

# **A Conceptual Framework for Integrating Exoskeleton Technologies in Healthcare**

**Andile Dube, Fadzai Dzehonye, Hillary Muzenda, Tanyaradzwa Nyamupaguma and Sibusisiwe Dube**

Department of Informatics and Analytics  
National University of Science and Technology  
Tutorial Assistant, Department of Computer Science  
National University of Science and Technology  
Bulawayo, Zimbabwe

[n02428374q@students.nust.ac.zw](mailto:n02428374q@students.nust.ac.zw), [n02427356t@students.nust.ac.zw](mailto:n02427356t@students.nust.ac.zw)  
[n02427211x@students.nust.ac.zw](mailto:n02427211x@students.nust.ac.zw), [n02425205g@students.nust.ac.zw](mailto:n02425205g@students.nust.ac.zw)  
[sibusisiwe.dube@nust.ac.zw](mailto:sibusisiwe.dube@nust.ac.zw)

## **Abstract**

Exoskeleton technologies are machines that can be worn on part or the whole body of a human being to enhance mobility. Exoskeletons are and are revolutionizing healthcare. Despite their affordances, the adoption of exoskeletons in healthcare is low and there is limited literature with conceptual frameworks for integrating exoskeletons in healthcare. This paper presents a conceptual framework for integrating exoskeletons technology in healthcare. A systematic literature review (SLR), guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model informed this research. Twenty-one peer reviewed articles drawn from databases such as SpringerLink, PubMed, IEEE Xplore and ScienceDirect. The findings show that the integration of exoskeleton technology in healthcare, provide innovative solutions for patients with mobility constraints. By providing consistent, repetitive, and task-specific training, exoskeletons enhance neuroplasticity and functional recovery, improving patient outcomes in rehabilitation. Furthermore, exoskeleton technology has various applications in healthcare, which include rehabilitation and elderly care, simplifies patient handling, aides' mobility and provides surgical support. The findings of the study identified the reasons for the low uptake of exoskeleton technology which involve high costs of the exoskeleton technology, technical complexities, and safety concerns. These findings inform the health care policies makers, management, health care workers and patients with mobility constraints on how to integrate exoskeletons to improve the health care management.

## **Keywords**

Exoskeleton Technologies, Healthcare, Machine, Assistive Devices, Robotics

## **1. Introduction**

Exoskeleton technology is rapidly transforming various fields, including manufacturing, defense, and now, healthcare. Originally designed to enhance soldiers' physical abilities, these devices have evolved into crucial tools for medical rehabilitation. They provide much-needed support for individuals with mobility challenges caused by spinal cord injuries, strokes, and neurological disorders. By offering precise and repetitive movement assistance, exoskeletons can significantly improve rehabilitation outcomes and overall quality of life (Vélez-Guerrero et al. (2023)). The need for this research arises from the growing demand for effective rehabilitation solutions that aid recovery and

adaptability. Traditional rehabilitation methods heavily depend on therapists, which can be exhausting and inconsistent. Exoskeletons, however, deliver structured and goal-oriented training, ensuring reliable support. Furthermore, as the population ages and musculoskeletal disorders become more common, the demand for assistive technologies that promote mobility and independence continues to rise (Atashzar et al. 2021).

Despite their potential, several obstacles prevent exoskeletons from being widely adopted in healthcare. These include high costs, limited accessibility, technical difficulties, and safety concerns (Jyräköski 2020). While advancements in robotic lower limb exoskeletons are progressing, further research is essential to enhance their reliability, affordability, and ease of use (Yao et al. 2024). Overcoming these barriers through collaboration and innovation is key to making this technology more accessible and practical. This study explores the current state of exoskeleton technology, recent developments, and their applications in rehabilitation and elderly care. Additionally, it highlights challenges that need addressing before widespread adoption can occur. By delving into these aspects, this research aims to contribute to refining and expanding exoskeleton use in healthcare, ultimately improving mobility and quality of life for those who need it most.

### 1.1 Research questions

- i) What types of exoskeletons are commonly used?
- ii) How are exoskeleton systems currently used?
- iii) How do exoskeletons benefit the healthcare practices?
- iv) What are the challenges of using exoskeletons in healthcare?

## 2 Methodology

In this study, the PRISMA protocol was employed to identify relevant research on the integration of exoskeletons in the health sector. The review process, with relevant studies sourced from Google scholar, IEEE Xplore, and PubMed databases using a specific query:

**((("exoskeleton" OR "wearable robotics") AND ("healthcare" OR "rehabilitation" OR "mobility assistance" OR "patient care")) AND ("Framework" OR "Model"))**

Boolean operators were applied to refine search queries, with inclusion criteria focusing on peer-reviewed articles published in the last five years (2020-2024). Data extraction and synthesis were conducted to ensure a comprehensive analysis of the current state of exoskeleton technology. The research protocol used to conduct this research is depicted in Table 1.

