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Ergonomic footwear design for Rheumatoid Arthritis patients: A Systematic review of Anthropometric and Footwear solutions

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ABSTRACT

Rheumatoid arthritis (RA) is an autoimmune disease that gets worse over time. It can cause stiffness, pain, and trouble moving around, which can make daily life very difficult. For RA patients, proper shoes are extremely important for increasing mobility, lowering pain, and improving general quality of life. Focusing on anthropometric data, material advancements, and smart footwear technologies, this systematic review investigates ergonomic footwear solutions created especially for RA patients. Custom-made therapeutic shoes, orthotic insoles, and sensor-integrated shoes were evaluated using a methodical literature search of Google Scholar, Scopus, PubMed, and Web of Science. The results s how different methods, such as 3D scanning for a precise fit, IoT-enabled smart insoles for real-time gait monitoring, and tailored midsole density for better pressure distribution. Material developments, such as sustainable and antimicrobial insole materials, also help to improve both comfort and durability. Findings show sensible RA shoes need appropriate arch support, cushioning, pressure distribution, and lightweight materials. Although tailored therapeutic shoes are still the most efficient, retail footwear options with ergonomic changes provide good substitutes for everyday usage. Still major obstacles, though, are aesthetic issues, cost, and lack of uniformity in anthropometric data. This study emphasises the need to combine medical, technical, and user-centred design strategies to provide practical yet comfortable shoes for RA patients. It also stresses the need for more study to standardise foot measurement methods, improve smart shoe use, and create creative ideas that balance medical advantages and daily wearability, hence supporting ongoing work in this vital area.

Keywords: Rheumatoid Arthritis, Elderly, Footwear, Anthropometric Dimension, Foot

BACKGROUND

Rheumatoid arthritis (RA) is a chronic autoimmune disease that primarily affects synovial joints, leading to inflammation, pain, stiffness, and progressive deformities. The earliest medical description of RA was provided by Augustin Jacob Landré-Beauvais in 1800 while in the Saltpêître asylum in France (Wolfe & Pincus, 2002). Although RA can occur at any age, it is most common between 30 and 60 years, with women affected two to three times more often than men (Scott et al., 2010).

Recent Global Burden of Disease (GBD) 2020–2021 estimates indicate that approximately 17.6–17.9 million people worldwide live with RA, reflecting a notable increase over the past three decades (GBD 2020; GBD 2021). The burden is highest among older adults, with incidence peaking in the 65–69 age group and remaining elevated into the 75–79 range, where functional disability is common (GBD 2021). Earlier studies also reported that about 5% of women over 55 are affected, and that disability rates are particularly high among those over 75 (Cross et al., 2014; Salaffi et al., 2005).

RA most commonly affects the hands, wrists, elbows, knees, ankles, and feet, leading to chronic pain, stiffness, tenderness, swelling, and joint warmth. These symptoms progressively limit mobility,

making routine tasks such as walking, standing, and maintaining balance difficult. RA also contributes to foot-specific complications, including hallux valgus (bunions), hammertoes, subtalar joint instability, and metatarsalgia (Otter et al., 2010; Cabrera-Sánchez et al., 2024). Local research has similarly highlighted the importance of bunion-related footwear design, where geometric analysis of the hallux valgus angle (HVA) in Malaysian women informed new shoe prototypes (AlMurid et al., 2022).

Each of the four clinical phases of RA shows a growing degree of severity. Early stage (Stage 1) joint inflammation starts, producing discomfort, stiffness, and oedema; X-rays usually reveal no apparent bone damage. Stage two moderate RA causes cartilage degradation, lowering joint mobility, discomfort, and stiffness. Severe RA (Stage 3) causes bone erosion, which causes joint abnormalities, muscular weakness, and mobility loss. Late-stage (Stage 4) inflammation decreases; joints lose function completely; however, because of significant bone and cartilage degeneration, they commonly need walking aids (Aletaha et al., 2010).

Proper shoes are important in RA since foot pain and joint abnormalities are common, helping mobility and lowering pain. To fit their deformities and gait irregularities, many RA patients need customised shoes, orthotic insoles, and pressure-relieving shoes (Cabrera-Sánchez et al., 2024). However, many of the shoes on the market lack the required support, which makes RA patients sacrifice comfort and appearance (Tehan et al., 2019).

