

Ergonomics 4.0 and Exoskeletons

Myths, legends and truths



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Background

In accordance with Law 35/2014 of December 26th, Spanish mutual Insurance Companies for Work Accidents and Occupational Illnesses work in collaboration with the Spanish Social Security System to develop preventive activities in the scope of Social Security protection.

Part of these assistance services aim to control and reduce work accidents and occupational illnesses within the Social Security System.

Furthermore, they carry out an Annual Preventive Activities Plan, in compliance with Royal Decree 860/2018 of July 13th and the Resolutions published annually by the Secretary of State for Social Security to provide guidance, information, advice and technical assistance.

The Ergonomics Laboratory of Mutua Universal presents this document within this framework of activity.

This work is based on our experience in recent years, during which we have worked together with associated companies in the study, analysis and research on the use of exoskeletons.

Inside this booklet you will find useful tips and information to help you to decide whether you need an exoskeleton for your workplace, and if so, how to select it and implement it properly.



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What is Ergonomics 4.0?

Collaborative robots, virtual and augmented reality, the internet of things, data analysis, and additive manufacturing are some of the technologies included in the so-called "Industry 4.0" or "Fourth Industrial Revolution".

The inclusion of these technologies in the workplace gives rise to different challenges and to a number of considerations, particularly in the field of Occupational Risk Prevention.

In a "Smart Factory", the complete automation of production systems and processes and the intercommunication between them take on great importance. However, humans remain an essentiality in the process because they are both integrated and connected to the system. Hence the arrival of "Worker 4.0".

Ergonomics 4.0 efficiently incorporates employees into that digital environment through wearable devices and according to ergonomic principles, to better maintain their health, efficiency and well-being.

Devices called "exoskeletons," whose purpose is to make workers' jobs easier and safer, have appeared under the concept of "Ergonomics 4.0".



However, some myths have emerged about these technological devices according to which they are magical solutions. These stories are not grounded in reality and overestimate their true performance.

Myths about exoskeletons include the following:

"Musculoskeletal problems will be reduced by 80%"

"Workers will be able to handle 50 kg-sacks without fatigue"

"Production will increase with less people working"

All the above is not possible with the current development of this technology. Specifically, exoskeletons are designed to help users carry out tasks in their workplace more safely.

It is critical to know what they are, their exact use, as well as how to carry out an in-depth analysis of their appropriateness and how to best implement them in the workplace.

Therefore, the objective of this document is to help you decide whether an exoskeleton is the most appropriate solution for the ergonomic problem you are trying to solve and, if so, what guidelines you should follow to successfully implement it in the workplace.

What is an exoskeleton?

In nature, an exoskeleton is the shell that encases the body of arthropods and other invertebrates, serving as protection and support for their body.



Since ancient times, humankind has used armour for protection in a similar way to exoskeletons, especially in combat. Indeed, it is in the military sphere that the first exoskeletons were developed.

An artificial exoskeleton helps the locomotor system to perform its function, in the same way that glasses help the visual system or a hearing aid helps the auditory system.



When applied to people, an exoskeleton is an assistive device that works together with the user, helping their locomotor system to perform a certain task.





What applications does an exoskeleton have?

Military

Military exoskeletons were designed and adapted to protect soldiers in combat and other military tasks. Over time they have been refined to increase their performance.



Medical

Medical exoskeletons provide strength and mobility to people who have suffered a reduction in their functional capacity, either due to impaired motor skills or an accident.



Industrial

Industrial exoskeletons have been designed to assist people with the physically demanding tasks they usually perform in their jobs. The aim of an exoskeleton is to protect and provide assistance, thus preventing the use of excessive effort and minimizing fatigue.



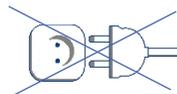
Which industrial exoskeletons are there?

The main functions of industrial exoskeletons are to compensate for the weight of a user's body part, a tool or a load, and to amplify force so that the user guides the device and exerts force in conjunction with it.

Exoskeletons can be classified according to their power supply:

Passive exoskeletons

These have no external power supply. They work with rigid mobile structures, springs and shock absorbers that distribute the load from the most affected body area to other body areas that have more powerful muscle groups.



Active exoskeletons

They have an external power supply that provides energy through batteries or small electric motors. Integrated software provides extra strength to move the body parts when required by the worker.





They can also be classified according to the body area they protect:

Arm exoskeletons

These keep the arms raised, thereby relieving tension in the upper back and the shoulder muscles.

The structure of such exoskeletons supports the weight of the arms and redistributes it from the muscle groups of the shoulders to the muscle groups of the back and hips.



Back exoskeletons

These help keep the back flexed, to relieve tension and protect the lower back.

They work by redistributing the upper body weight, which is normally only supported by the back, to the chest and legs areas that have more powerful muscle groups.



Hand exoskeletons

These provide extra strength to both hands and fingers to open and close. They are normally active exoskeletons.

They can act by articulating all the fingers at the same time or separately. When the fingers and hand attempt to grasp an object, the glove sensors detect the pressure and activate the movement.



Leg exoskeletons

These allow the user to maintain a semi-sitting posture, releasing the tension of the muscle groups in the legs. They can be useful for tasks in which workers must adopt a standing posture without walking.

Alternating between a sitting and semi-sitting posture facilitates venous return in legs and releases the lower back.





Used for

Not used for

Shoulders



- ✓ Static postures with arms raised for long periods.

- ✗ Manually handling and carrying loads.
- ✗ Tasks that require raising and lowering the arms quickly and repetitively.

Lumbar



- ✓ Postures with the back flexed for long periods.
- ✓ Manual handling from floor level.

- ✗ Tasks with the back upright.
- ✗ Tasks in sitting postures.

Legs



- ✓ Standing postures with short displacements.

- ✗ Tasks in sitting postures, as a substitute for a chair, stool or buttock support.

Hands



- ✓ Exerting sustained grip force.

- ✗ Tasks that require quick movements with hands and fingers.

What should I know?

As with any new work device, the introduction of an exoskeleton implies changes that will have an impact on users, their colleagues and their environment. It affects the overall performance in the company. Consequently, it should be introduced with caution.

Before introducing an exoskeleton, it is advisable to consider different aspects to assess the best choice and verify the suitability of the device.

Some questions to consider are:

- Do I really need an exoskeleton?
- If needed, which one is the most appropriate?
- What impact can the exoskeleton have?
- Will it be suitable for my workplace?
- How can I make implementation easier?



Do I need an exoskeleton?

Article 15 of Law 31/1995, on Occupational Risk Prevention, entitled "Principles of preventive action", indicates the application, among others, of the following principles:

- *Avoiding risks*
- *Assessing risks that cannot be avoided.*
- *Eliminating risks at their source.*
- *Adopting measures that put collective protection before individual protection.*

Under these premises, it appears that the implementation of collective measures that affect the origins of the risks should prioritise the elimination of risks before they appear.

When risks cannot be eliminated, an assessment should be carried out to diagnose and identify critical factors in order to eliminate or minimise them.

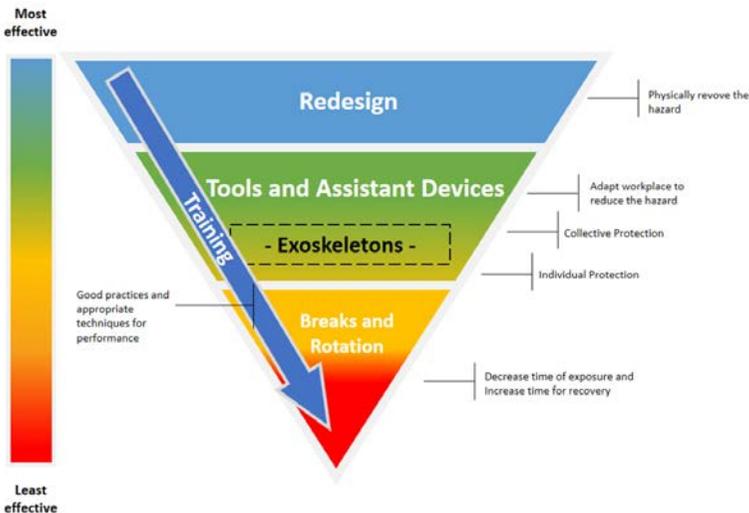
In the presence of an ergonomic risk, the first option to consider should be redesigning the workplace is to physically eliminate the hazard.

When redesigning is not feasible, it is suggested to first work on the implementation of other technical measures such as mechanical aids, tools and work equipment.

Subsequently, other organizational measures can be implemented, such as establishing adequate breaks or

rotating to other jobs. Individual measures should be considered as the last option.

Providing suitable training transversally through all levels is a decisive factor for any action to be effective.



An exoskeleton can be considered a piece of work equipment. Therefore, it is a second-level measure that should not replace the implementation of technical measures at the source. An exoskeleton is a palliative solution that does not eliminate the hazard.

An exoskeleton may be an option when a technical alternative that solves the ergonomic problem does not exist or is not feasible



Which exoskeleton is the most appropriate?

Much like not all glasses are suited to all vision problems, not all exoskeletons are suitable to solve all musculoskeletal disorders.

Just as we go to the ophthalmologist for an accurate diagnosis and a prescription for the ideal lenses to solve our problem, it is highly recommended to have an expert analyse, assess and recommend the best type of device to solve the problem involved in the task at hand.

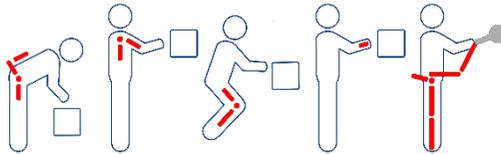
This assessment must be done according to the methods and criteria specified by current regulatory standards, and this may often prove to be a complex task. It should therefore be carried out by an ergonomist.

The results of the assessment will help in the selection of the most suitable exoskeleton for the workplace. It will likewise provide information about the nature of the risk factors to be decreased and the body areas to protect.

Exoskeleton technology is evolving quickly. For this reason, it is crucial to have up-to-date information available.

Some decisive elements to select an exoskeleton are:

- Determining the body area to protect and/or assist.



- Verifying compatibility between the task for which help is needed and the function for which the exoskeleton has been designed.
- Studying basic aspects of exoskeleton with regards to their usability, comfort, lightness, adaptability, ease of adjustment, etc.
- Analysing possible impacts on safety, the rate of production, product quality and the environment.

The most suitable exoskeleton is that which reduces risk, is compatible with the required task, meets usability and comfort requirements, and generates the least negative impact.



What impact can an exoskeleton have?

An exoskeleton is a device worn by a worker. It is heavy, rigid and bulky. This will have both an internal impact on the person and an external impact on the work environment.

Impact on the user

The weight of the device and its rigid structure, as well as the resistance offered by the springs and mechanical elements that make up its assistance system, exert forces and reaction torques on the joints of the person wearing the exoskeleton.

As a result, some parts of the user's body might be overloaded and may eventually end up suffering from musculoskeletal disorders.

Furthermore, the structure of the exoskeleton could hinder the performance of a specific task and, contrary to expectations, increase the effort required in the workplace.

Poor adjustment of the device to the user, its rigidity and the lack of transpiration of the cloth and materials covering the mechanical parts of the exoskeleton could also produce chafing, sweat, and discomfort.

Impact on the environment

An exoskeleton could physically interfere with the workplace by colliding or rubbing against the facilities or disturbing other workers, giving rise to entirely new risks.

These interferences might damage manufactured products and affect their quality. They might even alter the time required to perform the task and consequently have a negative impact on production.

The introduction of an exoskeleton also entails the need for further means and resources, for example, for storage (cabinet, hangers...), maintenance (cleaning, setup, repairs...) and use management.

Moreover, putting on, adjusting and taking off the exoskeleton, perhaps with the help of a workmate, is a time-consuming process.

Assess the impact the exoskeleton has on the workers' health, their environment, and job safety, quality and organization.



Would an exoskeleton be suitable for my workplace?

The exoskeletons available on the market are effective at fulfilling the mechanical functions for which they have been designed.

However, you should be aware that the laboratory conditions in which manufacturers carry out their tests generally differ from the work conditions in which exoskeletons are intended to be used.

Therefore, before incorporating an exoskeleton, you should:

- Assess the “objective” impact of the exoskeleton on the worker’s body to verify that it does not overload any parts of the body.
- Assess the “subjective” impact of the exoskeleton on the worker's comfort to ensure that they suit them without affecting their health and well-being.
- Assess the impact on production pace, the environment and the manufactured products to ensure that there is a balance between the advantages and the possible drawbacks and interferences caused by the exoskeleton.

Mutua Universal has developed a methodology to assess the implementation of exoskeletons, which combines objective and subjective analyses the production process offline and inline.

It is a structured and systematic work procedure for the subjective and objective analysis of the use of exoskeletons in the field. It involves several phases of work, from the search for the most suitable devices to their approval in the workplace.

Objective measurement techniques and subjective perception questionnaires are used, including:

- 3D motion capture systems.
- Surface electromyography.
- Dynamometry.
- Surveys.



The assessment of an exoskeleton covers both its positive and negative aspects. The balance between them has to be strongly positive for an exoskeleton to be considered suitable for the workplace.

An exoskeleton will be suited to the workplace if, after its analysis, the final balance between improvements and drawbacks is positive.



How can I implement one in my company more easily?

Once we have ensured that the introduction of the exoskeleton is the right decision and it offers clear advantages in the face of any discomfort that it may cause, the worker is the key to make its implantation easier.

Information and commitment

Information provided to workers is a decisive factor to achieve their involvement and collaboration throughout the entire process. This information should begin with the offering the exoskeleton as an option to improve ergonomic conditions until it is used in the workplace regularly and voluntarily.

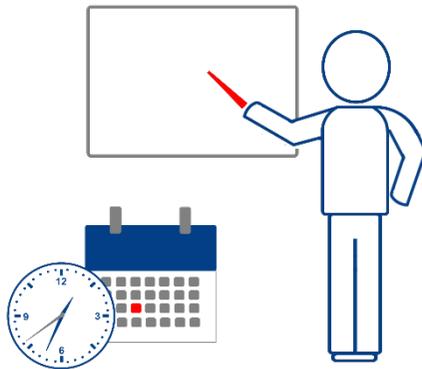
Training

Workers who will wear the exoskeleton must receive sufficient and appropriate training, specifically focused on its use. They must be aware of its benefits and features, learn to regulate the assistance level, learn how to put it on and take it off, as well as any possible new risks it may give rise to.

Progressive adaptation

The exoskeleton must have different sizes to fit the measurements of different workers. A correct device-to-worker adjustment will increase comfort and make adapting to the exoskeleton easier.

Users will need to progressively adapt to the use of the exoskeleton in order to carry out the production process with the same efficiency and productivity as without it.



Exoskeleton implementation can be easier when the workers are informed, trained and involved and have the time required to adapt to the exoskeleton and how to work with it



Which concerns and challenges do we face?

Exoskeletons are a relatively recent technology that is continually developing and evolving.

This fact, together with the difficulty to carry out long and complex analysis, means there is currently a dearth of studies and scientific evidence on the consequences of using exoskeletons in the workplace. We are therefore faced with a number of challenges and unknown factors.

Observe possible side effects

There is currently a debate on the possible adverse effects of exoskeletons in the medium and the long term.

Some of them are related to the reactions and sustained impact on the joints, blood supply difficulties in certain postures induced by the exoskeleton, or the possibility of muscular atrophy in those areas that the device protects.

Regulation and integration

There are currently no generally applicable regulations on exoskeletons, as there is no uniform consensus on their status.

The European Agency for Safety and Health at Work recommends dealing with each type of exoskeleton individually depending on its intended use.

According to the use that the device will have, as either work equipment, personal protective equipment, or medical equipment, it must be certified according to the appropriate rules or regulations.

On the other hand, the use of exoskeletons should be approached from an exclusively preventive point of view and should not be geared towards increasing physical demands.

Other aspects of the discussion are their influence on risk assessment methods or reference criteria, and the consequences that the use of exoskeletons has on risk evaluation.

Evolution and development

In addition to optimizing their performance, the immediate challenges faced by exoskeleton manufacturers include improving their comfort, reducing their weight, improving their maintenance for better hygiene, or making them more flexible to adapt them to users like a second skin.

Exoskeletons are a new technology in continuous development, like many others belonging to Industry 4.0.

It is important to be correctly informed about their advantages and disadvantages, not to believe in false myths or carried away by baseless assertions.

Searching for and analysing exoskeletons is a complex task that requires a rigorous and systematic analysis backed by specialists.

Mutua Universal, a pioneer in the implementation of ergonomics in companies that is committed to the search for innovative solutions aimed at reducing and preventing musculoskeletal disorders, supports its associated companies throughout this entire process.