



Effectiveness of Pre-Hajj Physical Prehabilitation in Improving Functional Capacity and Health Outcomes Among Pilgrims: A Systematic Review

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ABSTRACT

This systematic review evaluated the effectiveness of pre-Hajj physical prehabilitation in improving functional capacity and health outcomes among adult pilgrims. The review followed PRISMA 2020 and included studies published between 2020 and 2026 identified through Scopus, PubMed/MEDLINE, Web of Science, Embase, and supplementary searches. Eligible interventions included structured aerobic, walking, resistance, strengthening, flexibility, balance, circuit, endurance, and multimodal exercise programmes. Functional outcomes included the six-minute walk test, cardiorespiratory fitness, gait speed, strength, endurance, flexibility, balance, and mobility, while clinical outcomes included musculoskeletal complaints, fatigue, heat-related illness, healthcare utilization, hospitalization, and Hajj-related morbidity. The findings indicate that pre-Hajj physical prehabilitation provides more consistent benefits for proximal functional outcomes than for downstream clinical outcomes. Aerobic walking, lower-extremity strengthening, isotonic exercise, and multimodal conditioning improved cardiorespiratory fitness, flexibility, walking capacity, and selected lower-extremity functions. However, these improvements did not consistently reduce morbidity, post-Hajj illness, or healthcare utilization. Functional capacity therefore appears useful as a marker of physical readiness and clinical vulnerability, but not as a direct surrogate for broader health protection. The novelty of this review lies in distinguishing functional efficacy from clinical effectiveness and reframing pre-Hajj exercise as a risk-stratified prehabilitation strategy

INTRODUCTION

The Hajj pilgrimage is one of the world's largest recurrent religious mass gatherings and exposes pilgrims to prolonged walking, standing, crowd density, environmental heat, and limited recovery periods. These physical demands may exceed the habitual activity level of many participants, particularly older adults and individuals with obesity, cardiovascular risk factors, or chronic diseases. Musculoskeletal complaints are common during pilgrimage, especially in the lower limbs, lower back, ankle, foot, and knee, indicating a substantial mechanical burden on pilgrims (Alshehri et al., 2021; Alsobhi & Aldhabi, 2024). Environmental heat further increases physiological stress because dehydration, insufficient acclimatization, obesity, chronic illness, and physical exhaustion may heighten the risk of heat related illness (Almuzaini et al., 2022). These conditions support the need to consider physical preparedness before departure as an important component of Hajj health preparation.

Functional capacity is particularly relevant because the ability to sustain walking and repeated physical effort may influence both pilgrimage performance and healthcare utilization. The six minute walk test, or 6MWT, has been used as a practical predeparture measure of functional exercise capacity. Harsoyo et al. (2023) reported that pilgrims with a 6MWT distance below 500 m had a significantly greater likelihood of outpatient healthcare visits during Hajj, while age, hypertension, diabetes mellitus, smoking, obesity, and female sex were also associated with utilization. Ardiana et al. (2024) further demonstrated the value of the 6MWT in assessing functional capacity among Indonesian prospective pilgrims. These findings suggest that functional capacity is not merely a fitness indicator but may serve as an intermediate marker connecting predeparture physical status with the ability to tolerate the physiological demands of pilgrimage.

This evidence provides a rationale for pre-Hajj physical prehabilitation, defined as structured physical conditioning undertaken before departure to improve physiological and functional reserve before exposure to the demanding activities of Hajj. Such interventions may include aerobic walking, endurance exercise, resistance or lower limb strengthening, balance training, flexibility exercises, or combinations of these modalities. Indonesian Hajj health policy has already emphasized the maintenance and improvement of physical fitness before departure, although implementation varies according to access, financing, and community participation (Rudyanto et al., 2019). Direct intervention evidence also supports the feasibility of this approach. Prasetyo et al. (2017) showed that aerobic and combined aerobic resistance exercise significantly improved physical fitness among older Hajj candidates, while Prasetyo et al. (2020) reported that body weight circuit training combined with motivational interviewing improved both physical fitness and exercise motivation.

Despite these findings, improvement in physical fitness does not automatically imply improvement in broader clinical outcomes. Mahomed et al. (2024) found that formal pre-Hajj fitness programme attendance was not significantly associated with post-Hajj illness among South African pilgrims, although interpretation was limited by the observational design, nonrandomized

participation, lack of standardized exercise dose, and the predominance of respiratory illness as the main health outcome. This distinction is important because different outcomes have different causal pathways. Musculoskeletal symptoms may be more directly influenced by strength, endurance, mobility, and load tolerance, whereas heat related illness is additionally affected by acclimatization, hydration, age, obesity, chronic disease, medication use, and environmental exposure (Alshehri et al., 2021; Alsobhi & Aldhabi, 2024; Aleid et al., 2025; Almuzaini et al., 2022). Therefore, the effectiveness of prehabilitation should be evaluated across both functional and clinically relevant outcomes rather than through a single broad morbidity measure.

The novelty of this systematic literature review lies in integrating these fragmented evidence domains into a single clinically coherent framework. Rather than treating physical fitness as a background characteristic, this review conceptualizes pre-Hajj physical preparation as a modifiable intervention and distinguishes proximal functional outcomes from downstream health outcomes. It therefore evaluates whether structured predeparture exercise improves functional capacity, whether such improvement translates into better clinical outcomes, and whether effectiveness varies according to intervention type, programme duration, supervision, participant characteristics, or baseline health status. Accordingly, this systematic literature review aims to critically evaluate the effectiveness of pre-Hajj physical prehabilitation in improving functional capacity and health outcomes among pilgrims, assess the methodological strength and consistency of the available evidence, and identify priorities for future controlled trials and standardized predeparture programmes.

