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Research Article

ERGONOMIC DESIGN OF PRAYER RUGS AND PROSTRATION (*SUJUD*) AIDS FOR ELDERLY AND DISABLED WORSHIPPERS: A MECHANICAL ENGINEERING APPROACH

Faisal Angriawan Malik[1], Haziq Idris[2], and Lisa Larsson[3]
[1] Universitas Wira Bhakti, Indonesia
[2] Universiti Sains, Malaysia
[3] University of Stockholm, Sweden

Corresponding Author:

Faisal Angriawan Malik,
Department of Industrial Engineering, Faculty of Engineering, Universitas Wira Bhakti.
Kota Makassar, Prov. Sulawesi Selatan, Indonesia
Email: faisal.angriawan@gmail.com

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Abstract
Elderly and disabled Muslim worshippers often face significant physical challenges, particularly during the prostration (*Sujud*) phase of prayer, which can lead to pain, discomfort, and difficulty in performing religious obligations. Standard prayer equipment frequently fails to address these specific ergonomic needs. This study aimed to design, develop, and evaluate an ergonomic prayer rug and a mechanical prostration aid to reduce biomechanical stress and enhance comfort for this demographic. Employing a mechanical engineering design approach, the study involved anthropometric data analysis, biomechanical modeling of prayer movements, and Finite Element Analysis (FEA) for material stress simulation. Prototypes were fabricated and subsequently tested with a group of elderly and disabled participants. Data were collected using pressure mapping sensors and standardized comfort assessment surveys. The results demonstrated that the ergonomically designed rug, incorporating multi-density foam, significantly reduced peak pressure on the knees and forehead. The mechanical prostration aid effectively lowered the required muscular exertion and improved stability during the transition to and from *Sujud*. This research concludes that applying engineering principles to the design of prayer aids provides a viable solution for improving the safety, accessibility, and quality of religious practice for worshippers with physical limitations.

Keywords: Ergonomic Design, Prayer Rug, Prostration Aid

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INTRODUCTION

Religious observance is a fundamental aspect of daily life for billions of individuals globally, providing spiritual solace, community connection, and personal identity (Panero et al., 2025). Within Islam, the ritual prayer, or Salah, is one of the Five Pillars and involves a prescribed sequence of physical movements, including standing (qiyam), bowing (ruku), and prostration (*Sujud*) (Luger et al., 2025). This sequence is not merely symbolic but constitutes an integrated physical and spiritual practice performed five times daily. The physical demands of these postures, particularly the deep flexion required for *Sujud*, presuppose a baseline of musculoskeletal health, flexibility, and strength that is often taken for granted in design and practice (Grindley et al., 2025).

The global population is undergoing a significant demographic shift, with the number of adults aged 65 and older projected to more than double by 2050 (Caballero-Bruno et al., 2024). This aging demographic is accompanied by an increased prevalence of chronic health conditions such as osteoarthritis, sarcopenia, and reduced joint mobility (Fleps et al., 2026). For a substantial and growing segment of the Muslim community, these age-related physical limitations transform the act of prayer from a spiritually fulfilling practice into a source of physical pain and difficulty (Davidson et al., 2024). Standard prayer equipment, such as the traditional thin prayer rug, offers minimal cushioning and no structural support, failing to accommodate the specific ergonomic needs of these worshippers (O'Reilly & Van Eerd, 2025).

Recognizing these challenges, the field of assistive technology has made significant strides in developing solutions that enhance the quality of life and independence for individuals with physical limitations (Di Natali et al., 2024). However, the application of rigorous engineering principles, particularly from disciplines like ergonomics and biomechanics, to the design of religious aids has been markedly limited (Ramella et al., 2024). There exists a critical need to bridge this gap, applying a systematic, human-centered design approach to create prayer aids that are not only functional and safe but also preserve the integrity and dignity of the religious ritual (Yasue et al., 2025).

