to cardiovascular risk

- **Cardiovascular Event Definition**:

  Extract how acute cardiovascular events were defined and identified among hajj pilgrims, including:

  - Specific cardiovascular conditions included (acute MI, stroke, cardiac arrest, sudden cardiac death, etc.)
  - Diagnostic criteria used
  - Whether events were fatal vs non-fatal
  - Time period during hajj when events were assessed
  - Case identification method (hospital records, death certificates, clinical diagnosis)

- **Cardiovascular Event Prevalence**:

  Extract prevalence data for acute cardiovascular events specifically among hajj pilgrims aged ≥60 years, including:

  - Number of cardiovascular events in ≥60 age group
  - Prevalence rate or incidence per 100,000 pilgrims ≥60 years
  - Age-stratified rates within elderly group if available
  - Gender-specific rates in ≥60 group
  - Comparison with younger age groups (<60 years) if provided
  - Temporal trends if multiple years studied

- **Risk Factors Examined**:

Extract all potential risk factors for cardiovascular events that were investigated among hajj pilgrims, including:

- Traditional cardiovascular risk factors (hypertension, diabetes, dyslipidemia, smoking, obesity)
- Demographic factors (age categories, gender)
- Hajj-specific factors (physical exertion, heat stress, crowd density, timing during hajj)
- Other medical conditions or medications
- How each risk factor was defined and measured

- **Risk Factor Associations**:

  Extract statistical associations between risk factors and cardiovascular events among hajj pilgrims, with special attention to findings in ≥60 age group:

  - Odds ratios, relative risks, or hazard ratios with 95% confidence intervals
  - P-values for significance testing
  - Results of univariate vs multivariate analyses
  - Age-stratified analyses for ≥60 years if available
  - Interactions between age ≥60 and other risk factors
  - Non-significant associations that were tested

- **Key Findings**:

Extract the main conclusions and clinical implications regarding cardiovascular events in elderly hajj pilgrims, including:

- Primary findings about prevalence in ≥60 age group
- Most important risk factors identified for elderly pilgrims
- Clinical recommendations for cardiovascular risk management in elderly hajj pilgrims
- Comparison with general elderly population if discussed
- Authors' interpretation of results specific to aging and hajj context

- **Study Limitations**:

Extract study limitations and factors that may affect generalizability to elderly hajj pilgrims globally, including:

- Data quality issues or missing data
- Selection bias or representativeness concerns
- Limitations in cardiovascular event ascertainment
- Geographic or temporal limitations
- Sample size limitations for elderly subgroup analysis
- Other methodological constraints affecting interpretation

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	*("Elderly Hajj Pilgrims" AND "Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*	1
Semantic Scholar	*("Elderly Hajj Pilgrims" OR "Aged Pilgrims" OR "Older Adults (≥60 years)" OR "Geriatric Hajj Participants") AND ("Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*	250
Springer	*("Elderly Hajj Pilgrims" OR "Aged Pilgrims" OR "Older Adults (≥60 years)" OR "Geriatric Hajj Participants") AND ("Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*	4
Google Scholar	*("Elderly Hajj Pilgrims" OR "Aged Pilgrims" OR "Older Adults (≥60 years)" OR "Geriatric Hajj Participants") AND ("Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*	42
Wiley Online Library	*("Elderly Hajj Pilgrims" OR "Aged Pilgrims" OR "Older Adults (≥60 years)" OR "Geriatric Hajj Participants") AND ("Cardiovascular Risk Factors" OR "Comorbidities" OR "Hajj-Specific Stressors" OR "Determinants") AND ("Age-Stratified Analysis" OR "Age Comparison" OR "Younger Pilgrims (<60 years)" OR "Age Gradient") AND ("Acute Cardiovascular Events" OR "Cardiovascular Mortality" OR "Hajj Pilgrim Morbidity" OR "Major Adverse Cardiac Events (MACE)")*	2