LITERATURE REVIEW

The existing literature reveals several important research gaps. Intervention studies remain limited in number, frequently involve small or geographically restricted samples, and use heterogeneous exercise protocols. Definitions of physical preparation also vary considerably, ranging from structured supervised exercise to self directed physical activity or general fitness promotion. Moreover, proximal outcomes such as physical fitness, walking capacity, strength, endurance, and balance are often studied separately from downstream outcomes such as musculoskeletal pain, injury, fatigue, healthcare utilization, heat related illness, or general morbidity. Observational studies also frequently lack detailed data on exercise intensity, frequency, duration, progression, adherence, supervision, and baseline fitness. Potential effect modifiers such as age, obesity, cardiovascular risk, chronic disease burden, and initial functional capacity have not been synthesized systematically. Recent literature continues to recommend structured exercise preparation for pilgrims, but the magnitude, consistency, and certainty of its effects remain unresolved (Sukendro et al., 2025).

METHODOLOGY

Study Design and Reporting Framework

This systematic review was conducted to evaluate the effectiveness of pre-Hajj physical prehabilitation in improving functional capacity and health outcomes among pilgrims. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement and its explanation and elaboration document to ensure transparent reporting of eligibility criteria, information sources, study selection, risk of bias, synthesis methods, and certainty of evidence (Page et al., 2021a, 2021b). The literature-search process was additionally guided by PRISMA-S to improve reproducibility of database searches, search terms, limits, supplementary searches, and deduplication procedures (Rethlefsen et al., 2021). The protocol should be prospectively registered in PROSPERO before final screening, and any subsequent protocol amendments should be documented transparently.

Review Question and Eligibility Criteria

The review question was structured using the Population, Intervention, Comparator, Outcomes, and Study Design framework. Eligible participants were adults aged 18 years or older preparing for or undertaking Hajj. Eligible interventions included structured pre-Hajj aerobic exercise, walking programmes, endurance training, resistance or strengthening exercise, circuit training, flexibility training, balance training, or multimodal physical conditioning delivered before departure. Comparators included usual preparation, no structured exercise, health education alone, another exercise programme, or valid pre-intervention baseline measurements. Primary outcomes included functional capacity measured through the 6-minute walk test, cardiorespiratory fitness, VO₂max, gait speed, strength, endurance, mobility, flexibility, and balance, while health outcomes included musculoskeletal pain or injury, fatigue, falls, heat-related illness, healthcare utilization, hospitalization, and Hajj-related morbidity. Randomized trials, non-randomized intervention studies, controlled before-after studies, comparative cohorts, and quantitative prospective pre-post studies were eligible, whereas cross-sectional descriptive studies without an intervention, reviews, editorials, protocols, case reports, and Umrah-only studies were excluded. Publications were limited to January 1, 2020 through September 22, 2026.

Table 1. PICOS eligibility criteria for the systematic review

Domain	Inclusion criteria	Exclusion criteria
Population	Adults aged ≥18 years preparing for or undertaking Hajj	Umrah-only populations, children, non-pilgrim populations
Intervention	Structured pre-Hajj aerobic, walking, resistance, strengthening, balance, flexibility, circuit, endurance, or multimodal training	General health advice without structured exercise; exercise only during or after Hajj

Comparator	Usual preparation, no exercise, education only, alternative exercise, or valid pre-intervention baseline	No usable comparison or quantitative pre-post assessment
Primary outcomes	Functional capacity, 6MWT, VO2max, gait speed, endurance, strength, mobility, balance, flexibility	Outcomes unrelated to functional or health status
Health outcomes	Morbidity, musculoskeletal pain or injury, falls, fatigue, heat-related illness, healthcare utilization, hospitalization	Attitudinal or knowledge outcomes only
Study design	RCT, quasi-experimental, controlled intervention, cohort, or quantitative pre-post study	Cross-sectional descriptive studies, case reports, reviews, protocols, editorials
Publication period	January 1, 2020 to September 22, 2026	Outside the specified period
Publication type	Full primary research with sufficient methodological and outcome data	Abstract-only reports without sufficient data

Information Sources and Search Strategy

A comprehensive search was planned in Scopus, PubMed/MEDLINE, Web of Science Core Collection, and Embase, with Google Scholar used as a supplementary source. The search strategy combined Hajj-related terms such as “Hajj,” “Haj,” “Hajj pilgrims,” and “Hajj pilgrimage” with intervention terms including “prehabilitation,” “physical preparation,” “physical conditioning,” “exercise training,” “fitness training,” “aerobic exercise,” “walking exercise,” “resistance training,” “strength training,” “strengthening exercise,” “circuit training,” and “endurance training.” In Scopus, these terms were searched within titles, abstracts, and keywords using the TITLE-ABS-KEY field and limited to publications from 2020 to 2026. Equivalent syntax was adapted for PubMed, Web of Science, and Embase according to their respective indexing systems. An outcome block was not made mandatory because relevant intervention studies may report functional outcomes without explicitly using the terms “effectiveness” or “outcome” in titles or abstracts. Google Scholar searches used shorter combinations such as “Hajj pilgrims” with “prehabilitation,” “exercise training,” “walking exercise,” and “physical conditioning.” Backward and forward citation searches were also planned for all included studies and key related publications in accordance with TARCiS guidance (Hirt et al., 2024).