Many RA patients still have trouble finding shoes that provide medicinal advantages and a reasonable appearance despite improvements in orthopaedic footwear, which results in poor compliance with recommended footwear solutions (Williams et al., 2007). RA footwear commonly presents issues such as inadequate arch support in regular shoes, restricted availability of fashionable yet practical RA shoes, and high prices for innovative or customised shoe solutions.

Recent advances, including 3D foot scanning, AI-enabled smart insoles, pressure-mapping systems, and sustainable antimicrobial materials, have expanded opportunities for personalised and comfortable solutions (Sorrentino et al., 2020; Naseem et al., 2024; Chaturvedi & Verma, 2024). Similarly, local design research emphasises the potential of upcycled fashion materials as part of sustainable innovation in wearable products (Othman et al., 2022). However, despite these innovations, significant gaps remain, including the absence of standardised anthropometric datasets for RA patients, limited affordability of customised footwear, and insufficient integration of wearable technologies into everyday designs.

Focusing on anthropometric measuring approaches, material selection, and technological improvements to enhance functionality, comfort, and accessibility for RA patients, this systematic review investigates current studies on ergonomic footwear for RA patients.

OBJECTIVE AND METHODOLOGY

This systematic review examines the most recent changes to previous research findings on developing shoes that are more comfortable for people with Rheumatoid Arthritis (RA) and other foot problems caused by the disease. This research finds solutions to foot issues by combining anthropometric measurements, material advances, and new technologies to improve comfort, movement, and quality of life. The study also wants to assist consumers in understanding what kinds of shoes they need and how they should be produced. This will help the designers design more comfortable shoes that fit their needs. The ultimate aim is to provide a framework that guides healthcare professionals and shoe designers in creating a small-scale fashion company serving RA patients, guaranteeing functional and visually attractive shoe choices. By bridging the gap between user needs and design practices, this research aspires to enhance the overall well-being of RA patients by promoting greater participation in the footwear market.

To achieve these objectives, the study focuses on answering two key questions:

1) What are the current trends and advances in ergonomic footwear design for RA patients?
2) What are the gaps in current research on footwear design for RA patients?

The literature search and screening follow a three-tier procedure. The primary search involved a systematic search of PubMed, Scopus, and Google Scholar databases to identify relevant peer-reviewed studies published between 2015 and 2024. These databases were selected due to their extensive medical, biomechanical, and industrial design research coverage, ensuring a multidisciplinary perspective on RA footwear solutions. The search strategy utilised carefully chosen keywords, including:

1) “Rheumatoid arthritis user/users"
2) "Rheumatoid arthritis" + "foot deformities"
3) "Rheumatoid arthritis" + "ergonomic footwear design"
4) "Orthotic inserts" + "RA patients"
5) "Rheumatoid arthritis" + "footwear customization"

Additional searches were conducted using related terms such as "gait analysis," "foot biomechanics," "custom footwear," and "3D scanning" to enhance the retrieval of relevant studies.

The initial literature search yielded 1260 sources. Titles and abstracts were systematically screened to identify full-text articles related to RA and studies related to footwear or tools that assist patients in improving the comfort of their footwear. Only English-language peer-reviewed journal articles and dissertations were included. After screening, 20 studies were considered directly and indirectly relevant to the footwear needs of RA patients (see Figure 1). Ancestor searches used references to identify further articles pertinent to the review. Studies were included if they focused on:

1) Design and development of footwear for RA patients and individuals with other foot deformities;
2) Shoe needs and purchasing behaviour of RA patients;
3) Marketing and environmental support for RA patients and individuals with related foot deformities;
4) Rehabilitation methods involving footwear as a solution.
5) Patient care when footwear is considered part of medical attire.