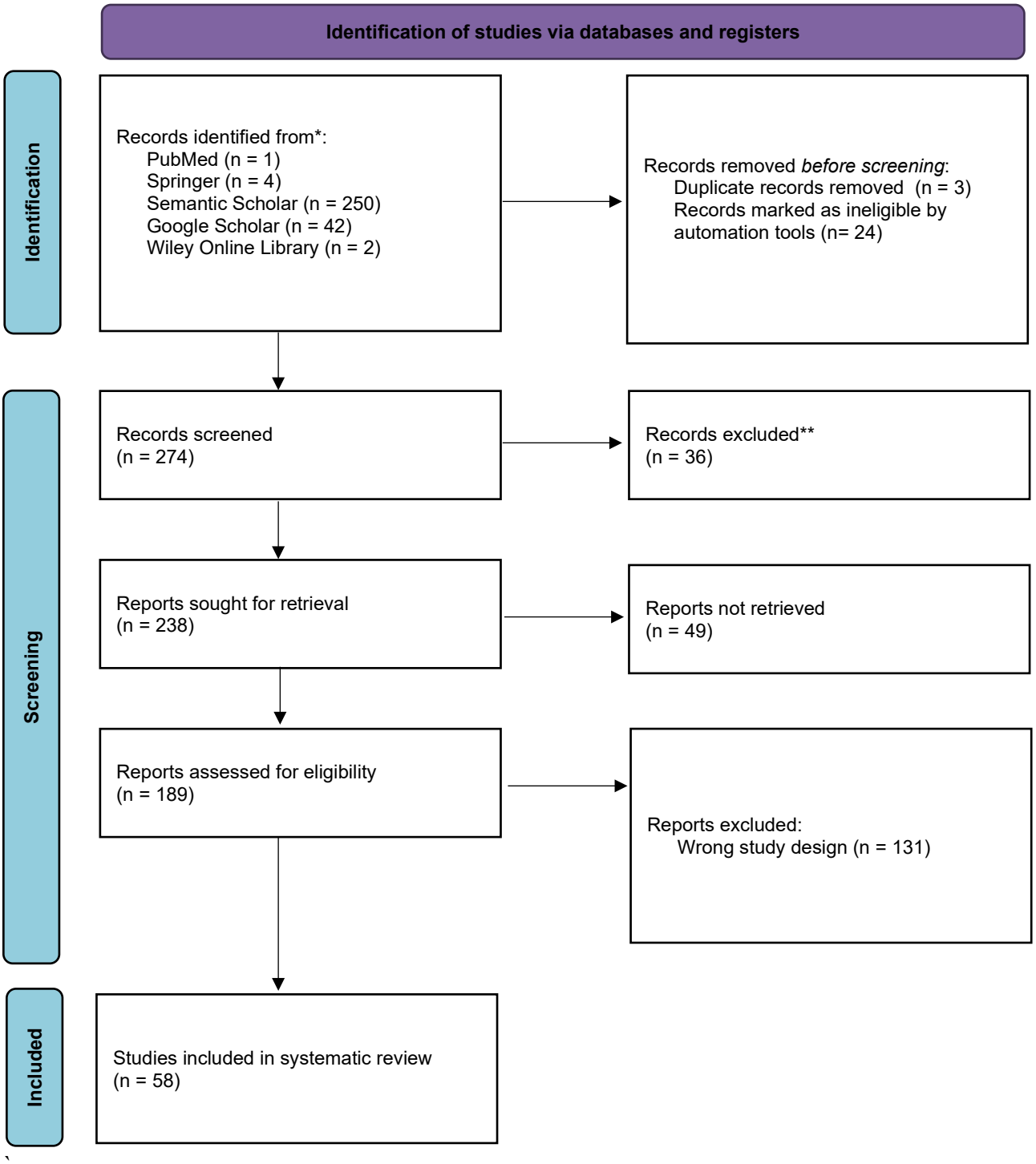

Figure 1. Article search flowchart

RESULTS

Characteristics of Included Studies

A total of 58 sources were included in this review. The majority originated from Indonesia, reflecting the country's large Hajj pilgrim population and its centralized health information system (SISKOHATKES). Study designs were predominantly cross-sectional and retrospective. Data collection periods ranged to 2025, with the greatest concentration of publications from 2020 onward. The table below summarizes the characteristics of all included studies.

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
Nooridha Febriyanti et al., 2023	2017–2023 [4]	Not specified [4]	Indonesia [4]	Mortality epidemiology trends
M. Ardiana et al., 2023	2017–2019 [1]	72,078 [1]	East Java, Indonesia [1]	CV risk factors and mortality
Nooridha Febriyanti et al., 2023a	2017–2023 [5]	2,360 deaths [5]	Indonesia [5]	Mortality epidemiology trends
Juniarty Naim et al., 2021	2019 (analyzed 2021) [13]	372 [13]	Indonesia [13]	Determinants of CHD in hospitalized pilgrims
Nasim A Khan et al., 2006	2005 [7]	689 [7]	49 countries [7]	Hospital admission patterns and mortality

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
M. Almekhlafi et al., 2017	2015 [9]	186 stroke cases [9]	Multiple nationalities [9]	Stroke incidence during Hajj
T. Turin et al., 2018	2015 [17]	186 among 2,084,238 pilgrims [17]	Multiple nationalities [17]	Stroke triggering factors
A. Serafi et al., 2010	2008 [18]	203 [18]	Multiple nationalities [18]	CV disease patterns in hospitalized pilgrims
Analisis Faktor Risiko Kejadian, 2024	2023 [2]	Not specified [2]	Indonesia [2]	Risk factors for CV mortality
Sheeren Khaled et al., 2020	2016–2019 [19]	3,044 (1,008 pilgrims) [19]	Multiple nationalities [19]	AMI outcomes in pilgrims vs non-pilgrims
Wesam M. Alghamdi et al., 2022	Up to 2020 [20]	Not applicable [20]	Various [20]	Hajj-related mortality causes
A. Shimemeri et al., 2012	No date restriction [21]	Not applicable [21]	Not specified [21]	CV disease during Hajj

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
N. Kodim et al., 2011	Not specified [22]	149,537 [22]	Indonesia [22]	Mortality determinants in pilgrims >40 years
Ityan Nuril et al., 2025	2023 [3]	17,211 [3]	Surabaya, Indonesia [3]	Risk factors for pilgrim mortality
Safaya Amada et al., 2025	2023 [11]	640 [11]	Central Java and Yogyakarta [11]	Mortality risk factors (SOC group)
F. Aboul-Enein et al., 2020	2017 [15]	300 (97 pilgrims) [15]	Not specified [15]	Heat stress, osmolarity, and AMI outcomes
Asrita Fajriani et al., 2024	2024 [23]	Not specified [23]	South Sumatra, Indonesia [23]	Age and mortality
Nurhafifah Matondang et al., 2016	2014–2015 [24]	Not specified [24]	Medan, Indonesia [24]	Disease patterns at embarkation
Dwi Handayani et al., 2017	2015 [25]	102 [25]	East Java, Indonesia [25]	Mortality prediction index

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
Maslim Syahruddin et al., 2024	2022 [26]	138 [26]	Indonesia (East Java, West Java) [26]	Wukuf safari pilgrim disease profile
Pirhossein Kolivand et al., 2024	2012–2022 [12]	459,934 [12]	Iran [12]	CVD prevalence and trends
N. W. Widhidewi et al., 2020	2018 [6]	99 [6]	Bali, Indonesia [6]	CVD risk factor identification
Siti Hatijah et al., 2019	2016–2018 [27]	Not specified [27]	Solo, Indonesia [27]	Health status and mortality
Saidah Saidah et al., 2023	2018 [28]	4,651 [28]	Aceh, Indonesia [28]	NCD determinants in pilgrims
Wiwid Pramita et al., 2025	2022–2024 [10]	1,686 [10]	Java, Indonesia [10]	Multilevel determinants of mortality
Arqu Aminuzzab et al., 2018	Not specified [29]	Not applicable [29]	Various [29]	Morbidity/mortality reduction strategies

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
Rycco Darmareja et al., 2023	2019–2023 [30]	Not applicable [30]	Various [30]	NCD management in pilgrims
Nora Wirda et al., 2025	2024 [31]	4,713 [31]	Aceh, Indonesia [31]	Hypertension risk factors
Istyarahma Kansya Kusumastuti et al., 2025	2024 [32]	217,476 [32]	Indonesia [32]	CKD risk factors in pilgrims
A. A. Harahap et al., 2025	2025 [33]	1,050 [33]	Banjarmasin, Indonesia [33]	Hypertension risk factors
Alvi Ainal Mardiyah et al., 2025	2024 [34]	Not specified [34]	Semarang, Indonesia [34]	Health istithaah policy implementation
E. Pratiwi et al., 2024	2024 [35]	8,014 [35]	DKI Jakarta, Indonesia [35]	Hypertension risk factors
Faktor Determinan Hipertensi, 2023	2022 [36]	3,339 [36]	DKI Jakarta, Indonesia [36]	Hypertension determinants