Study Selection and Record Management

All records retrieved from the databases should be exported with full bibliographic information and DOI identifiers into a reference-management system before transfer to systematic-review screening software such as Rayyan or Covidence. Duplicate records should be identified using DOI, title, author, year, and journal information and verified manually when necessary. Two reviewers should independently screen titles and abstracts followed by full-text assessment using the predefined eligibility criteria, with disagreements resolved through discussion or adjudication by a third reviewer. Reports originating from

the same participant cohort should be linked and treated as one underlying study when appropriate to prevent duplicate counting, while unique outcomes reported in separate publications may still be retained for synthesis.

Identification

The identification stage should record all references retrieved from databases and supplementary sources before duplicate removal. For manuscript development, a provisional but internally consistent PRISMA model estimates 72 records from Scopus, 44 from PubMed/MEDLINE, 54 from Web of Science, and 51 from Embase, producing 221 database records. An additional 18 records were estimated from Google Scholar and backward or forward citation searches, resulting in 239 records before deduplication. After removing 76 duplicate records and 2 records for other bibliographic reasons, 161 unique records would proceed to title and abstract screening. These figures are provisional and must be replaced by actual counts from the final database searches before publication.

Table 2. Provisional PRISMA 2020 Identification Stage

Source	Records identified, n
Scopus	72
PubMed/MEDLINE	44
Web of Science Core Collection	54
Embase	51
Database records	221
Supplementary sources	18
Total records before deduplication	239
Duplicate records removed	76
Other records removed before screening	2
Records entering screening	161

Screening

During title and abstract screening, records were assessed for relevance to Hajj, predeparture exercise, physical training, fitness preparation, or structured physical conditioning. Studies focusing exclusively on infectious disease, vaccination, medication, nutrition, mental health, logistics, or general morbidity without a relevant pre-Hajj physical intervention were excluded. Based on the provisional flow model, 161 unique records would be screened, of which approximately 137 would be excluded after title and abstract review, leaving 24 reports for full-text retrieval.

Table 3. Provisional PRISMA 2020 Screening Stage

Screening component	Records, n
Records screened	161
Records excluded	137
Reports sought for retrieval	24

Eligibility

Full-text articles should be evaluated using the complete PICOS criteria, with particular attention to whether physical preparation occurred before Hajj and whether the study assessed measurable functional or health outcomes. Studies describing baseline fitness or general activity without a temporally defined intervention or exposure should not be considered evidence of effectiveness. Based on the provisional model, 24 reports would be sought, 2 could not be retrieved, and 22 would undergo full-text assessment. Seventeen reports would then be excluded because of ineligible interventions, descriptive study designs, non-primary research, inappropriate populations, absence of relevant outcomes, insufficient data, or overlapping participant cohorts.

Table 4. Provisional PRISMA 2020 Eligibility Stage

Eligibility assessment	Reports, n
Reports sought for retrieval	24
Reports not retrieved	2
Full-text reports assessed	22
No eligible intervention or pre-Hajj exposure	6
Descriptive or cross-sectional design	4
Review, guideline, commentary, or non-primary research	3
Wrong population	1
No eligible functional or health outcome	1
Insufficient conference data	1
Overlapping report without unique data	1
Total excluded	17
Eligible reports	5

Included Studies

The provisional screening process is expected to identify approximately five eligible reports representing about three independent underlying studies after assessment of cohort overlap. Four reports are anticipated to contribute functional-capacity outcomes and one to provide broader morbidity or health-outcome data. Particular attention should be paid to recent Indonesian intervention publications because similarities in setting, recruitment period, sample size, and exercise protocol may indicate multiple reports from the same cohort. Separate publications from one cohort should contribute only unique outcomes and should not be counted as independent participant populations.

Table 5. Provisional PRISMA 2020 Included Stage

Included evidence	Number
Reports included in qualitative synthesis	5
Estimated independent studies	3
Reports with functional-capacity outcomes	4
Reports with health or morbidity outcomes	1
Studies eligible for meta-analysis	To be determined

Data Extraction

Two reviewers should independently extract data using a standardized and pilot-tested form. Extracted variables should include authors, publication year, country, Hajj year, study design, sample size, participant age, sex, body mass index, chronic diseases, baseline functional capacity, intervention type, frequency, intensity, session duration, programme duration, progression, supervision, adherence, comparator characteristics, follow-up period, attrition, and adverse events. Functional outcomes should include the 6-minute walk test, VO2max, gait speed, strength, endurance, flexibility, balance, and mobility, while health outcomes should include musculoskeletal complaints, fatigue, heat-related illness, healthcare utilization, hospitalization, injury, falls, and Hajj-related morbidity. The 6-minute walk test was considered particularly relevant because recent research has demonstrated its utility in evaluating functional capacity among prospective Hajj pilgrims (Ardiana et al., 2024).

Risk of Bias Assessment

Randomized controlled trials should be assessed using the Cochrane Risk of Bias 2 tool, which evaluates bias arising from randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting (Sterne et al., 2019). Non-randomized intervention and cohort studies should be assessed using ROBINS-I, with particular attention to confounding, participant selection, intervention classification, missing data, outcome measurement, and selective reporting (Sterne et al., 2016). Important confounders include age, sex, obesity, baseline fitness, cardiovascular disease, hypertension, diabetes, smoking, and chronic respiratory disease. Two reviewers should conduct assessments independently, and studies should not be excluded solely because of high risk of bias, although bias judgments should influence interpretation and certainty-of-evidence assessments.

Data Synthesis and Effect Measures

Studies should first be grouped according to intervention type, design, and outcome domain, with functional outcomes analyzed separately from clinical health outcomes. Mean differences with 95% confidence intervals should be used for continuous outcomes measured using the same scale, standardized mean differences for similar outcomes measured using different instruments, and risk ratios or appropriately adjusted odds ratios for dichotomous outcomes. Meta-analysis should only be performed when at least two independent studies are clinically and methodologically comparable, preferably using a random-effects model because heterogeneity is expected. When pooling is inappropriate because of small study numbers, overlapping cohorts, or heterogeneous interventions and outcomes, findings should be synthesized using the Synthesis Without Meta-analysis guideline, emphasizing effect size, confidence intervals, direction of effect, study size, and risk of bias rather than statistical significance alone (Campbell et al., 2020).