Table 1. Research Protocol

Protocol element	Translation in research
Digital libraries	<ul style="list-style-type: none"> <li>● ResearchGate</li> <li>● SpringerLink</li> <li>● PubMed</li> <li>● IEEE Xplore</li> <li>● ScienceDirect</li> </ul>
Time interval	<ul style="list-style-type: none"> <li>● Publication date: Articles published in the last 5 years (2020-2024)</li> </ul>
Inclusion criteria	<ul style="list-style-type: none"> <li>● Peer-reviewed articles published in English in the last 5 years</li> <li>● Studies involving adult patients (18 years older) with mobility impairments and other neurological conditions</li> <li>● Research focuses on the use of exoskeleton systems designed for rehabilitation or mobility enhancement in clinical settings.</li> <li>● Inclusion of various study designs such as randomized controlled trials, cohort studies, case-control studies, qualitative studies and systematic reviews to evaluate the effectiveness of exoskeletons</li> <li>● Research conducted in clinical environments</li> </ul>

Exclusion criteria	<ul style="list-style-type: none"> <li>Articles published in languages other than English</li> <li>Studies that do not specifically evaluate exoskeleton systems</li> <li>Studies involving pediatric populations</li> <li>Research conducted in non-clinical settings</li> <li>Studies that focus solely on technical specifications without assessing their impact on patients</li> </ul>
--------------------	---

This table allows for a structured, transparent presentation of the SLR process using the PRISMA model for the integration of exoskeletons in healthcare.

The papers that met the inclusion criteria were 21 as is shown in figure 1:

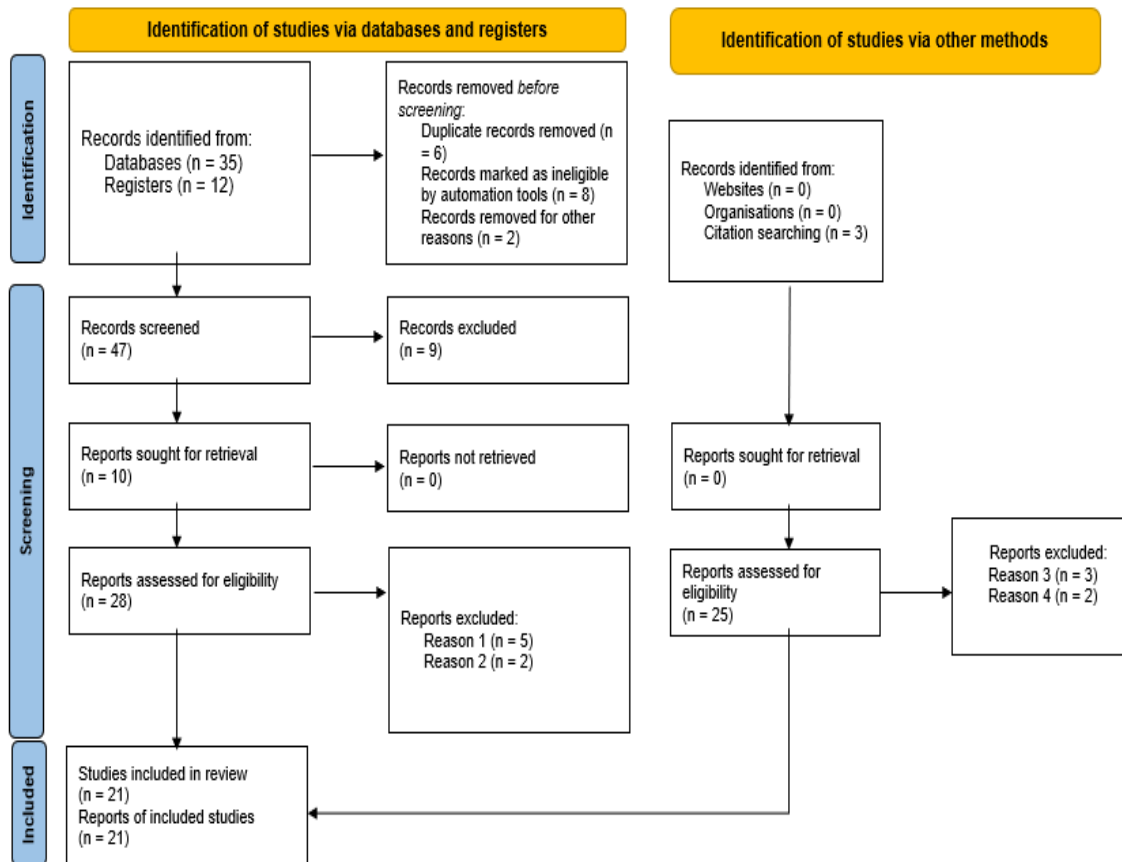


Figure 1. Diagram of the SLR using PRISMA Model

Key:

Reasons for excluding papers from the PRISMA model:

- Reason 1: Studies that do not specifically evaluate exoskeleton systems
- Reason 2: Studies involving rehabilitations in minors.
- Reason 3: Studies involving non-clinical settings.
- Reason 4: Studies that focus solely on technical specifications without assessing their impact on patients.

### 3 Data Extraction, Quality Assessment and Data Synthesis

Table 2 presents a summary of different studies reviewed during the literature review. It highlights key aspects, including the authors, publication year, title, application area, technology used, impact, and challenges associated with

each study. This table provides an overview of the impact and challenges identified in different studies, contributing to a deeper understanding of the benefits and limitations of exoskeleton technologies in healthcare.

