IFA
Institut für Arbeitsschutz der
Deutschen Gesetzlichen Unfallversicherung

# Risk assessment for exoskeletons
# Version 1.1 – draft

**Documentation in accordance with Section 6 of the German Occupational Health and Safety Act (ArbSchG) and Section 14 of the Maternity Protection Act (MuSchG)**

**Company:**

**Room No:**

**Workplace:**

**Exoskeleton:**

**Employee:**

**Date:**

**Assessor:**

**Result of the assessment:**

☐ No measures necessary;
forwarded to the departmental manager on:

☐ Measures necessary
(see list; involve OSH professional if necessary)

☐ All measures reviewed;
forwarded to the departmental manager on:

**Next assessment:**

The checklist below is intended to assist in performance of the risk assessment for a workplace at which an exoskeleton is used. It covers a range of hazards that may arise during the use of an exoskeleton. This checklist is a provisional working draft. It will be subject to further, iterative development and should not be considered exhaustive.

As a general rule, an exoskeleton may not be used as a measure for reduction or elimination of a hazard that has already been identified in order to make a task possible in the first instance, unless the exoskeleton is used as personal protective equipment (PPE).

Workplaces or tasks with working conditions of the same nature may be grouped for the purposes of assessment.

Where a hazard falling within the scope of the maternity protection regulations exists, the work/workplaces must be organized such that a hazard no longer exists. Should this not be possible, the expectant or nursing mother may no longer be employed in the area or perform the task concerned.

Please e-mail any comments or suggestions for improvement to: Martin.Liedtke@dguv.de

**Contents**

## 1 Mechanical hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Unguarded moving parts** | Does the exoskeleton have unguarded moving parts? If so, what parts?<br>Can the wearer of the exoskeleton come into contact with danger points and be injured?<br>• Crushing of hands or fingers<br>• Trapping of clothing or hair<br>• Shear points<br>• Collision with large parts<br>Can danger points arise during particular situations or operations (such as cleaning of the exoskeleton, its donning/removal, replacement of parts of the exoskeleton)? | • Ensure that safe products are procured (where required: CE mark for the Machinery Directive, EMC Directive, etc.; observe relevant standards)<br>• Use exoskeletons without sharp edges, crushing points or other dangerous surfaces<br>• Observe the manufacturer's information on safeguards<br>• Assess the efficacy of safeguards<br>• Mark danger points | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Parts with dangerous surfaces** | Can the exoskeleton cause cut or tear injuries? Caused for example by:<br>• Corners, sharp edges, sharp points<br>• Rough surfaces<br>• Tools used<br>• Stab injuries caused by pointed parts<br>• Breakage | • Observe the manufacturer's information on ageing and function tests for the exoskeleton and components<br>• Wear protective gloves and if appropriate additional protective clothing<br>• Observe storage instructions for the exoskeleton and components<br>• Observe the manufacturer's information on residual risks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Autonomously moving parts** | Can items begin moving of their own accord?<br>• Axis movements<br>• Spring resetting<br>• Falling (e.g. of individual parts) | • Observe safety distances (second person)<br>• Wear safety goggles and if appropriate a full-face mask<br>• Observe the manufacturer's information on residual risks | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| **Fall on the level** | Can persons wearing an exoskeleton fall, slip, trip, twist their ankle or mis-step owing to:<br>• Dirt (e.g. oil, grease)<br>• Uneven surfaces, differences in floor level (e.g. doorsteps)<br>• Constraints upon movement<br>• Increased body width<br>• Additional weight of the exoskeleton<br><br>Is it ensured that the floors of circulation routes and working areas are stable, unobstructed, and their width not constrained? | • Use non-slip floor coverings<br>• Eliminate dirt and tripping hazards immediately<br>• Provide warning signage of any residual tripping hazards<br>• Adapt circulation routes and working areas to the increased body width<br><br>Observe the manufacturer's information on the procedure to be followed in the event of a person falling whilst wearing the exoskeleton | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Falls** | Does wearing of an exoskeleton give rise to particular fall hazards?<br>• On ladders, steps, stairways<br>• On scaffolds<br>• At elevated workplaces (e.g. elevated control stations, work platforms, roofs)<br>• On openings and recesses (e.g. in floors, platforms, installation apertures, hatches and pits, wall apertures)<br><br>Workplaces at vats, basins and tanks containing substances into which persons are able to sink (e.g. fluids, mud, grain, pastes) | • Observe the manufacturer's information on environments and conditions of use<br>• Cordon off edges of areas at which a risk of falling exists<br>• Prohibit the wearing of an exoskeleton during the performance of tasks at/in basins | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |

## 2 Fluid engineering hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Hazards presented by media employed** | • Can media (oils, gases) be released?<br>• Does the exoskeleton employ tanks that could potentially burst?<br>• Media released under pressure (e.g. gases) | • Observe the manufacturer's information<br>• Use and check safety pressure relief valves in accordance with the manufacturer's information<br>• Observe the manufacturer's maintenance information | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |

## 3 Electrical hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Faulty electrical equipment (e.g. rechargeable batteries)** | Does the exoskeleton exhibit hazards presented by electric current (drives, motors)?<br>• Damaged wiring insulation, e.g. kinks, bare wires<br>• Damaged equipment enclosures<br>• Faulty plugs and sockets<br>• Use of electrical equipment other than as intended<br><br>Use of electrical equipment whilst damp (e.g. owing to moisture in the environment, perspiration, etc.) | • Check for visible defects before starting work<br>• Have checks performed regularly by a skilled electrician<br>• Ensure that safe products are procured (where required: CE mark for the Machinery Directive, EMC Directive, etc.; observe relevant standards)<br>• Should equipment be damaged or faulty: take off the exoskeleton, report the damage and have it repaired<br>• Select and use equipment suitable for the areas of application (e.g. IP ingress protection, mechanical protection, explosive atmospheres)<br>• Use equipment with extra-low voltage/protective separation | ☐ ☐ ☐ ☐ ☐ ☐ | ☐ ☐ ☐ ☐ ☐ ☐ | ☐ ☐ ☐ ☐ ☐ ☐ | ☐ ☐ ☐ ☐ ☐ ☐ |
| **Comments/reasoning** | | | | | | |

## 4 Hazardous substances

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Use of exoskeletons containing hazardous substances** | Are hazardous substances or hazardous preparations used in or on the exoskeleton (observe hazard symbols on the exoskeleton, safety data sheets)? | • Obtain and observe EC safety data sheets from the manufacturer<br>• Observe the storage conditions as specified on the safety data sheet<br>• Observe the operating instructions<br>• Prevent contact with food, drink and tobacco<br>• Select and use personal protective equipment in accordance with the instructions for use or the safety data sheet | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Hazardous substances released during the work process** | Can the combination of the exoskeleton and the substances released during the work process give rise to further hazards?<br>• Reaction of the released substances for example with metals or alloys in the exoskeleton<br>• Deposits on the exoskeleton | • Obtain and observe EC safety data sheets from the manufacturer<br>• Exhaust of harmful substances at the point of creation or release<br>• Room ventilation<br>• Ensure that constituent materials and products of decomposition do not impair the safety and health of the user of the exoskeleton | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 5 Biological agents