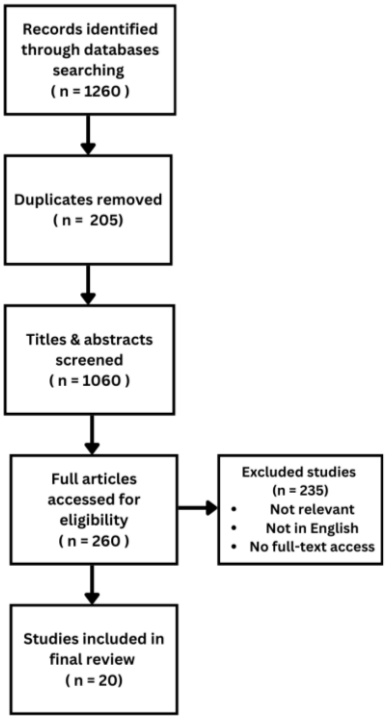

Figure 1. Flow chart of the literature selection process.

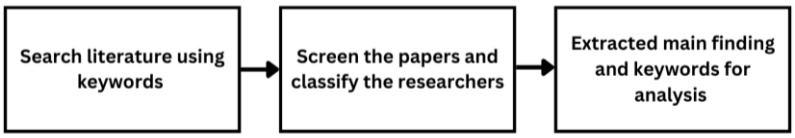

Figure 2. The information process in the literature review.

The studies included in this review were carefully screened using a structured three-step process (see Figure 2). This method fully understands the needs and difficulties related to shoes for rheumatoid arthritis (RA) patients.

The first stage was examined from the literature to find significant barriers and needs. Focusing on the actual problems of RA patients and related deformities, these insights came straight from patient experiences and study results. Original descriptions from interviews and narratives were used to guarantee accuracy, as they did not depend on second-hand readings. This helped to get an honest viewpoint on problems associated with shoes experienced by RA patients and related deformities.

The obtained responses were then grouped into themes depending on recurring ideas and terms. Derived from the survey participants' viewpoints and expert recommendations from the researchers, these keywords captured the essential characteristics of shoe demands. Grouping comparable issues and recommendations helped to clarify the most important elements affecting shoe design for RA patients and related deformities.

Lastly, the classified responses were examined to find trends and gaps in existing research. This phase helped identify which features of RA shoes had been well-researched and emphasized those needing additional research. The purpose is to highlight possible changes and future directions in ergonomic shoe design for patients with RA and related foot abnormalities by summarizing current knowledge.

Following this methodical approach signifies a fair and thorough examination based on patient experience and supported by research data.

To interpret the results of the literature, a three-stage data analysis procedure was implemented (see Figure 3). This helped organize the data in order to provide a better understanding of shoe needs among RA patients.

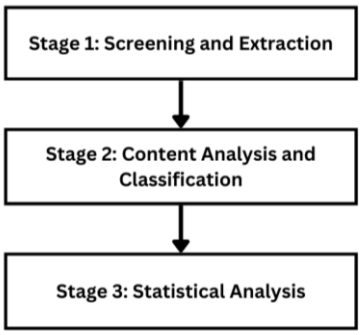

Figure 3. The procedure of data analysis using the literature.

1) The first step was to thoroughly filter through all chosen studies directly addressing the footwear demands of RA patients. Among the key information gathered were frequent issues, significant design elements, and developments in tools or shoes that could benefit RA patients or associated foot abnormalities. This action gave a wide picture of the advancements in footwear research for RA patients. Possible biases and restrictions were also considered in individual studies to provide a thorough examination.

2) Key results were gathered and categorized according to shared themes using the Functional, Expressive, and Aesthetic (FEA) model by Lamb & Kallall, 1992. This approach allowed for the categorization of shoe needs into three key groups:

- Functional (e.g., comfort, support, stability)
- Expressive (e.g., personal preference, cultural influence)
- Aesthetic (e.g., design appeal, visual aspects)

The model was slightly modified to align with the literature's identified requirements, as various studies prioritized distinct factors. This guarantees that all important elements of RA shoes are covered and meaningfully classified.

3) Examining the trends in the classified results is the last stage. This shows the most often mentioned shoe characteristics and fields currently underexplored by researchers. The study highlights areas where more research is required to provide a suitable shoe for patients by summarizing current information and identifying deficiencies. These results will help steer future research and developments in ergonomic shoe design for RA patients.

This systematic approach to analysis enables the breakdown of complex data into a clear and useful framework. The study provides a thorough viewpoint on RA shoe needs by merging patient views with professional advice.