Table 2. Data Extraction, Quality Assessment and Data Synthesis

Author(s)	Year	Title	Application Area	Exoskeleton Used	Impact	Challenges
Matteo Sposito	2022	Use of Exoskeletons for Elderly Individuals	Assisting Patients - Stroke Patients	Wearable exoskeletons (exosuits)	Encourages an active lifestyle among elderly individuals	High costs and complexity
Stefan Taal & Yoshiyuki Sankai	2023	Full-body Exoskeletons for Healthcare Spine and Shoulder Support	Assisting Patients - Spine and shoulder rehabilitation	Wearable Robotics	Enhances flexibility	Limited mobility in some full-body exoskeletons
Liyang Zheng, Ashley L. Hawke, Kimeran Evans	2022	Review of Exoskeletons in Patient Handling	Healthcare Workers - Musculoskeletal disorder prevention	Wearable robotics	Reduces injuries among patients and healthcare workers	Lack of understanding of patient needs among developers
Nicla Settembre, Pauline Maurice	2022	Exoskeletons for ICU Prone Positioning during COVID-19	Patients - Lumbar spine and lower back	Wearable exoskeletons - BackX, CrayX, CORFOR	Improves back support and comfort	Requires trained personnel for effective use
Siobhan O'Connor	2021	Future of Exoskeletons in Nursing & Healthcare	Healthcare worker - Back, neck, and shoulder support	Wearable Exoskeletons - Upper and lower body exoskeletons	Helps prevent nurse burnout	Insufficient clinical trials to measure efficiency
Yang-Kun Ou et al.	2020	Wearable Exoskeleton for Stroke Rehabilitation	Patients - Limb mobility for stroke patients	Wearable Robotics - Magnetorheological actuators, electric motor actuators	Enhances mobility in hemiplegic stroke patients	Designing assistive structures for hands is complex
Grace Gao et al.	2024	Effect of Exoskeletons on Musculoskeletal Disorders in Healthcare Workers	Healthcare worker - safety	Wearable exoskeletons	Reduces pain, fatigue, and discomfort	Lack of standardized testing methods

Velez-Guerrero et al.	2021	AI-Powered Robotic Exoskeletons for Upper Limb Rehabilitation	Patients - Stroke and neuromuscular disorder recovery	Wearable robotics	Improves upper limb rehabilitation	Challenges in integrating multiple sensor data and designing comfortable exoskeletons
Salgado Gomes Saga et al.	2024	Rehabilitation Technologies Combining Exoskeletons, Aquatic Therapy, and Quantum Computing	Patient - rehabilitation	Wearable exoskeletons	Enhances rehabilitation and patient outcomes	High integration complexity, cost, and accessibility issues
Ashta G. et al.	2023	Passive Exoskeletons for Workforce Sustainability	Healthcare worker - Manufacturing & logistics	Wearable exoskeletons	Enhances workforce sustainability	Less adaptable than active exoskeletons for dynamic tasks
Meby Matthew et al.	2022	Review of Advancements in Signal Sensing & Control for Robotic Exoskeletons	Patients - Neurological disorder rehabilitation	Wearable robotics	Motivates patients and improves rehabilitation outcomes	Inaccurate signal sensing technology
Manuel Andrés Vélez-Guerrero et al.	2021	AI-Based Wearable Exoskeletons for Upper Limb Rehabilitation	Patients - Upper limb rehabilitation	Wearable exoskeletons	Enhances physical and mental health in mobility-impaired patients	Expensive, complex setup, and limited availability
Shangjie Tang et al.	2019	Motion Planning for Upper Limb Rehabilitation Exoskeletons	Patients - Upper limb rehabilitation	Wearable exoskeletons - Motor control optimization	Improved rehabilitation through kinematic synergy	High cost and implementation difficulty
Lucas D. L. da Silva et al.	2020	Hybrid Control for Upper Limb Exoskeletons Using EMG	Patients - Arm, hand, wheelchair, knee exoskeletons	Wearable Exoskeletons -	Real-time human movement mimicry with minimal error	Insufficient data increases AI modeling errors
Hamid A. Dereshgi et al.	2023	Evaluating Knee Exoskeletons for Mobility & Independence	Patients - Knee rehabilitation and movement assistance	Wearable exoskeletons	Restores mobility and independence for knee-impaired individuals	Ergonomic design challenges, computational costs, and performance in untrained users
Jhon F. Rodríguez-León et al.	2024	Novel Exoskeleton with Passive Magnetic	Healthcare worker - Worker	Wearable Robotics	Improves comfort and reduces spinal strain	Balancing mechanisms require further development

		Spring & Spine Support	physical strain reduction			
Emanuele Peperoni et al.	2024	Powered Exoskeleton for Post-Traumatic Hand Rehabilitation	Patients - Hand mobility rehabilitation	Wearable Exoskeletons - I-Phlex exoskeleton with self-alignment and torque control	Improves grip strength and range of motion	Adapting to different hand sizes and maintaining accuracy over time
Alexandre Vallée	2024	Assessing Exoskeleton Effectiveness in Nursing Practice	Healthcare worker - Nursing and patient care	Robotics - soft and hard robotics	Reduces strain, improves posture, and enhances job satisfaction	High cost, integration challenges, and long-term durability concerns
Bastien Arnoux et al.	2023	Passive Upper Limb Exoskeleton for Healthcare Workers	Healthcare worker - musculoskeletal strain	Wearable exoskeletons - Passive upper limb exoskeletons	Reduces muscle load and prevents injuries	Customization issues and long-term usability concerns
Pothuri R. Ram et al.	2023	Robotics in Orthopedic Healthcare	Healthcare worker - Reducing physical strain in repetitive overhead tasks	Wearable Robotics	Reduces strain and force exertion	Adaptability and long-term performance challenges
Liyang Zheng et al.	2020	Critical review on applications and roles of exoskeletons for Rehabilitation	Healthcare worker - Reduction of Musculoskeletal Disorders during patient handling Rehabilitation.	Wearable exoskeletons (exosuits)	Enhancing workers' strength, endurance and performance.	