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Fungi, bacteria, hygiene** | Does the exoskeleton constitute a potential habitat for bacteria or fungi?<br>• Deposits of substances released during the work process<br>• Perspiration<br><br>Is a potential hazard presented by the formation of mould or germs?<br>• Is the exoskeleton used by more than one person? | • Use suitable products to protect the body<br>• Draw up a skin-protection plan<br>• Regular cleaning and maintenance<br>• Where the exoskeleton is used by more than one person, take measures to ensure that the different users do not face any health or hygiene issues<br>• Ventilation<br>• Observe the manufacturer's information concerning the storage conditions for the exoskeleton | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 6 Fire and explosion hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Fire hazard** | Does the exoskeleton contain easily flammable substances?<br>• Flammable liquids<br>• Flammable solids<br><br>Are sources of ignition present?<br>• Sparks, for example from electrical equipment, drives or friction, batteries<br>• Thermal conduction | • Do not use exoskeletons featured with easily flammable substances<br>• If necessary, remove any superfluous flammable material as per the manufacturer's instructions<br>• Use exoskeletons manufactured from flame-resistant materials<br>• Pay attention to sources of ignition and eliminate them if possible<br>• Mark fire hazards<br>• Observe the manufacturer's information on residual risks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Explosion hazards** | • Do explosive mixtures arise on the exoskeleton?<br>• Air and gas mixtures (e.g. uncontrolled release of gas)<br>• Batteries | • Natural or forced ventilation<br>• Monitor the concentration<br>• Pay attention to sources of ignition and eliminate them if possible<br>• Observe explosion protection zones<br>• Use exoskeletons that are approved for areas requiring explosion protection (in accordance with the manufacturer's information) | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Fire fighting** | Can a fire be fought whilst an exoskeleton is worn?<br>• Is it more difficult or even impossible to fight a fire whilst wearing an exoskeleton? | • Conduct training specifically on the use of an exoskeleton in the event of a fire | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 7 Thermal hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Contact with hot media** | Do hazards arise when the exoskeleton comes into contact with hot media?<br>• Transmission of heat to the skin<br>• Heat storage<br>• Hot surfaces on the exoskeleton caused by electrical equipment | • Insulate the exoskeleton against heat<br>• Apply the required markings<br>• Observe the manufacturer's information<br>• Avoid contact with hot media | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Contact with cold media** | Do hazards arise when the exoskeleton comes into contact with cold media (work in refrigerated areas etc.)?<br>• Transmission of cold to the skin<br>• Cold storage | • Insulate exoskeletons against cold<br>• Observe the manufacturer's information<br>• Apply the required markings<br>• Avoid contact with cold media | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Overheating owing to strong envelopment in the exoskeleton** | Are persons wearing an exoskeleton at risk of overheating owing to the working environment or strong envelopment in the exoskeleton?<br>Self-heating of the exoskeleton | • Reduce wear times<br>• Absorb perspiration<br>• Observe the manufacturer's information | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 8 Physical hazards

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Noise** | Does the exoskeleton present a new source of noise (e.g. as a result of movement)?<br>Do the operating noises of the exoskeleton mask hazard signals or other important audible sounds? | • When procuring exoskeletons, compare noise data of the available products<br>• Select suitable hearing protection and make available/use | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| **Vibration (e.g. body)** | • Does the exoskeleton cause the body to be subjected to vibration?<br>• Does clearly palpable impulsive vibration arise?<br>• Do unfavourable or contorted body postures arise?<br>• Transfer of vibration to other regions of the body | • Procure exoskeletons with low vibration intensity<br>• Reduce durations of use<br>• Use vibration-absorbent sandwich layers in accordance with the manufacturer's information | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Vibration (e.g. hand-arm)** | Are manually guided tools and work equipment used in combination with the exoskeleton that lead to strong hand-arm vibration?<br>• Pneumatic tools, power saws<br>• Percussive drilling machines, impact screwdrivers, chisels, milling machines, grinders<br>• Hammers, pickaxes, tampers, vibrating plate compactors | • Use low-vibration tools in accordance with the manufacturer's information<br>• Handles with dampers or sprung handles<br>• Reduce durations of use<br>• Avoid low temperatures on tool handles | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Electromagnetic fields** | Does the exoskeleton result in persons being exposed to electromagnetic fields?<br>• By the motor functions or their drives | • Check and observe the limit values for electric and magnetic field strengths<br>• Persons with active implants: inform affected persons; it may not be possible to assign these persons to the workplace concerned<br>• Observe the manufacturer's information on residual risks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 9 Hazards presented by the conditions of the working environment