RESULT

General Overview of the Literature

The overall information collected from the selected literature is listed in Table 1. Twenty papers on ergonomic shoe solutions for rheumatoid arthritis (RA) patients and related foot deformities were included in this systematic review. Among other aspects, the study looked at ergonomic shoe design, anthropometric issues, material innovation, and smart technology applications.

Twenty results revealed that RA patients need certain shoes because of foot deformities, joint instability, and discomfort, which usually cause mobility issues, particularly for elderly patients with RA health concerns. Many studies highlight that off-the-shelf shoes are unsuitable for RA patients

because of inadequate pressure redistribution, inappropriate fit, and lack of customisation. Rather, studies support adaptive shoe technologies, orthotic insoles, and custom-made shoes that can fit personal demands.

Most examined studies aim to create shoes that precisely match the patient's feet using anthropometric measurements, including 3D foot scanning, pressure mapping methods, and gait analysis. Lightweight and flexible materials like memory foam insoles, shock-absorbing midsoles, and thermoplastic elastomers (TPE) have also been highlighted as crucial for lowering foot pressure.

Smart shoe technology, including IoT-based insoles, real-time gait tracking, and pressure sensors, which seek to enhance foot health monitoring and user comfort, is another expanding field of study. Still, major obstacles include price and accessibility, which limit the broad use of these technologies, particularly for rural users and elderly patients.

Though shoe design has improved, major research gaps exist, especially in standardising RA-specific shoe sizes, including affordable changes, and making ergonomic shoes more accessible. These disparities draw attention to the need for more studies on economical, flexible, and generally accessible options for RA sufferers.

Keywords Extraction and Classification

To better understand the recurring themes in the literature, this section classifies the most frequently used keywords related to ergonomic footwear, customization, and material innovations for RA patients. The selected keywords offer an analysis of the fundamental qualities of RA shoes and their functional outcomes.

Clarification of Keywords from Literature Review

Table 1. Clarification of Keywords from Literature Review

Theme	Representative Keywords	Relevant Studies
Smart Footwear & Technology	- Smart shoes - Fuzzy logic - Wearable tech - Connected insoles - IoT - Remote monitoring	Ferreira et al. (2022), Stavropoulos et al. (2021), González et al. (2022), Charlon et al. (2020), Moon et al. (2021), Tan et al. (2022), Chaturvedi & Verma (2020)
RA Management	- RA - Foot pain - Deformity - Custom-made footwear - Activity limitation - Orthoses - Therapeutic shoes	Cabrera-Sánchez et al. (2024), Dahmen et al. (2023), Tehan et al. (2019), Wilson et al. (2020), De Souza & Lempp (2022), Hunter et al. (2020), Menz & Golightly (2014)
Materials & Sustainability	- Polyurethane - Recycled polyester - Antibacterial insole - Durability - Sustainability	Naseem et al. (2021), Uddin et al. (2020)
Foot Pressure & Gait Analysis	- Gait - Plantar pressure - Biomechanics - Insole design - Pressure sensors - Real-time analysis	Sorrentino et al. (2023), Razak et al. (2022), Tan et al. (2022), Uddin et al. (2020)
User Preferences & Psychosocial Factors	- Footwear comfort - Aesthetics - Femininity - Style - Personal experience -Support - Acceptability	Tehan et al. (2019), De Souza & Lempp (2022), Wilson et al. (2020), Anderson et al. (2021)
Fall Risk & Elderly Balance	- Fall prevention - Balance - Posture - Toe deformities - Cushioning - Arch support	Ferreira et al. (2022), Menz & Golightly (2014), Moon et al. (2021), Charlon et al. (2020)

Table 1 presents a thematic classification of keywords extracted from 20 peer-reviewed studies included in this literature review. To simplify the analysis, these keywords were grouped into six main themes: Smart Footwear & Technology, Rheumatoid Arthritis (RA) Management, Materials & Sustainability, Foot Pressure & Gait Analysis, User Preferences & Psychosocial Factors, and Fall Risk & Elderly Balance. This grouping reflects the primary focus and objectives of each study, providing a more organized overview of the research landscape.