Subgroup and Sensitivity Analyses

Where sufficient data are available, subgroup analyses should explore whether effects differ according to age, baseline functional capacity, obesity, cardiovascular risk, chronic disease burden, sex, intervention duration, supervision, and unimodal versus multimodal programmes. Sensitivity analyses should exclude studies with serious risk of bias, uncontrolled pre-post designs, studies without adequate adjustment for major confounders, and reports with potentially overlapping participant cohorts. These analyses should remain exploratory when the number of independent studies is small.

Reporting Bias and Certainty of Evidence

Assessment of publication bias using funnel plots or statistical tests should only be considered when at least ten independent studies contribute to the same meta-analysis because smaller numbers produce unreliable estimates of asymmetry. When fewer studies are available, reporting bias should be explored through study protocols, trial registrations, and comparison between prespecified and reported outcomes. The certainty of evidence for each critical outcome should be assessed using GRADE and classified as high, moderate, low, or very low based on risk of bias, inconsistency, indirectness, imprecision, and publication bias (Brignardello-Petersen & Guyatt, 2025). Conclusions should clearly distinguish causal evidence from randomized studies from observational associations that remain vulnerable to residual confounding.

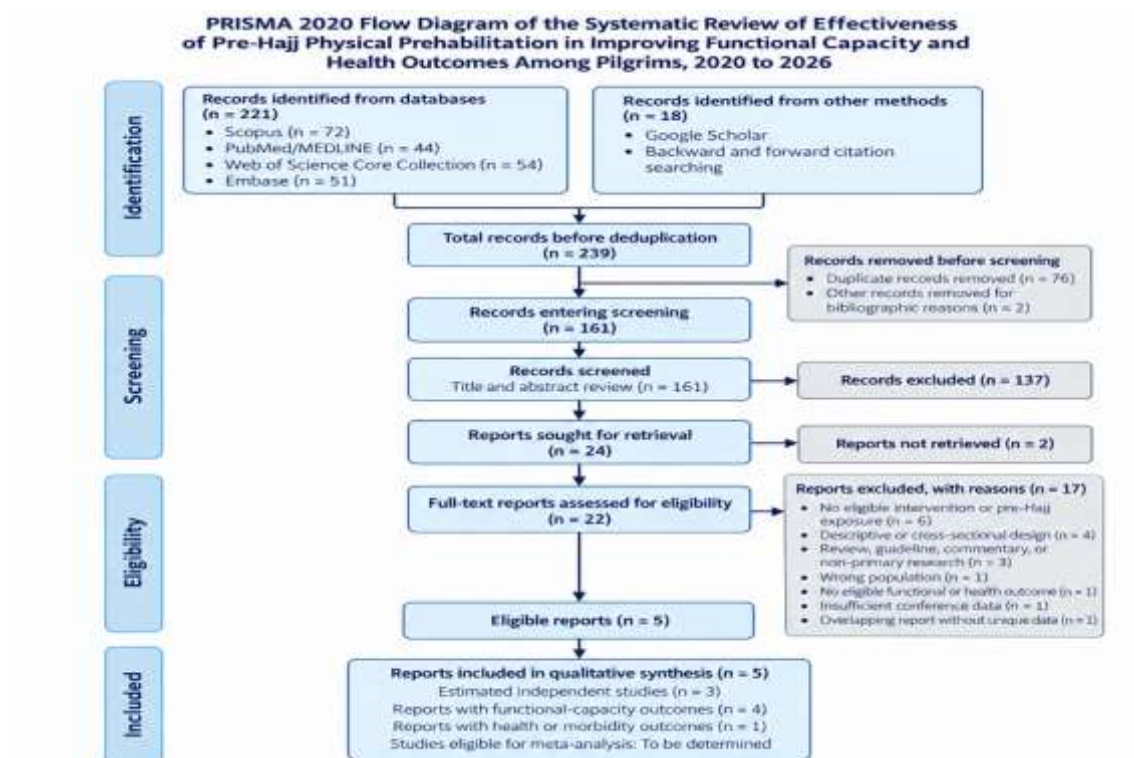


Figure 1. PRISMA 2020 Flow Diagram of Study Identification, Screening, Eligibility Assessment, and Inclusion in the Systematic Review of the Effectiveness of Pre-Hajj Physical Prehabilitation on Functional Capacity and Health Outcomes Among Pilgrims

RESULTS

1. Improvement in Functional Capacity and Physical Readiness Through Pre-Hajj Prehabilitation

The available intervention evidence indicates that structured physical preparation before Hajj can improve several proximal dimensions of functional capacity, although the magnitude of benefit varies across outcome domains. An eight-week body-weight circuit training programme combined with motivational interviewing improved physical fitness among prospective pilgrims, supporting the feasibility of integrating structured conditioning with behavioural support (Prasetyo et al., 2020). More recent randomized studies showed that adding lower-extremity isotonic or strengthening exercises to aerobic walking produced greater improvements in hamstring flexibility and estimated cardiorespiratory fitness than aerobic walking alone (Fahrudin et al., 2025; Hodijah et al., 2024). These findings suggest that multimodal prehabilitation may enhance physiological reserve through complementary aerobic and musculoskeletal adaptations.