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Room climate** | Does the additional wearing of an exoskeleton give rise to aggravated conditions (physical stresses)?<br>• Room temperature too high/too low<br>• Room air too dry/too humid<br>• Dusty environment | • Use the exoskeleton as intended (in accordance with the manufacturer's information)<br>• Adjust the temperature as required (heating, air-conditioning)<br>• Reduce the duration for which the exoskeleton is worn<br>• Absorb perspiration | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Catching and dragging** | Does a risk exist of the exoskeleton being caught and dragged by moving parts in its vicinity? | • Guarding or shrouding of moving parts in the vicinity<br>• Constrain the use of the exoskeleton<br>• Mark the danger zone | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Incidence of dangerous work performed in isolation** | • Can the exoskeleton result in "normal work" becoming "dangerous work performed in isolation"? | • Where dangerous work is performed in isolation, check whether measures such as personal distress alarm systems, a second person, CCTV monitoring, etc. are required | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Poor weather conditions during work outdoors** | • Heat/direct sunlight<br>• Cold<br>• Precipitation | • Where heavy physical work is performed in which heat is generated and the body temperature increases owing to envelopment in the exoskeleton, organize appropriate breaks<br>• Use shading/sunscreen products/protection against precipitation<br>• Select and use suitable, compatible protective clothing | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| **Electrical hazard** | • Does the use of an exoskeleton increase existing electrical hazards? | • Observe the manufacturer's information<br>• Task impossible when wearing an exoskeleton | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ |
| **Comments/reasoning** | | | | | | |

## 10 Mental factors

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Mental stresses** | Can persons wearing an exoskeleton be subjected to hazards to their mental health, owing for example to:<br>• A lack of acceptance of the exoskeleton (including during secondary tasks)<br>• Being forced to use an exoskeleton<br>• Group pressure<br>• Single workstation, isolation | • Create opportunities for communication<br>• Conduct information events on the subject of exoskeletons<br>• Inform persons working with an exoskeleton of its benefits<br>• Make use of the exoskeleton optional (where it does not constitute PPE)<br>• Conduct wearer trials before introducing exoskeletons | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 11 Physical stress/work intensity

<table>
<tr><th>Possible hazard</th><th>Situations, work processes or parts of equipment potentially giving rise to this hazard</th><th>Measures for reducing or eliminating the hazard</th><th colspan="2">Risk evaluation</th><th colspan="2">Need for action?</th></tr>
<tr><th></th><th></th><th></th><th>😐</th><th>☹</th><th>Yes</th><th>No</th></tr>
<tr>
<td>Physical stresses caused by the exoskeleton</td>
<td>Does wearing of the exoskeleton impose additional loads upon the body? Additional stresses upon various parts of the body, such as the head, arms, trunk, spine, legs, etc.<br><br>Are loads frequently lifted and carried that, together with the load of the exoskeleton, exceed the following values:<br><br>
<table>
<tr><th>Age in years</th><th>Load in kg for women</th><th>Load in kg for men</th></tr>
<tr><td>15 to 17</td><td>10</td><td>15</td></tr>
<tr><td>18 to 39</td><td>15</td><td>25</td></tr>
<tr><td>40 and over</td><td>10</td><td>20</td></tr>
</table>
<br>Does the exoskeleton cause an unfavourable body posture (e.g. strongly bent, contorted) to be adopted during lifting and carrying?</td>
<td>• Important: observe COUNCIL DIRECTIVE of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (90/269/EEC)<br>• Use exoskeletons only where other technical aids such as handling and transport aids and lifting equipment cannot be used<br>• Reduce the load weights<br>• Wherever possible, carry loads close to the body and with the spine erect<br>• Enlist the assistance of further persons<br>• Provide back training and instruction<br>• Use only exoskeletons that have been shown to be effective<br>• Observe the manufacturer's information on the body regions for which support is provided<br>• Where forward bending of the trunk exceeds 20°, an exoskeleton should not be used to extend the duration of trunk inclination beyond one hour per shift without efficient breaks (for forward trunk inclinations exceeding 20°, times may be shortened)</td>
<td>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐</td>
<td>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐</td>
<td>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐</td>
<td>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐<br>☐</td>
</tr>
<tr><td>Comments/reasoning</td><td colspan="5"></td></tr>
</table>