The Smart Footwear & Technology theme highlights innovations in wearable devices, including sensorized insoles, IoT integration, and real-time gait monitoring. The RA Management theme encompasses research on pain relief, support for foot deformities, and functional improvement through orthotic interventions and specialized footwear. Materials & Sustainability covers advancements in insole fabrication, antimicrobial treatments, and the use of recycled materials. Studies under Foot Pressure & Gait Analysis focus on biomechanical evaluations, while those under User Preferences & Psychosocial Factors examine comfort, design expectations, and the subjective experiences of users. Finally, the Fall Risk & Elderly Balance category looks at research aimed at improving balance and preventing falls in older adults.

This thematic mapping not only helps clarify the current state of the literature but also highlights areas of convergence and identifies potential gaps for future research.

Attributes and Products of Each Finding

Ergonomic shoe options for rheumatoid arthritis (RA) patients can be classified based on physical and psychological (physiological) attributes identified across the literature. These attributes play an essential role in ensuring adequate foot support, reducing joint stress, and improving overall mobility. Understanding how these qualities are addressed in footwear design helps to identify current priorities and directions in RA-related footwear research.

Table 2 lists the key findings from 20 peer-reviewed studies, mapping the main physical and psychological attributes considered, along with the types of products introduced or discussed. Physical attributes commonly addressed include balance, toe space, weight distribution, posture, and movement support, which are factors that directly impact comfort and joint health. Psychological attributes such as comfort, confidence, and suitability of style preferences reflect the broader user experience, especially among older adults and women with RA.

The table also links these attributes to specific types of footwear or technologies, such as smart insoles, therapeutic shoes, and patient-informed design recommendations. It provides a clear reference for how the literature approaches both biomechanical function and wearer satisfaction.

Table 2. Key physical and physiological attributes along with relevant products identified in the literature

Author	Attribute										Product
	Physical						Psychology				
	Protect	**Balance**	**Toe Space**	**Weight Distribution**	**Posture**	**Movement**	**Comfort**	**Style**	**Confidence**	**Function**	
Ferreira et al., (2021)	✓					✓	✓			✓	- Anti-Fall Shoes - Sensor Detection
Stavropoulos et al., (2020)	✓				✓	✓				✓	- IoT - Sensor - Devices
Sorrentio et al., (2021)						✓	✓			✓	-Insole -Monitoring -Device
Uddin et al., (2024)	✓					✓	✓			✓	-Midsole
Anderson et al., (2020)		✓		✓	✓		✓			✓	-Insoles.

continued

Chaturvedi and Verma (2024)	✓					✓				✓	-Smart shoes for Health Monitoring -GPS tracking and gait analysis.
Naseem et al., (2024)	✓					✓				✓	-Shoe insole with antibacterial properties.
Cabrera-Sánchez et al., (2024)						✓	✓				- Evidence supporting the effectiveness of foot orthoses in reducing pain and disability in RA.
Dahmen et al., (2014)				✓		✓	✓			✓	-Custom-made therapeutic footwear
Menz and Golightly (2024)	✓				✓	✓	✓			✓	-Guidelines for footwear selection to enhance mobility and prevent falls in elderly populations.
Tehan et al., (2019)	✓	✓	✓		✓	✓	✓	✓	✓	✓	-A guideline for designing retail footwear that meets the needs of women with RA.
Hunter et al., (2020)	✓		✓			✓		✓		✓	-Guidelines for designing appropriate footwear for individuals with psoriasis and psoriatic arthritis (PsA).
González et al., (2015)	✓					✓				✓	- Wireless sensorized insoles for gait monitoring. - Real-time gait phase detection system.
Razak et al., (2012)	✓				✓	✓	✓			✓	- Provides a comprehensive review of existing plantar pressure measurement systems. -The review categorizes plantar pressure measurement systems into in-shoe systems, platform-based systems, and walkway-based systems.
Tan et al., (2015)				✓	✓	✓	✓			✓	-A prototype of a low-cost smart insole with pressure sensors for real-time plantar pressure measurement. -The study provides a foundation for future research and development in wearable foot pressure monitoring systems for medical and sports applications.
Tehan, Morpeth, etal., (2019)	✓	✓	✓		✓	✓	✓	✓	✓	✓	-Provides insights into the unmet needs of women with RA regarding retail footwear.