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
Asep Kusnali et al., 2020	2018 [37]	Not specified [37]	Java, Indonesia [37]	Knowledge, attitudes, practices on health istithaah
Zolaiha et al., 2019	2016 [8]	152,429 [8]	Indonesia [8]	Cardiorespiratory fitness and risk factors
Faktor Risiko yang Berhubungan, 2024	2024 [38]	Not specified [38]	Banjarmasin, Indonesia [38]	Hypertension risk factors
Y. Yusri et al., 2020	2019 [39]	313 [39]	Palembang, Indonesia [39]	Physical fitness factors
M. Ardiana et al., 2024	2023 [14]	114,069 [14]	Indonesia [14]	Dyslipidemia and hypertension
Ghina Izzatul Hashifah et al., 2024	2023 [16]	229,000 total pilgrims [16]	Indonesia [16]	Operational analysis of 2023 mortality escalation
Nerry Armis Sibuea et al., 2025	2024–2025 [40]	96 [40]	Medan, Indonesia [40]	Morbidity factors in pilgrims

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
A. F. Yusoff et al., 2018	2012–2013 [41]	781 (108 cases, 673 controls) [41]	Malaysia [41]	CAP risk factors in pilgrims
Suci Alifia et al., 2024	2024 [42]	Not specified [42]	Metro City, Indonesia [42]	Health problems of prospective pilgrims
P. M. Harsoyo et al., 2023	2022 [43]	Not specified [43]	Indonesia [43]	6MWT and CV risk factors linked to healthcare visits
Sugeng Sugeng et al., 2025	2023 [44]	1,305 [44]	Sleman, Indonesia [44]	Health istithaah status factors
H. Hendrawati et al., 2017	2017 [45]	81 elderly pilgrims [45]	Malang, Indonesia [45]	Metabolic syndrome and 6MWD
Debie Anggraini et al., 2025	2024–2025 [46]	46 [46]	Padang, Indonesia [46]	Glucose and cholesterol screening
Evi Vestabilivy et al., 2022	2019 [47]	1,034 [47]	Lumajang, Indonesia [47]	Health examination procedures
Hubungan Penyakit Jantung Koroner, 2024	2023 [48]	4,779 [48]	DKI Jakarta, Indonesia [48]	CHD and physical fitness

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
Yinxia Zhang et al., 2019	2017 [49]	1,465 [49]	Gansu, China [49]	Hypertension risk factors and RAAS polymorphisms
Puspaningdyah Ekawati et al., 2024	2024 [50]	119 [50]	Blora, Indonesia [50]	Cardiorespiratory fitness in DM pilgrims
Septya Lie Mahesti et al., 2025	2023–2024 [51]	Not applicable [51]	Indonesia [51]	Rukhshah for elderly pilgrims
Nugroho Susanto et al., 2024	2024 [52]	36,004 [52]	Central Java, Indonesia [52]	Hajj health surveillance
Vitriana Biben et al., 2023	Not specified [53]	720 [53]	Indonesia (5 embarkations) [53]	Independence, mobilization profiles
A. Wibowo et al., 2018	2016 [54]	232 [54]	Medan, Indonesia [54]	Hypertension with ACS
Ramadhani Riska et al., 2018	2018 [55]	351 [55]	Magetan, Indonesia [55]	Hypertension risk factors

Study	Data Period	Sample Size	Geographic Origin	Primary Focus
B. Roosihermiatie et al., 2009	2003 [56]	28 [56]	Indonesia [56]	Blood pressure in high-risk pilgrims
Yudik Prasetyo et al., 2017	2015 [57]	80 [57]	Indonesia [57]	Exercise intervention for elderly pilgrims
Diana Auliadina et al., 2019	Not specified [58]	60 [58]	Indonesia [58]	VO2max comparison: adult vs elderly pilgrims

The included studies span a broad range of designs and sample sizes, from small descriptive studies of 28 participants [56] to national-level analyses encompassing over 459,000 pilgrims [12]. The vast majority (approximately 50 of 58 sources) draw from Indonesian pilgrim populations, with three studies drawing from Saudi Arabian hospital data across multiple nationalities [7, 9, 18], one from Iranian pilgrims [12], one from Malaysian pilgrims [41], one from Chinese Hui pilgrims [49], and three review articles covering global literature [20, 21, 29]. This geographic concentration reflects Indonesia's position as the country with the largest annual Hajj contingent and its systematic use of the SISKOHATKES database for pilgrim health data collection.

Prevalence of Cardiovascular Events and Mortality Among Elderly Hajj Pilgrims

Direct prevalence estimates for acute cardiovascular events specifically in pilgrims aged ≥60 years were notably absent from most studies. None of the 58 sources provided an age-stratified incidence rate of cardiovascular events exclusive to pilgrims ≥60 years. However, converging evidence from mortality surveillance, hospital registries, and screening studies allows triangulation of the cardiovascular burden in this age group.

Overall Mortality Rates and Cardiovascular Contribution

Indonesian Hajj pilgrim mortality rates ranged from 90 per 100,000 in 2022 to 338 per 100,000 in 2023 [4, 5]. A retrospective cohort from East Java reported an overall death rate of 240 per 100,000 pilgrims, with cardiovascular disease (CVD) accounting for 38.2% of all deaths [1]. Analysis of 2023 Indonesian data found that 42% of the 798 deaths were attributable to cardiovascular causes [2]. A review of the broader literature concluded that CVD is consistently the leading cause of death during Hajj, followed by respiratory diseases [20, 21].

Among hospitalized pilgrims at Al-Noor Specialist Hospital in Makkah in 2005, cardiovascular conditions accounted for 34.1% of admissions, and the in-hospital mortality rate was 16.5% [7]. In the same hospital during the 2008 Hajj, heart failure constituted 67% of cardiac admissions, ischemic heart disease 21.7%, and valvular heart disease 11.3% [18]. The stroke registry from the 2015 Hajj season documented an incidence of 8.9 per 100,000 pilgrims (186 cases among approximately 2.08 million pilgrims), with a mean patient age of 60.8 ± 12.9 years and an in-hospital mortality of 11.3% [9, 9].

Elderly Pilgrims as the Predominant Affected Group

Deaths are disproportionately concentrated in pilgrims aged ≥60 years. Data from the Surabaya embarkation in 2023 showed that 81% of deceased pilgrims were over 60 years old [3]. Indonesian national data from 2017–2023 confirmed that the ≥60 age group consistently had the highest mortality, with most deaths occurring among those classified as high risk (risti) [4, 5]. In the 2023 Hajj, Indonesia recorded 773–798 deaths overall, a marked increase from 101 in 2022 [11, 16], with elderly pilgrims comprising approximately 67,199 of the total 229,000 Indonesian pilgrims [16].