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Work in an unfavourable body posture** | • Are unfavourable body postures frequently assumed?<br>• Poorly adapted exoskeleton<br>• Constrained posture owing to lack of space (e.g. low ceilings, shafts, tanks)<br>• Loose/slipping of the exoskeleton during the wear time<br><br>Note: About overhead activity s. page 18 as well | • An exoskeleton should not be used to extend work of longer duration above shoulder height beyond a total of two hours per shift<br>• Use ergonomically designed exoskeletons<br>• Place tools within the area of reach<br>• Prevent the exoskeleton from working loose/slipping over the entire wear time<br>• Fit each worker individually with the exoskeleton<br>• Observe the manufacturer's information on the scope of use | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Facility for adjustment – ergonomics** | • Poorly adapted exoskeleton<br>• Loose/slipping of the exoskeleton during the wear time<br>• Excessive dead weight of the exoskeleton | • Fit each worker individually with the exoskeleton (select correct sizes)<br>• Select exoskeletons with low dead weight<br>• Use suitable systems to adjust and secure the exoskeleton/procure such systems from the manufacturer<br>• Procure exoskeletons with suitable systems for adjustment and securing | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 12 Work organization and behaviour

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Motivation for occupational safety and health** | Do employees have difficulty observing the protective measures when wearing an exoskeleton?<br>Conversely, does an exoskeleton enable protective measures to be circumvented more easily? | • Provide instruction regularly, if necessary with practical exercises<br>• Promote safety awareness and responsibility among employees<br>• Provide information on possible harm caused by the circumvention of safety measures | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ | ☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| **Workplace not suitable for exoskeletons** | • The exoskeleton is not compatible with the work process<br>• The exoskeleton is not compatible with the work environment<br>• Cable-bound exoskeletons give rise to new tripping hazards | • Select and procure exoskeletons suitable for the work process and work environment<br>• Observe the manufacturer's information | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Instruction** | Possible failure to provide employees with the necessary workplace-specific instruction For example:<br>• Proper use of the exoskeleton<br>• Instruction on potential hazards arising from use of the exoskeleton<br>• Proper donning and removal of the exoskeleton<br>• Proper fitting of the exoskeleton<br>• Wear times<br>• Benefits to the employees of an exoskeleton<br>• Instruction on the combination of exoskeleton and PPE | • Provide specific instruction on the workplace involving a exoskeleton<br>• Apply the required markings<br>• Observe the behavioural measures<br>• For use as PPE and/or in conjunction with PPE: observe European Directive on the use of personal protective equipment (Council Directive 89/656/EEC) or national transpositions of it (and for details: DGUV rules governing PPE – in German) | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Hazards arising from the combination of exoskeleton and personal protective equipment (PPE)** | • Where an exoskeleton is used in combination with PPE, the two impair each other's protective action | • Where an exoskeleton is used, select and procure compatible PPE in consideration of the situation at the workplace and of each individual user<br>• Check the serviceability each time before use<br>• Observe the manufacturer's information<br>• Observe the DGUV Rules governing PPE (information compiled at https://ppecombinations.ifa.dguv.de/ | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Employees not fitted correctly with the exoskeleton<br>Exoskeleton unsuitable for the work process** | • Employees not fitted individually with the exoskeleton<br>• Adjustment system may work loose unintentionally<br>• Removable components are difficult to release<br>• Safety class inappropriate for the risk level (PPE) | • Observe the manufacturer's information (use as intended)<br>• Observe supported region of the body<br>• Fit each worker individually with the exoskeleton<br>• Provide instruction in donning and removal of the exoskeleton | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ | ☐<br>☐<br>☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| | | | | | | |