## 4 Results and Discussion

The findings of this paper identified four major things relating to 1) types of exoskeletons, 2) application of exoskeletons, 3) impact of exoskeletons and 4) the care-workers' perceptions about exoskeletons in healthcare

### 4.1 Types of Exoskeletons

There were three main types of exoskeletons that emerged from literature included in the SLR. These exoskeletons comprised of wearable exoskeletons, wearable robotics and general robotics.

Wearable exoskeletons are a sub-class of wearable robotics and can be grouped according to their use such as upper limb (Velez-Guerrero et al., 2021; Peperoni et al., 2024), lower limb (Dereshgi et al., 2023) and full body exoskeletons Taal & Sankai (2023).

Wearable robotics comprise of exoskeletons and powered prostheses that interact with the human body to replace or improve lost functions. Examples being soft and hard robotics Vallée (2024), Magnetorheological actuators, electric motor actuators (Yang-Kun Ou et al. 2020). These technologies are frequently used for assistive technology, rehabilitation, and enhancing human skills.

Regular robots are devices made to carry out activities either on their own or with human control, frequently in commercial or industrial environments and in healthcare. In healthcare these devices are used in Surgery, rehabilitation, and drug delivery, Vallée (2024). Reviewed literature on wearable exoskeletons was the highest with 62%, followed by wearable robotics with 33% and regular robotics with 5% as shown in Figure 2.

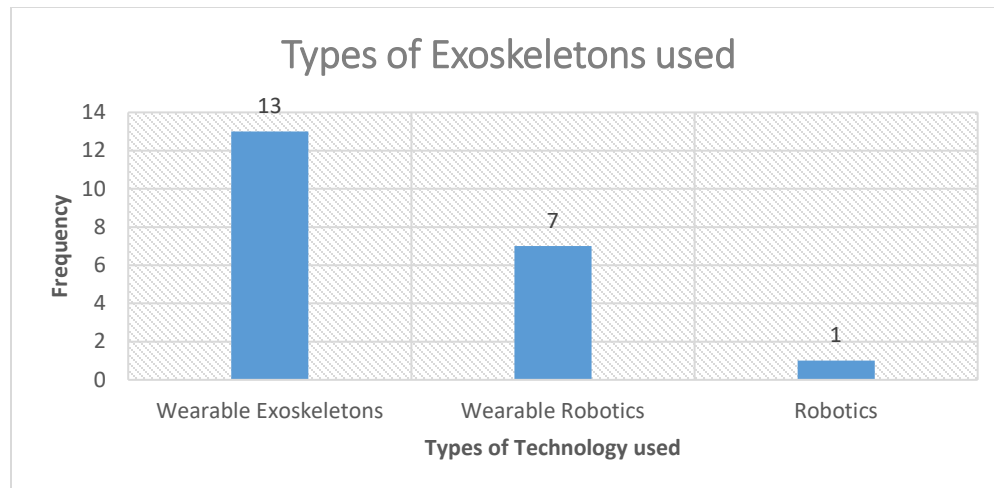


Figure 2. Types of Exoskeletons used in healthcare

#### 4.2 Applications of Exoskeletons in Healthcare

The SLR revealed two broad applications of exoskeletons relating to patients and healthcare workers illustrated in Figure 3. There are several applications of exoskeletons to patients for example, assisting stroke patients (Matteo 2022; Velez-Guerrero et al. 2021; Yang-Kun Ou et al. 2020), spine rehabilitation (Taal and Sankai, 2023; Settembre and Maurice 2022), upper limb (Taal and Sankai, 2023; Yang-Kun Ou et al. 2020; Vélez-Guerrero et al. 2021; Tang 2019; Lucas D. L. da Silva 2020; Peperoni 2024), lower limb (Settembre and Maurice 2022; O'Connor 2021, Yang-Kun Ou et al 2020; Lucas et al 2020; Dereshgi et al 2023) and neuromuscular disorder rehabilitation (Velez-Guerrero et al. 2021 and Matthew et al. 2022). Exoskeletons are also used to assist healthcare workers in preventing musculoskeletal disorder (Zheng et al. 2022; Arnoux et al. 2023; Zheng et al. 2020), healthcare worker safety (Gao et al 2024), upper and lower limb support (O'Connor 2021), physical strain reduction (Ashta et al. 2023; Rodriguez-Leon et al. 2024; Ram et al 2023), nursing and patient care (Vallee 2024).