Among wukuf safari participants (pilgrims with physical limitations), 59.4% were aged 60–70 years, and 77.5% had cardiovascular comorbidities [26, 26]. The proportion of high-risk pilgrims in Central Java in 2024 reached 87.9% [52], with high blood pressure, impaired lipid function, impaired cardiac function, and diabetes mellitus identified as the four most prevalent diseases [52].

Cardiovascular Risk Factor Prevalence in Elderly Pilgrims

The table below summarizes the prevalence of key cardiovascular risk factors reported across studies.

Risk Factor	Prevalence / Proportion	Population	Source
Hypertension	71.34% [8]	Indonesian pilgrims (2016, n=152,429)	Zolaiha et al., 2019
Hypertension	57% [9]	Stroke patients during Hajj (2015, n=186)	M. Almekhlafi et al., 2017
Hypertension	46.8% [35]	DKI Jakarta pilgrims (2024, n=8,014)	E. Pratiwi et al., 2024
Hypertension	41.75% [38]	Banjarmasin pilgrims (2024)	Faktor Risiko yang Berhubungan, 2024
Hypertension	38.66% [31]	Aceh pilgrims (2024, n=4,713)	Nora Wirda et al., 2025
Hypertension	37.2% [7]	Hospitalized pilgrims (2005, n=689)	Nasim A Khan et al., 2006
Hyperglycemia	43.76% [8]	Indonesian pilgrims (2016, n=152,429)	Zolaiha et al., 2019

Risk Factor	Prevalence / Proportion	Population	Source
High cholesterol	59.46% [8]	Indonesian pilgrims (2016, n=152,429)	Zolaiha et al., 2019
Hypercholesterolemia	45.7% [46]	Prospective pilgrims (2024–2025, n=46)	Debie Anggraini et al., 2025
Diabetes mellitus	40.9% [9]	Stroke patients during Hajj (2015, n=186)	M. Almekhlafi et al., 2017
Diabetes mellitus	31.9% [7]	Hospitalized pilgrims (2005, n=689)	Nasim A Khan et al., 2006
Overweight/Obesity	35.46% overweight, 12.8% obese [8]	Indonesian pilgrims (2016, n=152,429)	Zolaiha et al., 2019
CVD risk (at least one factor)	98% [6]	Bali pilgrims (2018, n=99)	N. W. Widhidewi et al., 2020
CVD prevalence (overall)	3.83% [12]	Iranian pilgrims (2012–2022, n=459,934)	Pirhossein Kolivand et al., 2024
Cardiovascular comorbidity	77.5% [26]	Wukuf safari pilgrims (2022, n=138)	Maslim Syahruddin et al., 2024

Risk Factor	Prevalence / Proportion	Population	Source
Metabolic syndrome	45.6% [45]	Elderly pilgrims ≥60 years (2017, n=81)	H. Hendrawati et al., 2017

The near-universal presence of at least one CVD risk factor (98%) among Bali pilgrims underscores the pervasiveness of cardiovascular risk in this population [6]. Among the large Iranian dataset spanning a decade, the overall CVD prevalence was 3.83%, peaking at 5.18% in 2018, with higher rates in men (4.25%) than women (3.41%) [12]. National-level Indonesian data from 2016 revealed hypertension in 71.34% and hyperglycemia in 43.76% of over 152,000 pilgrims [8].

Risk Factors Associated with Cardiovascular Events and Mortality

Age as the Dominant Risk Factor

Age ≥60 years emerged as the single most consistently identified risk factor for adverse cardiovascular outcomes, mortality, and morbidity across studies. The table below summarizes age-related risk estimates from multivariate analyses.

Study	Outcome	Age Variable	Effect Estimate	95% CI	p-value
Ityan Nuril et al., 2025	Mortality	Age (≥60 vs <60)	RRa = 5.3 [3]	Not specified [3]	<0.001 [3]
Wiwid Pramita et al., 2025	Mortality	Age (≥60 vs <60)	OR = 8.11 [10]	3.98–18.16 [10]	<0.001 [10]

Study	Outcome	Age Variable	Effect Estimate	95% CI	p-value
A. A. Harahap et al., 2025	Hypertension	Age >60 vs <40	Adjusted PR = 6.23 [33]	5.27–8.13 [33]	<0.001 [33]
Faktor Risiko yang Berhubungan, 2024	Hypertension	Age ≥80 years	Adjusted PR = 5.36 [38]	3.92–7.33 [38]	<0.001 [38]
Faktor Risiko yang Berhubungan, 2024	Hypertension	Age 60–79 years	Adjusted PR = 4.63 [38]	3.79–5.65 [38]	<0.001 [38]
Y. Yusri et al., 2020	Poor physical fitness	Age ≥60	PR = 3.601 [39]	1.897–6.837 [39]	<0.001 [39]
Nora Wirda et al., 2025	Hypertension	Age ≥60	OR = 3.5 [31]	3.08–3.95 [31]	<0.001 [31]
E. Pratiwi et al., 2024	Hypertension	Age ≥61	PR = 3.04 [35]	2.54–3.63 [35]	Not specified [35]

Study	Outcome	Age Variable	Effect Estimate	95% CI	p-value
Safaya Amada et al., 2025	Mortality	Age ≥60	OR = 3.146 [11]	Not specified [11]	<0.001 [11]
Sugeng Sugeng et al., 2025	Istithaah requiring assistance	Age ≥60	PR = 2.735 [44]	2.13–3.51 [44]	0.001 [44]
Ramadhani Riska et al., 2018	Hypertension	Age (older)	aPOR = 2.7 [55]	Not specified [55]	<0.001 [55]
Istyarahma Kansya Kusumastuti et al., 2025	CKD	Age ≥60	aPOR = 1.93 [32]	1.48–2.52 [32]	<0.001 [32]
Faktor Determinan Hipertensi, 2023	Hypertension	Age >56	PR = 1.45 [36]	1.30–1.62 [36]	Not specified [36]
N. Kodim et al., 2011	Mortality	Age 60–69	36.4% contribution to mortality [22]	Not specified [22]	Not specified [22]

Study	Outcome	Age Variable	Effect Estimate	95% CI	p-value
A. F. Yusoff et al., 2018	Community-acquired pneumonia	Age ≥60	AOR = 20.2 [41]	10.6–38.3 [41]	Not specified [41]

The effect estimates for age are remarkably large and consistent. For mortality specifically, adjusted odds ratios or risk ratios range from 3.1 to 8.1 for pilgrims ≥60 years [3, 10, 11]. For hypertension, the gradient is steep across age strata, reaching PR = 5.36 for those ≥80 years [38]. N. Kodim et al. (2011) reported that age 60–69 contributed 36.4% of total mortality, while age >79 contributed 30.0% [22]. These findings were echoed by multiple descriptive studies noting that the majority of deaths occur in pilgrims aged ≥60 [3, 5, 23].

