FUTURE-PROOF THE HEALTHCARE SECTOR WITH **EXOSKELETONS**

MSD-CARE SUSTAINABILITY REPORT

Interreg
North-West Europe
Co-funded by the European Union
MSD-CARE

This sustainability report was prepared by Bax Innovation on behalf of the MSD-CARE project partners.

MSD-CARE is co-funded by the European Union's Interreg North-West Europe (NWE) programme (NWE0300450), with the overarching objective of overcoming the barriers to the adoption of innovations preventing musculoskeletal disorders (MSDs) among NWE caregivers. The project consortium includes HAWK University for Applied Science and Arts Hildesheim (Germany), Roessingh Research and Development (Netherlands), and the University of Galway (Ireland).

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1. Introduction

Musculoskeletal disorders (MSDs) are a collection of injuries that affect the muscles, bones, nerves, and other soft tissues caused by repetitive movements, excess force on the body, awkward body positions, or a workplace that does not allow for sufficient rest and recovery (Golabchi et al., 2023).

Healthcare workers are particularly susceptible to developing MSDs as they consistently perform strenuous tasks for prolonged periods while caring for patients. A nurse's day-to-day activities might include tasks such as positioning and moving patients, assisting with hygiene, or providing emergency help such as after a fall. These can all lead to static postures, prolonged bending of the upper body, lifting, and other unnatural body positions, significantly increasing the risks of various MSDs (Freitag et al., 2007).

Traditionally, the mitigation of MSDs in the healthcare sector has been focused on training, ergonomic workplace interventions, and organisational support. However, these measures have proven largely insufficient. Over 50% of caregivers (3.5 million NWE workers, Eurostat) report pain caused by various MSDs, resulting in millions of potential care-providing days lost.

The MSD-CARE project (2024-25) was established to explore ways of preventing the development of MSDs among vulnerable NWE caregivers, focusing specifically on identifying the barriers to the adoption of exoskeleton technologies, as well as providing suggestions to increase their use within healthcare. These devices are defined as wearable robot technologies that modify internal or external forces acting on the body (OSHA, 2019).

Exoskeletons have already been widely adopted in manufacturing, agriculture, and logistics, yet their use in healthcare remains limited, despite clinical tests showing their potential to prevent injury and support health professionals when caring for patients.

Under Interreg NWE (Priority 4.5), the MSD-CARE project aims to tackle the imbalances and needs necessary to access the healthcare sector. The consortium is comprised of HAWK University (coordinator, Germany), Roessingh Research and Development (the Netherlands), and University of Galway (Ireland), working collaboratively to assess the usability, effectiveness and practicalities of adopting exoskeletons under healthcare settings. The results of the project were promising, as nurses across sites agreed that they felt the use of exoskeletons supported their lower backs during day-to-day tasks. In addition, pilot activities successfully identified required changes to facilitate the adoption of exoskeletons in the healthcare sector.

The MSD-CARE sustainability report aims to create a roadmap to ensure the positive outcomes from the project are carried forward following the finalisation of Interreg NWE funding. With a quadruple-helix strategy, we establish fields where the consortium can facilitate the adoption of exoskeletons in healthcare by ensuring long-term impact for nurses and other associated stakeholders. This report also provides insights into future trend developments and identifies relevant Interreg projects that could benefit from the MSD-CARE results. The outputs presented in this report have been developed by the MSD-CARE consortium to sustain the progress achieved and thus, ensure the adoption of innovative solutions for the prevention of MSDs in the NWE region and beyond.

2. Opportunities, challenges, and emerging trends

Existing staff shortages in the healthcare sector are well-documented and are projected to worsen. The OECD highlighted that 15 EU countries reported a shortage of nurses between 2022 and 2023 (OECD, 2024). This shortage is believed to be caused by the dual demographic challenges of an ageing population, which increases the demand for health services, and an ageing health workforce, which increases the need to replace current health workers as they retire. Indeed, a quarter of nurses in the EU are aged over 55 and are expected to retire in the coming years (OECD, 2024).

Exoskeletons can be generally categorised as either rigid or soft, depending on the material from which they are made, and active or passive, depending on whether they have additional power actuators. Unlike traditional rigid models, soft exoskeletons use flexible, lightweight materials to mimic natural body movements. As the healthcare sector increasingly leverages advanced assistive technologies, soft exoskeletons are rapidly emerging as a transformative solution for workers when performing strenuous tasks. The MSD-CARE project has paved the way to facilitate the adoption of such promising technology across the NWE region.

In this section, we provide a summary of drivers and challenges shaping the adoption and impact of exoskeletons in the healthcare sector. We focus on their unique benefits, evolving applications, and challenges for future integration. Understanding existing trends is a key step prior to developing a highly effective sustainability approach that ensures that the results from MSD-CARE are galvanised to maximise impact.

2.1 Future trends in the exoskeleton market

The exoskeleton market is experiencing growth, revolutionising a range of industries such as manufacturing, construction, logistics, and defence. Industrial applications are increasingly embracing exoskeleton technology to enhance productivity and worker safety, with the industrial exoskeleton market projected to surpass USD 5 billion by 2033 (Global market insights, 2022). Introducing exoskeletons to a workforce can reduce fatigue, minimise lost work hours as a result of injury, and support ageing workers (Geographic scope and forecast, n.d.).

In the healthcare sector, exoskeletons are being used to support both patients and professionals; enabling rehabilitation, reducing work-related injuries among clinical staff, and addressing ergonomic challenges that contribute to MSDs (O'Connor, 2021). The global medical exoskeleton market alone is expected to grow to a value of USD 2.2 billion by 2032, driven by a surging demand in neurological rehabilitation and an ageing population (Coherent Market Insights, 2025). In terms of European adoption, the biggest markets in Europe are countries in the NWE region, while there is also growth in Eastern Europe.

As previously outlined, exoskeletons can be divided into 4 categories depending on their characteristics (soft/rigid and active/passive), which in turn shape the exoskeleton market into four sectors: soft active, soft passive, rigid active and rigid passive. The soft active section of the market is the least developed, in comparison with the soft passive market, which is considered saturated. Rigid exoskeleton markets lie somewhere between the two, with room for further development and competition. Soft-passive exoskeletons were identified by the MSD-CARE consortium as the most suitable option for nurses handling patients, due to their flexibility, ease of use, and visual appeal to patients.

The global soft exoskeleton market is forecast to grow to a market size of USD 6 billion by 2033 (Geographic scope and forecast, n.d.), with products segmented into upper body, lower body, and full body models, each serving distinct functions. The rapidly expanding and increasingly competitive market indicates a strategic willingness from manufacturers to develop new models. Ongoing innovation, improvements in product quality, and declining costs could create favourable conditions for the wider adoption of exoskeleton technology in the underexplored healthcare sector.

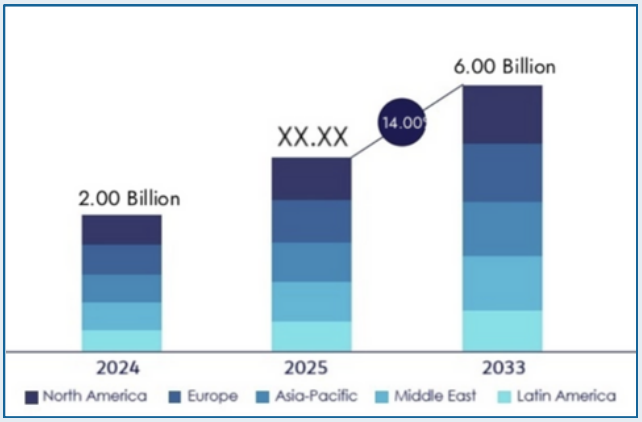

Figure 1: Global soft exoskeleton market size and growth. XX.XX denotes unspecified amount. From https://www.verifiedmarketreports.com/product/soft-exoskeleton-market/

To form a more rounded understanding of the market trends and requirements to facilitate the adoption of exoskeletons in the healthcare sector, the MSD-CARE consortium performed expert interviews with selected stakeholders from industry (LAEVO[1]), insurance (BOCHUM University[2]), research (POLIMI[3]), occupational therapy associations (OSHA[4]) and nurse associations (ESNO[5]). Despite different backgrounds and perspectives, all interviewees converged in two main areas: adoption and acceptance.

The variety of exoskeletons on the market and the diversity of their functions complicates **adoption**, as there is no uniform regulation or certification pathway. Depending on their intended use, exoskeletons can be classified as either personal protective equipment (PPE), or medical devices (MD) (OSHA, 2019). On one hand, classification as a medical device implies that the exoskeleton is used to support the completion of tasks, and not as a preventative measure for MSDs. On the other hand, the definition of PPE translates to worker protection from physical loads that might lead to MSDs, representing a preventative function. The practical application of exoskeletons is strongly correlated to the specific certification. Further details of the advantages and disadvantages of each classification can be found in table 1.

	Advantages	Disadvantages
Personal Protective Equipment (PPE)	• No resource-intensive certification process required • Lower responsibility for manufacturers • Focus on preventing MSDs	• Obligatory use translates into additional costs • Hesitance from some employees to wear them
Medical Devices (MD)	• Voluntary opt-in • Used after injury to avoid further aggravation	• CE certification required • Medical efficacy is hard to demonstrate with exoskeletons

Table 1: Advantages and disadvantages of exoskeleton classifications.

There is an active debate across the healthcare sector on whether exoskeletons should be considered PPE, used to avoid work-related or repetitive injuries such as MSDs, or MDs, used as an aid for rehabilitation or for medical purposes. These contrasting opinions were mirrored in expert interviews, where some interviewees considered them an MD (e.g. OSHA), with other stakeholders classing exoskeletons as PPE (e.g. POLIMI). Other interviewees had no classification for the technology within the healthcare sector. For exoskeletons to be widely implemented within healthcare settings, agreements must be reached among key stakeholders, with clear policies and regulations established to determine the classification of this technology.

[1] LAEVO Exoskeletons: https://www.laevo-exoskeletons.com/
[2] Bochum University of Applied Sciences: https://www.hochschule-bochum.de/en/
[3] Politecnico di Milano: https://www.polimi.it/en/
[4] European Agency for Safety and Health at Work: https://osha.europa.eu/en
[5] The European Specialist Nurses Association: https://www.esno.org/

Target user groups for exoskeletons within the healthcare sector can be categorised into service users or healthcare workers. The first group, including patients undergoing rehabilitation, may be eligible for reimbursement from insurance companies in certain cases, for example, in Germany. However, the distribution of exoskeleton use for rehabilitation purposes is largely imbalanced. The interview with an insurance expert highlighted that the prescription of an exoskeleton to aid rehabilitation was directly correlated to the caregiver's awareness of exoskeletons, which is generally low, thus limiting their widespread use.