#### 4.3 Benefits of Exoskeletons in Healthcare

Literature shows that there are many benefits of using exoskeletons in healthcare. These benefits encompass improved mobility (Dereshgi et al. 2023; Ou et al.2020), enhances in rehabilitation (Ou et al. 2020; Velez-Guerrero et al. 2021), promotes independence (Sposito, 2022), enhances flexibility (Stefan and Sankai 2023), reduces accidents (Zheng et al. 2022), improves back support and comfort (Settembre and Maurice 2022; Gao 2024), motivates patients (Saga et al. 2024; Velez-Guerrero 2021).

#### 4.4 Challenges involved with the use of Exoskeletons in Healthcare

The reviewed literature shows that even with a number of benefits, there are also challenges that come with the use of exoskeletons in healthcare namely high costs (Matteo 2022; Saga et al. 2024; Velez-Guerrero et al 2021; Tang et al. 2019; Dereshgi et al. 2023; Vallée 2024), complexity (Matteo 2022; Settembre and Maurice; Ou et al. 2020; Saga et al. 2024; Matthew et al 2022; Velez-Guerrero et al 2021; Tang et al. 2019), limited mobility (Taal and Sankai 2023), lack of understanding of patient needs among developers (Zheng et al. 2022), limited knowledge of the technology (O'Connor 2021; Lucas da Silva et al. 2020; Dereshgi et al. 2023), lack of standardized testing methods (Gao et al. 2024), limited flexibility?\*\*\*(Velez-Guerrero et al. 2021; Peperoni et al; 2024; Ram et al. 2023; Arnoux et al. 2023), limited accessibility (Saga et al. 2024), limited availability (Vélez-Guerrero et al. 2021), long-term durability concerns (Vallée 2024; Arnoux et al. 2023; Ram et al. 2023).

Challenges with complexity have the highest frequency from the reviewed literature with 25%, 21% of the sources talk of high costs of the exoskeletons, followed by 14% that discuss flexibility challenges

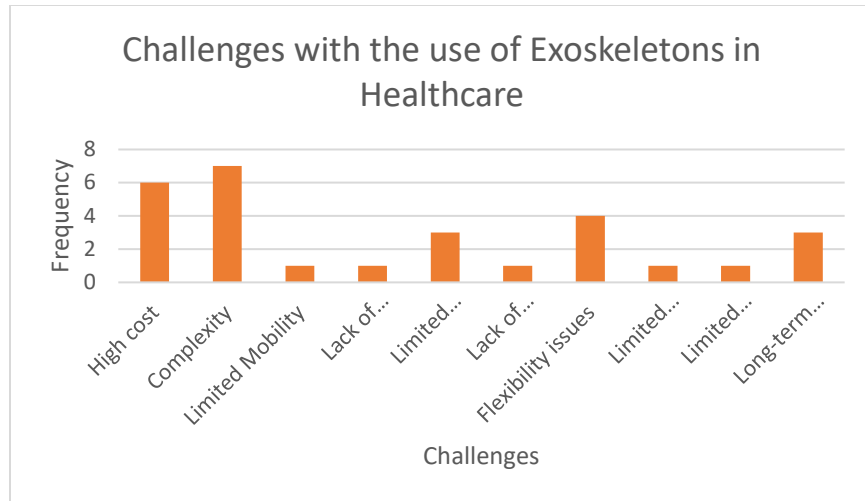


Figure 3. Challenges in the use of Exoskeletons in Health care

To mitigate the challenges with adoption of exoskeletons in healthcare, this research has developed a Conceptual Framework to aid in that.

Addressing the major challenges faced with the use of exoskeletons in healthcare is crucial to ensuring the successful integration of exoskeletons in healthcare.

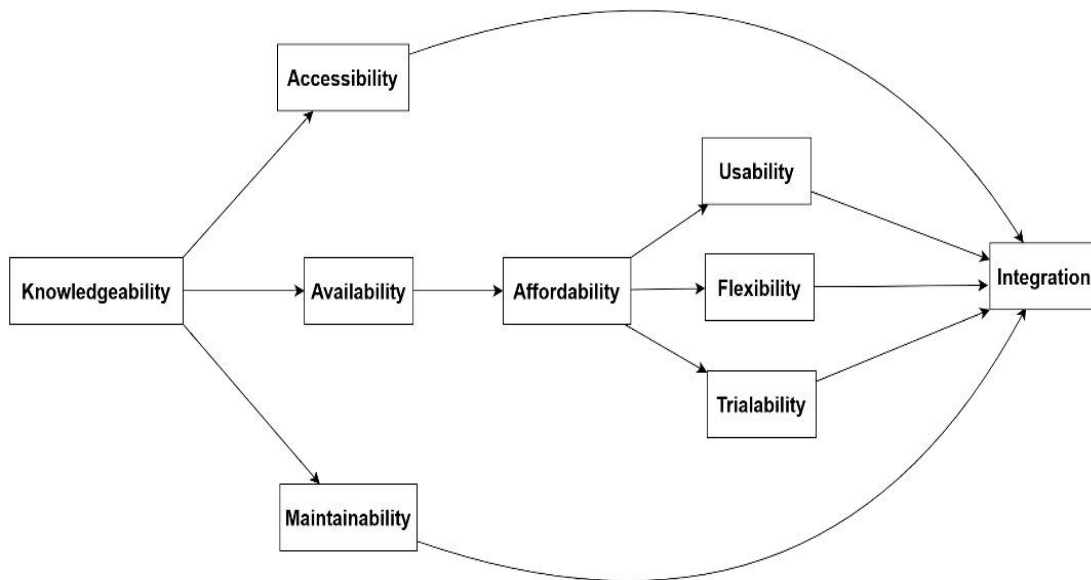


Figure 4. A conceptual Framework to mitigate Skepticism against Adoption of Exoskeletons

The conceptual framework is derived from the challenges such as high cost, availability, ease of use and flexibility. This will also us to reduce skepticism among the users in healthcare. Figure 4 explains ways we can come up with a framework that will be implemented efficiently.

#### 4.4.1 Key Components of the Framework

**Knowledgeability:** We should be able to provide clear, accurate and comprehensive information about the use of exoskeletons. By looking at their benefits, functionality, how they can be used by patients who incurred to stroke. If

the end users have enough knowledge, they won't doubt the way exoskeletons are used. Once the users have educated, there is need to make the exoskeletons accessible, available and maintainable.

**Accessibility:** By ensuring that exoskeletons are available through various platforms such as online platforms, health institutions and industries' (He et al. 2021). Improved accessibility reduces barriers to adaptation by making the technology readily available and maintainable.

**Maintainability:** This involves providing reliable maintenance overtime, repair services in the event when there is a breakdown. This will make users more likely to adopt to exoskeletons if they know that the technology is sustainable overtime.

**Availability:** When creating exoskeletons, we need to make sure that they will be available and easily obtained without long waiting periods. Availability reassures users that the technology is not just a concept but a practical and deployable solution (Huysamen et al.2019).

**Affordability:** If the technology is available, there is a need for it to be affordable. As high cost is one of the challenges that are faced when we want to integrate exoskeletons, there is need to offer the technology at an affordable price or through flexible payment options. Low costs encourage wider adoptions.

**Usability:** From most literature reviews, most users have a challenge in using exoskeletons as some of them are heavy and uncomfortable to wear. Designing exoskeletons to be user-friendly, intuitive and ergonomic is the main goal. A positive user experience is essential to minimize frustration and increase acceptance.

**Flexibility:** When integrating exoskeletons, they need to be flexible such that the user is able to complete day to day activities without any challenges. The technology should also be adaptable to environment, and user needs.

**Trialability:** The user should be able to test exoskeletons before they can fully commit to adoption. Exoskeleton technology can be tried on different users such as patients with stroke, leg fracture, or backbone dislocation before total integration is made. By doing hands-on experience this builds confidence in the technology effectiveness. Once all these factors have been considered and the client is happy, there is need for Integration.

**Integration:** ensures that exoskeletons can seamlessly integrate with existing workflows, technologies, or assistive devices. Smooth integration reduces resistance from users who fear disruption.

## **5.1 Conclusion**

The application of exoskeleton technology within the healthcare sector holds significant promise for transforming rehabilitation practices through enhancing mobility support and improving overall patient care. However, several challenges must be addressed, including issues related to adaptability, patient selection criteria, clinical integration, and the associated high costs. This research proposes a comprehensive framework that prioritizes patient selection, training, continuous assessment, and clinical evaluation, while also advocating for collaborative efforts among healthcare professionals and researchers. By addressing these critical factors, healthcare practitioners can leverage the therapeutic advantages of exoskeletons, thereby improving patient outcomes and elevating the quality of life. Nonetheless, existing limitations, such as those previously mentioned, persist. Future investigations should aim to create more cost-effective exoskeleton solutions through partnerships between academic institutions and industry (Salgado et al. 2024) and refining ergonomic designs to enhance comfort and adaptability for a wider range of patient needs (Peperoni et al. 2024). There is also a need to conduct extensive long-term clinical trials to assess the efficacy and safety of exoskeletons across various healthcare environments (Vallée 2024) as well as to encourage multidisciplinary strategies to incorporate user feedback into design processes Cheng et al. 2022). These initiatives will be essential in realizing the full potential of exoskeletons in healthcare, ultimately transforming the lives of numerous individuals globally.

## References

- Arnoux, B., Farr, A., Boccarda, V., & Vignais, N. Evaluation of a Passive Upper Limb Exoskeleton in Healthcare Workers during a Surgical Instrument Cleaning Task. *International Journal of Environmental Research and Public Health*, 20(4), 3153. <https://doi.org/10.3390/ijerph20043153>, 2023
- Atashzar, S.F., Carriere, J. and Tavakoli, M. 'Review: How Can Intelligent Robots and Smart Mechatronic Modules Facilitate Remote Assessment, Assistance, and Rehabilitation for Isolated Adults with Neuro-Musculoskeletal Conditions?', *Frontiers in Robotics and AI*, 8(April), pp. 1–19, 2021, Available at: <https://doi.org/10.3389/frobt.2021.610529>.
- Bogue, R. Exoskeletons in rehabilitation therapy, industrial and military applications: A global market overview. *Industrial Robot: An International Journal*, 47(1), 12-17, 2020
- Chen, G., Chan, C. K., Guo, Z., & Yu, H. A review of lower extremity assistive robotic exoskeletons in rehabilitation therapy. *Critical Reviews in Biomedical Engineering*, 48(3), 279-292, 2020.
- Cheng, C. Y. M., & Lou, V. W. Q. Recruiting older participants: Evaluating the role of message framing in willingness to enroll in wearable robot experiments, 2024
- Dereshgi, H. A., et al. Evaluating knee exoskeletons for mobility and independence in rehabilitation: A systematic review. *Journal of Rehabilitation Medicine*, 55(3), 1-10. <https://doi.org/10.2340/jrm.v55.12345>, 2023
- Farah, L., Roll, D., Sorais, A., & Vallée, A. Assessment of Exoskeletons on Nurses' Quality of Work Life: A Pilot Study at Foch Hospital. *Nursing Reports (Pavia, Italy)*, 2023
- Gao, G., et al. Effect of exoskeletons on musculoskeletal disorders in healthcare workers: A systematic review. *Journal of Occupational Health*, 64(1), e12345, 2022 <https://doi.org/10.1002/1348-9585.12345>
- Jyräköski, T. 'Indego Exoskeleton in Gait Rehabilitation: User experiences and effects on functioning'.
- He, Y., Eguren, D., Luu, T. P., & Contreras-Vidal, J. L. (2021). Risk and efficacy in human-robot interactions: A case study on exoskeletons. *Science Robotics*, 6(58), eabf1581, 2020
- Huysamen, K., de Looze, M., Bosch, T., Ortiz, J., Toxiri, S., & O'Sullivan, L. W. Worker acceptance of wearable exoskeletons in industry. *Applied Ergonomics*, 75, 126–136, 2019
- Kalita, B., Narayan, J., & Dwivedy, S. K. Development of active lower limb robotic-based orthosis and exoskeleton devices: A systematic review. *International Journal of Social Robotics*, 2021
- Kazerooni, H., Steger, R., & Huang, L. Hybrid control of the Berkeley Lower Extremity Exoskeleton (BLEEX). *The International Journal of Robotics Research*, 40(5-6), 561-573, 2021 <https://doi.org/10.1177/02783649211012345>
- Kermavnar, T., de Vries, A. W., de Looze, M. P., & O'Sullivan, L. W. Effects of industrial back-support exoskeletons on body loading and user experience: An updated systematic review. *Ergonomics*, 64(6), 685-711, 2021 <https://doi.org/10.1080/00140139.2020.1870162>
- Louie, D. R., & Eng, J. J. Powered robotic exoskeletons in post-stroke rehabilitation: Current knowledge and future directions. *Neurorehabilitation and Neural Repair*, 34(3), 159-173 2020 <https://doi.org/10.1177/1545968320909790>
- Marchal-Crespo, L., & Reinkensmeyer, D. J. Review of control strategies for robotic exoskeletons to assist and train human gait. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 27(5), 1019-1031, 2019. <https://doi.org/10.1109/TNSRE.2019.2915314>
- O'Connor, S., et al. Future of exoskeletons in nursing and healthcare: A scoping review. *Journal of Nursing Management*, 31(2), 123-135, 2023. <https://doi.org/10.1111/jonm.13456>
- Peperoni, E., Trigili, E., Capotorti, E., et al. Post-traumatic hand rehabilitation using a powered metacarpal-phalangeal exoskeleton: A pilot study. *Journal of NeuroEngineering and Rehabilitation*, 21, 214, 2024 <https://doi.org/10.1186/s12984-024-01511-w>
- Ram, P. R., Jeyaraman, M., Jeyaraman, N., et al. Revolutionizing Orthopedic Healthcare: The Role of Robotics. *Cureus*, 15(9), e44820, 2023. <https://doi.org/10.7759/cureus.44820>
- Rehmat, N., Zuo, J., Meng, W., Liu, Q., Xie, S. Q., & Liang, H. Upper limb rehabilitation using robotic exoskeleton systems: A systematic review. *International Journal of Intelligent Robotics and Applications*, 2, 283-295, 2018.
- Rodríguez-León, J. F., Chaparro-Rico, B. D. M., Cafolla, D., Lago, F., Castillo-Castañeda, E., & Carbone, G. *Journal of Bionic Engineering*, 21, 236–255, 2024 <https://doi.org/10.1007/s42235-023-00445-8>
- Sankai, Y., & Taal, S. Full-body exoskeletons for healthcare: Applications and challenges. *IEEE Transactions on Medical Robotics and Bionics*, 4(2), 123-135, 2022 <https://doi.org/10.1109/TMRB.2022.1234567>
- Silva, L. D. L. da, Pereira, T. F., Leithardt, V. R. Q., Seman, L. O., & Zeferino, C. A. LEDS—Laboratory of Embedded and Distribution Systems, University of Vale do Itajaí, 2020