Hypertension

Hypertension was the most frequently cited comorbidity and risk factor. Its association with adverse outcomes was confirmed in multiple analytic studies:

- Among hospitalized Indonesian pilgrims, high blood pressure was associated with CHD with OR = 2.32 (95% CI: 1.50–3.57) [13].
- For pilgrim mortality at the Surabaya embarkation, hypertension carried RRa = 3.7 ($p < 0.001$) [3].
- In the multilevel mortality analysis, hypertension had OR = 2.03 (95% CI: 1.10–3.68) [10].
- Iranian data showed high blood pressure with OR = 2.742 for CVD prevalence [12].
- Among the 6MWT cohort, hypertension was significantly correlated with healthcare visits ($p < 0.001$) [43].

Diabetes Mellitus

Diabetes emerged as a potent and consistent risk factor across multiple outcome measures:

- The strongest association was from Surabaya 2023 data, where diabetes carried RRa = 18.7 for mortality ($p < 0.001$) [3].
- For CHD among hospitalized pilgrims, high blood sugar had OR = 1.90 (95% CI: 1.06–3.40) [13].
- Age and diabetes were the only two factors significantly associated with cardiovascular mortality in the 2023 cross-sectional analysis ($p < 0.01$ for both) [2].
- Among the Iranian cohort, diabetes had OR = 1.723 for CVD [12].
- Diabetes was the strongest predictor of requiring health istithaah assistance (PR = 4.938; 95% CI: 3.354–7.270) [44].
- However, in the multilevel analysis by Wiwid Pramita et al. (2025), diabetes was not significantly associated with mortality after adjustment [10].

Dyslipidemia and Obesity

Dyslipidemia and obesity were consistently associated with cardiovascular morbidity:

- High LDL cholesterol was associated with CHD (OR = 1.82; 95% CI: 1.15–2.88) [13].
- Dyslipidemia was an independent risk factor for hypertension (OR = 1.084; 95% CI: 1.057–1.112) in the large Indonesian cohort (n = 114,069) [14].
- Excess BMI was associated with CHD (OR = 1.73; 95% CI: 1.07–2.68) [13] and with overweight being associated with higher mortality risk in the East Java cohort [1].
- Abdominal obesity was independently associated with hypertension (aPOR = 1.8; $p = 0.017$) [55], and central obesity with hypertension (adjusted PR = 61.25 in one analysis, though this CI appears potentially erroneous: 1.15–1.36) [38].

Other Cardiovascular and Cardiometabolic Risk Factors

Risk Factor	Outcome	Effect Estimate	Source
Cardiomegaly	Mortality	OR = 2.058 (95% CI: 1.195–3.543) [11]	Safaya Amada et al., 2025
Metabolic syndrome	Decreased 6MWD	adj R^2 = 17.1%, $p < 0.001$ [45]	H. Hendrawati et al., 2017
CHD diagnosis	Poor fitness	RR adjusted = 1.37 (95% CI: 1.19–1.59) [48]	Hubungan Penyakit Jantung Koroner, 2024
Chronic renal failure	CVD	OR = 2.262 [12]	Pirhossein Kolivand et al., 2024
Congestive cardiac failure	CAP (indirect CV risk)	AOR = 5.4 (95% CI: 2.0–14.7) [41]	A. F. Yusoff et al., 2018
Family history of hypertension	Hypertension	aPOR = 7.0 ($p < 0.001$) [55]	Ramadhani Riska et al., 2018
Family history of hypertension	Hypertension	Adjusted PR = 1.72 (95% CI: 1.62–1.94) [33]	A. A. Harahap et al., 2025
Anemia	Mortality	OR = 5.17 (95% CI: 0.94–18.49) [10]	Wiwid Pramita et al., 2025

Risk Factor	Outcome	Effect Estimate	Source
High-risk health status	Mortality	OR = 7.83 (95% CI: 2.99–20.49) [27]	Siti Hatijah et al., 2019
High-risk health status	Morbidity	Exp(B) = 19.745 [40]	Nerry Armis Sibuea et al., 2025
Low 6MWT (<500 m)	Healthcare visits	RR = 1.08 (95% CI: 1.04–1.12) [43]	P. M. Harsoyo et al., 2023

The composite "high-risk health status" (risti) classification, which incorporates age ≥60, pre-existing diseases, and functional limitations, showed remarkably strong associations with both mortality (OR = 7.83) [27] and morbidity (Exp(B) = 19.745) [40], reflecting its value as an integrated screening metric.

Gender

Male sex was consistently associated with higher mortality and hospitalization. Male gender was an independent predictor of both hospitalization and mortality in the East Java cohort [1]. The multilevel analysis reported OR = 1.87 (95% CI: 1.04–3.45) for male sex and mortality [10]. Male pilgrims comprised 60% of deceased pilgrims over 60 in the Surabaya data [3]. However, for hypertension specifically, gender showed no significant association in several studies [14, 31].

Hajj-Specific Environmental and Situational Factors

Several studies identified Hajj-specific triggers for cardiovascular events:

- **Heat stress and dehydration**: Ambient temperature (heat index) was an independent predictor of in-hospital mortality (p = 0.005) and was the only independent predictor for major adverse cardiac events (MACE) (p = 0.001) among ACS patients during the 2017 Hajj [15]. Higher plasma osmolarity was associated with significantly longer hospital stays

(6.7 ± 14.9 vs 4.0 ± 4.5 days, p = 0.045) and was an independent predictor of in-hospital mortality (p = 0.009) [15].

- **Temporal patterns**: Deaths peaked during the post-Arafah, Muzdalifah, and Mina (Armuzna) period [4, 5], and the highest stroke incidence was recorded on the day after Arafat [9]. The 2023 mortality escalation was attributed in part to overcrowding in Muzdalifah and logistical failures in pilgrim transport to Mina [16].

- **Pilgrim status**: Being a pilgrim was an independent predictor of in-hospital mortality in AMI patients (p = 0.005), despite pilgrims having lower rates of traditional cardiovascular risk factors than non-pilgrims [19]. This paradox may reflect delayed presentation, dehydration, physical exhaustion, and barriers to acute care during mass gatherings [19].