continued

											-The research highlights the physical, emotional, and social challenges these women face when choosing shoes.
Wilson et al., (2017)	✓				✓	✓	✓				-Insights into RA patients' experiences regarding foot problems and healthcare access. -Recommendations for improving foot care services, including greater awareness, early interventions, and patient-centered approaches to treatment.
De Souza and Lempp (2015)	✓		✓			✓	✓	✓		✓	-First-hand insights from RA patients regarding their footwear needs and struggles. -Recommendations for improved footwear designs, emphasizing both comfort and aesthetics.
Charlon et al., (2019)	✓			✓	✓	✓	✓			✓	-A connected smart insole equipped with sensors for gait analysis and movement tracking. -A real-time health monitoring system that provides data for fall prevention and mobility assessment.
Moon et al., (2020)	✓			✓	✓	✓	✓			✓	- Smart insoles embedded with active support mechanisms are designed to assist postural control and balance. -The technology could be integrated into rehabilitation footwear or sportswear to prevent injury.

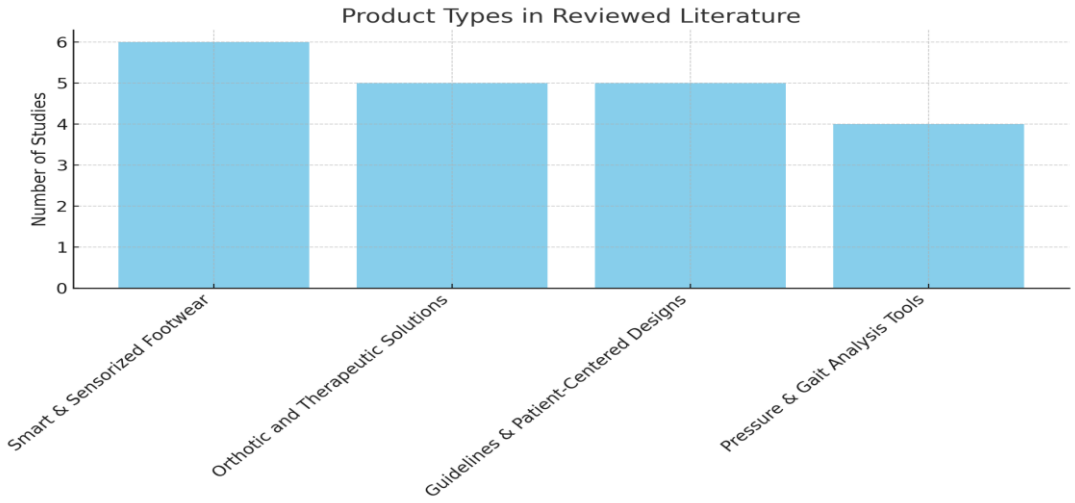

Figure 4. Distribution of product types addressing RA-related footwear needs.

To give a broader perspective on these findings, the products were further grouped into four main categories. This is shown in Figure 4, a bar chart illustrating how many studies fell under each product type:

1. **Smart & Sensorized Footwear** – Technologies that monitor gait, posture, and foot pressure in real time, often using IoT systems and wearable sensors.
2. **Orthotic and Therapeutic Solutions** – Custom-made insoles, supportive shoes, and materials aimed at managing pain, deformities, and biomechanical stress.
3. **Guidelines & Patient-Centered Design** – Studies offering design strategies based on patient feedback, emphasizing comfort, usability, and aesthetics.
4. **Pressure & Gait Analysis Tools** – Devices used in both clinical and research settings to assess foot biomechanics, helping to inform future product development.

Together, the table and figure provide a comprehensive view of how footwear for RA is being approached, highlighting both the progress made and the need for further integration of technology, comfort, and personalized design in future solutions.

Types of Shoes Common Among RA Patients in Malaysia

Finding appropriate shoes is especially difficult for RA patients in Malaysia because of the weather, cost, and accessibility. Research shows that lightweight materials, breathability, and flexible soles are crucial since Malaysia's hot and humid climate calls for non-restrictive and well-ventilated shoes. Many RA patients, therefore, depend on reasonably priced, mass-produced shoes that may lack necessary ergonomic qualities.