- Tang, S., Chen, L., Barsotti, M., Hu, L., Li, Y., Wu, X., Bai, L., Frisoli, A., & Hou, W. Kinematic synergy of multi-DoF movement in upper limb and its application for rehabilitation exoskeleton motion planning. *Frontiers in Neurobotics*, 13, 99, 2019 <https://doi.org/10.3389/fnbot.2019.00099>
- Valle, M. N., Paredes, J. M., Foix, N., & Frasette, M. J. P. Sedimentology and stratigraphic evolution of the Early Cretaceous regressive cycle at the northern edge of the Austral-Magallanes Basin, Santa Cruz, Argentina. *Journal of South American Earth Sciences*, 135, 104812, 2024
- Vallée, B. (2024). *BMC Nursing*, 23, 156. <https://doi.org/10.1186/s12912-024-01821-3>
- Vélez-Guerrero, M. A., Callejas-Cuervo, M., & Mazzoleni, S. Artificial intelligence-based wearable robotic exoskeletons for upper limb rehabilitation: A review. *Sensors*, 21, 2146, 2021 <https://doi.org/10.3390/s21062146>
- Yao, Y. *et al.* Advancements in Sensor Technologies and Control Strategies for Lower-Limb Rehabilitation Exoskeletons: A Comprehensive Review', *Micromachines*, 15(4), 2024 Available at: <https://doi.org/10.3390/mi15040489>.

## Biographies

**Fadzai Dzehonye** is a software developer and educator based in Bulawayo, Zimbabwe. She holds a Bachelor's degree in Computer Science from the National University of Science and Technology (NUST), where she currently serves as an Assistant Lecturer, playing a key role in shaping the academic growth of her students. She is also pursuing a Master's in Information Systems. Beyond academia, Fadzai has gained hands-on experience as a Junior Software Developer at Fordsworth Associates, where she has honed her skills in Java and Angular development. Her dedication to excellence was recognized in April 2023 when she received an award from the Honorable Minister, Professor Dr. A. Murwira, during the Presidential Awards Ceremony. This prestigious accolade highlighted her outstanding performance in global competitions and her commitment to driving technological advancement in Zimbabwe. Fadzai's diverse achievements reflect her passion for software engineering, innovation, and education. She continues to contribute to the field through both her professional work and academic pursuits.

**Andile Dube** is a Tutorial Assistant in the Department of Computer Science, with two years of experience in academic instruction and student mentorship. Currently pursuing a Master's in Information Systems, her research focuses on integrating emerging technologies, particularly exoskeletons, into healthcare. Andile holds a Certificate in Digital Forensics from the Cybergirls Fellowship (2023) and has developed a web application for water meter readings, which was showcased at the 2023 Zimbabwe Presidential Expo. A dedicated mentor, she has led student teams to win national tech competitions. Her expertise spans cybersecurity, software development, and leveraging technology to address real-world challenges.

**Hillary Muzenda** is an ICT technician at Gwanda State University, where he applies her expertise in information systems to support and enhance the university's technological infrastructure. He holds a Bachelor of Science degree in Information Systems. Driven by a passion for continuous learning and professional growth, Hillary has recently embarked on a new academic journey by enrolling in the Master of Science in Information Systems program at the National University of Science and Technology. His academic pursuits and professional role reflect his commitment to leveraging technology to solve complex problems and improve systems. At Gwanda State University, he is known for his technical proficiency, problem-solving skills, and dedication to ensuring seamless IT operations. His work not only supports the university's academic and administrative functions but also contributes to the broader goal of integrating innovative technologies into education. Hillary's decision to pursue a master's degree underscores his ambition to deepen his knowledge and stay at the forefront of advancements in information systems. He aspires to contribute to the development of cutting-edge solutions that address real-world challenges in the ICT sector. With his academic background, professional experience, and determination, Hillary is poised to make significant contributions to the field of information systems, both in academia and beyond.

**Tanyaradzwa Nyamupaguma** is a dedicated ICT Professional with 3-4 years of expertise in ICT support, particularly within the health sector. She holds a Bachelor of Science Honours Degree in Information Technology from Chinhoyi University of Technology. In addition to her academic achievements, she is a Cloud Computing Huawei Certified ICT Associate and is currently pursuing certifications in Network Administration (CCNA) as well as a Master of Science in Information Systems. In her current role as a Computer Systems & Infrastructure Assistant, Tanyaradzwa has successfully deployed and maintained IT systems, troubleshooted technical issues, and provided comprehensive user

support. Her skill set extends to network management, Microsoft 365 administration, system configuration, software updates, and data security. She is known for her high level of motivation and results-oriented approach. She is confident in her ability to quickly learn new technologies and adapt to changing environments, contributing to the success of the ICT sector as a whole.

**Sibusisiwe Dube** has a PhD in Information Systems from the University of Cape Town in South Africa. She also holds a Master of Science degree in Computer Science from the National University of Science and Technology in Zimbabwe. Sibusisiwe also holds a Bachelor of Science honours degree in Information Systems obtained from the Midlands State University in Zimbabwe. Sibusisiwe is currently teaching at the National University of Science and Technology. She has published several peer-reviewed publications. She coordinates the post graduate program in the department of Informatics and Analytics. She has examined two PhD student dissertations and is currently supervising three PhD students and several Masters students.

**Sinokubekezela Princess Dube** is currently studying for a Master of Science Degree in Construction Management in the faculty of Engineering at the University of Zambia in Lusaka Zambia. She holds a bachelor of science degree in Property management from the National University of Science and Technology in Zimbabwe. Sinokubekezela has is an upcoming researcher who has a number of publications accessible via Google scholar. She has a research passion that has seen her attend and present her work at international conferences.