Exoskeleton use becomes yet more complicated when considering adoption by healthcare workers, as the cost of the technology is not reimbursed by governments across Europe. This means that each healthcare employer must decide whether or not to buy exoskeletons for their staff. During the OSHA interview, it was noted that employers across other sectors are known to purchase exoskeletons for their staff for two primary reasons: to avoid injuries amongst their workforce, or to enable staff to work longer hours and carry heavier weights. This approach was validated by the Laevo interviewee, adding that it is also common within the healthcare sector. Moreover, some nurses involved in the MSD-CARE pilot activities showed reluctance to using exoskeletons, even when performing strenuous tasks. Given these circumstances, the role of the institution is paramount in communicating not only the importance of utilising exoskeletons, but also the rationale behind it.

In terms of **acceptance**, worker hesitance to utilise exoskeletons has been reported across sectors. An OSHA discussion paper underscores how gaps in knowledge and discomfort contribute to widespread unwillingness to use exoskeletons when performing tasks at work (OSHA, 2020). Similarly, results from the Interreg NWE EXSKALLERATE project (2019-2023) highlighted workers' concerns on how they would be perceived by their colleagues as a major determining factor regarding their reluctance to adopt. This was also a concern raised by nurses participating in the MSD-CARE pilots, who were worried about how they would be perceived by their patients as well as their colleagues.

Having said this, the interview conducted with an ESNO representative demonstrated a more positive tone, as the respondent felt that nurses and nursing assistants are open and enthusiastic about innovation when included in decision making, and they are happy to participate in studies. In addition, an OSHA interviewee noted that workers that are forced to retire due to MSD-related injuries often do so "through the back door", with minimal retirement pensions. The MSD-CARE project highlighted the importance of providing sufficient training, having local champions, and, most importantly, securing institutional support to overcome barriers to adoption.

2.2 Understanding exoskeleton use in the healthcare sector

To understand how the field has evolved regarding the use of exoskeletons in the healthcare sector, MSD-CARE partners conducted a comprehensive review of studies published on the topic. The findings will be published in a peer-reviewed journal.

For the review, the consortium utilised databases including PubMed[6], CINAHL[7] and Web of Science[8], identifying 13 relevant publications on the impact of exoskeleton use on individuals across various countries, including France, Finland, Spain, the Netherlands, Ireland, the USA, and the UK. The studies also covered individuals with and without a nursing background, exoskeleton effects while performing simulated nursing activities such as repositioning, mobilisation, hygiene assistance, and examinations of muscle activity, mobility during tasks, centre of gravity displacement, heart rate, and perceived workload. These studies assessed possible applications, individual user experiences, and subjective workload during tasks.

[6] pubmed.ncbi.nlm.nih.gov
[7] www.ebsco.com/products/research-databases/cinahl-complete
[8] clarivate.com/academia-government/scientific-and-academic-research/research-discovery-and-referencing/web-of-science

Following the conclusion of the review, all studies were found to report significant differences involving trunk rotation and flexion, knee flexion, and several other parameters. More importantly, all participants considered the use of exoskeletons as beneficial in their practice.

2.3 Facilitating regional implementation

Given the expected growth of the exoskeleton market and the limited number of studies and countries that have tested exoskeletons in healthcare settings, obtaining first-hand experience is key to facilitating regional adoption. To gain perspectives, members of the MSD-CARE consortium hosted focus groups and biomechanical tests with healthcare professionals throughout 2024.

Over 50 healthcare workers – nurses and physiotherapists - participated in demonstrations of exoskeletons, and more than 20 participated in dedicated and targeted focus groups, aimed at providing an opportunity to share open and honest opinions and feedback related to their potential use of the technology.

The MSD-CARE pilot results revealed that participants felt supported by exoskeletons in the lower back region and were more aware of their improved posture when using the devices. In addition, the pilots identified adjustments required for the practicalities of the healthcare sector, described in table 2.

Pilot results	Work environment	Practicality and design	Hygiene	Perception
Issues	• High costs • Value of use vs. time saved • Questions on legal issues such as liability and the handling of exoskeletons • Not useful for high pace environments or departments	• Bulky, restrictive, uncomfortable • Time consuming and difficult to adjust, don/doff • Lack of pocket accessibility • Awkward sizing, not considering different body shapes	• Cleaning at 30 °C (as some require) is not realistic in the healthcare sector • Difficult to clean • Sanitation between patients and carers is necessary	• Negative impact on self-image • Patient acceptance • Judgment from co-workers
Solutions	• Develop specific training for nurses on the appropriate use of exoskeletons • Involve the procurement team early • Secure institutional support • Conduct further research to fill gaps in knowledge	• Limit areas of work to units with slower paces of work (e.g. stroke units) • Provide regular feedback to industry • Generate internal plans for their adoption	• Swab tests to detect pathogens • Limit use to avoid cross-contamination • Use plastic sleeves to facilitate cleaning	• Possibility to wear exoskeletons under uniform • Use early adopters to showcase success • Implement voluntary use
Next steps	• Assessment of appropriate departmental use • Conduct additional research in identified areas	• Develop storage and maintenance plans	• Introduce infection control measures	• Roll out ongoing training on the benefits of use to change work culture

Table 2: Conclusions from the MSD-CARE pilots.

Considering these results from the MSD-CARE pilots, the consortium believes that, with suitable adjustments, exoskeletons can have an impactful future within healthcare.

To support adoption, the following actions are recommended:

1. **Involve healthcare workers** in the entire acquisition process.
2. **Develop institutional plans** to enable exoskeleton use for healthcare workers.
3. **Provide institutional support** and continuous training to shift work culture and encourage uptake.
4. **Encourage manufacturers** to design exoskeletons specifically for healthcare, tapping into significant market potential.
5. **Conduct formal research** to generate evidence on benefits in healthcare settings.

In summary, the MSD-CARE findings align with existing literature and expert interviews. The project is timely: while the soft exoskeleton market nears saturation, manufacturers are seeking new opportunities. Given the complexity of adoption and acceptance in healthcare, a comprehensive sustainability roadmap is essential.

Figure 2: Using an exoskeleton during a patient repositioning simulation

3. The quadruple-helix sustainability approach

To ensure the impact of this project is continued following the conclusion of funding, the MSD-CARE consortium developed various activities and outputs using a quadruple-helix approach. The four helices - Academia, Industry, Government and Society - each have distinct strengths and areas where they can foment change. The use of this approach facilitates continuity by bringing together diverse perspectives to provide a comprehensive solution that ensures implementation success.

3.1 Academia

Academia is a fundamental pillar of innovation as the group represents primary creators of knowledge and technology through research and development. The involvement of universities guarantees that project methodologies and outcomes are scientifically robust and technologically advanced, as well as ensuring social relevance and ethical transparency. Moreover, the role of academia in education and the development of professional skills shapes the work culture of future generations of healthcare professionals. As the three MSD-CARE partners belong to academia, it was natural to develop a series of activities that would enable a continuation of knowledge gathering from an early stage.

An important aspect of academia is free and open access to knowledge and dissemination of results to the research community. This ensures field advancement through the collective building of knowledge. To follow these principles, the project partners have hosted events, spoken at academic conferences, shared results and findings, and developed a report to be published in a scientific journal. These efforts are detailed in table 3.

Dissemination activity	Details	Participants
The use of passive exoskeletons by nurses providing patient care-a scoping review	The three partners have written a review to be published in a scientific journal.	HAWK, RCR & UGal
Presentation for the Working Group Meeting of the State Representation of the Chambers of Crafts of Lower Saxony (LHN)	Presentation of project results with a focus on transfer possibilities to other areas of application, e.g., skilled trades (Hanover, 2025).	HAWK
Research Day presentation	Results presented at a research-focused event in Germany (Göttingen, 2024).	HAWK
FOHNEU International Congress presentation	Project results to be presented at an international congress with key healthcare stakeholders and decision makers (Cork, 2025).	UGal
Project presentation and key stakeholder workshop	Project presented and workshop facilitated with nurse managers, a manual handling coordinator, senior inspector and chief of ergonomics from the Health Safety Authority, and rehabilitation unit staff (Galway, 2025).	UGal
Poster presentation at the Day of Education and Exchange	Poster showcasing project results to students, researchers, nurses, managers, and leaders at the HAWK Health Campus (Göttingen, 2024).	HAWK
Project presentation	Project results presented to researchers, nursing staff, and innovation teams (Enschede, 2025).	RCR
Nursing Leaders networking event presentation	Project results presented at a networking event for nursing leaders at the Evangelic Hospital Weende (Göttingen, 2025).	HAWK

Table 3: Dissemination activities conducted by project partners.

Having learned from these experiences, all three partners are committed to sharing the final MSD-CARE results during the Future Technologies Conference (Lower Saxony, November 2025). Additionally, each partner will seek further opportunities to share project findings to support the growth of the international scientific community specialising in the use of exoskeletons in the healthcare sector. During the duration of MSD-CARE, four bachelor's theses were completed at HAWK University related to the project. Results from this research will be disseminated to technical audiences. Meanwhile, the College of Science and Engineering at the University of Galway School of Physics purchased a passive exoskeleton to use as part of their teaching programme in Occupational and Environmental Health & Safety (MSc/HDip) and research in the department.

While free access to scientific content is a cornerstone of academia, raising awareness among end-users is a key aspect of emerging technologies. Exoskeletons are relatively new, especially in the healthcare sector. For this reason, the partners engaged in various awareness-raising activities to expose healthcare workers to the advantages of exoskeletons for the first time. Throughout the duration of the MSD-CARE project, partners organised 5 dedicated workshops attended by 52 healthcare professionals (table 4).

Awareness activities	Attendees	Participants
Use of Exoskeletons in Healthcare Settings: Stakeholder Workshop	17	UGal
Project Presentation at Ev. Hospital	7	HAWK
Intensive Ward Workshop at University Medical Centre	15	HAWK
Workshop at University Hospital Schleswig-Holstein	9	HAWK
Workshop for Nurses	4	RCR
Video and posts for social media	N/A	UGal, HAWK, RCR
International Press Release	N/A	UGal, HAWK, RCR

Table 4: Awareness raising activities organised by the project partners.

In addition, partners created a video and coordinated a press release to ensure widespread dissemination of project objectives, to be utilised during the final dissemination activities.

Encouraged by the results of the MSD-CARE project, partners identified several factors which could be applied to improve the adoption of exoskeletons by nurses. A promising approach was to introduce the potential benefits of exoskeletons during the early stages of healthcare workers' education. In doing so, prolonged exposure and an opportunity to test and use the technology during placements would be likely to normalise their use and diminish any existing stigmas. Furthermore, providing a list of tasks which could benefit from exoskeleton application or appropriate scenarios for their use has the potential to be helpful for young nurses.

The project partners have committed to maintaining engagement and awareness-raising activities by organising additional workshops and attending dissemination events to share results, thus continuing the momentum of the project. In doing so, MSD-CARE will gain sustained exposure, ensuring that exoskeletons continue to be a topic of discussion within healthcare systems.

3.2 Industry

Industry plays a vital role in innovation, contributing essential expertise, resources, and market insight. Through the continuous development of new and improved product lines, industrial organisations and companies play a central role in sustaining and driving innovation. In the field of exoskeletons, they lead progress by designing and manufacturing models tailored to the specific needs of users.

As discussed in section 2.1, the continued saturation of the soft exoskeleton market is likely to encourage industrial players to expand into new markets. The work carried out through the MSD-CARE project resulted in valuable first-hand insights from nurses that have the potential to shape how future exoskeletons are designed with the healthcare sector in mind. To outline the requirements for this shift, the MSD-CARE consortium has developed an infographic (see section 5.1) which extracts the industry-relevant topics from the pilot results (table 2).

Analysis conducted during the MSD-CARE project also underscored the need for clinical studies that demonstrate the benefits of exoskeleton use in real-world settings. In an increasingly competitive sector governed by strict healthcare regulations, companies that invest in supporting such studies are better positioned to successfully enter and expand within the healthcare market. Moving forward, MSD-CARE partners will seek opportunities to engage with industry partners when disseminating pilot results to explore future collaboration related to these studies.

3.3 Government

Government represents a cornerstone of the quadruple-helix approach, establishing the policies and regulatory frameworks that enable innovation to flourish. By enacting laws, shaping policies, and creating funding streams, governments provide both direction and support for research and technological development. At regional and European levels, government agencies also serve as mediators, ensuring that innovation policies are inclusive, socially responsible, and aligned with broader societal goals.

Therefore, MSD-CARE partners will disseminate the results from the project to regional policymakers to raise awareness of the importance of developing guidance and promoting exoskeleton usage in healthcare settings to avoid MSD-related injuries.

As well as the critical role of government in establishing protocols for exoskeleton adoption in healthcare, institutional support emerges as a vital success factor. Healthcare professionals rely on their institutions to provide clear guidance and resources that enable the safe and effective integration of new technologies into daily practices. However, as outlined in section 2.1, some organisations have misused exoskeleton technology to increase workload rather than improve worker safety. To prevent such misuse, institutional leadership must ensure that exoskeleton adoption is framed and implemented as a protective measure for healthcare staff, reinforcing wellbeing and trust rather than exploitation.

To aid a smooth future adoption of exoskeletons in the NWE region, the MSD-CARE partners have procured letters of interest from various hospitals and other institutions. The MSD-CARE consortium will work alongside these institutions to ensure that the advantages of exoskeletons are understood and that there is no misuse of this new technology. A summary of the organisations is outlined in table 5.

Organisation	Status
University Medical Centre, Göttingen	Letter received on 07.05.2025
Evangelic Hospital Weende, Göttingen	Letter received on 25.04.2025
Health Service Executive (HSE) Ireland Galway University Hospitals manual handling coordinator	Letter received on 10.06.2025
HSE University Hospital Galway service providers i.e. senior occupational therapists and physiotherapists	Two letters received on 10.06.2025
Private home care company Galway, Ireland	Letter received on 13.06.2025

Table 5: Commitment letters secured by the project partners. All institutions showed interest in exoskeletons.

3.4 Society

Society plays a vital role in the quadruple-helix approach by bringing the voice, needs, and values of citizens into the heart of innovation processes. Civil society helps shape solutions that are not only technologically sound but also socially relevant and widely accepted. By contributing local knowledge, lived experience, and user feedback, society drives more inclusive, responsible, and democratic innovation.

The MSD-CARE project focused on nurses (and the broader disciplinary healthcare team) as the primary beneficiaries of exoskeleton use in daily patient positioning. Building on the lessons learned from the pilots, the MSD-CARE partners identified additional actors within healthcare that could likely benefit from the implementation of exoskeletons. These are summarised in table 6.

Other healthcare professionals	Healthcare adjecent sectors
Surgeons	Hospice / Long-term care
Surgical staff	Geriatric care
Visiting nurses	Cardiac/Stroke rehabilitation
Physiotherapists	Institutions for patients with disabilities
Occupational therapists	Post-surgery rehabilitation
Nursing aides / Healthcare assistants	Outpatient care / home care

Table 6: Identified members of society which could benefit from exoskeletons.

Insights from the MSD-CARE project suggest that exoskeletons may be easier to adopt in controlled scenarios. For example, physical and occupational therapists typically spend longer periods with the same patient, and appointments are scheduled in advance. This allows sufficient time to put on and remove an exoskeleton when needed, as well as to disinfect the device between patients. Similarly, nursing aides and healthcare assistants are key players in healthcare, yet they are often overlooked in research or the adoption of innovative solutions. MSD-CARE partners believe that including these groups in further studies would be highly valuable, as they frequently perform the most physically demanding tasks in hospital settings.

It has been suggested that non-professional carers could benefit greatly from the use of exoskeletons. A study on long-term informal care in Europe (Ecorys, 2021) found that 80% of people requiring additional help with daily activities receive informal care. Informal care providers are most often family members, offering assistance and support in non-urgent contexts. The MSD-CARE consortium also identified disease-specific non-governmental organisations (NGOs) working with patients with mobility issues as willing to provide carers with exoskeletons to help with daily tasks and responsibilities (e.g. for people living with multiple sclerosis).

That said, it is likely that the identified stakeholders would face challenges in navigating the complexity of the exoskeleton market. To support adoption, the MSD-CARE partners have developed a protocol (see section 5.2) to help future users assess whether an exoskeleton is suitable for them and, if so, which features to prioritise. This protocol will be disseminated to relevant regional stakeholders across the NWE region.

4. Learning from other Interreg initiatives

A core priority of Interreg projects is to avoid silo-working by encouraging learning from each other. Thus, MSD-CARE partners identified fellow Interreg initiatives that could learn and even adopt the findings. Table 7 provides a summary, including key points that may contribute to the reduction of MSDs and adoption of exoskeletons in the healthcare sector.

The MSD-CARE consortium plans to contact representatives from each of the identified Interreg projects as part of the dissemination of the project results. Synergies between MSD-CARE and other Interreg projects will be emphasised to ensure key findings are utilised beyond the project lifetime.

Figure 3: Irish project partner trying on an exoskeleton during a demonstration

Project	Summary	Key takeaways
RE:HOME	This project aims to improve access to new technologies for children with neurological disorders by delivering new exoskeletons, smart garments, and an IT platform to support digital technologies.	RE:HOME provided transnational training programmes for hospital and home use of exoskeletons based on pilot actions and is developing a comprehensive training scheme.
COTEMACO	This project focused on supporting SMEs in the automotive and food sectors in adopting collaborative robots (cobots) to remain competitive in markets where efficient use of employees is essential and health issues are prevalent. The project successfully established four field labs, supported 64 SMEs, and implemented 57 cobots.	Field labs and regional COTEMACO partners support SMEs. Continuous education, coaching, and the creation of a business plan aids the adoption of robots in the workplace.
TechSocialcare	The main objectives of this project are to engage governments, municipalities, and representatives of social service providers to establish a legal framework for assistive technologies, including ergonomics.	This project highlights that standardisation is key for the effective use of assistive technologies.

Table 7: Interreg projects with potential synergies.

5. MSD-CARE outputs supporting the future of exoskeletons

During the development of the MSD-CARE sustainability roadmap, partners recognised the need to compile the pilot results and lessons learned into new, digestible formats. As part of the quadruple-helix approach, two outputs were identified as paramount to reach their identified target audiences. The first, an infographic targeting industry stakeholders and the second, a protocol to facilitate the adoption of exoskeletons beyond nurses.

5.1 Industry infographic

As outlined in section 3.2, in order to effectively penetrate the healthcare market, the exoskeleton industry must adjust to the requirements of the sector, also allowing further expansion into markets beyond hospitals. To facilitate this expansion, the MSD-CARE partners summarised the industry-relevant results of the pilots into an engaging infographic (page 16).

5.2 Exoskeleton adoption protocol

MSD-CARE partners are committed to ensuring that the outcomes and findings from the three pilot sites can be transferred to other health-related sectors. At the same time, the consortium acknowledges the challenges associated with navigating the exoskeleton markets to identify the most suitable device for each specific use case. To support the sustainability roadmap, the partners conducted a brainstorming session in June 2025 to determine the most effective approach. The aim was to outline the key decisions to be made by individuals, organisations, and institutions when assessing the relevance of exoskeletons and, if applicable, the features they should prioritise.

This process resulted in the development of the MSD-CARE Exoskeleton Adoption protocol, featuring both a decision tree and a self-assessment.

The initial **decision tree** will empower those who are considering making use of an exoskeleton, helping them decide if it is an appropriate choice for them. The questions have been developed to help the user understand the need for an exoskeleton, and identify whether the device would aid in the completion of daily tasks.

Once adopters are confident that the use of an exoskeleton is appropriate, they will be directed to a **self-assessment form.** This form has been adapted from the discussion paper *Occupational Exoskeletons: Wearable Robotic Devices to Prevent Work-Related Musculoskeletal Disorders in the Workplace of the Future* (EU-OSHA, 2020), separating the different characteristics that define exoskeleton usage. To apply this tool to the healthcare sector, the MSD-CARE partners included additional information on topics to consider when deciding which exoskeleton is the correct one.

The decision tree and self-assessment form will be disseminated to organisations considered likely to use it at the regional and national levels, such as NGOs for certain diseases, regional and national professional associations, and any other relevant stakeholder identified in section 3.4.

A preview of the decision tree and self-assessment form can be seen on page 17.

PASSIVE EXOSKELETONS IN HEALTHCARE: INDUSTRY GUIDANCE

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WHY **HEALTHCARE** MATTERS

Relevance: MSDs are a leading cause of nurse sick leave. With staff shortages, prevention is critical.

Market potential: Easy spillover into related sectors (carers, elderly care, etc.).

Gender-proof your product: In healthcare, most strenuous tasks are done by women - design with this in mind.

The **MSD-CARE** project ran focus group interviews with nurses in Germany, Ireland, and the Netherlands to explore passive exoskeletons.

Nurses responded positively, saying exoskeletons helped protect them during strenuous daily tasks. They also agreed that adaptations are needed before these devices can be widely used in healthcare.

Recommendations from the MSD-CARE project

Hygiene is essential

- Design for easy cleaning and disinfection.
- Use materials that withstand frequent cleaning.

Adapt to patients

- Appearance matters: avoid intimidating designs for children or people with cognitive impairments.
- Avoid straps that could be pulled or cause discomfort.

Practicality in the workplace

- Minimise removable parts (to prevent loss during cleaning).
- Ensure simple, quick donning and doffing.
- Consider compact storage in crowded wards.

Uniform compatibility

- Avoid bulk that restricts movement in crowded wards.
- Keep access to uniform pockets.

Prioritise by department

- Prioritise slower-paced units (e.g., stroke wards before emergency care).
- Tailor to unit needs: surgery (static postures) vs. elderly care (frequent lifting, rapid movements).

Fit & design

- Adapt to diverse body shapes and sizes.
- Incorporate female-specific adjustments (e.g., no breast straps).

HAWK Faculty of Engineering and Health Göttingen
Ollscoil na Gaillimhe University of Galway
Roessingh Research & Development

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Figure 4: MSD-CARE infographic

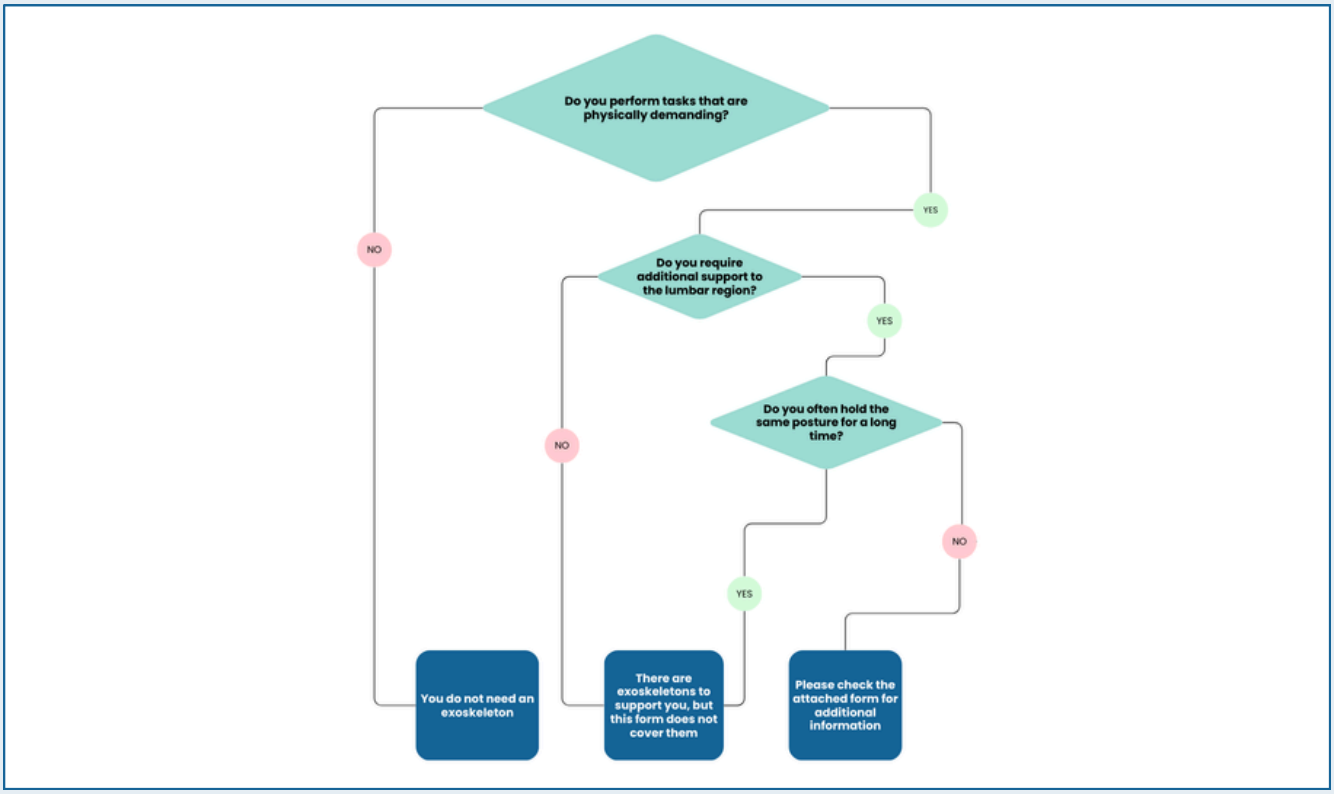

Figure 5: MSD-CARE decision tree

Which exoskeleton is right for you?

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Those who perform physically strenuous work—such as lifting and carrying heavy loads, pushing and pulling, moving objects regularly, or maintaining static postures—are likely to benefit from using exoskeletons. There are many variations of exoskeletons, which can make it difficult to determine which one is suitable for your needs. They come in a range of designs, each offering a unique combination of features, sizes, and usability characteristics.

This **self-assessment**, developed by the MSD-CARE consortium, helps you identify the key factors to consider when selecting an exoskeleton. Once completed, it provides a clear overview of your needs and priorities, making it easier to compare models and focus on the features that matter most.

TOPIC	QUESTION	YOUR ANSWER	COMMENTS
TYPE OF SUPPORT	What do your daily tasks include?		Choose the right model depending on if you require extra support in your arms, neck, lower back, or legs.
	What type of patients do you work with most often and with what frequency?		Those working with heavier patients might benefit from active support, while lower, more frequent effort might benefit from passive support.
	Do you regularly hold static work postures?		Choose a model which is focused on static support rather than lifting/carrying.
PRACTICALITIES	Will any exoskeleton be provided by your employer?		If it is not provided by your employer, make sure the cost aligns with your budget.
	Will it be reimbursed by your institution or insurance?		If you will be reimbursed, ensure the exoskeleton you choose fits the requirements from the payer.
	Do you have enough storage space for this prototype/model?		Choose a model apt for your space. Each model is made up of various parts which can be easily misplaced.
	Is there a system in place to monitor the exoskeleton?		Look for a model that you can maintain and keep up to standard according to your abilities/support available.
	Do you have a proper way of cleaning any exoskeleton purchased?		Consider necessary sanitation and disinfection between patients. Choose materials that can be wiped down or washed at high temperatures, following local hygiene regulations.
WORK ENVIRONMENT	Will you be the only one using it, or will it be shared?		If shared, additional aspects must be considered: 1) capacity to adjust to different body types, 2) maintenance and 3) hygiene.
	Will you get access to proper training on how to use the exoskeleton?		Look for manufacturers that provide training. Each exoskeleton is unique; it is important to ensure that you fully understand how to use it.
	Will you be wearing a uniform?		Try on the exoskeleton with the uniform to ensure that you still have access to your clothing/pockets, and other necessary parts for day-to-day activities.
	Do you feel comfortable while wearing it?		Choose a model that fits comfortably - you want to feel supported not constrained. Consider biomechanical factors like pressure on the chest and hips.
	Do you work with vulnerable patients?		Consider patients' needs and mental capacity - some may be unsettled by a carer in an exoskeleton. Avoid straps or loose parts that could be counterproductive.
	Will you have assistance when putting on / taking off the exoskeleton?		Some exoskeletons might require support from a second person, choose a model appropriate to your situation.
	How confident do you feel whilst wearing it?		Make sure that you are not only physically comfortable, but that your choice of exoskeleton allows you to feel secure regarding your self-image.

Figure 6: MSD-CARE self-assessment form

6. Conclusions

The MSD-CARE project's timing is perfect to disseminate its major findings: The soft exoskeleton market is saturated, whilst traditional methods to prevent MSD injuries in the healthcare sector remain unsatisfactory. MSDs continue to be a major cause of sick leave (and even early retirement) in a sector already facing significant staff shortages, making urgent action necessary.

MSD-CARE has provided a launching point to facilitate innovation in the exoskeleton market that will lead to its future widespread adoption. Moreover, it has identified barriers to acceptance and adoption, as well as customised solutions to ensure the MSD-CARE impact extends beyond the funding period. Addressing these barriers lies beyond the scope of this funded project, but it has identified opportunities for future research and multi-sector collaboration.

The MSD-CARE consortium used a quadruple-helix approach to ensure the project's momentum continues, by creating targeted outputs and committing to sustaining certain project-related activities. Project partners remain dedicated to dissemination and awareness-raising, ensuring free knowledge exchange, which is critical for academia. For industry, a summary of the pilot actions - with advice and action points - was translated into an infographic that will be disseminated to key stakeholders, fostering further innovation in the field. For government stakeholders, commitment letters from institutions at the regional level were collected, as institutional support is considered key for the future adoption of exoskeletons in the healthcare sector. Lastly, other members of society who could benefit from an exoskeleton were identified, and a protocol for new adoption was created to facilitate acquisition by prospective users. This protocol will be disseminated to the previously identified groups, supporting market growth with innovations aligned to NWE society's ambitions.

Considering existing trends and pilot results, the project partners have carefully crafted a sustainability roadmap, ensuring it touches all four pillars of innovation: growing the exoskeleton market, prioritising awareness-raising and knowledge-sharing, and building institutional support for the implementation of this new technology. Ultimately, this will keep the MSD-CARE project relevant beyond the end of the funding period and provide a basis for the adoption and acceptance of exoskeletons in the healthcare sector across the NWE region.

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