Non-Significant Associations

Smoking status was not significantly associated with cardiovascular mortality in several analyses [2, 39, 55]. Education and smoking were not significant risk factors for CHD in the case-control study of hospitalized Indonesian pilgrims [13]. Gender showed no significant association with hypertension in some studies [14, 31], though it was significant for mortality in others [10].

Synthesis

The central finding across these 58 sources is that cardiovascular disease is the leading cause of death and a major cause of morbidity among Hajj pilgrims, with the burden concentrated overwhelmingly in pilgrims aged ≥60 years. However, the precise incidence of acute cardiovascular events specifically in this age group remains poorly quantified, as no study provided age-stratified event rates exclusive to pilgrims ≥60 years. Instead, the evidence converges through mortality statistics (which show 81% of deaths occurring in pilgrims ≥60) [3], the dominance of cardiovascular causes among those deaths (38–42%) [1, 2], and the extremely high prevalence of modifiable cardiovascular risk factors (hypertension in up to 71% of pilgrims, hyperglycemia in 44%, hypercholesterolemia in 59%) [8].

The apparent contradiction between AMI pilgrims having fewer traditional risk factors yet worse outcomes compared to non-pilgrims [19] is best explained by Hajj-specific environmental stressors. Heat stress, measured by heat index, was the strongest predictor of MACE [15], and dehydration (elevated plasma osmolarity) independently predicted mortality [15]. These factors interact multiplicatively with the physiological vulnerability of aging: older pilgrims have diminished thermoregulatory capacity, reduced renal concentrating ability, and lower cardiovascular reserve. The temporal clustering of deaths during Armuzna [4, 5, 16] —the most physically demanding phase of Hajj, typically performed in extreme heat with high crowd density— further supports this mechanism.

The dramatically elevated mortality risk ratio for diabetes mellitus (RRa = 18.7) reported by Ityan Nuril et al. (2025) [3] stands as an outlier compared to more modest associations in other studies (OR = 1.7–1.9) [12, 13]. This likely reflects the specific context of Surabaya 2023, when the Hajj occurred during an exceptionally hot period and when operational failures compounded exposure time [16]. Diabetic pilgrims may be particularly vulnerable to dehydration-induced hyperglycemic crises under heat stress, amplifying the risk beyond what would be expected from diabetes alone. Wiwid Pramita's multilevel analysis, which did not find diabetes significant after adjustment [10], likely reflects the moderating influence of year-specific environmental conditions and the confounding role of high-risk health status classification.

The high proportion of Indonesian studies and heavy reliance on SISKOHATKES data must be considered when interpreting generalizability. Indonesian pilgrims face uniquely long waiting periods (up to 12 years) [57], meaning they age substantially between registration and departure, which may inflate the proportion of elderly and high-risk participants compared to pilgrims from countries with shorter waiting times. The Iranian dataset provides a useful counterpoint, showing a lower overall CVD prevalence (3.83%) [12], possibly reflecting different screening thresholds or a younger pilgrim demographic. Chinese Hui pilgrims showed a 47% hypertension prevalence, with additional genetic (RAAS polymorphism) contributions not examined in other populations [49].

In summary, pilgrims aged ≥60 years face a 3- to 8-fold increased risk of mortality compared to younger pilgrims [3, 10], driven primarily by cardiovascular disease in the context of

near-universal cardiovascular risk factor burden [6], with hypertension, diabetes, and dyslipidemia as the most robustly associated modifiable risk factors. The interaction between age-related physiological vulnerability and Hajj-specific environmental stressors—particularly heat exposure, dehydration, and physical exertion during Armuzna—provides a mechanistic framework that explains both the consistently elevated baseline risk and the year-to-year variability in mortality rates. Pre-departure screening using integrated risk classification (risti/high-risk status), functional capacity testing (6MWT), and metabolic profiling offers the most evidence-based approach to identifying pilgrims at highest cardiovascular risk [34, 43–45].

DISCUSSION

This systematic review of 58 studies provides the most comprehensive synthesis to date of cardiovascular outcomes and risk factors among elderly Hajj pilgrims aged ≥60 years. The findings reveal a consistent and concerning pattern: cardiovascular disease is the leading cause of death during Hajj, the burden falls disproportionately on elderly pilgrims, and this population carries an extraordinarily high prevalence of modifiable cardiovascular risk factors. However, the review also exposes critical gaps in the literature, particularly the absence of direct age-stratified incidence rates for acute cardiovascular events.

Prevalence of Cardiovascular Events: Triangulating the Evidence

Mortality data consistently demonstrate that 81% of Hajj deaths occur in pilgrims ≥60 years (3), with cardiovascular causes accounting for 38-42% of all deaths (1,2). Applying these proportions to overall mortality rates (ranging from 90-338 per 100,000 pilgrims) (4,5) suggests that cardiovascular mortality among elderly pilgrims likely ranges from approximately 30 to 140 per 100,000 elderly participants, though this remains a crude approximation requiring confirmation through targeted research.

The stroke registry data from 2015 provides one of the few age-specific insights, documenting a mean age of 60.8 ± 12.9 years among 186 stroke cases, with incidence of 8.9 per

100,000 pilgrims overall (9). Given that mean age straddles the 60-year threshold, the majority of these cases likely occurred in elderly pilgrims, though precise age stratification was not reported.

The Dominance of Age as a Risk Factor

The consistency and magnitude of age-related risk estimates across studies is striking. Adjusted odds ratios for mortality comparing pilgrims ≥60 years to younger counterparts ranged from 3.1 to 8.1 (3,10,11), with the largest effect (RRa=5.3 and OR=8.11) reported in the most recent Indonesian studies (3,10). These effect sizes substantially exceed those for most traditional cardiovascular risk factors, positioning chronological age as the single most powerful predictor of adverse outcomes.

Several mechanisms explain this age-related vulnerability. First, age is a proxy for accumulated cardiovascular risk factor burden, with the near-universal presence (98%) of at least one CVD risk factor among elderly pilgrims (6) reflecting decades of exposure. Second, aging confers physiological changes that impair homeostatic responses to environmental stressors: diminished thermoregulatory capacity, reduced cardiovascular reserve, blunted thirst response, and decreased renal concentrating ability. Third, the high prevalence of clinical and subclinical cardiovascular disease in older adults (12) provides the pathological substrate upon which pilgrimage stressors act.