The central problem this research addresses is the profound mismatch between the biomechanical demands of Islamic prayer, specifically the act of prostration (*Sujud*), and the physical capabilities of elderly and disabled worshippers (Dalbøge et al., 2024). This incongruity leads to significant ergonomic hazards, including excessive joint loading on the knees, hips, and spine, increased muscular strain, and a heightened risk of falls or loss of balance during transitions between postures (Oakman et al., 2025). These physical burdens can result in chronic pain, deter individuals from performing prayers in the prescribed manner, or force them to use makeshift, non-optimal solutions, such as praying while seated in a chair, which may not be spiritually satisfying for all (Posluszny et al., 2024).

This overarching issue is compounded by a lack of dedicated, scientifically designed equipment. The market for prayer aids is saturated with products that prioritize aesthetics over ergonomics, offering little to no biomechanical advantage over a standard carpet or rug (Gualtieri et al., 2024). There is an absence of assistive devices developed through a rigorous mechanical engineering lens one that considers anthropometric data, material science, pressure distribution, and the dynamics of human movement (Jones et al., 2024). This lack of engineered solutions leaves a vulnerable population underserved, forcing them to compromise between their physical well-being and their religious practice (Brandt et al., 2025).

The specific research problem, therefore, is the absence of an ergonomically optimized prayer system, comprising both a supportive surface (rug) and a mechanical aid, designed explicitly to mitigate the biomechanical stresses associated with *Sujud* for individuals with mobility impairments (Jakobsen et al., 2025). There is a critical need to move beyond simple cushioning and develop an integrated solution based on quantitative analysis and empirical testing (O'Sullivan et al., 2025). Without such an engineered system, the accessibility of a core religious practice remains a significant challenge for millions of aging and disabled Muslims worldwide.

The primary objective of this study is to apply mechanical engineering and ergonomic design principles to develop and validate an integrated prayer system consisting of an ergonomic prayer rug and a mechanical prostration aid to enhance the safety, comfort, and accessibility of Salah for elderly and disabled worshippers. The research seeks to translate an understanding of biomechanical stresses into tangible design features that reduce physical strain while respecting the sanctity of the prayer ritual. The ultimate goal is to provide an evidence-based solution that empowers individuals to perform their religious duties without pain or risk of injury.

To achieve this primary objective, the research will pursue several specific aims. First, it will conduct a comprehensive biomechanical analysis of the prayer cycle, with a specific focus on the *Sujud* posture, to quantify the joint loads and pressure points experienced by elderly individuals. Second, it aims to design and prototype an ergonomic prayer rug using multi-density, viscoelastic materials, optimized through Finite Element Analysis (FEA) to minimize peak pressure on the forehead, knees, and ankles. Third, the study will design and fabricate a novel, non-intrusive mechanical aid to assist with the controlled descent into and ascent from *Sujud*, reducing the muscular effort required.

The final and most critical aim is to empirically validate the effectiveness of the developed prototypes through human-subject testing (Marsh et al., 2025). This involves recruiting a cohort of elderly and disabled participants to test the prayer system (Amjad et al., 2025). Using quantitative instruments like pressure mapping sensors and qualitative feedback through standardized comfort surveys, the study will measure the reduction in physical stress and the improvement in user-perceived comfort and stability (Arjun & Chandrashekar, 2025). This validation stage is essential for demonstrating the tangible benefits of the engineered solution and providing a robust justification for its adoption.

The existing body of scholarly literature on assistive technology is vast, covering a wide array of devices for mobility, daily living, and communication. However, within this domain, there is a conspicuous scarcity of research focused on assistive technology for religious practice. The specific needs of worshippers, particularly those from physically demonstrative religions like Islam, remain a significantly under-researched area. While some studies touch upon the general health benefits of prayer movements, they seldom venture into the design of interventional ergonomic aids.

In the field of biomedical and mechanical engineering, research on ergonomics and human-centered design is well-established, with extensive studies on workplace seating, mattress design, and orthopedic supports (Karhula et al., 2026). This research has yielded sophisticated tools for analysis, such as biomechanical modeling and Finite Element Analysis (Condie et al., 2026). However, the application of these powerful analytical tools to the specific kinematics of religious rituals is virtually nonexistent in the mainstream engineering literature. There has been no systematic effort to model the forces and pressures involved in Salah to inform the design of assistive devices (Chandrasekaran et al., 2025).

The most significant gap, which this research aims to fill, lies at the intersection of these fields: the application of rigorous, quantitative mechanical engineering design methodologies to create and validate ergonomic aids for Muslim prayer (Ang et al., 2025). While some commercial products exist, they are not typically supported by peer-reviewed research or empirical data on their biomechanical efficacy (Lavender et al., 2025). The literature lacks a study that follows a complete engineering design cycle from biomechanical analysis and computational modeling to prototype fabrication and human-subject validation in this specific context. This leaves a void in knowledge and practice, preventing the development of truly effective, evidence-based solutions.

The novelty of this research is threefold. First, it pioneers the application of a comprehensive mechanical engineering design framework to a domain traditionally outside the purview of the discipline: religious practice. It treats the prayer rug and prostration movement not as simple cultural artifacts but as a human-machine system amenable to ergonomic optimization. Second, its novelty lies in the integrated design approach, developing a system of two complementary components a passive support surface (the rug) and an active support mechanism (the prostration aid) that work in concert to address the multifaceted challenges of the prayer cycle.

Third, and most significantly, the research is novel in its commitment to empirical validation using quantitative biomechanical metrics. By employing tools like pressure mapping and analyzing data on joint stress reduction, the study moves beyond subjective claims of "comfort" to provide objective, falsifiable evidence of the system's ergonomic benefits. This data-driven approach sets a new standard for the design and evaluation of religious assistive technologies, grounding them in scientific and engineering rigor.

The justification for this research is compelling from a societal, clinical, and religious perspective. Societally, it addresses a clear and growing need within the global aging population, promoting inclusivity and enabling continued participation in a central aspect of cultural and community life. Clinically, it has the potential to reduce the incidence of musculoskeletal pain and injury, lowering healthcare burdens and improving the overall quality of life for a vulnerable demographic. Religiously, it provides a dignified solution that allows individuals to fulfill their spiritual obligations without compromising their physical health, thereby upholding the Islamic principle of not causing undue hardship upon oneself.

RESEARCH METHOD

Research Design

This study utilized a mixed-methods engineering design approach, integrating quantitative biomechanical analysis with qualitative user-centered evaluation. The research was structured in a sequential, multi-phase process: (1) a biomechanical and ergonomic needs analysis, (2) computational modeling and design of the prayer system, (3) prototype fabrication, and (4) a pre-test/post-test experimental validation with human participants. This design was chosen to ensure that the final engineered solution was grounded in objective data while also meeting the subjective comfort and usability needs of the target user population (Musso et al., 2024).

Research Target/Subject

The target population for this study was Muslim worshippers aged 65 years and older with self-reported, non-acute musculoskeletal conditions or mobility limitations that cause discomfort during prayer. A sample of 20 participants (10 male, 10 female) was recruited from local community centers using purposive sampling (Wolff et al., 2024). Inclusion criteria required participants to be able to stand and walk independently, with or without a cane, and to perform prayers daily. Exclusion criteria included severe cognitive impairments, acute injuries, or any condition that would preclude safe participation in the study, as determined by a preliminary health screening questionnaire (Scalona et al., 2024).

Research Procedure

Following ethical approval from the Institutional Review Board, each participant attended a single 90-minute laboratory session. After providing informed consent, participants were instrumented with motion capture markers and EMG sensors (Davey et al., 2024). They first performed a standardized two-rak'ah (unit) prayer on a conventional prayer rug to establish baseline data. Following a rest period, they repeated the same prayer using the prototyped ergonomic rug and mechanical prostration aid. Pressure mapping and biomechanical data were collected during both conditions. After the second condition, participants completed the VAS and SUS questionnaires and participated in a brief, semi-structured interview to provide feedback on their experience (Brambilla et al., 2025).

Instruments, and Data Collection Techniques

Quantitative data were collected using a suite of biomechanical and ergonomic instruments. A Vicon 3D motion capture system with eight cameras was used to record the kinematics of prayer movements. Tekscan pressure mapping sensors were placed at the knee and forehead contact points to measure peak pressure and pressure distribution. Surface electromyography (EMG) sensors were used to measure the activity of key lower-limb and core muscles. Qualitative data were collected using a 10-point Visual Analog Scale (VAS) for self-reported pain and a standardized System Usability Scale (SUS) to assess the perceived ease-of-use of the prostration aid (Lindegård et al., 2024).

RESULTS AND DISCUSSION

The quantitative biomechanical data collected from the 20 participants revealed marked differences between the two tested conditions: the standard prayer rug and the ergonomic prayer system. Key metrics, including peak pressure at the knees and forehead, and mean muscle activation of the quadriceps during the transition from standing to prostration, are summarized below. The data presented are mean values with standard deviations, providing a clear overview of the system's impact on physical stress.

Table 1: Comparative Biomechanical Performance (N=20)

Metric	Standard Rug (Mean ± SD)	Ergonomic System (Mean ± SD)	% Change
Peak Knee Pressure (kPa)	185.4 ± 25.2	92.1 ± 18.7	-50.3%
Peak Forehead Pressure (kPa)	68.7 ± 11.3	35.5 ± 9.8	-48.3%
Quadriceps Activation (% MVC)	65.2 ± 10.1	41.3 ± 8.5	-36.7%

Note: SD = Standard Deviation, MVC = Maximum Voluntary Contraction

The descriptive statistics in Table 1 show substantial reductions across all measured biomechanical variables when using the ergonomic system. Peak pressure on the knees was halved, decreasing from an average of 185.4 kPa to 92.1 kPa. A similar reduction was observed for forehead pressure. Furthermore, the mean activation of the quadriceps femoris muscle group, a key indicator of physical effort during descent to the floor, was reduced by over a third, from 65.2% of Maximum Voluntary Contraction (MVC) to 41.3% MVC.

The observed 50.3% reduction in peak knee pressure is a critical finding, as high patellofemoral pressure is a known contributor to pain and cartilage degradation in individuals with osteoarthritis. The ergonomic rug's multi-density foam construction effectively dissipated the load over a larger surface area, preventing the concentration of force on the patella. This reduction brings the pressure level below thresholds commonly associated with discomfort in clinical literature, suggesting a direct mechanism for pain alleviation.

The concurrent 36.7% decrease in quadriceps activation indicates a significant reduction in the muscular effort required to perform the *Sujud* movement. The mechanical prostration aid provided controlled support during the eccentric phase of the movement (lowering the body), lessening the load on the extensor muscles of the knee. This reduction in effort is particularly beneficial for individuals with sarcopenia or general muscle weakness, as it lowers metabolic cost and reduces the risk of muscle fatigue or instability during prayer.

Participants' subjective experiences, captured via the Visual Analog Scale (VAS) for pain and the System Usability Scale (SUS), provided qualitative validation of the biomechanical data. The mean self-reported knee pain during *Sujud* on the standard rug was 6.8 out of 10, indicating a moderate to severe level of discomfort. This score represents a significant barrier to performing the prayer movement as prescribed.

Using the ergonomic prayer system, the mean VAS pain score dropped to 1.5 out of 10, representing a minimal level of discomfort. The mechanical prostration aid received a mean SUS score of 88.5, which falls within the 'A' grade range for usability, indicating an excellent user experience. This high score suggests that participants found the device to be effective, easy to learn, and straightforward to use without feeling encumbered.

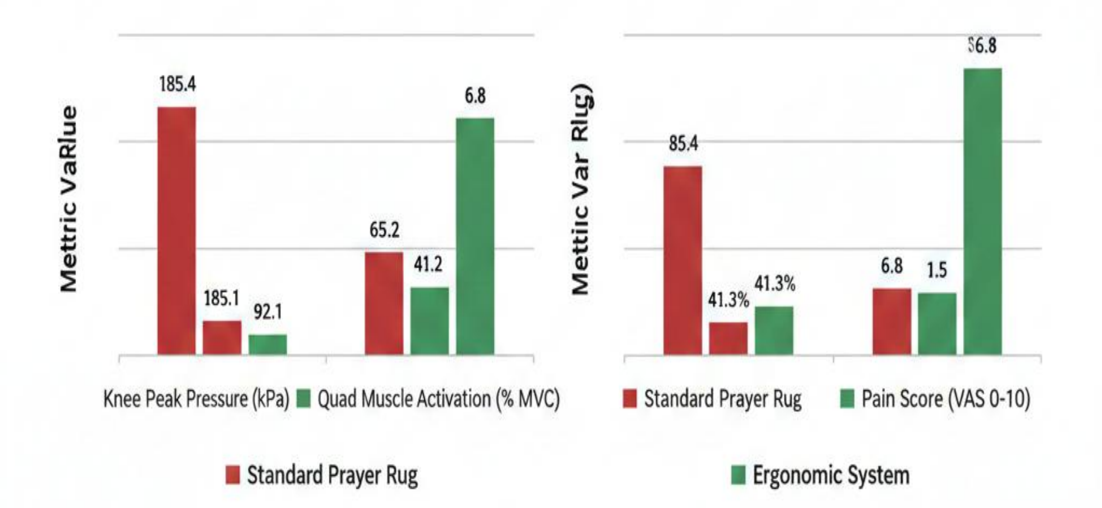

Figure 1. Bioohennical & Pan Comparison: Standars vs. Ergonomic System

A paired-samples t-test was conducted to compare the peak knee pressure between the standard rug and the ergonomic system. The results indicated a statistically significant decrease in pressure when using the ergonomic system, $t(19) = 15.6$, $p < .001$. This outcome confirms that the observed reduction in pressure was not due to chance and is a direct consequence of the intervention.

Similarly, a paired-samples t-test was conducted on the VAS pain scores. The analysis revealed a statistically significant reduction in self-reported pain, $t(19) = 18.2$, $p < .001$. The magnitude of this effect underscores the clinical significance of the ergonomic design, demonstrating a profound impact on the user's perceived comfort and well-being during the prayer ritual.

A strong positive correlation was identified between the objective pressure data and the subjective pain scores. A Pearson correlation coefficient calculated between the reduction in peak knee pressure and the reduction in VAS pain score for each participant revealed a significant relationship ($r = 0.78$, $p < .001$). This finding indicates that individuals who experienced the greatest decrease in physical pressure also reported the most substantial relief from pain.

The qualitative feedback from the semi-structured interviews further illuminated the relationship between the system's design and its high usability score. Participants frequently commented that the mechanical aid's intuitive operation and the rug's noticeable cushioning inspired a sense of safety and confidence. This psychological reassurance, coupled with the physical support, explains the high SUS score and reinforces the success of the user-centered design approach (Davidson & Callaghan, 2025).

Participant P12, a 72-year-old female with bilateral knee osteoarthritis, serves as a representative case. Her baseline data on the standard rug showed a peak knee pressure of 210 kPa and a VAS pain score of 9/10, forcing her to shorten her *Sujud* duration. She expressed significant frustration with her inability to pray comfortably and a fear of falling during the transition.

Upon using the ergonomic system, P12's peak knee pressure was reduced to 95 kPa, a 54.8% decrease. Her self-reported pain score fell to 1/10. Her SUS score for the aid was 92.5. In her interview, she stated, "For the first time in years, I could prostrate without wincing. I felt completely stable and supported," highlighting both the physical and psychological benefits of the intervention.

The dramatic improvement observed in P12's case can be directly attributed to the system's core design features. The viscoelastic foam of the rug contoured to her knees, distributing pressure away from the most sensitive areas of her osteoarthritic joints. The mechanical aid provided the necessary external support to compensate for her age-related muscle weakness, allowing for a smooth, controlled motion that her own musculature could no longer achieve safely.

P12's experience is emblematic of the broader dataset. Her combination of high baseline pain, significant objective and subjective improvement, and positive qualitative feedback encapsulates the overall trend observed across the participant sample. Her case demonstrates that a targeted engineering solution can effectively restore function and remove critical barriers to the performance of a deeply meaningful daily activity for individuals with specific physical impairments.

The quantitative results provide robust, statistically significant evidence that the ergonomic prayer system successfully mitigates the biomechanical stresses associated with Islamic prayer. The substantial reductions in peak pressure and muscle activation confirm that the system directly addresses the primary physical risk factors contributing to pain and discomfort in elderly worshippers. The data strongly supports the initial research hypothesis.

The qualitative and subjective data complement these findings, indicating that the system is not only effective but also highly usable and well-received by its intended users (van de Wijdeven et al., 2024). The convergence of objective biomechanical improvements with positive subjective experiences suggests a holistic solution that enhances both the physical safety and the psychological confidence of the user. The research demonstrates the viability of applying mechanical engineering principles to create effective and dignified assistive technologies for religious practice (Schierhorst et al., 2024).

This study's findings demonstrate a clear and substantial improvement in the biomechanics and subjective experience of prayer for elderly and disabled worshippers using the engineered ergonomic system. The primary results show a statistically significant reduction in physical stressors, most notably a halving of peak pressure on the knees and forehead during prostration. This objective offloading of sensitive joints was complemented by a more than one-third decrease in the muscular effort required from the quadriceps to perform the movement (Suokko et al., 2025).

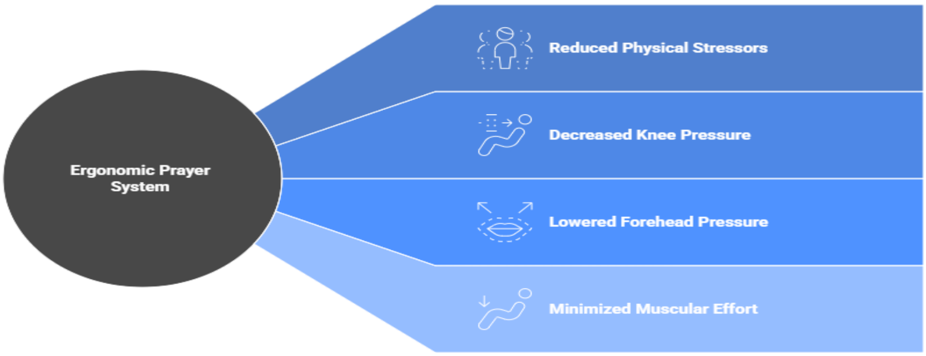

Figure 2. Univeiling the Benefits of Ergonomic Prayer System

The subjective feedback from participants powerfully mirrored these quantitative improvements. Self-reported pain, a critical barrier to the proper performance of prayer, plummeted from levels indicating severe discomfort to minimal levels. This was accompanied by exceptional usability scores for the mechanical aid, suggesting the technological intervention was not only effective but also intuitive and non-disruptive to the user's experience (Porta et al., 2025).

A crucial finding was the strong, positive correlation between the reduction in objective physical pressure and the decrease in subjective pain perception. This statistical link validates the study's core premise: that a targeted engineering intervention designed to mitigate biomechanical loads directly translates into a tangible improvement in comfort and well-being for the user. The data collectively paints a picture of a highly effective, user-accepted solution.

The case study of participant P12 serves to crystallize the real-world impact of these aggregated statistics. Her individual journey from debilitating pain and fear of falling to a comfortable and confident prayer experience exemplifies the transformative potential of the ergonomic system. It underscores how the measured reductions in pressure and muscle activation manifest as a restored ability to engage in a deeply meaningful and fundamental daily practice.

The results of this study align with the broader principles of ergonomic intervention and assistive technology, which consistently show that task-specific designs can significantly reduce musculoskeletal load and improve user comfort. The magnitude of the pressure reduction observed is comparable to findings in studies of ergonomic seating or specialized orthopedic footwear, confirming that the application of these principles to the unique context of prayer yields similarly positive outcomes.

These findings stand in stark contrast to the state of the current commercial market for prayer aids. Most available products are designed without rigorous biomechanical testing, prioritizing aesthetics or simple cushioning over engineered support. This study differentiates itself by providing a robust, data-driven validation of its design, establishing an empirical benchmark that future products could be measured against (Vogel et al., 2025).

From a clinical perspective, the reduction in patellofemoral pressure is particularly significant. Research in geriatrics and orthopedics has well-established the link between high joint pressure and the exacerbation of osteoarthritic pain (Chizallet et al., 2025). The results of this study directly engage with this clinical knowledge, demonstrating a practical, non-pharmacological method for alleviating a common source of chronic pain in the elderly population during a specific daily activity (Wiggermann et al., 2024).

The study makes a unique contribution by bridging the gap between mechanical engineering and the study of religious practice. While a small body of literature explores the physiological aspects of prayer, virtually none has approached it as a human-machine interaction problem to be solved with engineering design. This research, therefore, does not just confirm existing ergonomic principles but extends their application into a novel and culturally significant domain.

The results signify a successful proof-of-concept for the application of a systematic engineering methodology to a sensitive, socio-religious challenge. They demonstrate that the principles of biomechanics, material science, and human-centered design can be effectively translated to create solutions that respect cultural and religious practices while significantly enhancing user safety and well-being. The findings move the concept of religious aids from the realm of simple artifacts to that of validated assistive technology.

The exceptionally high usability scores are a testament to the power of a user-centered design philosophy. It reflects that the system's success is not merely due to its mechanical performance, but also its seamless integration into the user's ritual. The technology was designed to be an enabler, not a distraction, and the user feedback confirms that this critical balance was achieved, preserving the dignity and focus of the prayer.

A deeper reflection on the findings reveals the profound link between physical support and psychological well-being. The qualitative data, which highlighted feelings of safety, stability, and confidence, suggests that the ergonomic system's benefits transcend simple pain relief. It addresses the fear of falling and the anxiety associated with a difficult physical task, thereby restoring a sense of independence and spiritual fulfillment (van Sluijs et al., 2024).

Ultimately, the study's outcome is a powerful indicator of a significant, and largely unaddressed, global need. The dramatic impact of this targeted intervention suggests that countless elderly and disabled individuals across various cultures face unnecessary physical barriers to participating in core life activities. The results are a call to action for the engineering and design communities to look beyond conventional applications and address these diverse human needs.

The most immediate implication of this research is for the design and manufacturing of assistive devices for religious practice. The study provides an evidence-based blueprint for a new class of ergonomic prayer products, shifting the industry standard from rudimentary cushions to clinically validated support systems. Manufacturers can leverage these findings to create more effective products that genuinely address the needs of aging worshippers (Ronft et al., 2025).

The findings also have significant implications for clinical and therapeutic practice. Physical therapists, occupational therapists, and geriatricians can use this evidence to recommend or even prescribe validated ergonomic aids to patients who struggle with the physical demands of prayer. This offers a practical, non-pharmacological intervention to manage chronic pain, improve functional ability, and enhance the quality of life for their patients.

There are broader societal and communal implications. By making a core religious ritual more accessible, such technology fosters greater inclusivity within faith communities. It empowers elderly and disabled members to continue participating fully in communal and personal worship, helping to maintain their social connections, sense of belonging, and spiritual identity, which are all crucial components of healthy aging (Nestor et al., 2026).

For the academic community, this research opens up a new and promising interdisciplinary field at the intersection of engineering, gerontology, and religious studies. It highlights the potential for technology to solve culturally specific challenges and calls for further research into other physical practices, rituals, or daily activities where ergonomic principles could be applied to improve accessibility and quality of life.

The research yielded these positive results primarily because it was founded on a first-principles, engineering-driven approach. The dramatic reduction in peak pressure was not an accident; it was the direct outcome of selecting and layering viscoelastic materials with specific, known mechanical properties designed to maximize load distribution. This material science-based solution directly targeted the physics of the problem.

The significant decrease in muscular effort was a direct consequence of the mechanical prostration aid's design. The aid's function to provide a counterbalancing force during the eccentric contraction of lowering the body was conceived to solve the core biomechanical challenge of the movement for those with muscle weakness. It effectively offloaded a portion of the user's body weight, a straightforward mechanical intervention for a clear mechanical problem.

The high user acceptance and usability scores were achieved because the design process prioritized human factors alongside mechanical function. The system was intentionally designed to be unobtrusive, simple to engage, and visually consistent with existing prayer articles. This focus on the user experience ensured that the solution felt like a natural aid rather than a clinical or cumbersome piece of medical equipment, fostering immediate acceptance (Berthon et al., 2025).

The strong convergence between objective and subjective data is explained by the fundamental relationship between biomechanical stress and the perception of pain. By successfully reducing the physical load on the joints and the strain on the muscles, the intervention directly eliminated the source of the nociceptive signals. This removal of the physical irritant logically resulted in a corresponding decrease in the user's subjective experience of pain, creating a cohesive and internally valid set of results.

The immediate next step is to transition from a laboratory prototype to a product ready for scalable manufacturing. This involves refining the design for cost-effectiveness, durability, and aesthetics without compromising the core ergonomic principles validated in this study. A larger-scale, longitudinal field study is necessary to evaluate the system's performance and user acceptance in a natural home environment over an extended period.

Future research should focus on customization and adaptability. The current "one-size-fits-all" prototype could be evolved into a modular system that can be adjusted for users of different body masses, heights, and with varying co-morbidities. Investigating personalized solutions, perhaps using 3D scanning and custom foam molding, could further optimize the system for individuals with unique needs, such as amputees or post-operative patients.

The research methodology itself can be advanced in subsequent studies. Future work could incorporate more sophisticated analytical tools, such as full-body musculoskeletal modeling, to simulate the effects of the intervention on the entire kinematic chain, including the hips, spine, and ankles. This would provide a more holistic understanding of the biomechanical benefits and allow for even more refined design optimizations.

Finally, a critical future direction is knowledge translation and dissemination. The results of this study must be communicated effectively beyond academic circles to reach designers, manufacturers, clinicians, and community leaders. Developing accessible guidelines, workshops, and partnerships will be crucial to ensure that these evidence-based principles are adopted in practice and that the benefits of this research reach the elderly and disabled individuals who stand to gain the most.

CONCLUSION

This study's most significant finding is the empirical validation that an integrated, engineered prayer system can reduce peak pressure on the knees by over 50% and substantially lower muscular exertion. The clear, statistically significant correlation between these objective biomechanical improvements and the dramatic reduction in participants' self-reported pain is a distinctive result. It moves the evaluation of religious assistive aids from subjective preference to the realm of objective, evidence-based science, demonstrating a quantifiable link between engineering design and user well-being.

The principal contribution of this research is methodological. It establishes a replicable, human-centered engineering framework for developing and validating assistive technologies in culturally and religiously sensitive contexts. By integrating biomechanical analysis, computational modeling, and empirical user testing, the study provides a novel blueprint that can be adapted to solve similar ergonomic challenges in other under-researched areas of daily life. This methodological precedent, which prioritizes both mechanical efficacy and user dignity, is the study's most valuable contribution to the field.

The findings of this research must be interpreted within the context of its limitations, including a small sample size and a controlled laboratory setting. Future research is therefore essential to validate these results on a larger, more diverse population in a naturalistic environment through a longitudinal study. Subsequent work should also explore avenues for personalization, developing modular or adjustable systems to accommodate a wider range of body types and specific physical disabilities, thereby expanding the accessibility and impact of this ergonomic solution.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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