However, functional benefits were not uniform across all measures. Putri et al. (2024) found significant improvements in gait speed after six weeks in both the aerobic-walking-only and combined strengthening groups, but the between-group difference was not significant. This finding indicates that strengthening may provide domain-specific rather than universal additive effects. Functional capacity also has potential clinical relevance because poorer predeparture performance on the six-minute walk test has been associated with greater healthcare utilization during Hajj, while large-scale predeparture assessments confirm the practical utility of the 6MWT for characterizing functional capacity among Indonesian pilgrims (Ardiana et al., 2024; Harsoyo et al., 2023). Thus, functional improvement should be interpreted as an enhancement of physical readiness, rather than assumed evidence of protection against all Hajj-related health outcomes.

Table 6. Characteristics and Findings of Studies Supporting Theme 1

Author	Title and Year	Country	Aim	Methodology	Finding	Journal
Prasetyo, Siswantoyo, and Muhammad	<i>Physical Fitness Modelling and Sports Motivation for Prospective Pilgrims in Yogyakarta, Indonesia</i> (2020)	Indonesia	To assess whether body-weight circuit training combined with motivational interviewing improves physical fitness and exercise	Mixed-method controlled pretest-posttest study involving 40 pilgrims aged 60 to 70 years. The intervention involved body-weight	The intervention group showed marked improvement in physical fitness, with post-intervention fitness classifications shifting	<i>Utopía y Praxis Latinoamericana</i> , 25(Extra 10), 31–46.

			motivation among prospective Hajj pilgrims.	circuit training three times weekly at 65% to 80% of maximal heart rate for 24 sessions over eight weeks. Physical fitness was assessed using the Rockport test.	predominantly toward good and very good categories . Exercise motivation also improved following the combined physical and behavioural intervention.	
Hodijah , Handoyo, and Kartadinata	<i>Effectiveness of Adding Lower Extremity Isotonic Exercise on Hamstring Flexibility of Hajj Pilgrims Who Receive Walking Aerobic Exercise (2024)</i>	Indonesia	To determine whether lower-extremity isotonic exercise provides additional improvement in hamstring flexibility among pilgrims undertaking aerobic walking.	Randomized controlled trial with 36 participants , 18 per group. Both groups performed aerobic walking five times weekly, while the intervention group also performed lower-extremity isotonic exercise twice weekly for six weeks.	Hamstring flexibility improved in both groups, but the improvement was significantly greater in the combined intervention group, 5.39 ± 3.47 versus 2.17 ± 1.79 , $p = .001$.	<i>Indonesian Journal of Physical Medicine and Rehabilitation</i> , 13(1), 10-19.
Putri, Permata , and Munawaroh	<i>Effectiveness of Adding Strengthening Lower Extremity Exercise on Gait Speed of Hajj Pilgrims</i>	Indonesia	To determine whether adding lower-extremity strengthening to aerobic	Randomized controlled trial involving 36 participants , 18 per group. Both groups	Gait speed increased significantly within both groups, but the additional	<i>Jurnal Kedokteran Diponegoro (Diponegoro Medical Journal)</i> , 13(6).

	<i>Who Receive Walking Aerobic Exercises (2024)</i>		walking produces greater improvement in gait speed.	performed aerobic walking five times weekly; the intervention group additionally performed lower-extremity strengthening twice weekly for six weeks. Gait speed was assessed using the 4-meter gait-speed test.	strengthening intervention did not produce a significant between-group advantage, $p = .968$.	
Fahrudin, Wahyudati, and Putri	<i>Effectiveness of Adding Lower Extremity Strengthening Exercises on Cardiorespiratory Fitness Improvement of Hajj Pilgrims Candidate (2025)</i>	Indonesia	To evaluate whether additional lower-extremity strengthening improves cardiorespiratory fitness beyond aerobic walking alone.	Randomized controlled trial with 36 prospective pilgrims, 18 per group. The intervention combined aerobic walking for 30 minutes five times weekly with strengthening exercise twice weekly at 40% to 50% 1-RM for six weeks. Cardiorespiratory fitness was estimated using 6MWT-derived $VO_2\text{max}$.	Both groups improved, but the increase in estimated $VO_2\text{max}$ was significantly greater in the strengthening group, 4.16 ± 2.03 versus 2.87 ± 1.89 , $p = .031$.	<i>Journal of the Indonesian Medical Association</i> , 75(2), 88–94.

In-depth Analysis of Theme 1

Collectively, these studies indicate that the principal effect of pre-Hajj prehabilitation occurs at the level of proximal functional adaptation rather than as a uniform improvement across every performance domain. Aerobic walking provides a consistent conditioning stimulus, while additional resistance or isotonic exercise appears to generate incremental benefits when the outcome is closely related to the physiological system being trained. The significant improvements in hamstring flexibility and estimated cardiorespiratory fitness contrast with the absence of an additional effect on gait speed, indicating outcome specificity rather than generalized superiority of multimodal exercise (Fahrudin et al., 2025; Hodijah et al., 2024; Putri et al., 2024). This pattern is biologically plausible because gait performance reflects a broader interaction among strength, balance, neuromotor control, habitual walking capacity, and baseline functional status.

The clinical importance of these adaptations becomes clearer when they are interpreted alongside observational evidence. A predeparture 6MWT distance below 500 m was associated with a higher incidence of outpatient healthcare use during Hajj, suggesting that reduced functional reserve may identify pilgrims who are less able to tolerate pilgrimage-related workloads (Harsoyo et al., 2023). Musculoskeletal studies also demonstrate substantial pain burden during Hajj, supporting the relevance of lower-extremity strength, flexibility, endurance, and load tolerance as preparation targets (Aleid et al., 2025; Alshehri et al., 2021; Alsobhi & Aldhabi, 2024). Nevertheless, the intervention evidence remains geographically concentrated in Indonesia, involves small samples, and includes reports with highly similar recruitment settings and exercise protocols. These features limit external validity and require caution when estimating the independent magnitude of treatment effects.

Novelty and Contribution

The novelty of this systematic review lies in reframing pre-Hajj physical preparation as a modifiable prehabilitation strategy and distinguishing overall programme participation from domain-specific functional responses. Rather than concluding that exercise is uniformly effective, the review demonstrates that the strength of benefit depends on the functional endpoint assessed: cardiorespiratory fitness and flexibility show clearer incremental responses, whereas gait speed does not demonstrate the same additional benefit from strengthening. The review also connects these proximal adaptations with evidence that low functional capacity predicts greater healthcare use during Hajj. This framework contributes a clinically relevant basis for developing targeted, measurable, and risk-stratified predeparture programmes while highlighting the need for larger multicentre trials with standardized exercise dosage, adherence monitoring, functional endpoints, and independent participant cohorts.

2. Limited Translation of Functional Benefits Into Clinical Health Outcomes and the Need for Comprehensive Hajj Health Preparation

Evidence linking pre-Hajj physical preparation to downstream clinical outcomes remains limited and inconsistent. Parker et al. (2022) reported that pilgrims who completed a supervised 6 to 12 week walking programme experienced substantially fewer medical events during Hajj than non-participants, alongside improved six-minute walk performance. However, the comparison group was non-matched and participation was non-randomized, leaving substantial potential for selection bias and residual confounding. In contrast, Mahomed et al. (2024) found no independent association between attendance at a formal pre-Hajj fitness programme and post-Hajj illness after multivariable adjustment, with an adjusted odds ratio of 0.96 and a 95% confidence interval of 0.64 to 1.44. These contrasting findings indicate that improvements in physical conditioning cannot yet be assumed to produce consistent reductions in overall Hajj-related morbidity.

The limited translation from functional improvement to clinical protection is biologically and epidemiologically plausible because Hajj-related morbidity arises from multiple interacting exposures. Reduced functional capacity has been associated with increased healthcare utilization, but healthcare use is also influenced by age, hypertension, diabetes, obesity, smoking, and other cardiovascular risks (Harsoyo et al., 2023). Heat-related illness depends on host susceptibility, environmental heat, hydration, acclimatization, medication use, and exposure intensity, requiring prevention strategies that extend beyond exercise training (Almuzaini et al., 2022). Musculoskeletal morbidity is likewise shaped by body mass index, sleep, pre-existing disease, smoking, and sex, while high rates of lower-limb and back pain persist during pilgrimage (Aleid et al., 2025; Alsobhi & Aldhabi, 2024). Prehabilitation should therefore be embedded within a broader risk-stratified Hajj health preparation programme rather than considered an isolated preventive intervention.

Table 7. Characteristics and Findings of Studies Supporting Theme 2

Author	Title and Year	Country	Aim	Methodology	Finding	Journal
Parker, Jaffer, and Mahomed	<i>Effect of a Supervised Exercise-Training Programme on Morbidity and Wellness of South African Hajj Pilgrims in 2018: A</i>	South Africa	To determine the effect of a supervised pre-Hajj exercise programme on physical fitness, mood, and morbidity among pilgrims.	Prospective pilot cohort. Ninety-three accredited pilgrims completed a supervised graduated walking programme for 6 to 12 weeks; 88	Medical events during Hajj were reported by 13.7% of programme participants compared with 62.2% of non-participants. Mean 6MWT	<i>International Journal of Travel Medicine and Global Health</i> , 10(2), 64-69.

	<i>Pilot Study (2022)</i>			completed post-Hajj assessment . A non-matched comparison group of 82 non-participants provided morbidity data.	distance increased from 481.3 m to 506.3 m after training and remained higher after Hajj. The non-randomized and non-matched design limits causal inference (Parker et al., 2022).	
Almuzaini et al.	<i>Mitigation Strategies for Heat-Related Illness During Mass Gatherings : Hajj Experience (2022)</i>	Saudi Arabia	To identify individual and environmental risk factors for heat-related illness and develop preventive strategies for Hajj.	Extensive literature review structured using the Haddon matrix and Community Risk Reduction model.	Heat-related morbidity results from interacting host, agent, and environmental factors. Effective prevention requires hydration, environmental controls, preparedness, risk identification, and other strategies beyond physical conditioning alone (Almuzaini et al., 2022).	<i>Frontiers in Public Health</i> , 10, 957576.
Harsoyo et al.	<i>Lower 6-Minutes</i>	Indonesia	To examine whether	Retrospective cohort	A 6MWT distance	<i>European Heart</i>

	<i>Walk Test Result and Presence of Cardiovascular Risk Factors Linked to Healthcare Facility Visits of Pilgrims: The Importance of Fitness in Hajj Pilgrimage (2023)</i>		predeparture functional capacity and cardiovascular risk factors were associated with healthcare utilization during Hajj.	using data from Indonesian Hajj pilgrims in 2022, including demographic, clinical, anthropometric, and 6MWT measurements.	below 500 m was associated with a higher incidence of outpatient healthcare visits, RR 1.08, 95% CI 1.04 to 1.12. Age, hypertension, diabetes, obesity, smoking, and sex were also associated with healthcare utilization (Harsoyo et al., 2023).	<i>Journal, 44(Supplement 2), ehad655.2427.</i>
Mahomed, Jaffer, and Parker	<i>Morbidity Amongst South African Hajj Pilgrims in 2023: A Retrospective Cohort Study (2024)</i>	South Africa	To characterize morbidity before, during, and after Hajj and identify factors associated with post-Hajj illness.	Retrospective cohort involving 577 South African pilgrims who completed a self-administered post-Hajj questionnaire. Multivariable regression assessed factors associated with illness.	Formal fitness-programme attendance was not associated with post-Hajj illness after adjustment, AOR 0.96, 95% CI 0.64 to 1.44. Chronic disease and independent exercise were associated with higher odds of illness, while respiratory	<i>Scientific Reports, 14, 12622.</i>

					symptoms dominated post-Hajj morbidity (Mahomed et al., 2024).	
Alsobhi and Aldhabbi	<i>Understanding the Pattern of Musculoskeletal Pain and Its Contributing Factors Among Hajj Pilgrims (2024)</i>	Saudi Arabia	To estimate musculoskeletal pain prevalence and examine factors associated with pain among pilgrims during Hajj 2022.	Cross-sectional web-based survey involving 248 pilgrims recruited at Hajj ritual sites. Pain across ten anatomical regions and physical activity were assessed.	Overall, 78.6% reported musculoskeletal pain. The legs, lower back, knees, and ankles or feet were the most affected regions. BMI was significantly associated with musculoskeletal pain, demonstrating that clinical burden is influenced by factors beyond fitness alone (Alsobhi & Aldhabbi, 2024).	<i>Work, 79(1), 417-424.</i>
Aleid et al.	<i>Prevalence and Risk Factors of Musculoskeletal Pain Among Kuwaiti Pilgrims During Hajj 2024 (2025)</i>	Kuwait	To determine the prevalence of musculoskeletal pain and associated risk factors among Kuwaiti pilgrims.	Retrospective cross-sectional study involving 557 pilgrims with pre-Hajj and post-Hajj survey assessments; risk	Musculoskeletal pain was reported by 24% and injury by 5%. Female sex and sleeping less than six hours increased the risk of	<i>International Journal of Environmental Research and Public Health, 22(10), 1585.</i>

				ratios were estimated using multivariable binomial regression.	pain, while hypertension and smoking were also associated with the outcome, reinforcing the multifactorial nature of Hajj-related morbidity (Aleid et al., 2025).	
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In-depth Analysis of Theme 2

The evidence reveals a clinically important discrepancy between functional adaptation and downstream morbidity. Parker et al. (2022) suggested a large morbidity advantage among participants in supervised exercise, yet its non-randomized design, unmatched comparator, voluntary participation, and modest sample substantially weaken causal interpretation. Conversely, Mahomed et al. (2024), using a larger cohort and multivariable adjustment, found no protective association for formal fitness-programme attendance. These apparently conflicting results should not be interpreted as evidence that prehabilitation is ineffective. Rather, they indicate that the causal pathway from improved fitness to reduced morbidity is neither direct nor sufficient in isolation. Respiratory infections, heat exposure, chronic disease, crowding, travel fatigue, and environmental transitions may dominate clinical outcomes even when functional reserve improves.

The supporting observational evidence strengthens this interpretation. Low 6MWT performance predicts greater healthcare utilization, confirming that functional reserve remains clinically relevant, but cardiovascular comorbidities independently contribute to healthcare demand (Harsoyo et al., 2023). High musculoskeletal symptom prevalence during Hajj and variation across populations further indicate that morbidity reflects the interaction of physical workload with BMI, sleep, sex, hypertension, smoking, and baseline health status (Aleid et al., 2025; Alsobhi & Aldhabi, 2024). Heat-related risk adds another layer because environmental exposure, hydration, and acclimatization operate outside the direct mechanisms targeted by exercise training (Almuzaini et al., 2022). The evidence therefore supports multicomponent preparation that combines structured prehabilitation with clinical risk screening, chronic-disease optimization, heat adaptation, hydration planning, sleep management, and individualized education.

Novelty and Contribution

The novelty of this review lies in demonstrating that functional efficacy and clinical effectiveness represent distinct levels of prehabilitation evidence. Existing studies frequently treat fitness improvement and morbidity reduction as interchangeable indicators of success, whereas this synthesis shows that clinically meaningful protection depends on the interaction between functional reserve, comorbidity, environmental exposure, and pilgrimage-specific stressors. By integrating intervention evidence with healthcare-utilization, musculoskeletal, and heat-risk data, this review proposes a more clinically coherent framework in which pre-Hajj exercise functions as one component of risk-stratified preparation. This distinction provides a stronger basis for future multicentre trials that simultaneously measure functional change, adherence, exposure, morbidity, and healthcare utilization.

DISCUSSION

The findings of this systematic review support the conceptualization of pre-Hajj physical preparation as a form of prehabilitation designed to increase physiological and functional reserve before pilgrims encounter the substantial physical demands of Hajj. Structured aerobic walking, lower-extremity strengthening, isotonic exercise, and multimodal conditioning improved selected domains of functional capacity, particularly cardiorespiratory fitness and hamstring flexibility, although the effects were not uniform across all outcomes (Fahrudin et al., 2025; Hodijah et al., 2024; Putri et al., 2024). This pattern is consistent with the physiological reserve framework proposed by Gillis et al. (2022), which views prehabilitation as a proactive strategy to increase the capacity to tolerate a predictable physiological stressor. Although this framework was developed mainly in perioperative care, its underlying principle is applicable to Hajj because pilgrims face repeated walking, prolonged standing, musculoskeletal loading, environmental heat, and limited recovery periods.

The variation in functional responses also reflects the principle of exercise specificity. Adding lower-extremity isotonic exercise to aerobic walking produced greater improvements in hamstring flexibility, while additional strengthening improved estimated cardiorespiratory fitness, but did not provide a significant advantage for gait speed (Fahrudin et al., 2025; Hodijah et al., 2024; Putri et al., 2024). This indicates that multimodal prehabilitation is not universally superior across all functional domains, and that benefits depend on the match between the training stimulus and the outcome assessed. Similar findings have been reported in broader prehabilitation research. Punnoose et al. (2023) found improvements in selected measures of physical function and strength, while effect sizes varied across outcomes, and Díaz-Vidal et al. (2026) reported improved 6-minute walk distance after exercise-based prehabilitation despite substantial heterogeneity. These findings support the use of targeted rather than generic exercise prescriptions.

The clinical relevance of functional capacity is further supported by Hajj-specific evidence. Ardiana et al. (2024) demonstrated the practical utility of the six-minute walk test for predeparture assessment, while Harsoyo et al. (2023) found that a walking distance below 500 m was associated with greater

outpatient healthcare utilization during Hajj. However, this association should not be interpreted as proof that increasing 6MWT performance will directly reduce healthcare use. Functional capacity is better understood as an indicator of physiological reserve and vulnerability rather than a validated surrogate for all clinical outcomes. This interpretation is consistent with Díaz-Vidal et al. (2026), who found that prehabilitation improved functional performance but did not consistently reduce hospital length of stay or mortality. Therefore, functional improvement should be regarded as clinically relevant, but not sufficient by itself to guarantee protection from broader Hajj-related morbidity.

The second major finding concerns the limited translation of functional gains into clinical outcomes. Parker et al. (2022) reported fewer medical events among pilgrims who participated in a supervised pre-Hajj exercise programme, but the non-randomized design and unmatched comparison group limit causal inference. In contrast, Mahomed et al. (2024) found no significant association between participation in a formal fitness programme and post-Hajj illness after multivariable adjustment. This discrepancy suggests that improvements in physical conditioning do not automatically translate into lower morbidity. Similar patterns have been observed outside the Hajj context, where multimodal prehabilitation improves functional recovery but does not consistently reduce all postoperative outcomes (Molenaar et al., 2023). Clinical outcomes during Hajj are influenced by multiple factors, including respiratory infections, heat exposure, chronic disease, hydration, medication use, environmental conditions, and accumulated fatigue (Almuzaini et al., 2022; Mahomed et al., 2024).

These findings have important implications for Hajj health preparation. Prehabilitation should not be implemented as an isolated exercise intervention, but as part of a broader, risk-stratified programme that integrates functional assessment, chronic-disease optimization, medication review, hydration education, heat acclimatization, infection prevention, sleep and recovery planning, and individualized exercise prescription. This is particularly relevant because musculoskeletal pain remains highly prevalent during Hajj, especially in the lower limbs, lower back, knees, ankles, and feet, and is influenced by factors such as body mass index, sex, sleep, smoking, and hypertension (Aleid et al., 2025; Alsobhi & Aldhabi, 2024). Predeparture programmes should therefore assess baseline functional reserve using measures such as the 6MWT and should tailor aerobic, strengthening, flexibility, balance, and mobility training according to individual risk profiles. Future trials should also standardize exercise dosage, monitor adherence, and evaluate outcomes across the entire pathway from functional improvement to morbidity and healthcare utilization.

The principal contribution of this systematic review lies in distinguishing functional efficacy from clinical effectiveness in pre-Hajj physical prehabilitation. Current evidence more consistently supports improvements in cardiorespiratory fitness, flexibility, walking capacity, and selected lower-extremity functions than reductions in morbidity, injury, or healthcare utilization. By integrating intervention evidence with recent findings on physiological reserve, musculoskeletal burden, heat exposure, and healthcare use, this review proposes a more clinically coherent model in which exercise enhances functional reserve

but operates within a wider network of individual and environmental determinants (Gillis et al., 2022; Harsoyo et al., 2023; Almuzaini et al., 2022). This distinction advances Hajj health preparation from a general recommendation to improve fitness toward a measurable, individualized, and risk-stratified prehabilitation framework, while also identifying the need for larger multicentre trials capable of testing whether functional gains ultimately translate into safer pilgrimage.

CONCLUSIONS AND RECOMMENDATIONS

This systematic review shows that pre-Hajj physical prehabilitation produces more consistent benefits for functional capacity than for broader clinical health outcomes. Structured aerobic walking, lower-extremity strengthening, isotonic exercise, and multimodal conditioning improved cardiorespiratory fitness, flexibility, walking capacity, and selected lower-extremity functions. However, these gains did not consistently reduce Hajj-related morbidity, post-Hajj illness, or healthcare utilization. The main scientific contribution of this review is therefore the distinction between functional efficacy and clinical effectiveness. Pre-Hajj prehabilitation appears valuable for improving physical readiness, but improved fitness should not be treated as a direct surrogate for protection from all health risks during pilgrimage.

The current evidence remains limited by small samples, geographically concentrated studies, heterogeneous intervention protocols, inconsistent outcome measures, incomplete reporting of exercise dose and adherence, and possible overlap between participant cohorts. Evidence for clinical outcomes is also weaker than evidence for functional outcomes, which limits strong causal conclusions. Future studies should use larger multicentre randomized controlled designs, standardized exercise prescriptions, objective adherence measures, and harmonized functional and clinical endpoints. Pre-Hajj physical prehabilitation should therefore be integrated into a broader, risk-stratified Hajj health preparation strategy that also addresses chronic disease, heat exposure, hydration, and other pilgrimage-specific risks.

FURTHER STUDY

This research still has limitations, so further studies are needed on the topic of Effectiveness of Pre-Hajj Physical Prehabilitation in Improving Functional Capacity and Health Outcomes Among Pilgrims: A Systematic Review

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