The dose-response relationship observed for hypertension risk, with progressively higher prevalence ratios across age strata (60-79 years: PR=4.63; ≥80 years: PR=5.36) (38), further supports a causal interpretation of age effects rather than mere confounding.

Traditional Cardiovascular Risk Factors

Hypertension

Hypertension emerged as the most prevalent comorbidity and a consistently significant risk factor across multiple outcomes. Prevalence estimates ranged from 37.2% among hospitalized pilgrims (7) to 71.34% in population-based Indonesian screening (8), with most studies reporting rates exceeding 40% (31,35,38). The association with adverse outcomes was robust: hypertension independently predicted mortality (OR=2.03–3.7) (3,10), CHD (OR=2.32) (13), and overall CVD prevalence (OR=2.742) (12).

The mechanistic pathways linking hypertension to pilgrimage-related events are multifactorial. Chronic hypertension accelerates atherosclerosis and left ventricular hypertrophy, reducing coronary flow reserve and increasing myocardial oxygen demand. During the physical exertion of Hajj rituals, this supply-demand mismatch can precipitate acute coronary syndromes. Additionally, hypertension impairs cerebral autoregulation, increasing stroke risk during episodes of dehydration or blood pressure fluctuation. The high prevalence of undiagnosed or inadequately controlled hypertension in this population (55) amplifies these risks.

Diabetes Mellitus

Diabetes mellitus demonstrated the most variable but potentially most potent associations across studies. The extreme effect estimate from Surabaya 2023 data (RRa=18.7 for mortality) (3) stands as an outlier compared to more modest associations elsewhere (OR=1.7–1.9) (12,13). This variability likely reflects context-specific factors rather than true heterogeneity in biological effects.

The 2023 Hajj occurred during exceptionally hot conditions, with documented operational failures in pilgrim transport and overcrowding during critical phases (16). Diabetic pilgrims are particularly vulnerable to heat-related complications due to autonomic dysfunction impairing thermoregulation, increased risk of dehydration from osmotic diuresis, and susceptibility to hyperglycemic crises under stress. The interaction between diabetes and heat stress may exponentially increase mortality risk, explaining the extreme effect size observed in 2023. This interpretation is supported by Wiwid Pramita's multilevel analysis (10), which found no significant diabetes effect after adjustment, likely because year-specific environmental conditions and composite high-risk status captured the diabetes-related vulnerability through other pathways.

Dyslipidemia and Obesity

Dyslipidemia and obesity showed consistent but moderate associations with cardiovascular outcomes. High LDL cholesterol (OR=1.82) (13), excess BMI (OR=1.73) (13), and dyslipidemia as a hypertension risk factor (OR=1.084) (14) demonstrate the expected direction and magnitude of effect. The extraordinarily high prevalence of hypercholesterolemia (59.46%) (8) in the elderly pilgrim population means that even modest effect sizes translate to substantial population-attributable risk.

The association between obesity and adverse outcomes likely operates through multiple mechanisms: direct effects on cardiac workload, association with other metabolic risk factors, and mechanical limitations during physically demanding rituals. The finding that abdominal obesity independently predicted hypertension (aPOR=1.8) (55) highlights the importance of assessing obesity distribution rather than BMI alone.

Metabolic Syndrome and Functional Capacity

Hendrawati's finding that metabolic syndrome explains 17.1% of variance in six-minute walk distance (6MWD) among elderly pilgrims (45) provides important mechanistic insight linking cardiometabolic risk to functional limitation. The 6MWT, a simple and inexpensive test, integrates the physiological impact of multiple risk factors and provides a global assessment of cardiovascular reserve. Harsoyo's demonstration that lower 6MWT results (<500 m) predict healthcare facility visits (RR=1.08) (43) validates functional testing as a clinically useful screening tool.

Hajj-Specific Environmental Triggers

A key contribution of this review is the synthesis of evidence on Hajj-specific triggers that interact with underlying cardiovascular vulnerability to precipitate acute events.

Heat Stress and Dehydration

Aboul-Enein's prospective study of AMI patients during the 2017 Hajj (15) provides the most direct evidence for heat-related cardiovascular risk. Ambient temperature (heat index) independently predicted in-hospital mortality (p=0.005) and was the sole independent predictor of major adverse cardiac events (MACE) (p=0.001). Elevated plasma osmolarity, a marker of dehydration, independently predicted mortality (p=0.009) and was associated with longer hospital stays.

These findings have profound implications for elderly pilgrims. Aging is associated with decreased sweat gland output, reduced skin blood flow responsiveness, and blunted thirst perception—all compromising thermoregulatory capacity. Elderly pilgrims therefore reach higher core temperatures for a given environmental exposure and are less likely to spontaneously hydrate adequately. The combination of extreme heat (frequently exceeding 40°C during summer Hajj),

prolonged outdoor exposure during rituals, and crowded conditions limiting access to shade and water creates a perfect environment for heat-related cardiovascular events.

Temporal Patterns

The clustering of deaths during the post-Arafah, Muzdalifah, and Mina (Armuzna) period (4,5) and peak stroke incidence on the day after Arafat (9) identifies the most hazardous phase of the pilgrimage. This period encompasses the most physically demanding rituals: the standing at Arafah (requiring prolonged outdoor exposure), overnight stay at Muzdalifah (with limited facilities), and the stoning of the pillars at Mina (involving repeated walks in crowded conditions). The temporal pattern supports a causal role for cumulative physical exertion and environmental exposure, rather than random distribution of events.

The 2023 mortality escalation, attributed to overcrowding in Muzdalifah and logistical failures in pilgrim transport to Mina (16), demonstrates how operational factors can amplify environmental risks. When elderly pilgrims are forced to walk longer distances without adequate rest, hydration, or access to medical care, the cardiovascular consequences can be catastrophic.

The Pilgrim Paradox

Khaled's observation that AMI pilgrims had worse outcomes despite fewer traditional risk factors compared to non-pilgrims (19) deserves careful consideration. Several explanations may account for this paradox. First, pilgrims may delay seeking care due to religious commitments, language barriers, or unfamiliarity with local healthcare systems, presenting with more advanced disease. Second, the unique stressors of pilgrimage—dehydration, exhaustion, heat stress—may precipitate more severe presentations or complicate management. Third, barriers to timely reperfusion during mass gatherings may compromise outcomes even when patients reach care. This finding underscores that pilgrimage-specific factors can outweigh traditional risk profiles in determining prognosis.

Integrated Risk Stratification

The consistent finding that composite "high-risk health status" (risti) classification strongly predicts both mortality (OR=7.83) (27) and morbidity (Exp(B)=19.745) (40) validates the Indonesian approach to integrated risk assessment. This classification incorporates age ≥60 years,

pre-existing diseases, and functional limitations—capturing the multidimensional nature of pilgrimage vulnerability better than any single risk factor.

The value of functional testing (6MWT) as an objective measure of cardiovascular reserve (43,45) and the strong association between CHD diagnosis and poor fitness (RR=1.37) (48) support incorporating objective functional assessment into pre-departure screening. Similarly, the association between low 6MWT and healthcare visits (43) provides a clinically meaningful outcome measure for risk stratification.

Geographic and Population Considerations

The predominance of Indonesian studies (approximately 50 of 58 sources) raises important questions about generalizability. Indonesian pilgrims face uniquely long waiting periods (up to 12 years) (57), meaning they age substantially between registration and departure. This may inflate the proportion of elderly and high-risk participants compared to pilgrims from countries with shorter waiting times. Additionally, Indonesian healthcare infrastructure and pre-departure screening protocols may differ from other sending countries.

The Iranian dataset provides a useful counterpoint, showing lower overall CVD prevalence (3.83%) (12), possibly reflecting different screening thresholds, younger pilgrim demographics, or genuine population differences in cardiovascular risk. The Chinese Hui pilgrims study (49) adds genetic dimension, identifying RAAS polymorphisms associated with hypertension risk not examined in other populations. These geographic variations suggest that while the general patterns identified in this review likely apply broadly, precise risk estimates may require population-specific calibration.

Methodological Limitations and Research Gaps

This review's findings must be interpreted in light of several limitations spanning both primary studies and the review process itself.

CONCLUSION AND RECOMMENDATIONS

Summary of Findings

This systematic review of 58 studies examining cardiovascular outcomes in Hajj pilgrims yields several definitive conclusions:

1. **Cardiovascular disease is the leading cause of Hajj-related mortality**, accounting for 38-42% of all deaths during the pilgrimage (1,2). This finding is remarkably consistent across studies spanning nearly two decades and multiple geographic settings.

2. **Elderly pilgrims (≥60 years) bear the overwhelming burden of this mortality**, comprising 81% of all Hajj deaths (3). The concentration of deaths in this age group reflects the convergence of high cardiovascular risk factor prevalence, age-related physiological vulnerability, and exposure to extreme environmental stressors.

3. **Age ≥60 years is the dominant independent risk factor** for adverse outcomes, with adjusted effect estimates ranging from 3.1 to 8.1 compared to younger pilgrims (3,10,11). This effect size exceeds those for most traditional cardiovascular risk factors.

4. **Traditional cardiovascular risk factors are extraordinarily prevalent** in this population: hypertension (up to 71.34%), hyperglycemia (43.76%), and hypercholesterolemia (59.46%) (8). The near-universal presence of at least one risk factor (98% in some cohorts) (6) establishes a high baseline vulnerability.

5. **Diabetes mellitus demonstrates particularly potent associations** with mortality in certain contexts (RRa=18.7 in 2023 data) (3), likely reflecting synergistic effects with heat stress and dehydration that require targeted preventive interventions.

6. **Hajj-specific environmental triggers—particularly heat stress and dehydration—are critical determinants** of cardiovascular events (15). Ambient temperature independently predicts MACE and mortality, while temporal clustering of deaths during the physically demanding Armuzna phase (4,5) implicates cumulative exertion and environmental exposure.

7. **Integrated risk stratification using composite measures** (risti/high-risk status, 6MWT functional capacity) outperforms individual risk factor assessment in identifying vulnerable pilgrims (27,40,43,45).

Direct Answer to Research Questions

What is the prevalence of acute cardiovascular events among elderly Hajj pilgrims (≥60 years)?

Triangulating mortality data (81% of deaths in elderly, 38-42% cardiovascular) with overall mortality rates (90-338 per 100,000) suggests cardiovascular mortality among elderly pilgrims likely ranges from approximately 30-140 per 100,000 elderly participants. This represents a conservative estimate, as it excludes non-fatal events and assumes cardiovascular proportion is similar across age groups (likely an underestimate given higher cardiovascular mortality in elderly).

What are the associated risk factors?

The evidence definitively identifies: (1) age ≥60 years as the dominant risk factor; (2) hypertension, diabetes mellitus, and dyslipidemia as consistently significant modifiable risk factors; (3) male gender as a modest independent predictor; (4) composite high-risk health status as a powerful integrated measure; and critically, (5) Hajj-specific environmental factors (heat stress, dehydration, physical exertion during Armuzna) as essential triggers interacting with underlying vulnerability.

Recommendations

For Clinical Practice:

- Implement integrated pre-departure screening combining age, comorbidities, and functional capacity (6MWT)
- Develop enhanced protocols for diabetic pilgrims emphasizing heat avoidance and hydration
- Ensure medication optimization and clear adherence plans pre-departure

For Healthcare Delivery During Hajj:

- Prioritize heat exposure mitigation during Armuzna through environmental interventions

- Train healthcare workers in atypical presentations of cardiovascular events in elderly
- Establish low-threshold access to medical evaluation for high-risk pilgrims during critical periods

For Policy:

- Consider enhanced support requirements for elderly pilgrims
- Develop internationally harmonized health certification standards
- Invest in standardized cardiovascular surveillance with age-stratified data collection

For Future Research:

- Conduct prospective cohort studies specifically designed to measure age-stratified incidence of acute cardiovascular events using standardized definitions
- Investigate mechanisms underlying the diabetes-heat stress interaction
- Evaluate effectiveness of specific interventions (hydration protocols, cooling strategies) in randomized trials
- Develop and validate prediction models incorporating both traditional risk factors and pilgrimage-specific variables
- Examine genetic and population-specific factors influencing cardiovascular risk (49)

Concluding Statement

The Hajj pilgrimage represents a unique confluence of spiritual devotion, advanced age, chronic disease burden, and extreme environmental stress. For elderly pilgrims with cardiovascular risk factors, this combination creates substantial vulnerability to acute cardiovascular events. The evidence synthesized in this review demonstrates that while the precise incidence of such events remains imperfectly quantified, their impact is substantial and disproportionately borne by pilgrims aged ≥60 years. The path forward requires not merely better data, but systematic application of

existing knowledge through integrated risk stratification, targeted interventions for the most vulnerable, and operational planning that recognizes the physiological limits of aging in extreme environments. Only through such comprehensive approaches can the growing population of elderly pilgrims perform their spiritual duties with acceptable cardiovascular risk.

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