## 13 Other hazards/stresses

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Hazards resulting from secondary tasks** | Can the intended secondary tasks be performed when the exoskeleton is worn?<br>Examples of secondary tasks:<br>• Tasks in which the exoskeleton does not provide support or is not required to do so<br>• Breaks | • Take secondary tasks into account when selecting the exoskeleton<br>• Observe the manufacturer's information<br>• Reduce the duration for which the exoskeleton is worn<br>• Limit to a minimum the constraints during the tasks to be performed | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |
| **Hazards in the event of emergencies, e.g. fire alarm** | Are persons wearing exoskeletons able to use the specified escape route?<br>• Are they able to negotiate stairs?<br>• Does the exoskeleton impede faster walking or running?<br>• Must consideration be given to particular first-aid measures performed by or on persons wearing exoskeletons? | • Adapt escape routes to persons wearing exoskeletons<br>• Provide additional safety instruction on exoskeletons<br>• Extend first-aid measures to include persons wearing exoskeletons | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Hazards presented by constrained mobility/field of view/airways** | Can hazards arise as a result of constrained mobility when an exoskeleton is worn?<br>• Essential materials can be accessed only with the use of a climbing aid (constrained extension of the arms)<br>• Is a person wearing an exoskeleton able to stand up again without assistance after a fall or after adopting a required work position (e.g. sitting)?<br>• Are the airways or the field of vision constrained?<br>• Can the sense of balance be disturbed by the exoskeleton? | • Store required materials appropriately<br>• Make aids to standing up available<br>• Assign additional persons for provision of assistance<br>• Reduce constraints in the field of view to a minimum<br>• Reduce constraints upon the airways to a minimum<br>• Train the sense of balance with the exoskeleton worn; provide handrails if appropriate<br>• Observe the manufacturer's information on residual risks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 14 Protection of expectant and nursing mothers

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Hazardous substances** | Are the hazardous substances or substances released into the working environment of the expectant mother carcinogenic, mutagenic or teratogenic substances, for example with the following classifications:<br>• H 340 – May cause genetic defects (e.g. ethylene oxide)<br>• H 341 – Suspected of causing genetic defects<br>• H 350 – May cause cancer (e.g. benzene)<br>• H 350i – May cause cancer if inhaled<br>• H 351 – Suspected of causing cancer (e.g. formaldehyde)<br>• H 360d – May damage the unborn child<br>• H 361d – Suspected of damaging the unborn child<br><br>Do hazardous substances capable of percutaneous absorption come into direct contact with the skin?<br><br>Does the expectant mother have contact with lead or its derivatives presenting a risk of being absorbed by the human body? | • Adapt/modify the workplace in order to rule out an unacceptable hazard; no contact with or work involving hazardous substances (carcinogenic, mutagenic or teratogenic substances, for example with the classifications listed above)<br>• A nursing or expectant mother must not be assigned to these tasks | ☐<br><br>☐ | ☐<br><br>☐ | ☐<br><br>☐ | ☐<br><br>☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Hazardous substances** | Can the expectant mother be exposed during her tasks or under her working conditions to other hazardous substances on a scale that constitutes an unacceptable hazard to her or her child? | An unacceptable hazard is deemed ruled out when the hazardous substance:<br>• Has the classification "Y" in accordance with the German TRGS 900 technical rules, or ☐ ☐ ☐ ☐<br>• Is assigned to Pregnancy Risk Group C in accordance with the German MAK and BAT value list of the DFG (a risk of a teratogenic effect need not be anticipated provided the limit values are observed). ☐ ☐ ☐ ☐<br>**Recommendation:**<br>Do not assign pregnant women to work involving hazardous substances unless an unacceptable hazard presented by the substances concerned can be ruled out.<br>• A nursing or expectant mother must not be assigned to these tasks ☐ ☐ ☐ ☐ | | | | |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **Hazardous substances** | **For nursing mothers**<br>Is the nursing mother exposed to the following hazardous substances, which are classified as reprotoxic:<br>• H 362 – May cause harm to a breastfed child<br>• Lead or its derivatives presenting a risk of absorption by the human body<br><br>Can the nursing mother be exposed during her tasks or under her working conditions to other hazardous substances on a scale that constitutes an unacceptable hazard to her or her child? | • Adapt/modify the workplace in order to rule out an unacceptable hazard<br>• Adapt/modify the task in order to rule out an unacceptable hazard<br><br>An unacceptable hazard is deemed ruled out when the hazardous substance:<br>• Has the classification "Y" in accordance with the German TRGS 900 technical rules, or<br>• Is assigned to Pregnancy Risk Group C in accordance with the German MAK and BAT value list of the DFG (a risk of a teratogenic effect need not be anticipated provided the limit values are observed).<br>• **Is not** classified as H 362 (May cause harm to a breastfed child).<br>**Recommendation:**<br>Do not assign nursing women to work involving hazardous substances unless an unacceptable hazard presented by the substances concerned can be ruled out.<br>• A nursing or expectant mother must not be assigned to these tasks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation 😐 | Risk evaluation ☹ | Need for action? Yes | Need for action? No |
|---|---|---|---|---|---|---|
| **The following should be considered with respect to all hazards:** | Is the work of the expectant mother associated with elevated accident risks when an exoskeleton is worn?<br>Is the expectant mother required to stand continually (longer than four hours per day)?<br>Is facility provided for her to lie down?<br>Is the expectant mother frequently required to stretch or bend strongly, to squat continually or to maintain a bent posture? | • Only have tasks performed for which an unacceptable hazard can be ruled out.<br>• A nursing or expectant mother must not be assigned to these tasks | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ | ☐<br>☐ |
| **Comments/reasoning** | | | | | | |
| **Pathogens** | Exposure to pathogens (viruses, bacteria, fungi) that owing to disease and/or treatment of the expectant or nursing mother and/or her child may present a hazard in the sense of Annex 1 of the German Ordinance on the protection of mothers at work (MuSchArbV)<br>(Risk Groups 2 to 4) | • A nursing or expectant mother must not be assigned to these tasks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