Table 3. Common Footwear Among RA Patients in Malaysia

Type of Footwear	Why It is Commonly Worn	Keywords
Slip-On Shoes (Loafers, Moccasins) 	Easy to wear; accommodates limited hand/finger mobility; available in local stores	Easy wear, soft upper, no laces, wide fit, low effort
Velcro Sandals 	Adjustable fit for swelling; breathable in tropical climate; sold widely	Adjustable strap, open toe, comfort, wide foot-bed, velcro
Comfort Sneakers 	Good arch support and shock absorption; more stability for walking	Cushioned sole, arch support, wide toe box, breathable mesh
Orthopedic Shoes (Custom-made) 	Recommended for severe deformities; offers medical-grade support	Custom fit, anti-slip soles, insoles, therapeutic design
Traditional Malaysian Sandals (Capal, Slippers) 	Cultural preferences: easy to slip on, but lacks medical support	Flat sole, cultural, informal, minimal support

Many RA patients in Malaysia choose adjustable, breathable, and cushioned shoes because of climate and lifestyle considerations. Still, price is a significant obstacle since finding high-quality orthopaedic shoes can be costly and challenging. This underlines the demand for reasonably priced, locally accessible ergonomic shoe options satisfying the particular requirements of Malaysian RA patients.

DISCUSSION AND IMPLICATIONS

Discussion of Key Findings

This systematic study reveals several significant new viewpoints on the ergonomic shoe needs of rheumatoid arthritis (RA) patients. One important outcome is the unsuitability of commercially available shoes to match the specific biomechanical problems and deformities experienced by RA patients. Many off-the-shelf shoes lack arch support, pressure distribution, and fit customization, which are three vital factors for reducing discomfort and improving mobility.

The study confirms that adaptive design components, orthotic insoles, and custom-made shoes remain the gold standard in managing RA-related foot issues. Foot scanning, pressure mapping, and gait analysis are vital techniques in their own right, which have helped create patient-specific shoes. These technologies enhance alignment, stability, and load distribution, especially for those with significant abnormalities, including hallux valgus, hammertoes, and metatarsalgia.

Furthermore, material invention is crucial. The research emphasized using lightweight, breathable, shock-absorbing materials, such as memory foams and thermoplastic elastomers (TPE), which reduce joint stress and fit swelling. Especially in low- to middle-income communities, the cost and availability of such advanced materials continue to be challenges.

Creating smart footwear technologies, including IoT-enabled insoles and wearable gait monitoring devices, holds great promise. These devices can give doctors and patients real-time information, enabling proactive management of joint stress and foot health. These choices are still too expensive, but they must be included more in everyday footwear to improve their routine.

Another significant gap was the absence of consistent anthropometric data among RA patients, which hinders the mass customisation of orthopaedic shoes. This is particularly crucial in Malaysia, where climate and socioeconomic factors influence shoe choice. Many people use mass-produced, badly fitting shoes because of high prices and limited ergonomic alternatives.

Finally, aesthetic appeal and social acceptability are often overlooked aside from use. Emotional and symbolic benefits linked to shoes, such as confidence, dignity, and inclusion, are especially important for older people. Many people with RA feel self-conscious about wearing orthopaedic shoes because of how clinical and dismal they look. Because of that, the upcoming line of footwear needs to find a happy medium between practical medical use and stylish, user-friendly designs to boost compliance.

Implications for Research, Industry, and Healthcare

Research

The findings point to a pressing need for longitudinal studies that examine not just short-term comfort but also long-term benefits of ergonomic footwear on mobility, foot health, and quality of life. Future research should also focus on:

- Developing region-specific anthropometric databases for RA patients.
- Evaluating cost-effective 3D printing methods for insole and shoe production.
- Investigating the usability and acceptability of smart footwear in elderly populations.

Researchers should also consider involving RA patients in participatory design approaches to better reflect user experiences and expectations in product development.

Industry

Footwear manufacturers and industrial designers can create inexpensive, modular, customizable shoes to fit various degrees of RA severity. Partnerships with health technology firms might enable the subtle integration of wearable sensors into orthopedic shoes. Industry participants in Southeast Asian countries have to consider climate-appropriate materials and cultural tastes.

In addition, incorporating aesthetic flexibility, such as replaceable upper designs and attractive textures, can make orthopaedic footwear more appealing to users, reducing the stigma associated with the condition and improving user compliance.

Healthcare

Clinicians, podiatrists, and physiotherapists should be encouraged to adopt a multidisciplinary and user-centered approach to prescribing footwear. Healthcare providers can:

- Use 3D scans and digital gait analyses as part of clinical assessments.
- Offer patient education on the importance of RA management.
- Collaborate with designers to co-create clinic-to-market footwear pathways.

For vulnerable populations, including senior RA patients, public health organizations and non-governmental organizations could think about providing subsidies or purchasing ergonomic footwear for the general public. Additionally, educational initiatives may enhance patient interaction with future technology and demystify smart footwear.

CONCLUSIONS

This systematic review explored several designs, material advancements, anthropometric measures, and technology developments in creating ergonomic shoes for rheumatoid arthritis (RA) patients and those with foot deformities that could benefit from these results. The review structure was carefully developed to gather thorough data on present issues and difficulties. Of the twenty articles chosen for review, those that were well-designed shoes were shown to be essential in lowering foot discomfort, enhancing mobility, and avoiding more RA-related problems. Currently available commercial shoes, however, frequently do not fit RA-related foot deformities, swelling, and biomechanical issues, which underlines the need for tailored and ergonomic solutions.

One of this research's main points is the need for anthropometric measurements in shoe design. Research suggests that RA patients need tailored shoe solutions; 3D foot scanning, pressure mapping, and bespoke orthotic insoles are the most successful ways to enhance fit and support. Despite the increasing progress in footwear design, the lack of standardized anthropometric data for RA patients remains a significant barrier that will limit the development of orthopedic footwear to meet the diverse needs of RA patients. This allows for potential research directions in developing footwear designs for RA patients. The findings suggest that future studies can focus on exploring solutions that benefit the wearer and reduce the additional burden of using the product. In addition, symbolic meaning and emotional well-being were also found to be associated with footwear. There is a lack of appropriate, stylish designs that allow RA patients to wear their orthopedic footwear confidently for various events and daily activities. Having orthopedic footwear that can provide perfect aesthetic value will enable patients to feel included in social settings, reducing the stigma of aging and preventing feelings of isolation.

Lastly, technological advances in smart footwear solutions have offered promising real-time gait monitoring and pressure redistribution opportunities. IoT-enabled insoles and wearable foot health tracking systems can revolutionize RA footwear by providing data-driven support personalized to their needs. However, cost will always remain a major limitation preventing its widespread use. Therefore, future research should focus on developing cost-effective smart shoe solutions that can be integrated into commercially viable everyday orthopedic shoes.

Research Contributions and Practical Implications

This study has contributed to improving knowledge about ergonomic footwear for RA patients by integrating findings from multiple fields, including biomechanics, materials science, industrial design, and healthcare. It also provides a total understanding of current trends, research gaps, and practical

challenges in footwear design for RA patients. It offers valuable insights for footwear designers, medical professionals, and researchers working toward more effective solutions.

From a practical perspective, the findings emphasize the importance of interdisciplinary collaboration between footwear manufacturers, orthopedists, and engineers to develop affordable, functional, and aesthetically acceptable footwear for RA patients. Policymakers and healthcare organisations should also consider subsidising orthopedic footwear or implementing patient education programs to raise awareness of the importance of proper footwear in managing RA patients.

Limitations and Future Research Directions

In spite of the fact that it makes contributions, this study has a few shortcomings. First, even though the review covers research from many geographical areas, it is crucial to recognize that cultural, social, and environmental factors may influence footwear demands and preferences, which may restrict the applicability of some findings. This emphasizes the importance of future research to look at ergonomic footwear options specific to a certain area and suited to its climate and population.

Another constraint is the absence of long-term clinical research assessing the continuing advantages of ergonomic shoes. With insufficient information on long-term compliance, durability, and real-world effectiveness, most research has concentrated on short-term pain alleviation and enhanced mobility. Future studies should give top priority to longitudinal studies assessing how ergonomic shoes affect RA patients' quality of life, mobility, and foot health outcomes over time.

At last, the price of smart and customized orthopaedic shoes is still difficult. Future research should look into economical production methods, 3D printing technology, and alternative material solutions to produce efficient ergonomic shoes for RA patients.

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