| Possible hazard | Situations, work processes or parts of equipment potentially giving rise to this hazard | Measures for reducing or eliminating the hazard | Risk evaluation | | Need for action? | |
|---|---|---|---|---|---|---|
| | | | 😐 | ☹ | Yes | No |
| **Biological substances** | **For nursing mothers:**<br>Is the nursing mother exposed or can she be exposed, during performance of her task or by virtue of her working conditions, to biological substances in Risk Groups 2, 3 or 4 in the sense of Section 3, Paragraph 1 of the German Ordinance on biological substances (BioStoffV) on a scale that constitutes an unacceptable hazard to her or her child? | • A nursing or expectant mother must not be assigned to these tasks | ☐ | ☐ | ☐ | ☐ |
| **Comments/reasoning** | | | | | | |

## 15 List of measures

| Safety objective | Measure/comment | Person responsible | Deadline | Completed | Effectiveness | |
|---|---|---|---|---|---|---|
| | | | | | Yes | No |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |

## 16 List of maternity protection measures

| Safety objective | Measure/comment (*) | Person responsible | Deadline | Completed | Effectiveness | |
|---|---|---|---|---|---|---|
| | | | | | Yes | No |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |

(*) Where a hazard falling within the scope of maternity protection regulations exists, the work/workplaces must be organized such that a hazard no longer exists. Should this not be possible, the expectant/nursing mother may no longer perform tasks whilst wearing the exoskeleton.

## 17 Means of determining risk

| Frequency | Severity of harm | | | | |
|---|---|---|---|---|---|
| | No hazard to health | Minor injuries (no reportable lost working time) | Moderately severe consequences (lost working time, no permanent harm) | Severe consequences (non-reversible injuries) | Fatal consequences |
| Not probable (<1 per year) | Low | Low | Low | Medium | High |
| Conceivable (once per year) | Low | Low | Medium | High | High |
| Possible (once per month) | Low | Medium | High | High | High |
| Probable (once per week) | Medium | High | High | High | High |
| Very probable (once per day) | High | High | High | High | High |

Source: IFA – draft, Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA)