

BOOK OF ABSTRACTS

SUSTAINABLE MSDs PREVENTION: NEW CHALLENGES FOR RESEARCH AND PRACTICE

5-7 MAY 2026

Centre de congrès Prouvé,
Nancy, France



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TUESDAY, 5 MAY 2026

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INDINGS FROM COHORT AND EMERGING METHODS

TUESDAY, 5 MAY 2026

KEYNOTE PRESENTATION

14:30 - 15:30 – AUDITORIUM 300, LEVEL 1

Musculoskeletal disorders in the digital era - Epidemiology, risk factors and tools for prevention



P. Madeleine and Y. Roquelaure



Pascal Madeleine is Professor, PhD, DSc, ExerciseTech at the Department of Health Science and Technology of the Faculty of Medicine, at Aalborg University.

He has a background in biomedical engineering. His solid technical background has enabled him to develop and implement new approaches targeting the prevention and treatment of musculoskeletal disorders (MSD). The role of wearables and digital signal processing approaches for extraction of pertinent information and of technological solutions like exoskeletons as tool for MSD prevention are essential for better understanding and preventing MSD at work.

Yves Roquelaure (MD, PhD) is a professor of occupational medicine at Angers University Hospital and director of the Ester research team at the Institute for Research on the Environment and Health, France's leading academic research unit in occupational medicine.

He is a senior researcher specializing in ergonomics and occupational epidemiology of work-related musculoskeletal disorders. During his PhD, he developed a multidimensional approach combining basic science, biomechanics, occupational medicine, ergonomics, epidemiology, and public health. He has conducted several epidemiological studies on the risk factors for musculoskeletal disorders and intervention studies aimed at preventing MSDs and improving return to work after an MSD. He has contributed to the development of compensation scales for MSDs as occupational diseases. He set up a major epidemiological surveillance program for MSDs in France in 2000 (the Pays de la Loire study) and participated in the design of the large French Constances cohort (200,000 participants) on work-related health outcomes and exposure assessment.

He has published more than 350 international and national articles (including 219 indexed in PubMed, H-Index 37). He has published working papers for EU-OSHA summarizing scientific knowledge on the relationship between “psychosocial factors and musculoskeletal disorders” and “hybrid work: new opportunities and challenges for occupational safety and health”.

Although traditional forms of musculoskeletal-intensive activities persist in many jobs, e.g., construction sector, a clear set of new work forms has emerged recently in the digital age, reshaping how workers earn a living, how companies organize labor, and how skills are developed. The main drivers behind these changes are digitalization, AI, and Industry 4.0 technologies. These most common forms of work-whose prevalence in the workforce varies from country to country according to the European OSH Pulse 2025 survey¹-consist of (i) platform work, (ii) remote and hybrid work, (iii) AI-supported and algorithmically managed work, (iv) atypical and on-demand work, (v) digital nomadism, (vi) knowledge-intensive digital work, and (vii) human-Machine collaboration.

This shift toward digital age work forms has deep consequences for both the prevention and the compensation of work-related musculoskeletal disorders (WMSDs) (Roquelaure 2021). New forms of work modify the patterns

of exposure to workplace hazards increasing exposure to psychosocial factors, cognitive overload and other forms of mental burden. This is resulting in a hybridization of occupational exposure profiles that are emerging between the two archetypal categories of situations at high risk for WMSDs, on the one hand intensive dynamic motor tasks requiring repetitive and/or vigorous movements (“soft tissue overuse”) - leading to musculoskeletal discomfort and pain, tendinopathies, and nerve compression - traditionally observed in the agricultural and industrial sectors, and, on the other hand, prolonged static work of low intensity (“soft tissue underuse”) leading to chronic non-specific pain in workers performing psychosocially and cognitively demanding static tasks. The relative contribution of biomechanical risk factors and psychosocial and organizational factors is changing accordingly in many current work situations: Platform work is characterized by higher physical load (repetitive lifting), awkward postures, and long hours



¹ <https://osha.europa.eu/en/tools-and-publications/infographics/osh-pulse-2025-digitalisation-work>



as well as algorithmic pressure (time pressure and performance metrics), increasing stress and reducing recovery time. To these, one can add psychosocial factors and limited ergonomic control. ICT work has also evolved into intensive work with increased screen time accompanied by more static postures and repetitive hand movements, increased cognitive and more automated movement since physical movement like walking to a colleague is replaced by digital communication. Human-machine collaboration is correlated with new ergonomic risks (need to adopt different postural strategies and attentional demands), skill mismatch increasing WMSDs risks but also potential benefits as exoskeletons and robots can reduce the biomechanical load related to heavy lifting and repetitive tasks.

In summary, these new forms of work underline real prevention challenges jeopardizing the sustainability of these forms of work. Poor ergonomics, high physical load, time pressure, longer sedentary time, longer screen time including smartphones and skill stress. Musculoskeletal symptoms are complex due to a complex interplay of physical and psychological factors calling for new assessment methods at both workplaces and homes considering ethical issues related to the collection and use of such data. We thus believe that the scientific community has to embrace the development and use sensors and devices enabling us to record the type, duration and load of home workplaces and decrease the musculoskeletal load. This can be achieved using for instance inertial measurement units, smart garments, connected glasses, as well as electronic devices like home computers, tablets and smartphones to enable a precise quantification of the workload as well as the delivery of interventions like active pauses and breaks introducing variations at work (Madeleine *et al.*, 2024). Inertial measurement units have been used

to characterize spine kinematics during office computer work and smartphone use (Xie *et al.*, 2018). Smart garments embedded with sensors collecting e.g., electrocardiogram, respiration, and micro-computer extracting and sending the relevant data to a cloud solution are available (Tamantini *et al.*, 2025). Connected glasses besides being used as a tool for maintenance also enable the extraction of oculometrics data that in turn can be used to deliver individualized biofeedback mitigating e.g., fatigue development (Zargari *et al.*, 2019). Similarly, computers and electronics devices like smartwatches are likely to be used to decrease stress and improve wellbeing (Pozzato *et al.*, 2025). Finally, other technologies like exoskeletons and collaborative robot are becoming more and more common at work requiring to document human-machine interaction their effects in terms of WMSDs prevention (Jakobsen *et al.*, 2025; Schoose *et al.*, 2023). As well as risk assessment, epidemiological surveillance must be adopted by using both quantitative and qualitative methods to accommodate the diversity of risk factors in more diverse, dispersed, and constantly changing working populations. Big Data and Job-Exposure-Matrix will help to merge individual data and risk assessment at the meso or macro levels.

The shift toward digital age work forms creates compensation challenges as the work-relatedness of musculoskeletal symptoms can be difficult to prove (Roquelaure *et al.*, 2024). Moreover, these workers are often excluded from compensation system. Adjustments to the populations covered by the compensation system, compensation rules, and/or medical and exposure criteria used to characterize situations recognized at risk of WMSDs are necessary to accompany these changes and better include new forms of work and new employment contracts.

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PARALLEL SESSIONS

01. ORAL COMMUNICATIONS NEW TECHNOLOGIES – EXOSKELETONS

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Sensorimotor adaptations to the use of a passive shoulder occupational exoskeleton during repeated training sessions for an overhead work task

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The Impact of Training and Extended Use of Back-Support Exoskeletons on Worker Biomechanics, Discomfort, and Perceived Workload in Logistics

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Workers' opinions on exoskeletons and their ability to reduce MSDs: a cross-section of the literature and a field study

L. Gonella, I. Berget, D. Denis..... P.09

Postural awareness as a precondition for safe, task-specific use of industrial exoskeletons and as a lever to develop it

C. Vignola, C. Pigni, A. Pagano..... P.10

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Evaluation and implementation of exoskeletons in the workplace

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KEY WORDS

Familiarization | Assistive device | Muscle activity | Kinematics | MSD

Sensorimotor adaptations to the use of a passive shoulder occupational exoskeleton during repeated training sessions for an overhead work task



K. Desbrosses¹ and C. Hayot¹

Occupational exoskeletons are assistive devices that may reduce muscle effort of an operator. As with any new technology, a training period appears necessary to adapt to the system and to assess the lasting biomechanical consequences related to its use. Indeed, repeated use of the exoskeleton would allow a gradual achievement of a stabilization of sensorimotor responses, defined as a familiarization state. The aim of this laboratory study was to identify the minimum training period required to achieve this familiarization and to evaluate the sensorimotor adaptations induced during this period.

After completing 7 learning sessions (L1 to L7, without exoskeleton) of an overhead work task involving precise and repeated arm-raising movements on the right side, 14 participants completed 7 training sessions (T1 to T7) in this same task using a passive shoulder occupational exoskeleton. Task completion time and number of errors were quantified to assess work performance. EMG activity of 16 muscles, whole-body kinematics, and ground reaction forces were collected to analyze sensorimotor adaptations.

Compared to the last learning session (L7), the work performance with the exoskeleton was lower during the first training session (T1). This performance then improved during the training period to become stable near the 8th session (obtained by extrapolation). Activity of the right anterior deltoid muscle was lower for T1 compared to L7

and then progressively increased until T7 while remaining weaker than L7. Similarly, activity of the left erector spinae progressively increased between T1 and T7 to reach values greater than L7. The fluidity of movement at the level of the tool to be handled, assessed by the SPARC, was lower for T1 compared to L7. This fluidity then improved to reach stability close to T7.

When using an occupational exoskeleton for the first time, there are sensorimotor adaptations and an alteration in work performance. These consequences are transitory since a period of training in the use of the device allows these adaptations to evolve and, ultimately, a state of familiarization to be obtained. Although overall, the evolution of these adaptations is in the direction of improved use of the assistance provided by the exoskeleton (increased performance, lower activity of agonist muscles, etc.), there are nonetheless undesirable effects which become established over time (higher activity of the lumbar muscles, for example). In terms of MSD prevention, these results are important on two levels. On the one hand, for scientific research, the effects associated with the use of an exoskeleton should only be assessed after a sufficient training period, once sensorimotor adaptations have stabilized, and on the other hand, for companies, operators should have sufficient training time before they are asked to perform their work tasks under normal conditions with this physical assistive device.

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PARALLEL SESSIONS

01. ORAL COMMUNICATIONS: NEW TECHNOLOGIES – EXOSKELETONS

16:20 - 16:40 – AUDITORIUM 300, LEVEL 1 – #115

KEY WORDS

Occupational Exoskeletons | Passive Assistive Devices | Workload | Training | Long-term Use

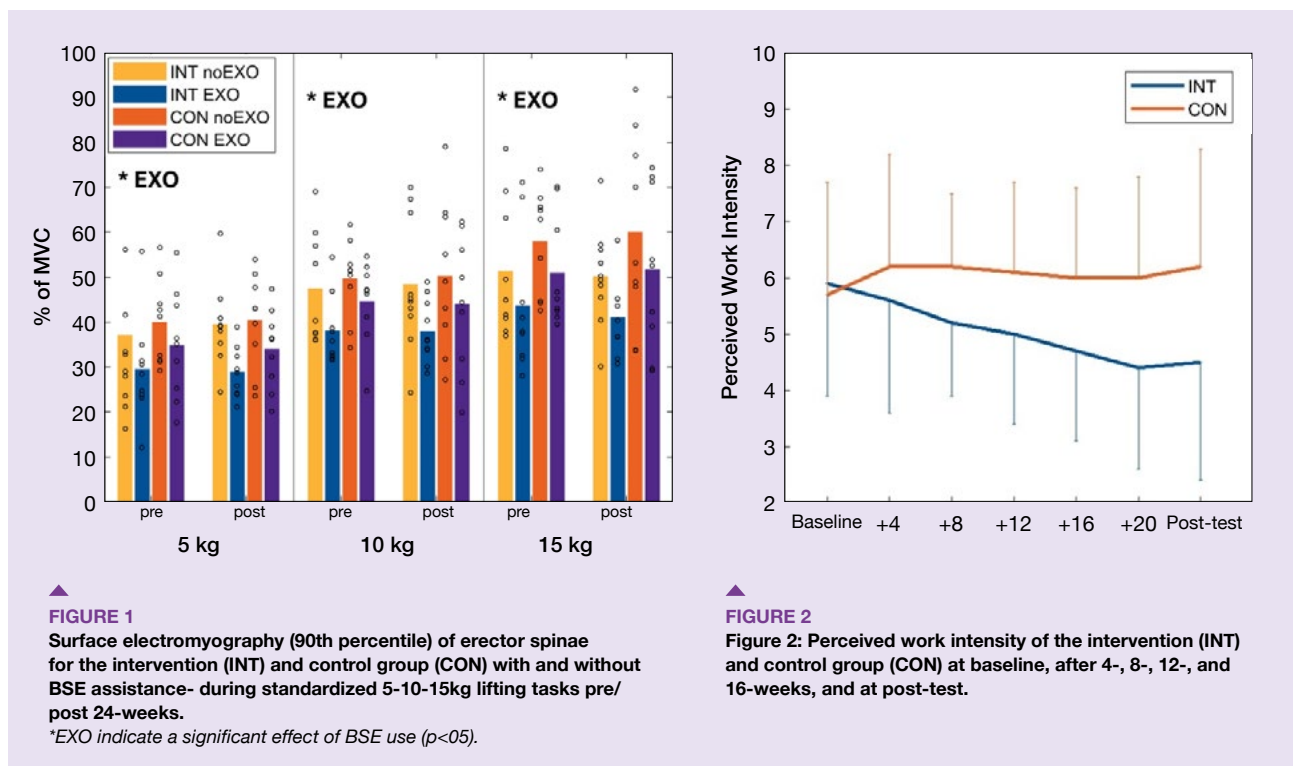
The Impact of Training and Extended Use of Back-Support Exoskeletons on Worker Biomechanics, Discomfort, and Perceived Workload in Logistics



L. S. Jakobsen¹, A. Samani¹, K. Desbrosses², M de Zee¹, B. Steinhilber³ and P. Madeleine¹

Back-support exoskeletons (BSEs) represent a promising ergonomic intervention to mitigate the high prevalence of work-related musculoskeletal disorders (WMSDs) among manual logistic workers. However, successful industrial implementation depends on understanding the effects of both user training and prolonged in-field exposure. This work synthesizes findings from two complementary investigations

evaluating training and long-term use of a passive BSE (BackX-S, SuitX by Ottobock) among logistics workers (Jakobsen *et al.*, 2024; 2025). The first study examined the effects of a structured five-week training program (n = 19), while the second implemented a 24-week randomized controlled trial (n = 20) to assess biomechanical and perceptual outcomes during extended in-field use.



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In both studies, surface electromyography and inertial motion capture quantified back muscle activity and joint kinematics during standardized lifting tasks. Perceived effort, usability, and musculoskeletal discomfort were collected using questionnaires. The first study revealed reduced back muscle activity when using the BSE. Furthermore, training elicited a 6-9% additional reduction in peak erector spinae activity compared with pre-training values. Training also reduced knee flexion angles by 6-16°, indicating a shift toward a more stooped lifting strategy. Adherence to the protocol averaged 74%, highlighting the feasibility of training BSE usage in occupational settings.

The 24-week randomized controlled trial confirmed persistent biomechanical benefits, as BSE assistance consistently reduced lumbar extensor activation (*Fig. 1*).

Participants reached weekly adherence to exoskeleton use of 16.2 hours, accompanied by a steady decline in self-reported work intensity (*Fig. 2*). Contrary to the first study, the magnitude of muscle-activity reduction remained constant from pre- to post-test.

These studies suggest that structured in-field training substantially enhances exoskeleton efficiency, while long-term utilization maintains biomechanical relief and lowers perceived workload. A combined structured training followed by sustained integration, emerges as critical for realizing the ergonomic benefits of passive BSEs in logistics. Future work should explore more effects of prolonged BSE use, including impact on socioeconomic factors, e.g., work efficiency, development of WMSDs, sick leave, and employee-turnover to support evidence-based industrial deployment.

ACKNOWLEDGEMENTS

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PARALLEL SESSIONS

01. ORAL COMMUNICATIONS: NEW TECHNOLOGIES – EXOSKELETONS

16:40 - 17:00 – AUDITORIUM 300, LEVEL 1 – #52

KEY WORDS

Exoskeleton | Perceptions | Filed study | Qualitative data

Workers' opinions on exoskeletons and their ability to reduce MSDs: a cross-section of the literature and a field study



M. Gonella¹, I. Berger² and D. Denis²

Exoskeletons are popular in the workplace and in the scientific sphere for preventing MSDs (Botti & Meloni, 2023). Results from workers' perceptions following use in the workplace are showing. What do they really think?

Methodology

This paper proposes results from two sources: 1. A literature review (n=35 studies, from 2010 to 2023; Gonella *et al.*, 2025). Data were collected via questionnaires, group interviews, or open-ended consultations. 2. A case study conducted in Quebec (n=17 tasks, n=51 workers, nine exoskeletons; Denys *et al.*, 2025; Berger *et al.*, 2025). Perceptions were obtained through questionnaires (before and after), individual and group interviews, verbalizations. Qualitative syntheses were carried out (usability, intention and ease of use, perceived usefulness, rejection and acceptance factors).

Results

Participants from source 1 reported: 1. That positive effects would be visible in the longer term (\geq three months): reduction in back strain, in effort and fatigue, improvement in posture; 2. Negative effects on comfort, restriction of movement and in tight spaces, on balance, difficulties with adjustments, heavy weight and interference with PPE, or on safety. For effort reduction: opinions are divided (depending on the exoskeleton and limbs supported). The reported reductions are more positive when adopting static postures. For performance, participants report interference with work, there is no consensus on the impact on productivity. Participants often report the need for improvements to device designs and advocate for exoskeletons to be worn only on a voluntary basis. Some authors mention that there is certainly a pla-

cebo effect: they note a feeling of reduced perceived effort but no objective measure of reduction in muscle stress.

The perceptions of the workers (source 2) are mixed. They commented on four points about the devices: the ability to adopt various postures, usability, usefulness to reduce efforts and comfort. For postures: opinions are positive, but it is difficult to adopt postures close to the ground (squatting, kneeling), which are necessary for dynamic work (e.g. horticulture, construction). They consider usability to be good for certain models. For comfort, opinions are divided, some feel restrictions or discomfort, others do not. Following the tests, the intention of use was low or mixed, exoskeletons are often considered unsuitable for real work, but the opinion varies according to the individual, the tasks and the models. In fact, the more dynamic the work is, the less the cost-benefit balance seems to lead to a strong intention to use (and vice versa). Participants mainly report rejection factors: discomfort (heat, pressure points), a reduction in effort deemed insufficient, a negative impact on productivity, incompatibility with tasks or interference with work and an altered sense of security. It should also be noted that comfort is the variable that seems to influence users' perceptions the most.

Discussion / conclusion

The results of our study are in line with the literature review, but they are a bit more diverse and negative. We mainly find elements of rejection, negative points regarding the use of exoskeletons in the workplace. The participants seem to evaluate the technical performance of the devices quite positively in their potential to reduce MSDs. The problem would rather come from their suitability for the work. Overall, the results in the workplace are more mixed than in the laboratory.

ACKNOWLEDGEMENTS

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PARALLEL SESSIONS

01. ORAL COMMUNICATIONS: NEW TECHNOLOGIES – EXOSKELETONS

17:00 - 17:20 – AUDITORIUM 300, LEVEL 1 – #87

KEY WORDS

Industrial exoskeletons | Postural awareness | MSD prevention | Ergonomics | Training

Postural awareness as a precondition for safe, task-specific use of industrial exoskeletons—and as a lever to develop it



C. Vignola¹, C. Pigni² and A. Pagano²

Industrial back-support and upper-limb exoskeletons can reduce biomechanical load and perceived exertion in specific tasks, yet they may introduce new risks when deployed without clear task windows, exclusion criteria and user training (de Looze *et al.*, 2016; Madinei *et al.*, 2020; Golabchi *et al.*, 2022; Kranenborg *et al.*, 2023; EU-OSHA, 2019; NIOSH, 2016, 2022). We argue that postural awareness—the capacity to perceive, interpret and modulate alignment and tension in real time—is a prerequisite for safe, sustainable assistance; conversely, lightweight exoskeletons can be used as didactic amplifiers to accelerate somatic learning of efficient patterns.

We present a fit-for-task implementation framework that couples ergonomic assessment (RULA/REBA; time in critical postures), workload and exertion ratings (NASA-TLX; Borg CR10, district-specific), and a structured perceptual-motor training module using with/without contrasts, short verbal cues

and explicit stop rules (McAtamney & Corlett, 1993; Hignett & McAtamney, 2000; Borg, 1998; Hart & Staveland, 1988; Hart, 2006). A decision matrix (**Table 1**) links job demands (e.g., trunk flexion ~20–60°, overhead reach >60–90°), device family (soft back-support; passive shoulder assist) and exclusions (stairs/ramps, tight spaces, rapid torsions).

We translate a validated Back School approach—originally combining depth-camera observation with coached practice—into an exoskeleton-assisted protocol that makes differences in load distribution and movement freedom immediately perceptible; implementation materials include an adverse-event taxonomy (pressure points, paresthesia, mobility restrictions, non-target load transfer), acceptance/compliance checks, and integration with PPE and emergency procedures consistent with relevant standards (ISO 13482:2014; ISO/TR 23482-1/-2). This protocol aims to minimize the risks associated with a lack of awareness of overloads and pressure points resulting from the use of exoskeletons.

Case vignettes from manufacturing and logistics illustrate feasibility and the type of outcomes prioritized: reduced time in critical postures, improved RULA/REBA classes, and lower Borg CR10 in the target district without increases elsewhere, with stable or reduced NASA-TLX and no reportable events.

Postural awareness is the integration of interoception and proprioception to regulate alignment and muscle tone during task execution. In exoskeleton use, it functions as a cognitive-perceptual filter that prevents dysfunctional compensations and optimizes human–device interaction (Vignola C. 2023). Functionally, awareness enhances fine motor control, reducing compensations and non-target loads, lowering exertion, and promoting safer, more efficient performance.

Representative task	Critical ranges	Suggested device	Fit notes	Exclusions / stop rules
Repeated trunk flexion pick-&-place	20–60° trunk flexion, limited torsion	Soft/“hybrid” back-support	Coach hip-hinge; verify belt/anchor comfort	Stairs/ramps; tight spaces; rapid twisting
Overhead painting/cabling	Shoulder elevation >60–90° sustained	Passive shoulder support	Verify scapulo-thoracic freedom; adjust assistance	Paresthesia, pressure marks >20–30 min, PPE interference
Precision forearm tasks (demo)	Static reach, wrist neutral	Forearm support (demo only)	Use to highlight wrist trade-offs	Avoid for prolonged production use

TABLE 1
Task-matching table examples.

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TUESDAY, 5 MAY 2026

SYMPOSIUM

16:30 - 17:30 – ROOM 103, LEVEL 1

KEY WORDS

Industrial exoskeletons | Prevention of musculoskeletal diseases | Ergonomic intervention | Workplace

Status Quo on Industrial Exoskeleton Research



U. Glitsch¹ and T. Luger²

Industrial exoskeletons have become a frequently recommended tool at workplaces for reducing the workers' musculoskeletal loads. However, successfully introducing exoskeletons remains a significant challenge for employers, workers, and associated stakeholders. This session will present an overview of the various challenges involved in selecting the most suitable exoskeleton for a given workplace. Finally, an example of how to conduct a long-term assessment of exoskeleton usage in the workplace will be provided.

THE CONTRIBUTIONS TO THE SESSION ARE

The updated German medical guideline on exoskeletons for preventing work-related musculoskeletal disorders: T. Luger, K. Heinrich, S. Weiler, J. Hegewald, N. S. Korrapati, P. Schwenkreis, S. Middeldorf, U. Glitsch, F. Liebers, A. von Glinski, T. A. Schildhauer, G. Winter, G. Schnalke, S. Wischniewski, M. Peters, I. Schalk, D. Kern, R. Schick, M. Jäger, U. Daub, B. Steinhilber; **Evaluation and implementation of exoskeletons in the workplace:** I. Schalk, U. Glitsch, S. Huis, D. Kern, K. Steindorf, G. Winter, L. Ralfs, R. Schick; **Analysis of the relief of the lumbar spine by different back-support exoskeletons during lifting and holding:** U. Glitsch, J. Johns, K. Heinrich; **Using musculoskeletal simulation for knowledge-based selection of industrial exoskeleton:** D. Scherb, T. Drees, B. Kuhlentötter, R. Weidner; **Shoulder Exoskeletons in Aircraft Assembly: A Field Study on Potential Long-Term Effects:** K. Heinrich, R. Grzeszick, M. Kaufmann, T. Wagner, C. Böhm.

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KEY WORDS

Exoskeletons | Guideline | Work-related musculoskeletal disorders | Systematic literature search | Evidence assessment

The updated German medical guideline on exoskeletons for preventing work-related musculoskeletal disorders



T. Luger¹, K. Heinrich², S. Weiler³, J. Hegewald^{4,5}, N. S. Korrapati¹, P. Schwenkreis⁶, S. Middeldorf⁷, U. Glitsch², F. Liebers⁵, A. von Glinzki⁸, T. A. Schildhauer⁹, G. Winter¹⁰, G. Schnalke¹¹, S. Wischniewski¹², M. Peters¹², I. Schalk¹³, D. Kern¹⁴, R. Schick¹³, M. Jäger¹⁵, U. Daub¹⁶ and B. Steinhilber¹

Specific work characteristics like handling heavy loads, repetitive lifting, static postures, and overhead work play an important role in the development of work-related musculoskeletal disorders (WRMSD). Potential interventions for relieving employees exposed to these physically demanding occupational tasks and for WRMSD prevention could be the implementation of exoskeletons, which are assistive devices worn directly on the body aiming to reduce physical loads on particular body parts. To support occupational practitioners, a German medical guideline on the use of exoskeletons for preventing WRMSD was published in 2020 and is being updated.

The 2020-guideline was a consensus-based guideline (level S2k) including expert opinions supported by published scientific studies. The update is accompanied by an upgrade to a combined evidence- and consensus-based guideline (level S3) including systematic literature search and assessment along with expert opinions from a representative body of professional societies and advisory institutions. In a structured consensus conference, independently moderated, the developed recommendations and key statements are voted on and adopted.

Systematic searches in four databases and one trial register resulted in 1,467 records. Two reviewers independently screened 1,035 unique records and selected 206 reports that met the eligibility criteria. Only four studies (five reports) were longitudinal field studies that could serve as evidence base for the current guideline regarding primary and secondary prevention. No study dealt with

tertiary prevention. Studies were judged on risk of bias using ROBINS-I V2 and quality of evidence using Oxford Levels of Evidence. All studies had a moderate or high risk of bias and the final level of evidence was 3 or 4 (after downgrading based on sample size, potential conflict of interest, statistical significance level adjustments, intervention period, risk of bias). In general, the body of literature addressed short-term effects, mostly conducted in laboratory environments. It clearly shows that effects of the exoskeleton depend on the selected occupational task and anthropometric characteristics of the user and that usability and wearing comfort may be key elements for successful implementation. The 206 selected reports were considered by all experts to derive and consent recommendations.

The three studies on primary prevention could not indicate a clear effect of wearing exoskeletons compared to not wearing exoskeletons on musculoskeletal disorders and symptoms among healthy employees. The one study on secondary prevention showed that wearing exoskeletons had a pain-reducing effect compared to not wearing an exoskeleton among workers with unspecific back pain.

The evidence that exoskeletons can play a preventive role in the development of WRMSD is very limited. This is an appeal that further research is needed: conducting high-quality longitudinal randomized controlled trials; being aware that the effect of wearing exoskeletons depends on the occupational task and characteristics of the wearer; warranting acceptance of exoskeleton implementation at all hierarchical levels.

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PARALLEL SESSIONS

02. SYMPOSIUM: STATUS QUO ON INDUSTRIAL EXOSKELETON RESEARCH

KEY WORDS

Exoskeleton | Workplace | Evaluation | Implementation

Evaluation and implementation of exoskeletons in the workplace



I. Schalk¹, U. Glitsch², S. Huis³, D. Kern⁴, K. Steindorf⁵, G. Winter⁶, L. Ralfs⁷ and R. Schick¹

Exoskeletons are a novel ergonomic tool, aiming to reduce work related musculoskeletal diseases. Exoskeletons have the potential to reduce excessive physical strain during occupational tasks. This has been shown mainly in laboratory studies (Luger *et al.*, 2022). However, each workplace must be specifically assessed regarding the potential benefit of exoskeletons as well as the most suitable exoskeleton for the specific task. This requires an assessment of the suitability of exoskeletons, for which there is currently no standardized and reliable procedure. Selection and evaluation are not easy for end-user-companies due to the large number of products available on the market (Weidner *et al.* 2020). Exoskeletons can support different body regions and differ in terms of their design, construction, and mechanical and biomechanical functionality (Ralfs *et al.*, 2023). Furthermore, exoskeletons are usually designed for specific tasks and/or working postures that can occur in workplaces in different forms, frequencies and durations. Choosing the right exoskeleton, based on the individual needs and strategically implementing it into the workplace is crucial for the long-term success.

To guide potential users of exoskeletons, we have designed an information brochure on the evaluation and implementation of exoskeletons in the workplace by the German social accident insurance. The aim of this brochure is to provide a basis for evaluating exoskeletons in the workplace and sustainably implementing a suitable solution. We describe a systematic step-by-step procedure, supplemented with checklists, questionnaires, diagrams and recommendations for action. This ensures reliable and comparable test results and enables the selection of a suitable exoskeleton for the respective application.

Stakeholders are occupational health and safety professionals that are planning the implementation of exoskeletons in the workplace. The key steps in the selection and evaluation process, as well as essential recommendations for action, are summarized in a compact and practical format for users. The alignment with health and safety guidelines as well as labour protection laws is another important aspect that is considered and described.

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KEY WORDS

Industrial exoskeletons | Musculoskeletal loading | Lumbar spinal loading

Analysis of the relief of the lumbar spine by different back-support exoskeletons during lifting and holding



U. Glitsch¹, J. Johns¹ and K. Heinrich¹

In recent years, the number of commercially available industrial exoskeletons has increased substantially. Most previous studies gathered either only EMG data and were focused on passive BSEs (Kermavnar, T *et al.*, 2021). The objective of the present study was therefore to include multiple exoskeletons (one active, A1, and two passives, P1 and P2) in the investigation and to assess their impact on L5/S1 joint moments and erector spinae (ES) activity during lifting and holding of 10 kg. It was hypothesized that a BSE-specific but activity-independent support effect could be observed for passive systems. Conversely, a more task-specific support effect was expected for the active system.

As part of a laboratory study 12 subjects (6 m, 6 f; height: 1.77 ± 0.08 m; weight: 70.0 ± 11.4 kg; age: 25 ± 2 years) performed dynamic lifting (5 repetitions of freestyle lifting in front of the body) and static holding (20 s in 45° torso forward bend with legs extended) of a 10 kg load weight. Activities were performed in a randomized fashion under NoExo, A1, P1 and P2 conditions.

Full body 3D-motion capture (12 Cam, Vicon Nexus) of the subjects and the BSE was conducted at 100 Hz and used to calculate L5/S1 extension moments via inverse dynamics in accordance with the Plug-in Gait Standard. A 4-channel sEMG of the ES was recorded at vertebrae levels T11/12 and L2/3 at 1000 Hz.

For lifting and holding the mean and peak values for the lumbar extension moments and muscle activity were analyzed with separate 2-way mixed analysis of variance

(ANOVA) with the factors subject (random effects factor) and exoskeleton (fixed effects factor). The level of significance for all tests of $p < 0.05$ was used.

During the dynamic lifting task, the mean peak L5/S1 extension moments for NoExo were 1.76 ± 0.16 Nm/kg. The analysis of the EMG data revealed peaks in muscular activity of 39.9 ± 9.5 %MVC. The application of exoskeletons A1 and P1 resulted in an average reduction of the maximum L5/S1 extension moments of 15% ($p < 0.01$) and 11% ($p < 0.01$), respectively. A reduction of 22% ($p < 0.01$) was observed for P2. Maximum ES muscle activity during lifting was also significantly reduced with all systems (A1: 32%; P1: 13%; P2: 17%, $p < 0.01$).

During the holding task, average L5/S1 extension moments were 1.41 ± 0.15 BW, and the average ES activity was 20.9 ± 4.9 %MVC for NoExo. Comparable reductions in L5/S1 extension moments were observed for both passive systems, with a 12% reduction ($p < 0.01$) for P1 and a 20% reduction ($p < 0.01$) for P2. A greater reduction of 41% ($p < 0.01$) was observed for A1. The muscle activation data exhibited a comparable pattern, with a reduction in mean ES EMG amplitude for P1 of 23% ($p < 0.01$) and P2 of 16% ($p < 0.01$), and a greater reduction by A1 of 54% ($p < 0.01$).

The results confirm our hypothesis. The passive exoskeletons showed a support effect that was mostly unaffected by the activity. The active system in contrast showed a greater reduction for the static task. It can therefore be concluded that the task-specific fit of different exoskeleton types should be regarded in their analysis.

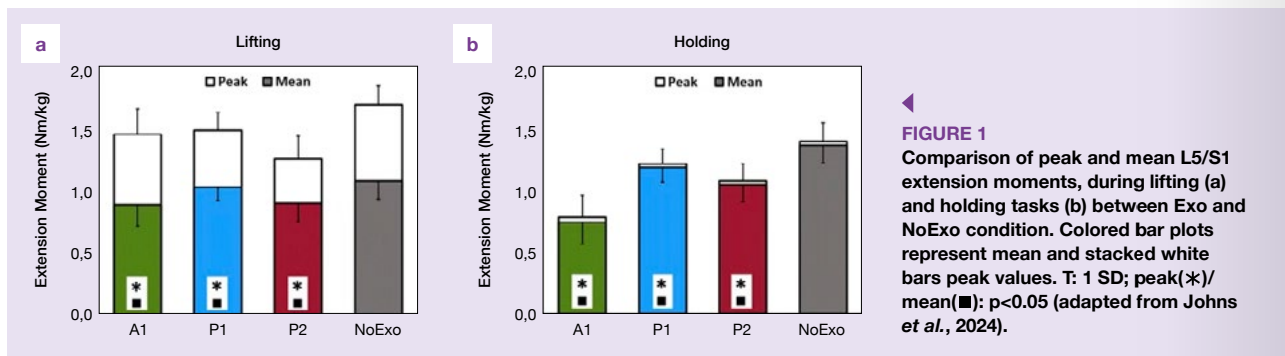


FIGURE 1
Comparison of peak and mean L5/S1 extension moments, during lifting (a) and holding tasks (b) between Exo and NoExo condition. Colored bar plots represent mean and stacked white bars peak values. T: 1 SD; peak(*)/mean(■): $p < 0.05$ (adapted from Johns *et al.*, 2024).

ACKNOWLEDGEMENTS

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PARALLEL SESSIONS

02. SYMPOSIUM: STATUS QUO ON INDUSTRIAL EXOSKELETON RESEARCH

KEY WORDS

Industrial exoskeletons | musculoskeletal simulation | knowledge-based selection | OpenSim | Support system

Using musculoskeletal simulation for knowledge-based selection of industrial exoskeletons



D. Scherb¹, T. Drees², B. Kuhlenkötter² and R. Weidner¹

Exoskeletons are support systems that are increasingly used in industrial context as they enable a reduction of physical stress on the worker (Weidner and Karafillidis 2018). By supporting, enabling or facilitating of movements or by stabilizing the posture, long-term strain-related injuries to the workers, mainly musculoskeletal disorders (MSDs) can be prevented (Kines *et al.* 2007). However, the selection of a suitable exoskeleton for companies regarding the individual situations (workers, specific tasks, tools, work environment etc.) remains a difficult task (Crea *et al.* 2021).

Simulation- and knowledge-based selection of exoskeletons provides numerous advantages, e.g., the digital testing of different exoskeletons without the need of user tests. Thus, a methodology for a comprehensive simulation- and knowledge-based tool is set up considering economic, ergonomic and biomechanical criteria (Drees *et al.* 2025). The key element of the methodology is a co-simulation model consisting of a task simulation and a musculoskeletal simulation incorporating the effects for the biomechanics of the worker.

This contribution mainly focuses on the biomechanical simulation via musculoskeletal human models (MHMs) and how this can aid the selection process of industrial exoskeletons. To show the usage of musculoskeletal simulation, MHMs with differing anthropometrics (5th, 50th and 95th percentile) are simulated performing an arm lifting- and lowering-task. In addition, the support torque of five different shoulder exoskeletons is applied to the different MHMs. The support torques were previously captured with a specifically designed test bench. A MHM with exemplary exoskeleton and the resulting muscle activations of the different supports are shown in *Figure 1*. The example represents the usage of musculoskeletal simulation to gain insight into the biomechanics of the worker. Based on this simulation and in combination with the task simulation, implications for the perceived ergonomics can be made. Thus, by considering

further factors (e.g., price, usability etc.) suggestions for the optimal exoskeleton selection for a company via the simulation- and knowledge-based tool can be derived.

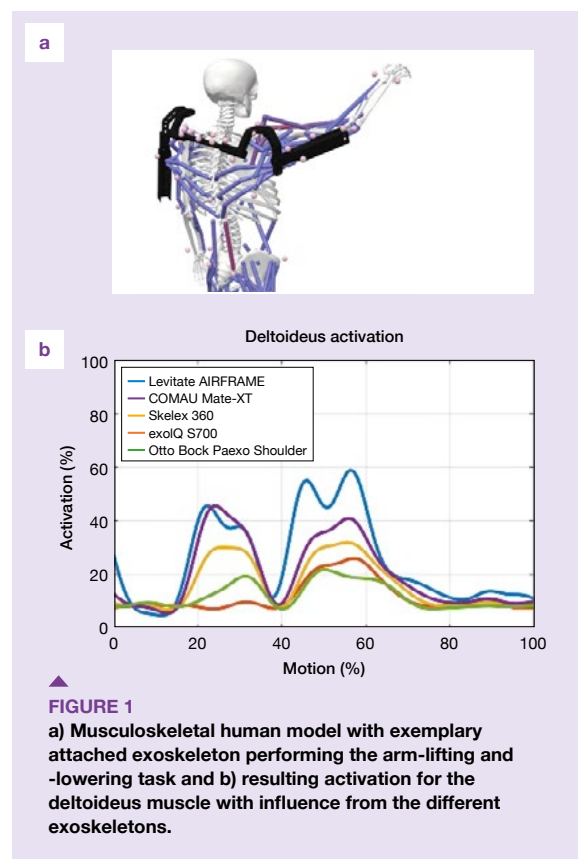


FIGURE 1
a) Musculoskeletal human model with exemplary attached exoskeleton performing the arm-lifting and -lowering task and b) resulting activation for the deltoideus muscle with influence from the different exoskeletons.

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KEY WORDS

Exoskeleton | Shoulder load | Measurement-based assessment | Biomechanics | Field study

Shoulder exoskeletons in aircraft assembly: a field study on potential long-term effects

K. Heinrich¹, R. Grzeszick², M. Kaufmann³, T. Wagner⁴ and C. Böhm⁵

Musculoskeletal disorders (MSDs), particularly those affecting the upper extremities, remain a leading cause of work-related sick leave. Tasks performed above shoulder joint (SJ) height impose considerable biomechanical loads, significantly increasing the risk of MSD development. Although interest in upper-extremity exoskeletons as assistive devices is growing within the industrial sector, conclusive biomechanical evidence regarding their long-term efficacy remains limited. This study investigates the biomechanical and physiological effects of a passive upper-extremity exoskeleton during overhead tasks in the context of aircraft manufacturing.

A field study was conducted at Airbus facilities involving 20 experienced employees performing typical overhead assembly tasks. Two representative tasks – structure assembly (S-Task) and equipment installation (E-Task) – were analysed. Inertial measurement units (IMUs) were used to capture movement patterns. Long-term recordings over > 12-month period was provided by MotionMiners, while the Institute for Occupational Safety and Health conducted detailed shift-based analyses. Each approach included assessments of shoulder elevation angles and the resulting joint moments. Both tasks were performed with and without the support of a passive shoulder exoskeleton (EXO, ottobock Shoulder). The biomechanical impact of the EXO was evaluated based on its known support characteristics. Additionally, participants completed questionnaires regarding usability, comfort, and acceptance. Workweeks with and without EXO support were compared using ergonomic assessment tools, including

the Key Indicator Method for Musculoskeletal Load (LMM) and the CUELA Method, as outlined in the MEGAPHYS reports [1].

CUELA and LMM evaluations indicated a high risk of musculoskeletal overload (S-Task: 37.7% NRPM / LMM score 140; E-Task: 32.3% NRPM / LMM score 133). Cumulative CUELA analysis of shoulder strain profiles (based on Potvin, 2012) revealed high muscular strain during S-Tasks (high-risk exposure >10% of working time) and increased strain during E-Tasks (increased-risk exposure >5% of working time). Use of the EXO reduced muscular strain by up to 11% MVC, corresponding to a reduction of shoulder joint moments of up to 9 Nm. Over the long term, EXO use led to a 14% increase in endurance (holding time improved from 5.0 s to 5.7 s) and a 12% reduction in handling events (from 387 to 340). Subjective evaluations indicated high perceived relief (4.1/5), increased well-being (4.4/5), and moderate comfort (3.9/5).

The high muscular strain observed, particularly in S-Tasks, suggests a potential for non-reversible fatigue of the shoulder musculature. The reduction in muscular strain by up to 11% MVC through EXO use may enable sufficient recovery and could help prevent chronic fatigue under certain working conditions.

Using a passive shoulder exoskeleton showed beneficial effects in reducing biomechanical load and muscular effort. While these results alone do not justify the general conclusion that exoskeleton use significantly lowers the risk of developing MSDs, they are promising and warrant further investigation.

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PARALLEL SESSIONS

03. ORAL COMMUNICATIONS: NEW AND ATYPICAL FORMS OF WORK AND ORGANIZATION

16:00 - 16:20 – ROOM 104, LEVEL 1 – #82

KEY WORDS

Depressive symptoms | Hybrid work | Low back pain | Structural equation model | Teleworking

Onset of low back pain, depressive symptomatology and teleworking conditions during lockdown in France: a structural equation modelling approach



N. Fouquet¹, C. Ménard¹, M. Fadel², J. Bodin³ and Y. Roquelaure²

Background

Following the health restrictions related to the COVID-19 pandemic, about a third of French workers experienced mandatory teleworking during the lockdowns. The objective of this study is to examine the complex relationships between teleworking conditions, depressive symptomatology, and the onset of low back pain (LBP) during France's third lockdown in spring 2021.

Methods

Based on the online CoviPrev survey, 466 workers from the French general population who teleworked at least one day a week during lockdown and were free of LBP at the start of lockdown were included in this study. A conceptual model was developed in which relationships between teleworking conditions, depressive symptomatology, and the onset of

LBP were assumed. Structural equation modelling was used to test the model.

Results

The model showed that teleworking conditions (both material conditions of teleworking and the amount of telework) have a substantial direct and indirect impact on the onset of LBP. As shown in the **Figure 1**, complex relationships have been observed between the conditions of teleworking (material conditions and amount of telework), depressive symptomatology and the onset of LBP, mediated by satisfaction with teleworking conditions.

The mediated effect sizes of the complex relationship by satisfaction with teleworking conditions were significant (-0.08 p<0.001). The material conditions of teleworking directly and significantly influenced the risk of LBP (standardised coefficient=0.24 p<0.05). In addition, the material conditions and the amount of telework were significantly associated with the level of satisfaction with teleworking conditions (respectively, 0.25 p<0.0001 and 0.12 p<0.05). The level of satisfaction was significantly associated with lower risk of depressive symptoms (-0.43 p<0.0001) and the onset of LBP (-0.42 p<0.0001). Additionally, the presence of depressive symptomatology was also significantly associated with the onset of LBP during the third lockdown (0.58 p<0.0001). Regarding personal risk factors, only two associations were significant in the model: the risk of LBP increased for women and the risk of depressive symptomatology decreased with age.

Discussion/Conclusion

This study suggests that there are complex relationships between teleworking conditions, depressive symptomatology, and the onset of LBP, which are essential to characterize to better understand the chain of determinants for the onset of LBP. They also highlight the importance of good working conditions to reduce the impact of teleworking on health, including the prevention of sedentary behaviours. However, this study was conducted in a specific context. The data should therefore be updated in order to document the situation in a normal context.

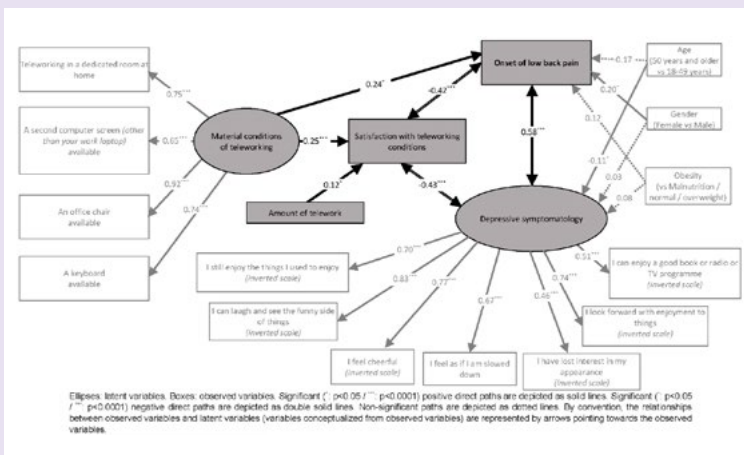


FIGURE 1
Structural equation model linking teleworking conditions to depressive symptomatology and onset of low back pain.

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KEY WORDS

Physical Activity | Hybrid Work | Sedentary Behaviour | Sleep Quality | Musculoskeletal Complaints

Sedentary behaviour and physical activity during hybrid work



K. Wechsler¹, R. Ellegast¹ and B. Weber¹

Introduction

Physical activity (PA) and sedentary behaviour (SB) in daily life and at work have long been the focus of research. A lack of PA and prolonged sitting are associated with adverse health outcomes, while regular activity can reduce such risks. Even prior to the pandemic, studies showed differences in PA and SB between home office (HO) and office work. However, the factors influencing a healthy activity level in the HO remain insufficiently understood.

This field study on behalf of the German Social Accident Insurance Institution for the raw materials and chemical industry investigates whether PA and SB among employees working at computer-based workstations differ between the HO and the office. Both total waking time and pure working hours were examined; the present analysis focuses on the latter.

Methods

Hybrid workers were observed during a regular workweek. Life circumstances, PA, and health-related behaviours were recorded. Objective PA data were collected using a thigh-worn ActivPAL 4+ sensor and analysed using the CUELA method. The study covered periods before, during, and after working hours, including breaks, commuting, and physical exercise. Parameters included steps, posture, postural changes, activities, and metabolic equivalent (MET). Daily routines such as sleep, working hours, and breaks were also documented.

Participants completed questionnaires assessing sleep quality (PSQI), subjective PA (IPAQ), and musculoskeletal complaints (CMDQ). PA and SB were compared between

HO and office days, considering postural changes and commuting. Further variables such as caregiving responsibilities, commuting distance, health behaviour, and musculoskeletal symptoms were included in the analysis.

Results

Data from 52 participants (29 w, 23 m) were included in the present analysis. The mean age of the sample was 42.7 years (± 10.7), with an average body mass index (BMI) of 25.3 kg/m² (± 3.5). In total, 947 hours of work in the HO and 932 hours in the office were analysed.

A higher proportion of SB was observed during HO work (74.6%) compared to office work (69.0%). Conversely, a slightly greater proportion of light physical activity (LPA; >1.5 MET) was recorded in the HO setting (2.6%) relative to the office (2.3%). In contrast, moderate to vigorous physical activity (MVPA; ≥ 3 MET) was more prevalent in the office (4.7%) than in the HO (2.5%). The frequency of posture changes was comparable (HO: 3.2 per hour, office: 3.0 per hour), whereas the proportion of prolonged sedentary bouts (>30 minutes) was higher in the HO (46.2%) than in the office (38.9%).

Discussion

This analysis focused on pure working hours. Most differences were found for PA. The higher LPA in the HO may reflect light domestic tasks performed during breaks. The increased MVPA in the office is likely related to stair use, walking to lunch, or moving during informal meetings. These findings will contribute to developing practical recommendations for healthier hybrid work routines.

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PARALLEL SESSIONS

03. ORAL COMMUNICATIONS: NEW AND ATYPICAL FORMS OF WORK AND ORGANIZATION

16:40 - 17:00 – ROOM 104, LEVEL 1 – #50

KEY WORDS

Home workstation ergonomics | Photographic analysis | Telework-related musculoskeletal disorders

The reality of home workstation: When self-assessment meets ergonomist evaluation



F. Kern¹ and N. Cianferoni¹

Teleworking has increased since the pandemic and now affects a significant portion of the working population. This means that some of the health risks for workers are no longer confined to the office but also extend to home workplaces. Studies have shown a correlation between poorly designed home workstations and health problems, particularly musculoskeletal disorders (MSD) (Cruz-Ausejo *et al.*, 2022; Kotowski *et al.*, 2022). It is therefore important to have knowledge of the ergonomic design of home workstations.

The State Secretariat for Economic Affairs (SECO) is responsible for monitoring risks for occupational health in Switzerland. In the context of its mandate, it launched a survey to assess home working conditions and to determine whether specific preventive measures are needed to improve health protection in teleworking. The survey was conducted between June and November 2024 among a convenience sample of 2,855 workers across 13 Swiss companies (response rate: 32.6%). Additionally, 149 employees submitted photos of their home workstations for photographic analysis.

This survey has two components. First, a self-reported component, using a questionnaire, to assess sociodemographic characteristics, working time, general and home-specific working conditions (organisation, constraints, and resources), environment and work equipment, perceived health, and teleworking framework conditions (regulations, training, etc.). Secondly, an observational component, using experimental photographic analysis to assess certain ergonomic aspects. This second component complements the questionnaire. Participants were asked to submit three photos of their home

workstation, following certain photography guidelines. Ergonomists evaluated these photos to assess furniture, work tools, space for movement, workstation orientation, etc. (Auf der Maur & al, 2025) All in all, this methodology helps to better understand home workstations and to identify any discrepancies between participant's self-reported assessments and ergonomists' evaluations. Most respondents indicated that their home workstation met ergonomic criteria. However, ergonomists' photographic analysis reveals a less favorable reality, with discrepancies observed in legroom, work surface depth, desk height and seat height. These basic ergonomic inadequacies are obvious biomechanical risks for MSDs. These findings suggest that self-assessments of teleworking workstation ergonomics tend to be overly optimistic. Evaluation based on self-measurement should be complemented by other measurements.

Privacy concerns make it more challenging for labor inspections (as well as for companies who are responsible for ensuring healthy working conditions) to assess the ergonomic design of home workstations compared to on-site workstations. One option would be to use photos to have the design checked by independent ergonomists.

The discrepancy between self-assessment and ergonomists' photographic assessment raises an interesting question: are teleworkers unaware of the constraints of their home workstation, or do the benefits of teleworking lead them to accept a certain level of risk, consciously or not? Traditional ergonomic methods such as activity analysis could be used to better understand the various interactions involved.

ACKNOWLEDGEMENTS

This work was supported by Health Promotion Switzerland and the Federal Office of Public Health

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PARALLEL SESSIONS

04. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS - INDINGS FROM COHORT AND EMERGING METHODS

16:00 - 16:20 – ROOM 105, LEVEL 1 – #103

KEY WORDS

Occupational | Musculoskeletal | Knee | Epidemiology | Job exposure matrix

Do cumulative work exposures affect the risk of knee meniscus surgery in the CONSTANCES cohort?



A. Descatha^{1,2}, M. Fadel¹, R. Colvin³, A. M. Dale³, C. Ribet⁴, A. Leclerc⁴ and B. A. Evanoff³

Background

Knee meniscus disorders represent a significant cause of work absence and work disability, and often result in surgical intervention. We aimed in a large-scale general population study to assess knee meniscus disease associated with cumulative workplace exposures over the working lifetime.

Material and Methods

Participants in a large prospective study (CONSTANCES) were surveyed. The survey included self-reported history of current and past jobs, allowing estimation of past and current workplace physical exposures using an existing job exposure matrix (JEM). Meniscus surgery cases were ascertained through matching the surveys to national health insurance data. Poisson regression analyses (controlling for age, Body Mass Index, and sex) computed the relative risks (RR) of future meniscus surgery associated with standing, kneeling/squatting, carrying loads > 25kg, and computer use. Eleven exposures including physical force, repetition, posture, and keyboard use were categorized into quartiles. Models included different time periods of exposure and/or different exposure lag times.

Results

More men than women had meniscus surgery (1,062 men vs. 541 women). Cumulative years of work in a job above the 75th percentile of population exposures to standing, kneeling/squatting, and carrying loads > 25kg were associated with statistically significant higher risks of meniscus surgery among men (RR per ten years of exposure 1.06-1.09), while years of computer work were associated with a lower risk of surgery (RR=0.93). Years of standing was associated with higher risk of surgery among women (RR=1.11). Placing a 5 year lag on exposures had minimal effects on the associations.

Conclusion

Our study found that working long hours standing, carrying heavy loads, and kneeling and squatting increased the risk of knee meniscus surgery among men during the working life. Time spent on computers was linked to a lower risk of future meniscus surgery.

ACKNOWLEDGEMENTS

The authors thank the CONSTANCES Cohort team, as well as the volunteers.

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CONFLICTS OF INTERESTS

None. Authors are paid by their institutions, AD and MF are also paid as editors of the Archives des Maladies professionnelles et de l'Environnement (Elsevier).

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PARALLEL SESSIONS**04. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS -
INDINGS FROM COHORT AND EMERGING METHODS**

16:20 - 16:40 – ROOM 105, LEVEL 1 – #107

KEY WORDS*Job Exposure Matrix | Past work exposures | Carpal tunnel syndrome*

Use of a Job Exposure Matrix to study both recent and past work exposures on the incidence of carpal tunnel release surgery in the CONSTANCES cohort

B. A. Evanoff¹, M. Fadel MD², R. Colvin¹, C. Ribet³, A. Leclerc³ and A. Descatha²**Introduction**

Most studies of Carpal Tunnel Syndrome have examined only current workplace exposures as risk factors. We examined the effects of both recent and past work exposures on the incidence of surgery for carpal tunnel release (CTR).

Methods

Participants in a large prospective French general population study (CONSTANCES) were surveyed between 2012 and 2017. The survey included self-reported history of current and past jobs, allowing estimation of past and current workplace physical exposures using an existing job exposure matrix (JEM). CTR cases were ascertained through matching the surveys to national health insurance data for the 8-year period 2009-2016. Analyses were restricted to workers with some period of full-time work in 1989 or later.

Poisson regression analyses (controlling for age, Body Mass Index (BMI), and sex) computed the relative risks (RR) of future CTR associated with different work exposures. Eleven exposures including physical force, repetition, posture, and keyboard use were categorized into quartiles, with the top quartile referenced on lower quartiles. Models included different time periods of exposure and/or different exposure lag times.

Results

777 cases of CTR were observed among the 56,289 persons in the cohort. Those with CTR were more likely to be female, older, and to have a higher BMI. In both men and women, each of the 11 exposures was significantly associated with the incidence of CTR. In the cohort as a whole, RR of CTR per 5 years of exposure in the upper quartile included 1.19[1.13-1.25] for pressing with the base of the hand, 1.17[1.12-1.23] for use of vibrating tools, 1.17 [1.12-1.22] for rotation of the forearm, and 0.88[0.84-0.91] for keyboard use. Women showed larger effect sizes than men for some exposures, including repetition, use of vibrating tools, and pressing with the base of the hand. Higher effect sizes were seen among current workers than among those who had not worked in 5 or more years. Lagging exposures by 3 and 5 years reduced the strengths of association.

Discussion

Use of a JEM in a large general population cohort allowed us to study the effects of both recent and past work exposures on the incidence of carpal tunnel syndrome. While more recent exposures had stronger associations with CTR, some past exposures were also associated with future risk of CTR.

ACKNOWLEDGEMENTS

The CONSTANCES Cohort Study is funded through the French National Agency for Research, and by the French National Health Insurance Fund (CNAM). This study was also funded by the American National Institute of Occupational Safety and Health (NIOSH).

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PARALLEL SESSIONS

04. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS - INDINGS FROM COHORT AND EMERGING METHODS

16:40 - 17:00 – ROOM 105, LEVEL 1 – #93

KEY WORDS

Margin of manoeuvre | Chronic problem | Musculoskeletal disorders | Expert consensus

Identification of questions characterizing the margin of manoeuvre from an epidemiological point of view



J. Bodin¹, M.E. Major², S. Caroly³, A. Cuny⁴, N. Vézina⁵ and Y. Roquelaure⁶

Introduction

The concept of “margin of manoeuvre” has long been used in ergonomics to identify situations that pose a risk to workers’ health (Vézina 2001; Coutarel *et al.* 2024). Insufficient margin of manoeuvre can hinder sustainable return to work after a chronic problem. However, from an epidemiological perspective, there are few tools to assess this concept. The objective of this study was to identify questions available in epidemiological surveys that could characterize the margin of manoeuvre.

Methods

Seventy-five questions related to the concept of margin of manoeuvre were identified by an interdisciplinary working group (ergonomics, epidemiology, and occupational medicine) in four epidemiological questionnaires on occupational health (Sumer 2017, Working Conditions 2016 and 2019 Surveys, Dares (Ministry of Labor – France) and European Working Conditions Survey 2015, Eurofound). The Technique for Research of Information by Animation of a Group of Experts (TRIAGE) was implemented to select questions that were relevant from an epidemiological point of view. An individual consultation phase and a collective consultation phase followed one another.

Twelve experts were solicited individually to express their agreement level, via an online questionnaire, in order to identify questions characterizing the margin of manoeuvre. The questions not retained at the end of this phase were discussed collectively during two online meetings between the ten experts available. Finally, the experts voted via an anonymous online questionnaire to retain (or not) each question

Results

A total of 42 questions were retained by the experts: 23 during the individual consultation phase (agreement >83.3%) and 19 during the collective consultation phase (agreement >85.7%).

Discussion

After a psychometric validation stage, the questionnaire could be used to access the margin of manoeuvre in epidemiological surveys and to study associations with sustainable return to work after a chronic problem. This questionnaire could also be relevant for ergonomic interventions to help identify work situations at risk for workers’ health. Finally, this questionnaire could be of interest for occupational health services to guide their prevention actions.

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PARALLEL SESSIONS**04. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS -
INDINGS FROM COHORT AND EMERGING METHODS**

17:00 - 17:20 – ROOM 105, LEVEL 1 – #58

KEY WORDS*Sedentary workplaces | Sensor-based assessment | Metrics | Physical activity | Sedentary behavior*

Towards Standardized Assessment of Sedentary Behavior and Physical Activity at Work: Metrics and Methods Using Thigh-Worn Sensors

B. Weber¹, K. Wechsler¹, I. Hermanns-Truxius¹ and R. Ellegast¹**Introduction**

In modern industrialized societies, levels of physical activity (PA) are declining, while sedentary behavior (SB) is becoming increasingly prevalent – both trends posing significant health risks. To address these concerns, it is essential to develop guidelines grounded in the relationship between PA/SB and health outcomes. However, the current body of evidence remains sparse and inconsistent. Emerging advancements in measurement technologies offer promising opportunities to establish a more reliable and standardized evidence base. This work introduces a set of metrics and evaluation strategies designed to quantify and assess work-related PA and SB.

Methods

Literature was searched to identify relevant measurement systems and output parameters. Appropriate devices and key metrics were compiled, and a proposal for assessing work related SB was developed. To evaluate feasibility and consistency, the proposed methods were applied to data from 52 hybrid office employees working in three settings: office (O), home office (HO), and business travel (BT). PA was tracked over a typical workweek using a thigh-mounted motion sensor (activPAL 4+).

Results

Single thigh-worn sensors are considered valid and reliable in distinguishing postures, locomotion, and varying PA intensities over extended periods. Proposed metrics include proportions of time spent in specific postures and activities, transitions between behaviors, bout length distributions, and energy expenditure indicators. A preliminary risk assessment approach for sedentary work was

developed using general recommendations and publicly available sensor-based exposure data. For the present dataset, 1,950 hours of work time were analyzed. SB was most prevalent in the HO setting (median: 77.1%), followed by O (74.1%) and BT (50.4%). The longest uninterrupted sitting bouts were similar between HO and O (median: 59.3 vs. 58.7 minutes), but prolonged sitting (≥ 30 minutes) was more frequent in HO (47%) than in O (40.5%) and BT (33.2%). Participants were most active during BT, with a median activity portion of 12.5% and a maximum bout length of 2.8 minutes (O: 5.8%, 2 min; HO: 4.4%, 0.9 min). These findings are reflected in the risk assessment, which tends to classify BT activity as moderately favorable, while O and HO fall into moderately unfavorable categories.

Discussion

The proposed assessment method proved effective for analyzing PA among office workers in different work environments. The metrics enable differentiation between activity profiles and reveal significant differences in SB and PA distribution and can be recommended for consistent use in future studies. Standardized assessments of PA and SB are crucial for generating comparable data across different studies and providing a consistent basis for dose-response analyses linking workplace activity to health outcomes. This is an important step toward developing evidence-based guidelines for risk assessment. One important requirement for the further development of measurement technology is smart documentation accompanying the measurements, as context-specific differentiation of activity behavior (e.g., working time – leisure time or different work tasks) is essential.

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WEDNESDAY, 6 MAY 2026

KEYNOTE PRESENTATION (AM) _____ P.25

Population and sector diversity and MSD:
what do we know, what don't we know, and where do we go?

PARALLEL SESSIONS (AM) _____ P.27

- 01. ORAL COMMUNICATIONSP.28
POPULATION AND SECTOR SPECIFIC APPROACHES – INTERVENTIONAL STUDIES
- 02. ORAL COMMUNICATIONSP.32
NEW TECHNOLOGIES – DIGITAL TOOLS
- 03. ORAL COMMUNICATIONSP.35
RISK ASSESSMENT AND HEALTH EFFECTS – SECTOR SPECIFIC APPROACHES
- 04. SYMPOSIUMP.38
“UNDERSTANDING THE LONG-TERME CONSEQUENCES OF EXOSKELETONS
IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE”

KEYNOTE PRESENTATION (PM) _____ P.45

Research challenges in developing sustainable
intervention strategies for the prevention of musculoskeletal disorders

POSTER SESSION _____ P.46

PARALLEL SESSIONS (PM) _____ P.46

- 01. ORAL COMMUNICATIONSP.47
IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (1)
- 02. ORAL COMMUNICATIONSP.50
NEW TECHNOLOGIES – HUMAN ROBOT INTERACTIONS
- 03. ORAL COMMUNICATIONSP.52
POPULATION AND SECTOR SPECIFIC APPROACHES – DESCRIPTIVE STUDIES
- 04. ORAL COMMUNICATIONSP.55
SOCIO-ECOLOGICAL CHALLENGES

PARALLEL SESSIONS (PM) _____ P.57

- 01. ORAL COMMUNICATIONSP.58
IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)
- 02. ORAL COMMUNICATIONSP.63
RISK ASSESSMENT AND HEALTH EFFECTS – CO-EXPOSURE
- 03. SYMPOSIUMP.66
“ASSISTIVE TECHNOLOGY OR PERSONAL PROTECTIVE EQUIPMENT?
IMPLEMENTATION QUESTIONS FOR EXOSKELETON SOLUTION”
- 04. SYMPOSIUMP.73
“PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL,
ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW ?”

WEDNESDAY, 6 MAY 2026

KEYNOTE PRESENTATION (AM)

09:00 - 10:00 – AUDITORIUM 300, LEVEL 1

Population and sector diversity and MSD: what do we know, what don't we know, and where do we go?



J. N. Côté and B. Evanoff



Julie N. Côté is Professor, at the Faculty of Health Sciences in University of Ottawa, Canada.

She just joined the University of Ottawa after a career of over two decades as a Professor at McGill University (Montreal, Canada). She will continue to lead a research program on neuromusculoskeletal determinants of health and performance. Her research focuses mainly on sex-specific mechanisms of injuries due to repetitive motions and to fatigue.

Bradley Evanoff is professor, in the School of medicine, Washington University in St. Louis, USA. He is an occupational health physician with interests in work-related musculoskeletal disorders. His work has included the creation of epidemiological case definitions for MSDs; the development and application of exposure methods, particularly Job Exposure Matrices; conducting large-scale epidemiology studies of MSDs and their relation to work exposures; and interventions to reduce MSDs in several industries including health care and construction.

Musculoskeletal disorders (MSDs) are among the most common and costly health problems that affect working populations, and constitute a major cause of disability [1]. Researchers and workplace stakeholders continue to invest time and efforts to increase understanding and resources to combat this problem. Unfortunately, the relationships of workplace exposures to MSDs are often difficult to assess, for a variety of reasons, which limits the impact of solutions. In this presentation, organized around the themes of “what do we know”, “what don't we know”, and “where should we go”, we will discuss the impact of both population and sector diversity in occupational health, attempting to cover a broad spectrum of knowledge from our complementary perspectives in epidemiological and biomechanical research. Using an interdisciplinary approach, we will identify challenges and opportunities for future impactful research to prevent and ameliorate MSDs.

The multifactorial nature of MSDs has been well described: personal, psychosocial, and workplace biomechanical exposures are all associated with higher rates of MSDs in working populations [2-7], and these factors all vary across different industries and employment sectors. Clarifying the etiologic and prognostic roles of these overlapping risk factors is a challenge to researchers. Recognizing and better understanding these relationships is needed to understand and improve occupational health on a significant, systematic scale.

In recent years, efforts have been made to increase access to work, and to safe working conditions, for an increasingly diverse working population. Evolving population and social dynamics have led to increased participation in work for a variety of equity-seeking groups, including women [8], and people within a larger range of age, abilities,

and ethnic origins. Rates and mechanisms of work-related MSDs vary according to well-researched personal factors such as age and sex/gender, and to less researched factors, such as handedness (i.e. both the side and strength of right-hand and left-hand dominance), in ways that can be explained using biomechanics and motor control research approaches [9-11]. Moreover, while several known integrated models of impairment and disability effectively describe a spectrum of MSD severity [12], they often fail to explicitly address the differences in work-related etiological or prognostic factors among workers with different outcomes [13-15]. In this presentation, we will expand on recent studies that present evidence for these inter-individual differences in MSD mechanisms, and will propose strategies and avenues to further address population diversity to better understand and prevent MSDs for all individuals, including methods that draw from recent research on the use of biomechanical monitoring using wearable technology in para-athletes [16-18].

Future research in WMSD should better address the role of gender as it influences exposures and exposure / outcome relationships, and better address the interactions of biomechanical exposures with other risk factors for MSD, including co-morbidities (obesity, arthritis), work organization, and other workplace factors such as precarious work [19], workplace policies and culture, and access to health-care [20-21]. Existing research often adjusts for these factors in order to focus on biomechanical exposures, and there are few in-depth studies of the interactions between different risk factors, or the differential distributions of risk factors across different industrial sectors. Most research on WMSDs is focused on current or recent workplace exposures; better understanding of the etiology of chronic degenerative MSDs





will require more research examining work activities over the life course [22]. There is also little research addressing the contingent or informal work sectors, which are more likely to have underreporting of MSDs, incentives to work while injured, and no paid sick leave.

In addition to inter-individual differences, occupational health practitioners must also address the reasons for variations in incidence of MSDs across a diversity of work sectors. While differences in biomechanical risk factors are a clear predictor of cross-sector differences, other determinants include differences in the demographics (age, sex, national origin), socioeconomic factors (income, education), and co-morbidities (obesity, tobacco use) of different working populations, that in turn intersect with varying risks of MSDs. The occurrence of MSDs is also influenced by workplace policies, work culture, and work-related psychosocial factors, which vary widely across different countries and different industrial sectors [23]. Related to this, one challenge to WMSD research is that the relative etiologic contributions of biomechanical exposures vs. other determinants of health to WMSD may depend on what case definition is used: while early symptoms of MSD are likely linked closely to biomechanical exposures, work disability resulting from WMSD has a more complex range of determinants [24]. Models that attempt to predict MSD outcomes according to

population and sector diversity must address social issues as well as individual determinants of health and biomechanical exposures.

Despite these considerable challenges, there are reasons to be optimistic about the potential for future research and practice to bring us closer to solving these important public health issues, starting with recent technological developments. Monitoring of biomechanical determinants of work exposure is a key part of effective safety measures, but drawing appropriate exposure limits has long been constrained by limits in measurement technology, and the need to identify salient exposure measures that are appropriate for the diverse workforce. Fortunately, recent advances in wearable technology, big data analytics and statistical parameters, and the democratization of research from open-source solutions hold promise for advancing our ability to address inter-individual differences in occupational health research.

A population that is increasing in size and diversity undoubtedly presents challenges, and also offers exciting opportunities to advance occupational health science, human performance, and worker health and well-being. Optimally effective MSD prevention research requires interdisciplinary scientific approaches to translate knowledge about population diversity into healthy workplaces accessible by all.

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PARALLEL SESSIONS (AM)

01. ORAL COMMUNICATIONS

POPULATION AND SECTOR SPECIFIC APPROACHES – INTERVENTIONAL STUDIES

10:30 - 11:30 – AUDITORIUM 300, LEVEL 1

The Weight of Precariousness: MSD Risk Factors in Temporary Construction Jobs

B. Langard, G. Plançon..... P.28

Work organization and MSDs in the liberal health profession. The case of ophthalmologists

W. Buchmann, E. Fortineau, E. Ribaute, A. Brézi..... P.30

Playing with Uncertainty: When the Unexpected Overloads Performing Artist

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02. ORAL COMMUNICATIONS

NEW TECHNOLOGIES – DIGITAL TOOLS

10:30 - 11:30 – ROOM 103, LEVEL 1

The health and performance dilemma in the logistics sector: challenges for the prevention of musculoskeletal disorders

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Design and deployment of a workplace-based mobile health application: a multidimensional approach to employee health

N. Roger, P. Delignieres, T. Lelard, F. Telliez P.33

Comparison of three approaches to understanding the challenges of human activity around a farm management software. What lessons can be learned for the design?

M. Salifou, N. Tricot, F. Coutarel..... P.34

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RISK ASSESSMENT AND HEALTH EFFECTS – SECTOR SPECIFIC APPROACHES

10:30 - 11:30 – ROOM 104, LEVEL 1

Work organization, bus ergonomics, and musculoskeletal disorders in Swiss bus drivers: Evidence from the TRAPHEAC cohort

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Impact of tool handling changes on posture and know-how

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Exploring the risks of musculoskeletal disorders associated with baggage handling in baggage room at an international airport

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04. SYMPOSIUM

“UNDERSTANDING THE LONG-TERME CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE”

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The biomechanical adaptation to exoskeleton use: from the familiarization to the acceptance

G. Mornieux, C. Thevenot, A. Favennec..... P.41

Persistent effects of upper-limb exoskeletons on inter-joint coordination

O. Dubois, R. Parry, R. Roby-Brami, G. Brunelli, N. Jarrassé P.42

Long-term adoption of professional exoskeletons: a five-year research review

L. Wioland, J-J. Atain Kouadio, I. Clerc-Urmès, F. Biraud, M. Dufraisse..... P.43

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PARALLEL SESSIONS (AM)

01. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES - INTERVENTIONAL STUDIES

10:30 - 10:50 – AUDITORIUM 300, LEVEL 1 – #55

KEY WORDS

Temporary Worker | Construction Sector | Precariousness | Work-related illnesses

The Weight of Precariousness: MSD Risk Factors in Temporary Construction Jobs



B. Langard¹ and G. Plançon²

The construction sector is the leading economic sector in France for temporary employment, representing 18.4% of all temporary workers. These workers face significantly higher risks: they suffer 1.3 times more serious accidents and 1.9 times more fatal accidents than permanent construction employees. In 2021, 52% of work-related illnesses among temporary workers occurred in the construction industry (Cnam, 2021), making them 2.7 times more likely to be affected than temporary workers in other sectors. Across all industries, over three-quarters of work-related illnesses reported by temporary workers were musculoskeletal disorders (MSDs). Others study also showed that temporary workers are more exposed to MSD-related occupational risk factors (Roquelaure *et al.*, 2010, 2012). A review of shows that risk of musculoskeletal injury is much higher for construction workers, about 50 percent higher than all other workers (Schneider, 2001). In USA, the rate of WMSDs in construction remained higher than in all industries combined (Wang *et al.*, 2017).

This action-oriented study, conducted by OPPBTP, ANACT, a user company, and a temporary employment agency, aimed to identify the causes of higher rates of occupational accidents and illnesses among temporary

workers (85% of which are MSDs (Cnam, 2025)). The study included a diagnostic phase with 50 interviews and 12 observation days, followed by a co-construction phase to develop solutions with field stakeholders.

Among the determinants revealed by this study, two key socio-economic factors explain the overexposure of temporary construction workers to occupational illness:

- **Task Allocation:** Physically demanding and undesirable tasks are often assigned to temporary workers. Both temporary and permanent employees confirmed that the most strenuous and thankless tasks are systematically given to temporary staff. Unskilled workers are particularly affected due to their roles and lack of qualifications. However, the temporary status itself seems to lead to similar treatment regardless of skill level. These tasks, while not always the most dangerous, contribute significantly to long-term health deterioration, especially MSDs. This pattern is also observed in other sectors (Coutrot & Léonard, 2018; Tranchant, 2018) or other country where temporary construction workers were significantly more likely to report moving or lifting materials more than 100 pounds than payroll workers (Caban-Martinez *et al.*, 2018).
- **Precariousness** ‘the mother of all risks’ (Ravallec *et al.*,

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2009), is a factor aggravating working conditions of temporary workers, particularly those with fewer qualifications, linked to their employment, which is unstable. Temporary workers are more willing to accept difficult or dangerous work (Scalvinoni *et al.*, 2023). It leads temporary workers to adopt three defensive strategies:

- Strategy 1: Do not refuse a dangerous and/or physically demanding task. This difficulty in 'saying no' can be a significant risk factor in a context where working days are intense and often long.
- Strategy 2: Not admitting that they 'don't know how to

do' a certain task and agreeing to perform tasks for which they are not trained or lack the technical skills, thereby putting themselves or their colleagues at risk.

- Strategy 3: Overcommitment on the part of temporary workers who hope to be offered permanent employment. These temporary workers may thus be led to overinvest in their work or take risks to prove their worth to the user company.

Finally, eleven potential solutions were co-developed with field professionals. Most were tested within the partner companies involved in the study.

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PARALLEL SESSIONS (AM)

01. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES - INTERVENTIONAL STUDIES

10:50 - 11:10 – AUDITORIUM 300, LEVEL 1 – #90

KEY WORDS

Ophthalmology | Planning | Doctor | Musculoskeletal disorders | MSDs | Surgery

Work organization and MSDs in the liberal health profession. The case of ophthalmologists



W. Buchmann¹, E. Fortineau², E. Ribaute³ and A. Brézin⁴

According to the epidemiological literature, the prevalence of MSDs of the upper limb and spine is a widespread phenomenon among ophthalmologists (Xie *et al.*, 2025). However, these studies do not point out, or only in a very general way, the determinants of work at the origin of these disorders (Buchmann *et al.*, 2025). The objective of this research is to document the work activity of ophthalmologists in France practicing in consultation and surgery, and more particularly the elements of work at the origin of MSDs.

According to the model of ergonomic intervention seen as a project management, with a constructive aim (Falzon, 2014), the research was carried out in two voluntary ophthalmology practices (in the Brittany region and the Rhône Alpes region). The Brittany practice is occupied by two ophthalmologists (1 man 65 years old and 1 woman 40 years old), 3 medical secretaries and 2 orthoptists. The Rhône Alpes practice is occupied by 2 ophthalmologists (1 man and 1 woman 40-45 years old), 4 medical secretaries and 3 orthoptists. The data collection consisted on 74 hours of observations (consultation and surgery), 6 semi-structured interviews, analysis documents (schedules), metrology (physical atmospheres, surface area of workspaces, anthropometry).

Practices receive 400 to 600 phone calls per day, and doctors provide 60 to 100 consultations per day. The main elements of ophthalmologists' MSDs' work are on the one hand the design of the examination equipment (e.g. slit lamp) and workstations (e.g. Computer Station) that do not comply with anthropometric design standards drastically limit doctors' gestural leeway. On the other hand, the design of schedules at the scale of the day or

the working week at an individual (doctor) and collective level (distribution of tasks and coordination between medical secretaries, orthoptists, operating room nurses and doctors), appear to be a powerful steering wheel regulating the physical (over)load: the days are punctuated by "bricks" of patient typologies (follow-up of AMD, glaucoma, post-operative, diabetic patients, emergencies, children, etc.) of 2 to 4 consecutive hours. This way of building schedules has two advantages: it automates certain reasoning limiting the risk of medical errors, and makes it possible to adapt resources that are also in terms of staff. But it causes a form of repetitiveness of gestures over the period, and an impoverishment of gestural diversity. According to doctors, the problem comes from the size of these "bricks" and their ordering in relation to each other, on the scale of the day or the working week.

In a context characterized by changes in the practice of ophthalmology and the populations to be treated, and in the face of an international literature sparse in clinical case studies, this research sheds light on the extent to which the regulations and arbitrations deployed by ophthalmologists and their collaborators allow them to reach (or not) their objectives of quality of care but sometimes to the detriment of their health at work. However, these results need to be tested in other modes of practice (e.g., hospital, individual practice). They also question the achievements of ergonomics in the prevention of MSDs, because the liberal work in health care settings by doctors who are both prescribers and victims of their work, but also prescribers and responsible for the work and health of their employees, remains to this day little investigated and documented.

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PARALLEL SESSIONS (AM)

01. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES - INTERVENTIONAL STUDIES

11:30 - 11:50 – AUDITORIUM 300, LEVEL 1 – #81

KEY WORDS

Occupational Health | Work determinants | Risk factors | Artists | Uncertainties

Playing with Uncertainty: When the Unexpected Overloads Performing Artists

A. Landry¹ and E. Laneyrie²

The health of performing artists is a growing concern. Both internationally (Record Union, 2019) and in France (INSAART, 2019), significant deterioration in mental and physical health has been reported, along with limited access to healthcare services. Occupational health issues have been mainly studied among musicians, particularly in symphonic orchestras, while few studies have focused on the health disorders of performing artists (Cura, 2019; Lhuillier *et al.*, 2008). The multiplicity of small companies, their size (very small enterprises), and employment status result in unequal access to resources and currently prevent satisfactory occupational support. A prevention culture remains to be established in the sector (Chalouin, 2018).

This communication aims to explore artistic performance activity of actors in order to understand how “the work as it is actually done” exposes artists to a constellation of risk factors and determinants affecting their health.

We conducted 30 hours of field observations involving five artists from a street theatre company during two different performances, to identify health determinants and risk factors. The same artists also completed a health questionnaire (Roquelaure *et al.*, 2010), and all intermittent employees of the company (12 individuals) participated in one-hour interviews. Analysis of the health questionnaires revealed that company members suffer from multiple musculoskeletal disorders (MSDs), mainly affecting the upper and lower back and the cervical region. These pains were reported both over the past 12 months and in the past

7 days by all respondents. The entire group (artists and administrative staff) reported stress and fatigue; two-thirds reported frequent irritability, and half reported sleep disturbances and anxiety.

Work activity data were analyzed using the “5M” framework (originally applied in viticulture work analysis, MSA, 2009), adapted here to artistic work. The objective of this analysis was to highlight the “permanent changes and unprecedented situations” that characterize artists’ work conditions (Ganem *et al.*, 2009). This modeling identified eight main categories of work determinants: “environment,” “equipment,” “programmer,” “company,” “work organization,” “individual,” “work technique,” and “audience.” Together, these represent 66 organizational, relational, or technical factors that may act as either constraints or resources in the artists’ performance work.

The analyses showed that six of the eight determinants primarily acted as constraints. The only resources available to cope with the instability of the work were the mastery of artistic techniques (performance, rehearsal, warm-up, and technical know-how) and the collective’s ability to manage the combination of constraints during work situations. Through several examples, we illustrate how uncertainty leads artists to continuous adaptation, significantly increasing their physical and mental workload. Finally, we discuss prevention strategies developed collectively by the artists to mitigate the health impacts of these multiple constraints.

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KEY WORDS

Desing | New technologies | Logistics | Occupational health | Sustainable performance

The health and performance dilemma in the logistics sector: challenges for the prevention of musculoskeletal disorders

A. Sicco¹, A. Landry² and M.E Bobillier Chaumon³

The logistics sector concentrates numerous tensions regarding relationship between occupational health and performance. According to the French Health Insurance, musculoskeletal disorders (MSDs) “account for 93% of recognized occupational disease in the transportation and logistics sector.” Constraining postures associated with activity in logistics are a major source of MSDs, particularly among young workers (Porta *et al.*, 2024). Physical wear appears to occur rapidly in this field, with pathologies emerging after only four years of work among order pickers (Benvegnù & Cazeneuve, 2023). In logistics warehouses, manual handling tasks are highly prevalent and place significant strain on operators’ lumbar regions (Loske *et al.*, 2021). In addition, pressure can be exerted on order pickers by other players in the logistics chain (customers), depending on the spatial layout of the warehouse, or from management, through incentives for productivity and bonuses, and quality objectives for pallets (limiting breakage, creating uniform pallets to facilitate the work of loading colleagues, creating sturdy pallets, etc. Consequently, warehouse organization is becoming increasingly flexible (Davezies, 2008), placing greater strain on operators’ work and activity. This general context is driving the mechanization of warehouses in order to absorb the constraints of the job and prevent occupational risks (Soulay *et al.*, 2024). Voice picking tools are used to optimize picking efficiency, but they contribute to intensifying work in the sector, resulting in an increase in musculoskeletal disorders and stress (Gaborieau, 2012).

This research aims to contribute to the design of a digital tool that integrate the multiple dimensions of occupational health (physical, cognitive, social, and developmental) within the logistics sector. This tool aims to fuel debate around organizational choices and their consequences on the occupational health of operators. These technological tools, particularly decision-making tools, therefore pose a managerial challenge: they can encourage company stakeholders to focus on performance and quantity indicators rather than quality. In addition, technology dematerializes work, depriving professionals of tangible benchmarks and contributing to the invisibility of workers by making them less present and identifiable within the organization (Bobillier Chaumon, forthcoming). These systems support forms of *algorithmic management*, by performing monitoring, evaluation, and decision-making functions (Sybord, 2024). In the pursuit of technological performance, profitability, and socio-economic efficiency, some digital devices risk excluding subjective engagement and individual initiative (Bobillier Chaumon, 2021). Technologies should therefore be designed for the activity and should integrate the human dimensions of work.

Our presentation will outline the determinants and risk factors for the health of order picking operators and will address the issue of integrating this data into the design of an organizational decision-making tool that promotes health and performance.

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PARALLEL SESSIONS (AM)

02. ORAL COMMUNICATIONS: NEW TECHNOLOGIES – DIGITAL TOOLS

10:50 - 11:10 – ROOM 103, LEVEL 1 – #72

KEY WORDS

Occupational health | Musculoskeletal disorders | Digital health monitoring | Workplace well-being | Mobile health application

Design and deployment of a workplace-based mobile health application: a multidimensional approach to employee health



N. Roger^{1,2,3}, P. Delignieres³, T. Lelard¹ and F. Telliez²

Introduction

Monitoring employee health is a strategic priority for organizations aiming to prevent health-related issues and promote well-being. Occupational health is physical, psychological, and social, requiring reliable indicators to guide prevention. This study presents a tablet-based mobile health application, deployable during working hours, enabling individualized, real-time monitoring across five dimensions: musculoskeletal pain, physical activity, perceived social support, fear of movement, and back pain-related beliefs.

Methods

A steering committee of researchers and company representatives selected validated questionnaires adapted to the workplace: Nordic Musculoskeletal Questionnaire (with pain scale), IPAQ, Karasek JCQ (social support), TSK-11, and Back-PAQ 10. The application was deployed over six months with three measurement points (T0: day 1, T1: 3rd month, T2: 6th month) among 100 meat-processing employees. Each completed three 20-minute interviews

during working hours. Data were entered into a secure digital interface by a workplace health PhD student.

Results

All participants gave informed consent. Confidentiality encouraged disclosure of sensitive health data. The participation rate was 100%, with 99 employees interviewed at T0, 92 at T1, and 82 at T2. Each completed three interviews, totaling one hour per person and approximately 100 hours of qualitative engagement.

Discussion and Conclusion

The application enabled longitudinal monitoring and revealed health trends, supporting evaluation of preventive actions. Its integration into daily routines and co-design by researchers and employee representatives ensured relevance and feasibility. Morning interviews allowed managers to anticipate and adjust work schedules. These findings support the potential of this tool for sustainable, context-sensitive workplace health prevention.

ACKNOWLEDGEMENTS

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KEY WORDS

Management system | UTAUT 2 | Bastien and Scapin criteria | New technologies | MSDs

Comparison of three approaches to understanding the challenges of human activity around a farm management software. What lessons can be learned for the design?



M. Sallifou¹, N. Tricot² and F. Coutarel¹

Musculoskeletal Disorders (MSDs) are very present in agricultural work. Contemporary technological developments promise less physical drudgery, particularly through robotisation, and less mental load, thanks to information systems and farm management. To these promises to reduce the arduousness and health risks of farmers (Bellon-Maurel *et al.*, 2019), in addition to those relating to improving crop yields and obtaining better agricultural results (Vinod Chandra *et al.*, 2024; Waksman, 2024).

However, in reality, these promises are struggling to materialize and effectively support the activity of operators in real contexts (Compan *et al.*, 2022) and seems to be accentuated in the context of the digital revolution. The major explanation lies not only in the fact that these developments are based on insufficient knowledge of the human activities of the intended users, but also that technocentric approaches most often ignore the fundamental issues of human work (Rabardel, 1995).

Various tools are now proposed to study the consideration of human activity issues in design. The study presented in this paper was carried out as part of a collaborative project between ergonomics and engineering. It will compare the contributions of 3 methods, deployed in the field of an INRAE experimental farm, having the status of reference site for this research, to characterize the benefits and limitations of the information and management system in place: an analysis of the operators' activity in a real context was carried out over two weeks, thanks to observations and cross-interviews, an expert evaluation of the tool to analyze its configuration from the Bastien and Scapin grid and an evaluation of the acceptability of the tool from UTAUT 2 in order to collect and analyze the feelings and opinions of operators regarding the use of the system. The results of these various investigations will be presented in this paper, particularly from the point of view of MSD prevention.

ACKNOWLEDGEMENTS

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PARALLEL SESSIONS (AM)

03. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS –
SECTOR SPECIFIC APPROACHES

10:30 - 10:50 – ROOM 104, LEVEL 1 – #84

Work organization, bus ergonomics, and musculoskeletal disorders in Swiss bus drivers: Evidence from the TRAPHEAC cohort

V. F. M. Remy¹, D. Petrovic¹ and I. Guseva Canu¹

Background

Professional bus drivers are recognized as a high-risk occupational group for several health problems, particularly musculoskeletal disorders (MSDs). Understanding the determinants of MSDs in this occupational group is therefore essential for targeted prevention. This study aimed to characterize the distribution and potential risk factors of MSDs in bus drivers participating in a Swiss occupational cohort.

Methods

We analyzed data from 549 bus drivers enrolled in the Transport Personnel Health Cohort (TRAPHEAC), a longitudinal study conducted in Switzerland that investigates the health, lifestyle, and working conditions of public-transport employees. MSD-related pain in the last 12 months was assessed using the Nordic questionnaire with a 0-10 numeric rating scale (0: “no pain at all”, 10: “pain as bad as it could be”) for neck, shoulder, upper back, elbow, lower back, wrist, hip, knee, and ankle. Each score was subsequently dichotomized for presence or absence of pain (score > 1). Work organization (e.g., long working hours, weekend work, frequency and duration of breaks) and exposure to vibration and ergonomic constraints in the bus cabin, measured using the Bus Exposure matrix (BEM) and the Bus Ergonomics Matrix (BERM), respectively, were examined as MSD risk factors using logistic regression models.

Results

MSD prevalence was high among bus drivers, ranging from 45% to 67% for upper back, shoulder, lower back, and neck, and between 18% and 30% for elbow, ankle, wrist, hip, and knee. Overall, these figures exceeded the general prevalence of MSD in the Swiss general population (Swiss Federal Statistical Office data (2019): 35% mild to moderate pain, 8% severe pain). Analyzing the effects of work organization features, we found that a higher number of weekly night/early-morning shifts was associated with an increased likelihood of hip pain (OR=1.12 95%CI(1.01–1.25)), whereas a higher number of work hours per day was associated with an increased likelihood of shoulder pain (OR=1.20 95%CI(0.99–1.46)). Preliminary analyses of vibration levels (BEM/BERM) in relation to MSD suggest that future models will need to account for the dynamic interdependence between seat and floor vibrations, which can influence each other through structural transmission.

Conclusion

Findings from the TRAPHEAC cohort confirm the high burden of MSDs among Swiss bus drivers and suggest that work organization features contribute to musculoskeletal strain. Further investigations are needed to better understand the complex interplay between work organization, and ergonomic design.

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PARALLEL SESSIONS (AM)

03. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS – SECTOR SPECIFIC APPROACHES

10:50 - 11:10 – ROOM 104, LEVEL 1 – #44

KEY WORDS

MSD | Posture | Know-how | Scissors

Impact of tool handling changes on posture and know-how



M.A. Gilles¹, J. Dellai^{1,2}, I. Clerc-Urmès¹, E. Quillerou¹ and G. Dietrich²

One of the measures used to prevent MSDs of the upper limbs is modifying the tool. This change involves learning a new technique, but the time required for learning is often not taken into account in work organisation and it often comes with a temporary loss of know-how. This loss is difficult for users to accept because their know-how reflects their expertise, but it is also hard for colleagues to accept because of the decrease in productivity often associated with the change. The hairdressing sector is an excellent example. The rate of musculoskeletal disorders is very high (Kang *et al.*, 1999; Wahlstrom *et al.*, 2010, Salerno & Giliberti, 2022) forcing hairdressers to quit early because of pain. Analysis of the hairdressing activity shows that 29% of the work involves cutting hair (Kitzig *et al.*, 2015; Kozak *et al.*, 2019), meaning: prolonged postures, arms raised, wrist twisting and repetitive movements (Chen *et al.*, 2010). Having fingers fixed in the two rings of the scissors could lead to awkward postures. Changing the way in which scissors are held could help to reduce these constraints, but it also risks disrupting a previously acquired skill. The aim of this study was to analyse upper arm postural modifications depending on the use of different scissors and to investigate the difficulties encountered by hairdressers when using new scissor grip in the salon.

Fourteen experienced, right-handed female hairdressers (median age 25.5 years old [Q1: 20; Q3: 34]) participated. Movement kinematics were recorded using an optoelectronic system (Motion Analysis 200hz) over four successive days in the lab when the participants performed three cutting movements [0° Elevation (0E); 90° Elevation (90E); 180° Elevation (180E)] for six minutes each (Fig.1). Cuts were made with Traditional Scissors (TS), then with Ringless Scissors (RS). None of the hairdressers had used RS before. Differences in right wrist, elbow and shoulder angle with each pair of scissors were analysed using Friedman tests. Then RS practice in the salon was followed up for the next four months. Participants were asked to use RS as much as possible during their work. Twice per week, a questionnaire inquiring the use of RS was sent by text message.

When using RS, wrist flexion significantly decreased ($p < 0.05$) to align with the forearm longitudinal axis. This alignment was associated with a significant decrease ($p < 0.05$) in shoulder abduction. In the salon, three kinds of practices were observed: 1) RS were quickly adopted for use 100% of the cutting time; 2) RS were used alternately with TS, and when this was the case, RS were essentially used for the 0E cut; 3) RS were used infrequently from the start and gradually abandoned.

Basic manipulation of RS can be quickly acquired through training by adopting new postural upper limb organisation resulting in less awkward postures. Participants reported a decrease in pain felt in both shoulders and the right wrist. However, they reported difficulties with successfully using RS in real work conditions and a fear of messing up their cut. For most of them, the time allocated for each haircut was not sufficient to confidently improve RS practice.

Motor learning of basic scissor handling can be achieved easily. However, specific conditions in terms of motivation and organisation must be in place for the change of tool to have a positive impact on posture and know-how development.



FIGURE 1
Example of the 3 haircutting movements analysed (left side); Scissor models analysed and typical handling placement (right side).

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PARALLEL SESSIONS (AM)

03. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS – SECTOR SPECIFIC APPROACHES

11:10 - 11:30 – ROOM 104, LEVEL 1 – #65

KEY WORDS

Airport | Baggage room | Baggage handling | Traffic of vehicles | Ergonomic approach

Exploring the risks of musculoskeletal disorders associated with baggage handling in baggage room at an international airport

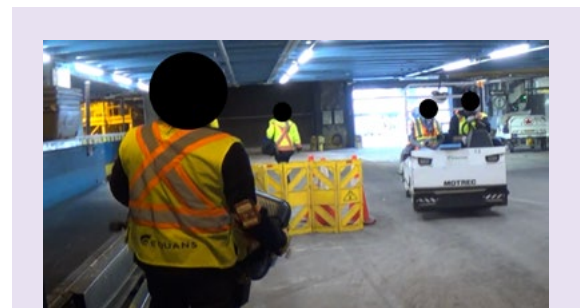
E. Goubault¹, M. Gonella¹, C. Jolly¹ and D. Bulet-Vienney¹

An international airport (IA) is part of a complex system involving different stakeholders for the implementation and running of operations. Subject to space constraints, it is sometimes necessary to superimpose conveyors to keep up with the increased flow, making it more difficult for baggage handlers who are already at high risk of developing musculoskeletal disorders (MSDs) (Fyongo & Ramdhan, 2024; Wang *et al.*, 2019). In defining the major transformation projects to come to respond to an increase in passenger flow and transit over the coming years, an IA wanted to carry out a diagnosis to explore avenues for occupational health and safety (OHS) improvements, initially targeting baggage room.

The aim of this exploratory study was to explore the risks of MSDs associated with baggage handling in baggage room.

To meet the IA's request, a literature review was carried out on the risks of MSDs associated with baggage handling and the possible technological solution to reduce them. Plus, three days of open observations were conducted with handlers and vehicle drivers (n=5 workers) in various strategic locations and environments of the airport (e.g., baggage rooms, exterior, arrivals conveyor rooms). Semi-structured interviews (n=8 interviews) completed the exploration of OHS needs associated with baggage handling. Content analyses of the verbatim interviews were carried out using NVivo software and syntheses combining interview and observation results were produced.

Among ground handlers (60 to 70%), MSDs mainly affect the lower back, knees, neck, upper back, hands/wrists and shoulders (Mostosi *et al.*, 2022; Zavitz & Lu, 2022). Fatigue, workload, insufficient breaks, work stress and uncomfortable positions were associated with increased risks of MSDs. In accordance with the literature review, the most frequently reported injuries are related to handling and unblocking baggage conveyors at the observed IA. There was 6.8 to 34.1% of workers who exceeded the cumulative mass rec-



▲
FIGURE 1
Worker transporting baggage to a vehicle.

ommended by ISO 11228-1 and 2.3 to 22.3% who exceed the critical mass of 6000 kg. Various aggravating factors were observed (e.g., physical exertion, high co-activity of various vehicles) and the workers proposed possible solutions to reduce the risks of MSDs related to baggage handling.

In addition to certain risks specifically linked to handling (e.g. load and volume of baggage), traffic of vehicles seems to be interrelated with handling risks, suggesting the need to address the risks of handling and traffic in interaction within airport structures. Studying the interaction between handling and driving activities should be considered to better prevent MSDs risk for handlers. It could help to have a more systemic approach for preventing their risks while introducing broader factors like conveyor conception and their installation regarding baggage handling and proximity to loading vehicles, traffic routes and parking places regarding efforts and re-handling, management of baggage rooms and space distribution between the different actors involved in these areas.

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SYMPOSIUM (AM)

10:30 - 12:00 – ROOM 105, LEVEL 1

KEY WORDS

Occupational exoskeleton | Physical assistance | Familiarization | Motor learning | Acceptance

Understanding the long-term consequences of exoskeletons in MSD prevention: a cross-disciplinary perspective



S. Lemonnier^{1,2}, A. Bucchieri² and P. Maurice²

Exoskeletons are devices worn on the body to support muscular effort. Passive exoskeletons use springs or mechanical structures to redistribute loads, whereas active exoskeletons rely on motors and sensors to provide dynamic assistance. These devices currently start to be deployed in industry, particularly for manual material handling, construction, or repetitive production tasks, with the aim of reducing physical strain and preventing musculoskeletal disorders (MSDs).

However, so far the scientific literature reports mixed results. Numerous studies show that wearing an exoskeleton can reduce muscle activation, improve posture, and decrease perceived fatigue, suggesting real potential for MSD prevention (Kim2018, De Bock2022, Moeller2022, Koopman2020). These effects are particularly well documented for the back and upper limbs, where the reduction in mechanical effort can relieve areas that are usually overworked. However, alongside these benefits, other studies highlight undesirable effects: discomfort, restricted mobility, pressure points, shifting of effort to other parts of the body, postural imbalances, and even cognitive overload associated with wearing the exoskeleton (Theurel2019, Kermavnar2021). In some cases, these transfers of stress

could shift the risk of MSDs rather than eliminate it. These limitations are not only physiological, but also affect the social and organizational acceptance of exoskeletons (Elprama 2020, Andrade 2022). Wearing an exoskeleton can be perceived as stigmatizing, constraining interactions, and reducing feelings of autonomy or professional value. Acceptance therefore depends as much on technical ergonomics as on psychological and social factors, and non-acceptance can lead to rejection of the exoskeleton.

The above-mentioned studies highlight the importance of considering the exoskeleton solution specifically for each situation. But there is another difficulty: most of the available research is based on short-term studies, ranging from a few minutes in the laboratory to a few days

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in real-life conditions (Kranenborg2023). Rare longitudinal studies show that perceptions and use evolve over weeks (Parri2025, Dufraisse2025, Favennec2024). The true long-term effects—both physiological and psychosocial—are the next necessary steps in studying the impact of exoskeletons and their adoption (Crea2021, Elprama2022, Baldassarre2022).

This gap raises crucial questions: could prolonged use of an exoskeleton induce new joint or muscle strain, cause chronic fatigue, or permanently alter motor strategies?

What will be the consequences for psychological health, motivation, and social dynamics at work? To address these issues, it is necessary to go beyond immediate biomechanical assessment and develop a long-term perspective, integrating both the prevention of MSDs and the long-term acceptance of the exoskeleton. In order to bring new insights into such questions, this symposium will gather experts from biomechanics, human motor control, technology acceptance, as well as offer some feedback from end-users.

THE CONTRIBUTIONS TO THE SESSION ARE

Transparency and intuitiveness of an active exoskeleton of the upper-limb: N. Vignais, Université Rennes, Inria, M2S, Rennes; **The biomechanical adaptation to exoskeleton use: from the familiarization to the acceptance:** G. Mornieux, C. Thevenot and A. Favennec, Research Unit DevAH, Université de Lorraine, Nancy; **Persistent effects of upper-limb exoskeletons on inter-joint coordination:** O. Dubois, R. Parry, R. Roby-Brami, G. Brunelli and N. Jarrassé, Institut des Systèmes Intelligents et de Robotique, Sorbonne Université, Paris and LINP2, Université Paris-Nanterre, Nanterre; **Long-term adoption of professional exoskeletons: a five-year research review:** L. Wioland, J.J. Atain Kouadio, I. Clerc-Urmès, F. Braud, and M. Dufraisse, INRS – Département Sciences Appliquées au Travail et Aux Organisations, Vandœuvre-lès-Nancy; **Ten years of exoskeleton integration: lessons learned and success factors:** B. Gourmaud and M. Brout, La Poste – Direction technique, DSI-O, Nantes.

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PARALLEL SESSIONS (AM)

04. SYMPOSIUM: UNDERSTANDING THE LONG-TERM CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE

KEY WORDS

Human-exoskeleton interaction | Transparency | Myoelectric contro

Transparency and intuitiveness of an active exoskeleton of the upper-limb



N. Vignais¹, D. Verdel¹, L. Quesada¹, S. Bastide¹, B. Treussard¹, F. Geffard¹, O. Bruneau¹ and B. Berret¹

Exoskeletons could nowadays be considered as a promising solution for preventing musculoskeletal disorders in industry. Although active exoskeletons have the potential to relieve more physical strain than their passive counterparts, the implementation of these devices can lead to new risks and shift the physical load to other regions of the body, or it can limit the comfort of the user as well as his freedom of movement (Theurel and Desbrosses, 2019). It is therefore necessary to understand what are key elements of the human-exoskeleton interaction (HEI) before applying this disposal in the field of ergonomics.

An active exoskeleton has to be able to follow the human movement while compensating efforts to relieve joints and muscles during motion. The ability of an exoskeleton to follow the human movement without perturbation is called transparency. More precisely, a transparent mode of control aims not to modify joint trajectories, end-effector trajectories and user's activation muscle patterns (Pirondini *et al.*, 2016). Theoretically, a full transparency is obtained when interaction forces between an exoskeleton and a user are null. Practically, a full transparency is never reached due to the multiple

parameters characterizing HEI. In a first part, experiments conducted on the ABLE exoskeleton about evaluation and improvement of transparency parameters will be presented through motor control analyses (Bastide, 2021; Verdel, 2023) (see *Figure 1*).

Moreover, to be intuitive, an active exoskeleton has to react in an efficient way, by almost anticipating user's future actions. This means that the command of the exoskeleton has to be based on a bioinspired control law. Innovative interactive tools have been recently introduced, especially concerning the use of electromyography (EMG) (Morais *et al.*, 2016). Indeed, EMG signals have been widely used for prosthetic or assisting arm control, probably in the light of electromechanical delay, i.e. time interval of 50 to 100 ms between EMG signal appearance and movement start (Begovic *et al.*, 2014). This type of command is thus called myoelectric control (Peternel *et al.*, 2016). Investigations about myoelectric control implemented into two different upper-limb exoskeletons will be secondly addressed through experimental studies related to two other doctoral projects (Treussart, 2021; Quesada, 2024) (see *Figure 2*).

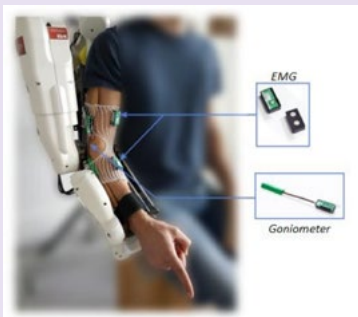


FIGURE 1
ABLE exoskeleton for HEI analysis with goniometer and EMG sensors (Bastide, 2021).



FIGURE 2
Upper-limb BHV2 exoskeleton used for myoelectric control (Treussart *et al.*, 2019).

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PARALLEL SESSIONS (AM)

04. SYMPOSIUM: UNDERSTANDING THE LONG-TERM CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE

KEY WORDS

Motor learning | Mechanical constraints | Assistance | CORFOR®

The biomechanical adaptation to exoskeleton use: from the familiarization to the acceptance

G. Mornieux¹, C. Thevenot¹ and A. Favennec¹

The effectiveness of passive soft back-support occupational exoskeletons in reducing lumbar muscular demand has been proven in the literature (Theurel and Desbrosses, 2019). But given the disparity of familiarization with the exoskeleton reported in the literature, inconsistent results are sometimes observed. First, further understanding biomechanical adaptations during the familiarization phase while wearing the exoskeleton would enable providing recommendations about the familiarization protocol and duration. Then, conducting exoskeleton evaluations after such a proper familiarization would ensure relevant findings to characterize the true biomechanical benefits of the exoskeleton.

A first study (Favennec *et al.*, 2024) was designed to characterize the familiarization process with a soft back-support occupational exoskeleton and determine the time needed to stabilize biomechanical variables. 18 participants carried out 6 familiarization sessions of 1 h to the CORFOR® soft back-exoskeleton. Each familiarization session consisted of a set of different general tasks (walking, lifting, manual handling, and fine handling) performed several times. Joint kinematics, postural stability, exoskeleton pressure perception, muscle activity, and performance were then measured at the beginning of the first session and at the end of each session during stoop and squat liftings.

A second study (Thevenot *et al.*, 2025) was carried out on the field, where 10 workers performed a 1.5-hour order picking task with and without the CORFOR® exoskeleton, while trunk muscle activity, upper-body kinematics and the exoskeleton's acceptance were assessed. The workers had 226 ± 204 days experience of using the CORFOR®. The task assessed was to prepare pallets of fruit and vegetable packages, by transferring packages from warehouse pallets to their order picking pallets.

Results showed that back kinematics (Figure 1), performance, and exoskeleton pressure perception changed during the first familiarization sessions and stabilized after sessions 3 or 4, depending on the variable. Also, erector spinae muscle activity was significantly reduced by 7.5% with the use of the exoskeleton. Moreover, trunk flexor muscles activity, trunk kinematics, or low-back pain were not affected. Further, the acceptance of the exoskeleton was rated as favorable.

The authors recommend a familiarization protocol for the CORFOR® soft back-exoskeleton of 4 sessions of 1 h duration. This recommendation could help CORFOR® users, for instance in the food retail industry, i) to operate with stable motor behaviour and ii) to reduce their low-back muscles exertion. This could eventually explain the good acceptance of the exoskeleton in the test company. All together, the integration of the CORFOR® exoskeleton for order picking tasks is promising.

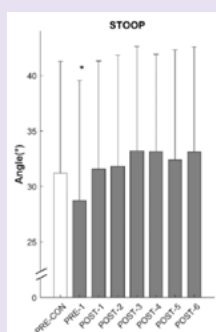


FIGURE 1
Thoracic flexion averaged value over the familiarization protocol during the stoop lifting task. *Statistically different from POST3-4-6.

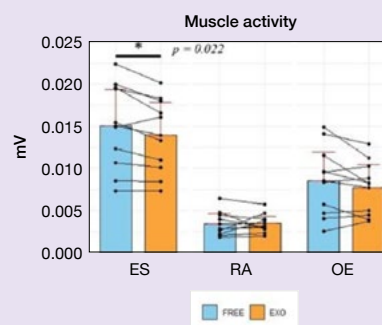


FIGURE 2
Comparison of mean RMS values of Erector Spinae (ES) and abdominal (RA and OE) muscle activity without (FREE) and with (EXO) the CORFOR during the order picking task. *Significant difference ($p < 0.05$).

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PARALLEL SESSIONS (AM)

04. SYMPOSIUM: UNDERSTANDING THE LONG-TERM CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE

KEY WORDS

Exoskeleton | Inter-joint coordination | Motor control | Residual effects

Persistent effects of upper-limb exoskeletons on inter-joint coordination



O. Dubois¹, R. Parry², R. Roby-Brami¹, G. Brunelli¹ and N. Jarrassé¹

Wearable exoskeletons are increasingly used in industrial settings to reduce physical strain and prevent musculoskeletal disorders, particularly in tasks involving repetitive overhead work (Schmalz, 2019). Passive shoulder exoskeletons, such as the Paexo Shoulder (Maurice, 2019), offer mechanical support by offloading the arm's weight using spring mechanisms. While immediate benefits of upper-limb exoskeletons, such as reduced muscle activity, improved posture, and lower metabolic demand, are well documented (Theurel, 2018) (Moeller, 2022), little is known about the effects that may persist once the exoskeleton is removed (Dubois, 2024). This is a critical oversight, given the adaptability of human motor control and the potential risks associated with repeated use.

This study investigates first whether a short, 25-minute session of exoskeleton-assisted work leaves measurable changes in upper-limb kinematics and muscle activation once the device is removed. Twenty healthy participants were divided into two groups: one used the Paexo Shoulder during a standardized overhead reaching task, while the control group completed the same task without assistance. Both groups were evaluated before and after the exposure using motion capture and surface electromyography (EMG) to assess joint coordination and muscular activity.

The findings reveal that even a brief use of the exoskeleton induces notable changes in motor behavior. Participants who wore the exoskeleton showed faster hand movements, increased shoulder joint range of motion (Figure 1), correlated with a heightened activation of the anterior deltoid after device removal. Coordination between the shoulder and elbow was also disrupted, indicating an altered distribution and timing of joint contributions. Interestingly, muscles not directly assisted, such as the biceps and triceps, also showed increased activation and co-contraction levels, suggesting a compensatory stiffening strategy by the nervous system to deal with the sudden removal of mechanical support. These effects persisted for at least ten minutes post-use.

These results highlight that exoskeletons, while effective during use, can cause transient motor adaptations that outlast the support period. If exposure is repeated daily, these changes may accumulate or lead to overuse of certain joints or muscles. The results of a second experiment suggests that temporal inter-joint coordination increases with the amount of exposure (Figure 2), raising concerns about long-term use. Therefore, strategies to monitor and mitigate these residual effects are essential to ensure safe and effective integration of exoskeletons in occupational environments.

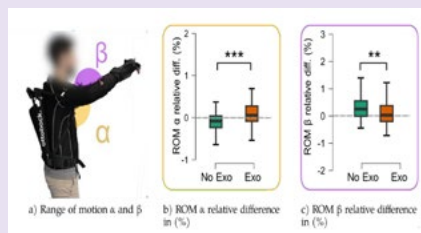


FIGURE 1
Range of motion of α (shoulder) and β (elbow). The relative difference between before and after exposure to the Paexo Shoulder are presented.

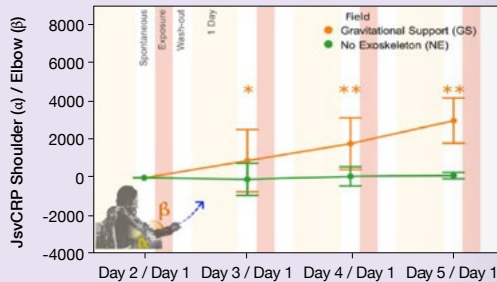


FIGURE 2
Evolution of the temporal synchronization of the elbow and shoulder joints over 5 days of exposure

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PARALLEL SESSIONS (AM)

04. SYMPOSIUM: UNDERSTANDING THE LONG-TERM CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE

KEY WORDS

Adoption | Familiarization | Embodiment

Long-term adoption of professional exoskeletons: a five-year research review

L. Wioland¹, J.-J. Atain Kouadio¹, I. Clerc-Urmès¹, F. Biraud¹ and M. Dufraisse¹

Occupational exoskeletons are considered when other musculoskeletal disorders prevention methods fail. They reduce muscular strain and effort, but their long-term adoption in workplaces remains a challenge. This presentation summarizes 5 years of INRS research (2021–2025) in about 20 companies, using mixed methods to formalize the exoskeleton adoption process.

The adoption of an exoskeleton is a dynamic process consisting of three stages: pre-adoption (before the user-exoskeleton interaction), familiarization (initial uses), and routinization (regular use) (Dufraisse *et al.*, 2025a). For each stage, adoption depends on users' evaluation of the quality of their interaction experience with the device. This evaluation covers six categories of interdependent determinants (for example: perceived ease of use, perceived usefulness, social influence, affect, etc.) (Wioland *et al.*, 2019; Elprama *et al.*, 2020). Between pre-adoption and routinization, these determinants affect adoption differently (Wioland *et al.*, 2025). For example, social influence plays a more important role in the first two stages than at the routinization stage, while affect remains decisive at every stage. Adoption also relies on change in activity induced by the use of the exoskeleton. Thus, during familiarization, to fully benefit from the exoskeleton's potential, the user adapts their movement strategies and manages possible side effects of the device (Kranenborg *et al.*, 2023). During the familiarization phase, the user also compares and adjusts their initial expectations,

formed during pre-adoption, with the reality of the work context and actual use of the exoskeleton. Ultimately, these dynamics lead to different familiarization trajectories from one individual to another. Alongside this dynamic, the exoskeleton, being worn by the user, leads to a bodily experience called embodiment (Paap *et al.*, 2024). This refers to incorporating the device as part of oneself. This phenomenon develops with exoskeleton use; the longer the use, the stronger the embodiment (Dufraisse *et al.*, 2025b). During familiarization, if all these factors are favorable, routinization is established, characterized by stable usage patterns and the integration of the technology into the user's routines. At this stage, although adoption still depends on evaluations of determinants and embodiment degree, the overall satisfaction with the quality of the interaction experience becomes the key factor. Similarly, as the user is often part of a group, adoption is strongly influenced by social dynamics. Negative social dynamics, such as exclusion or disrupted teamwork, can hinder the adoption of an exoskeleton, especially if its use is seen as going against group norms (Atain Kouadio *et al.*, 2021; Biraud, 2024). These social factors represent significant barriers, particularly during the pre-adoption and familiarization phases.

In conclusion, the adoption process takes place over time. This formalization helps define new guidelines for occupational risk prevention and can be transferred to other technologies.

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PARALLEL SESSIONS (AM)

04. SYMPOSIUM: UNDERSTANDING THE LONG-TERM CONSEQUENCES OF EXOSKELETONS IN MSD PREVENTION: A CROSS-DISCIPLINARY PERSPECTIVE

KEY WORDS

Exoskeleton | Musculoskeletal disorders (MSDs) | Prevention | Work adaptation | Ergonomics

Ten years of exoskeleton integration: lessons learned and success factors



B. Gourmaud¹ and M. Brout¹

For the past ten years, La Poste has been experimenting with the integration of exoskeletons for mail and parcel sorting as part of an innovative approach to preventing musculoskeletal disorders (MSDs). Given the diversity of distribution, sorting, and logistics jobs, the success of such projects—both in terms of exoskeleton adoption and long-term use—relies on a rigorous process and several clearly identified criteria. Multidisciplinary is therefore essential: the involvement of the occupational physician, the commitment of management, and the participation of field operators ensure a comprehensive approach. The next step is the analysis of the relevant work situations, which represents a fundamental basis for launching the project. Beyond biomechanical constraints, the ergonomic assessment also includes task organization, the social context, the physical environment, and time constraints. Adaptation to the user remains a decisive factor: it involves taking into account biomechanical constraints, body morphology, potential medical conditions, and individual expectations, while ensuring a balanced evaluation of benefits and risks. In

addition, the choice of exoskeleton must meet a set of criteria regarding the assistance sought, integrating user feedback and the ability to adjust the level of support. A favorable context is also necessary: social support, promotion of user autonomy, team-wide familiarization, training for supervisors and managers, as well as anticipation of impacts on work organization and production. Furthermore, this process requires close collaboration with suppliers, to guarantee model diversity, a clear contractual framework, appropriate maintenance, and ongoing monitoring. This methodological framework ensures a successful and sustainable integration of exoskeletons, benefiting both employee health and organizational performance. Based on this experience, La Poste has been able to transfer knowledge and formalize a dedicated method specifically tailored to the issue of job retention. The objective of this presentation is to share a feedback report on the approach deployed for the sustainable integration of exoskeletons, whether in the context of MSD prevention or job retention. Examples will be provided to illustrate this experience.

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KEY WORDS

Mouse | Pointing device | Surface electromyography | Performance | Perception

Computer work: central pointing device, slanted mouse or traditional mouse placed near to or in front of the keyboard, what is the best configuration?



C. Gaudez¹, I. Clerc-Urmès¹ and K. Desbrosses¹

In 2019, 79% of French workers used a computing tool in their professional activities, of which 54% used a desktop computer (DARES, 2023). With a desktop computer, the traditional mouse is the most often used pointing device. However, its prolonged use can lead to discomfort, pain and even musculoskeletal disorders of upper limbs. Several studies suggest that positioning the pointing device as close as possible to the user's mid-sagittal plane, i.e., in front of the keyboard, reduces muscle stress of the upper limbs. Furthermore, the most relaxed position of the forearm is obtained when the hand is inclined approximately 30° from the vertical axis. To meet these recommendations, various pointing devices, such as slanted mice (S) or central pointing devices (CD), have been developed (figure 1). Traditional (T) or S mice can be positioned either next to (N) or in front of (F) the keyboard. The CD is always placed in front of the keyboard and can be used with both hands. The aim of this study was to determine whether one of these pointing device configurations (PDC = pointing device X position on the desktop) should be favoured in terms of participants' perceptions, their performance to complete a working task and the electromyography (EMG) activity of the muscles involved in the occurrence of epicondylitis.

Thirty-one right-handed participants repeated a pointing-clicking-dragging task on 16 targets five times using the 5 PDCs: T and S mice placed next to (TN and SN, respectively) or in front of (TF and SF, respectively) the keyboard and CD. The two mice were operated only with their right hand. For the CD, pointing and dragging tasks were per-

formed using the right hand via a movable bar, and clicking actions with the left hand. Prior to the experimental session, participant completed 6 hours of training with all 5 PDCs. The participants' perceptions, their performance to complete the task and the EMG activity of the right and left carpal extensor (ECR) muscles were analysed.

Participants appreciated TN and TF more than SN, SF or CD. The task completion time was longer with the CD compared to both mice. It was shortest with TN or TF. The error rate, measured by the number of clicks, was higher with CD than with TN. The right ECR muscle activity was highest with TN and lowest with CD; TF, SN and SF showed no differences between them. The left ECR muscle activity was highest with CD; the other 4 PDCs showed no differences between them. The 10th percentile of the right ECR muscle activity exceeded 5% of the maximal voluntary contraction (MVC) with all 5 PDCs and the 10th percentile of the left ECR muscle only when using the CD.

Thus, considering all criteria investigated, no PDC is ideal. Indeed, participants' perceptions and task completion performance were better with the T mouse. However, based on the activity of the right ECR muscle, the CD appears preferable to the two mice. In addition, according to Jonsson (1978), a risk of the occurrence of muscle fatigue may occur if the 10th percentile of muscle activity exceeds 5% of MVC. Thus, a risk of ECR muscle fatigue, right or left, was present whatever the PDC. Consequently, to reduce muscle stress and reduce health risks, work organization must provide for alternation between different tasks and regular breaks.



Traditional mouse (T)



Slanted mouse (S)



Central pointing Device (CD)

▲ FIGURE 1 Pointing devices.

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POSTER SESSION

KEY WORDS

Cosmetic manufacturing workshop | Primary prevention | Ergonomic study | Action plan

How can a request for individual protection result in primary prevention action in a cosmetics manufacturing workshop?

R. Codron¹ and C. Zind¹

Employees of a cosmetics manufacturer ask the occupational doctor for knee protection equipment. To better understand the need, an ergonomic study of the activity is requested.

Method

- Observing the different phases of workshop activity,
- Job interviews,
- Equipment metrology,
- Discussions with the workshop manager to understand the organization.

Results

Following a recipe, raw materials are fed into a mixer weighing over 800 kg. The ingredients, including reverse osmosis water, are prepared in advance in buckets of up to 20 liters weighed to the nearest gram and transported by roll or whole pallet. The operator transports the buckets to the opening of the mixer by taking the stairs of an access platform and pours them through a porthole located 67 cm from the floor while the osmosis water is sucked in from below. For each ingredient, it validates the operation electronically.

We see :

- Significant handling (loaded roll, pallet of water, buckets weighing 430 kg),
- The design and size of the mixer require the presence of a platform. This, poorly designed, generates restrictive postures when filling the tank,
- The precise recipe requires the use of spatulas to scrape off all the substances, a source of repetitive movements made worse by viscosity,

- The need to adjust manufacturing based on results, particularly colorimetry,
- Manufacturing waste is collected by gravity (holding a pipe) in buckets which are weighed and complemented by scraping the tank via the porthole.
- After cleaning the mixer at high pressure between each production, the employees kneel down to scrape the pigment residues from the tank through the porthole, hence the request for kneepads.

The findings and proposals for improvements are the subject of discussions and co-building of an immediate and long-term action plan, because the workshop reorganization initially considered will be based on our recommendations.

Discussion

Accepting the intervention of an ergonomic analysis in the face of a restricted and relatively easy to satisfy request requires, on the part of the multidisciplinary team, a good knowledge of the company, expertise provided by the SPSTI and a durable relationship of trust with the company.

Conclusion

The limited initial request resulted in an exhaustive study of the activity and an action plan which benefited all workshop employees. We should underline the importance of consistently delving deeper into root causes, beyond an ordinary request, in order to broaden our interventions to stakeholders and act in primary prevention.

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KEY WORDS

Delivery driver | Job retention | Weak signals | Primary prevention

Support for maintaining employment, a driving force behind collective primary prevention action, based on a field study



C. Zind¹ and R. Codron¹

A frozen food delivery driver suffers from a shoulder condition (Table 57 of occupational illnesses) that limits his driving and severely limits his handling. His activity is being studied as part of a job retention program; possible solutions are to be tested during a supervised trial.

Method

- Analysis of the driver's activity on route by the ergonomist (photos, videos, and interviews, etc.),
- Highlighting of the difficulties encountered by the employee,
- Discussions with the employer that allow for linking with comments from other employees.
- Continuation of the discussion throughout the department with two further observations from other drivers.
- Presentation of the summary to management.
- Co-development of a prevention action plan with the company.

Results

The following issues were identified:

- Time-related, a source of cognitive load: time-sensitive delivery, heavy traffic, adherence to driving times,
- Organizational: unoptimized routes, packages loaded without taking into account delivery routes,
- Postural/handling: reorganizing packages on the pallet by customer, maneuvering vehicle compartment doors, delivering in unsuitable spaces (stairs, crossing sidewalks, etc.), loading and unloading trailers,
- Thermal: significant temperature gradients,

- Interpersonal: direct customer contact and cash registers.

Skills in caution, preservation, and personal organization to satisfy customers were identified.

The initial discussion for an individual employee was extended to the collective. An action plan addressing the identified difficulties was established for drivers, involving the logistics, sales, and IT departments. Accident rates in the department decreased, and requests for workstation adjustments became rare. The company maintains our recommendations and supports drivers in their search for best practices.

Discussion/Conclusion

The study highlighted the correspondence between the statements and the observed reality. Until now, the alerts remained individual, not considered as weak signals requiring further investigation.

The perception of the delivery driver profession was disrupted. The company assessed the reality of the observations, especially since they were also encountered at other sites. This awareness was the driving force behind the decisions made.

The SPSTI's multidisciplinary teams support and advise employers and employees over the long term, establishing a relationship of trust and thus fostering constructive exchanges with the company.

Many of our workplace initiatives begin with individual support for job retention, and we must seize this opportunity to work collectively and pursue primary prevention, our mission.

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POSTER SESSION

KEY WORDS

MSDs | Emotional demands | Physical pain | Professional disengagement

Physical work demands and frequency of physical pain: the moderating role of emotional demands

C. Gaubert-Trautmann¹ (Phd), M. Vonesch¹ and M. Weber¹ (M.D.)

Physical constraints are often taken into consideration to account for professional disengagement in highly physically demanding jobs. Indeed, it has been shown that pain (particularly chronic pain) plays a central role on workers' return to work (Grant *et al.*, 2019). However, this is often done with little regard to how psychosocial factors can moderate the effect of chronic pain on workers' return to work. Because highly physically demanding jobs are, *per se*, more prone to MSDs and constitute an increased risk of occupational disability, psychosocial constraints (such as *emotional demands*) are rarely investigated. Yet, we know that MSDs and psychosocial risks are linked (Bezzina *et al.*, 2023). A better understanding of this link may help us to better prevent professional disengagement.

Therefore, as part of a field study conducted in a food company, we decided to explore the relationship between physical and psychosocial constraints and their contribution to the perception of physical pain. We focused our attention on a particular psychosocial constraint—emotional demands—that plays an essential role in mental health at work (Bakker *et al.*, 2023).

Methods

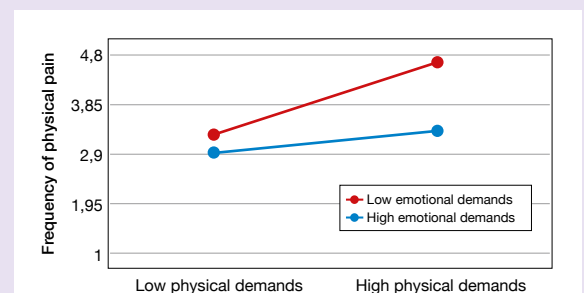
144 workers responded to a survey with 86 questions about work conditions (25% were over 50 years old, 62% were males). Physical constraints were measured by two items questioning movements' repetitiveness and the handling of heavy load ($\alpha=.69$). Emotional demands were assessed by two items (*confrontation with emotionally destabilizing situations and emotionally demanding work*, $\alpha=.86$). Finally, physical pain was assessed using one item "Do you ever experience physical pain (joint pain, muscle tension, back pain, etc.)?" Employees were asked to rate the frequency of their pain on a scale ranging from never (1) to all the time (5).

Results

By adopting an exploratory approach, multiple regression analyses were performed introducing physical demands, emotional demands and their product as predictors and perceived physical pain as the criterion. The full model was significant, $F(3, 140) = 18.24, p < .001, R^2 = .28$. Physical demands significantly and positively predicted perceived physical pain, $\beta = .38, t = 5.23, p < .001$. This relationship appeared to be moderated by emotional demands, $\beta = .20, t = 2.89, p < .005$. High physical demands positively predicted perceived frequency of physical pain only for workers exposed to high emotional demands, $t = 3.20, p < .002$.

Conclusion and perspectives

These results suggest that highly physically demanding jobs should not be reduced to their physical constraints only. Using a comprehensive approach to these jobs' evaluation allows for adjustments to be made both at the job level and at the organization level, which seems highly relevant for improving work conditions in general and preventing professional disengagement in particular.



▲ FIGURE 1

Perception of the frequency of physical pain depending on physical and emotional demands.

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KEY WORDS

Paramedics | Patient handling | Stair chair | Work situation | Organizational aspects

The importance of organizational aspects in the design of a stair chair for the prevention of msds in paramedics



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Reducing biomechanical constraints is a central concern in the prevention of musculoskeletal disorders (MSDs) when designing a stair chair (SC) used by paramedics for evacuating patients in staircases. However, the organizational dimension of work is equally important, as it indirectly influences exposure to biomechanical risk factors that workers face, leading to MSDs (Bodin et al., 2023). In this presentation, we aim to show how organizational factors influence work situations and how understanding these factors contributes to the design of the SC.

This data is part of a research project combining ergonomics, biomechanics, and engineering, in partnership with two ambulance companies. Two data sources were used: interviews with key stakeholders (n=15 interviews, average duration = 1h00) and controlled-environment simulations of stair evacuation scenarios with paramedics, followed by discussion periods (n=6 simulations, average dura-

tion = 3h00). The themes included: 1) models of SC used; 2) training in SC usage; 3) SC maintenance; 4) work organization. Verbatim transcripts were produced for thematic analysis with data triangulation.

Using the SC involves several steps beyond patient evacuation downstairs, such as transporting the SC to the patient or storing it in the ambulance (Nieto et al., 2025). All these steps must be considered in the design process to reduce constraints. Several themes emerged as challenges during SC use: location of the intervention, environment, patient health status, behavior and anthropometric characteristics, SC characteristics, paramedic characteristics and training, level of care needed, SC maintenance, harness, and work organization.

These elements are interrelated and influenced by macro-organizational aspects. For example, the role of each paramedic—positioned at the head and foot of the SC—is crucial for controlling movement (preventing falls) and reassuring the patient (Figure 1). Coordination between the pair is essential and facilitated by individual characteristics (e.g., height, strength, experience) and knowledge of each other. However, team composition is shaped by scheduling, which is determined by seniority, affecting team stability and the integration of new staff. Furthermore, paramedics received academic training using the most common SC model in the region. Another existing SC model may be more suitable in critical situations (e.g., stair climbing). This highlights the need to consider continuing training. However, interviewees reported a lack of resources (e.g., difficulty releasing paramedics for training) and budget constraints. Access to different SC models is also limited by ambulance space, scarcity and cost of spare parts, the high cost of the SC itself, and unequal access to support teams depending on the region.

Even if equipment and biomechanical factors are at the heart of the design process, organizational aspects also represent levers better understand all dimensions of work.

FIGURE 1
Figure illustrating the evacuation of a patient in a stair chair by a pair of paramedics.



ACKNOWLEDGEMENTS

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POSTER SESSION

Sustainable work: a pathway to sustainable prevention of MSDs?



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Since the Rio Conference (United Nations, 1993), the concept of sustainability has expanded into numerous fields of application, particularly within workplaces. In Quebec, the Workplace health, Safety, equity and compensation Commission defines sustainable development as follows: “Strengthening, enhancing, and adding new eco-responsible management practices; promoting social inclusion and reducing social and economic inequalities; improving population health through prevention.” (CNESST, 2019). Additionally, the International Labour Organization (ILO) published a Strategy to Promote Sustainable Enterprises (ILO, 2021). The scope of sustainability in the occupational health and safety (OHS) is broad. This presentation aims to explore the meaning of the concept of sustainability in OHS and to reflect on its potential contributions to the sustainable prevention of musculoskeletal disorders (MSDs).

We conducted a systematic literature review based on Walker and Avant's (2011) concept analysis method. A search in nine bibliographic databases were performed using key terms related with work (employees, workplace, job), sustainability (i.e. durable, sustain), and OHS (i.e. prevention, well-being, rehabilitation). The search was limited to literature in French and in English published from 2000 to 2022. Documents were coded using NVivo software. The thematic analysis of explicit definitions was based on the three pillars of sustainable development

(social, economic and environmental) as well as temporal benchmarks and workplace-related elements.

A total of 67 documents with explicit definitions in the field of OHS were referenced. In prevention, the most frequently used term is “sustainable prevention” (n=6), which applies equally to the prevention of MSDs, psychosocial risks and accidents. We also find the following usages: sustainable employment (n=5); sustainable work (n=5); sustainable health (n=4); program or intervention sustainability (n=3); sustainable well-being (n=2); corporate sustainability (n=2); sustainable production system (n=1); human sustainability (n=1); sustainable management (n=1) and sustainable performance (n=1). In rehabilitation, “sustainable return to work” (n=28) is the most common usage. Definitions are heterogeneous but several attributes are interesting for MSDs prevention. For instance, the concept of sustainable work (Crawford *et al.*, 2016; Boudra, 2016; Zink, 2014; Bolis *et al.*, 2014; Bäckström, 2006) refers to avoid pressures and constraints that are harmful to physical and mental health, to ensure good quality working conditions, to realize decent work, across the worklife course. As workplaces are ecosystems with macro-organizational determinant influencing the occurrence of disorders, all the concepts present interesting elements for the sustainable prevention of MSDs. Unfortunately, the definitions identified are rarely accompanied by case studies.

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KEY WORDS

Nursing assistants | Aging | Geriatrics | Musculoskeletal disorders | Job retention

Prevention of Musculoskeletal Disorders in Nursing Assistants Aged 50 and Over Working in Geriatric Settings



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The aging of the general population represents a major public health and societal challenge. The demographic transition and the increase in retirement age pose new challenges to work organization. In this context, health-care professionals, particularly nursing assistants, face demanding working conditions that may negatively affect their health and compromise their job retention (Curchod 2012). Nursing assistants, who are predominantly exposed to physically strenuous work, are at a high risk of developing musculoskeletal disorders (MSDs) (Walton et Rogers 2017). The onset of these disorders can lead to numerous difficulties and jeopardize their ability to remain in the workforce.

In this context, we conducted a systematic literature review on Scopus and PubMed, focusing on studies examining the working conditions and health status of nursing assistants aged 50 and older working in geriatric settings. As part of this larger project, we specifically examined the theme of MSDs and the preventive measures proposed by the authors.

A total of six articles were included in this review, four of which addressed MSDs. Results showed that 88.4% of nursing assistants reported at least one MSD, with associations identified between MSDs and age, shift work, or high psychosocial demands inherent to the profession. Regarding preventive measures aimed at reducing the risks associated with physically demanding work, proposed strategies included the acquisition of appropriate handling equipment, implementation of collective warm-up and stretching programs, and work reorganization to reduce physical strain.

Developing and implementing targeted preventive measures to reduce MSDs appears essential to ensure the continuity of high-quality care in geriatric settings and to prevent premature occupational wear among these professionals. The effectiveness and cost-efficiency of these proposed measures should be further evaluated through health economic studies.

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POSTER SESSION

KEY WORDS

MSD | Aeronautic | Prevention | Pain | Risk

MSD prevalence and associated occupational risk factors among workers in an aeronautic paint-sealing plant: comparison of two sectors

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Background

Musculoskeletal disorders (MSDs) represent a major public health concern in occupational settings. In the aeronautics sector, tasks often involve repetitive work, constrained postures, and confined spaces, increasing MSD risk. Risk factors have been studied among aircraft mechanics and maintenance technicians, but to our knowledge, never among sealers and painters (Ramlee *et al.*, 2025). This population is exposed to precise manual tasks requiring high quality standards, as their work is directly related to aircraft safety. This study aimed to evaluate the prevalence of MSDs among sealers and painters in the aeronautics industry and to identify associated risk factors.

Methods

A cross-sectional study was conducted among 47 sealer-painter workers from two different sectors (A and B) from April to June 2024. The two sectors were characterized by distinct work organizations. Sector A operated under a paced work rhythm with task rotation every 86 minutes, whereas Sector B followed a self-paced rhythm over a 7-hour workday. Work activities also differed by aeronautical programs: Sector A involved simple parts from a single aeronautical program, while Sector B handled complex parts from multiple aeronautical programs. An anonymized Nordic Musculoskeletal Questionnaire (NMQ) was distributed to all workers. MSD prevalence rates were calculated, and comparisons between two sectors were performed using parametric tests, chi-square test, and logistic regression to identify factors associated with MSDs.

Results

All workers (n= 47) responded to the questionnaire. The majority was men (94%), with an age of 35± 9 years, 10± 6 year of experience in the plant and 9± 6 at the work station. Overall, 96% reported musculoskeletal pain in relation with their work in the past 12 months with 3.5±2 anatomic localisation affected low back pain 81% (intensity 7 [IQR : 5.0-7.0]), knees 60% (7 ± 1.75), neck 55% (5 ± 1.94), upper back 34% (5 ± 1.68), Wrists/hands 22% (4 ± 2.94) and arms 13% (2 ± 1.21). No significant differences were observed between the two sectors regarding age, experience in the plant, or pain intensity. In contrast, workers from sector A reported a greater number of painful body localisation (4.3±2.3 vs 2.8±1.6; p=0.014), with higher prevalence of low back pain (p=0.005) and forearm pain (p= 0.036). Logistic regression revealed no significant association between MSDs occurrence with age, seniority or sectors.

Conclusion

Pilot study, first in this industrial field. Pain distribution varied by sector, emphasizing the need for tailored ergonomic interventions to mitigate MSD risk.

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KEY WORDS

Musculoskeletal disorders | Dynamic | RULA | Ergonomics | Workload

An approach to physical workload quantification by dynamic parameters investigation



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The prevention of musculoskeletal disorders in industry relies mainly on an assessment of the physical workload caused by a situation or workstation. The workload quantification is most often based on field observations by ergonomists and on ergonomic risk assessment methods such as RULA (McAtamney *et al.*, 1993). These methods are simple and quick to apply but suffer from several limitations: a high sensitivity to input data (Joshi and Deshpande, 2021), a representation of risk that is difficult to interpret (Huang *et al.*, 2024) and a postural analysis that does not take into account the dynamic aspects of the industrial context. Advances in motion capture technology now enable to model the human body with varying degrees of details and access biomechanical parameters to complete this assessment, in particular by automating their application or computing dynamic parameters (Jiang *et al.*, 2024). The aim of this study was therefore to investigate how the observation of dynamic parameters at joints could inform on the physical workload. Indeed, joint dynamics could provide an accurate and continuous indicator of the strains generated by movements, postures and load carrying, capable of overcoming the limitations of RULA scores.

The study was based on the ENSAM Pose Lifting dataset (Jiang *et al.*, 2024; CPP 06036, Ile de France VI). It consisted in 12 subjects performing a load lifting/lowering task while being recorded by a marker-based motion capture system

and completed with biplanar radiographs (EOS). These data were used to calculate kinematic and inertial parameters for each task and each participant. Then, joints forces and moments were computed by bottom-up inverse dynamics using force platform data. Finally, the RULA method was automatized by defining joints angle according to ISB recommendations, based on surface markers position data, to obtain a score for each acquisition frame.

The RULA score and some dynamic parameters were compared using Spearman's correlation test. Total ground forces demonstrated a significant medium to strong correlation with the RULA score (0.4 to 0.7). Since RULA is a method specific to the upper limbs, the forces and torques generated by the upper limbs at the L5S1 joints were estimated. These efforts were similarly correlated with the score as measured by total effort. However, moments norm at L5S1, which were only weakly correlated at ground, were significantly and strongly correlated with RULA score with a Spearman's rank correlation R_s mostly above 0.7. **Figure 1** illustrates the correlation for the subject 12 and across all acquisitions.

To conclude, joint dynamics could be a complementary and useful indicator to ergonomic scores and useful for generalizing assessment methods for all types of tasks and for addressing issues of individual consideration in risk assessment.

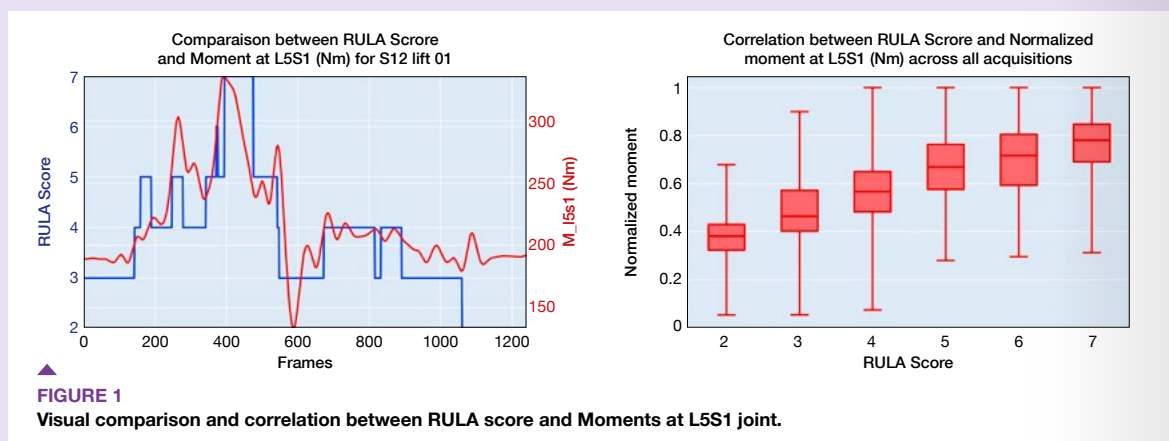


FIGURE 1 Visual comparison and correlation between RULA score and Moments at L5S1 joint.

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POSTER SESSION

KEY WORDS

MSDs | IMU | EMG | Kinematics | Clustering

Methodological consideration of a physical ergonomics intervention in real working conditions, application to cooperage work

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Musculoskeletal disorders (MSDs) are characterized by a multifactorial aetiology, which complicates the precise identification of their causal factors. This challenge is further exacerbated by the dynamic and often non-linear interactions among these factors. Regardless of their nature, working conditions directly impact the worker's body, particularly the neuromuscular system, whose anthropometric characteristics influence its response to mechanical stress. In this context, studying physical activity emerges as a relevant approach. Recent technological advancements, particularly the development of compact and non-obtrusive embedded sensors, enable real-time measurement of physical parameters related to muscle and joint activity under ecological conditions. Among the most effective methods for this purpose are electromyography and kinematic analysis using inertial motion units (IMUs) (Ross *et al.*, 2017). However, the lack of standardization in ecological study conditions necessitates the development of methods that account for the diversity of actions and the non-stationarity of collected data (Buttelli *et al.*, 2014). It is therefore essential to establish an efficient methodology for both data acquisition and processing. This paper presents an approach designed to achieve these objectives, facilitating a comprehensive field study of physical activity. We illustrate this methodology through a case study of coopers assembling barrels, an occupation particularly susceptible to MSDs. The cooper's barrel assembly process involves manually positioning six steel hoops around staves. The hoops are fastened ('hooping') by hand using a hammer, while the cooper moves around the barrel. The cooper also regularly checks and

adjusts the horizontal ("levelling") and vertical ('ballasting') alignment of the staves, often bending over and hammering directly. This physically demanding work involves standing, bending over, hammering repeatedly. Thus, the nature of the muscular contractions performed is not only dynamic, but above all static, particularly in the back-muscle groups involved in postural activity, and also in the forearm for hammering work. These conditions significantly increase the risk of developing MSDs, (Buchanan *et al.*, 2016). To start, a preliminary study was conducted using a view camera to capture the natural scene in the aim to evaluate the main muscular and postural constraints during cooper activities. Subsequently, whole-body segmental kinematics were recorded using inertial measurement units (IMUs), synchronized with electromyographic (EMG) activity from muscles selected based on the preliminary study. The use of IMUs is not limited to quantifying the time spent in critical angular ranges following ISO 11226 ISO standard. When synchronised with EMG measurements, they not only allow EMG data to be analysed according to angular ranges of activity, but also, thanks to non-supervised clustering methods, the kinematic data set enabled automatic classification of the postures and movements associated with the "hooping", "equalisation" and "ballotage" phases. This classification is particularly relevant, as visual analysis of these phases is difficult due to their non-sequential nature. Thanks to this approach, we were able to cross-analyse the EMG results and joint angles according to the different phases identified, thus providing a more detailed understanding of the biomechanical and muscular constraints involved.

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KEY WORDS

Musculoskeletal disorders | Midwife | Occupational health doctor | Prevention

Prevalence of musculoskeletal disorders among midwives: study conducted in Rabat (Morocco)



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Introduction

Musculoskeletal disorders represent a major occupational health issue, being the leading cause of sick leave. The healthcare sector, with its various professional categories, including midwives, is a high-risk sector for developing this occupational disease. Hence the importance of implementing prevention strategies tailored to the nature of this risk in order to manage it effectively and avoid its negative impacts.

Objective

To determine the prevalence of musculoskeletal disorders among midwives and their location, as well as their predisposing factors.

Methods

We conducted a descriptive cross-sectional study among midwives practicing at the Rabat University Hospital maternity ward over a period of three months. Information was collected using a self-administered Nordic questionnaire, which contained two sections: the first on socio-professional characteristics and the second on the assessment of musculoskeletal disorders.

Results

Our population consisted of 30 active midwives working in the delivery room of the maternity ward with a response rate of 100%, an average age of 33.7 ± 5.81 years, and 66.7% of whom were married. The majority of these midwives were overweight, with a body mass index of $28.9 \text{ kg/m}^2 \pm 4.91$. The average length of service in the position was 10.2 ± 6.08 years. Childbirth was performed by 93.3% of midwives, with an average number of deliveries per month of 274 ± 69.7 . In our population, during the last 12 months, 73.3% of midwives reported complaints in the neck and shoulder area, 57% in the shoulder area and 66.7% in the ankle/foot area.

In our series, the presence of symptoms in the shoulder and neck/nape of the neck over the last 12 months was significantly associated with performing deliveries. Furthermore, obesity was significantly associated with problems in the ankles/feet over the last 12 days.

Conclusion

Our study showed a high prevalence of symptoms, especially in the upper limbs (neck and shoulders) among midwives. These results highlight the importance of implementing technical and medical preventive measures for this professional category, based on risk mapping.

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POSTER SESSION

KEY WORDS

Motor variability | Biomechanical risk factors | Human-Machine Interactions | Workstation design | Motion analysis

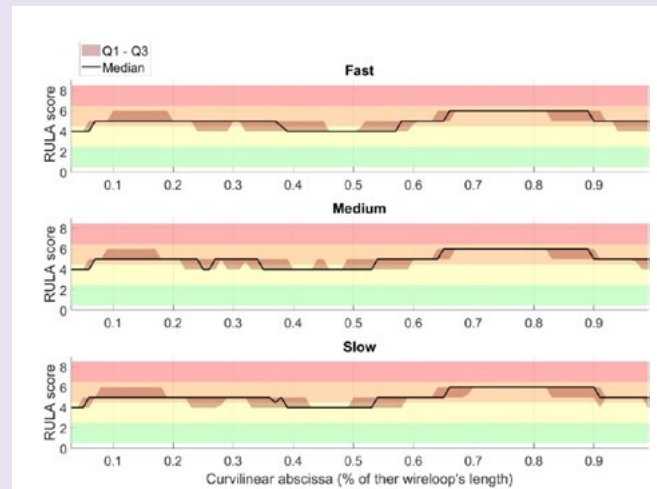
How motor variability influences the assessment of biomechanical risk factors of a trajectory-tracking task



J. Savin¹, C. Becques² and P. Maurice²

Motor variability (MV) is an essential feature of human movements. It stems from the large kinematic and actuation redundancy of the human body, as well as from possible redundancy at task level (Latash, 2012). At the workstation, it results in operators using different motor strategies (muscle activations, postures and joints coordination) to execute a given task. Studies suggest that MV could have beneficial effects against work-related musculo-skeletal disorders (WMSD) risks, by modifying the load distribution on the human body over time (Srinivasan & Mathiassen, 2012). Preserving operators' MV is then a major concern, even more so when deploying collaborative robots (cobots) which may reduce operators' ability to use their MV. We therefore launched a research project to investigate how upper-limb kinematic MV is influenced by the use of a cobot. In this paper, we report the analysis of MV in a trajectory-tracking task in the baseline condition (i.e. without cobot).

Nine right-handed female subjects participated in the experiment, which was approved by Inria's ethical committee (COERLE) and conducted according to the Declaration of Helsinki. Participants were asked to move a manual handle along a wireloop (about 50x25 cm) alternating curved and straight sections. They had to complete the task at a prescribed pace displayed with a light signal (Fig. 1). The handle was fixed on a passive mechanical device that could move along the wireloop such that participants only had to control



▲ FIGURE 2

Distribution of RULA scores (median: black line, interquartile range: shaded area) across participants and trials for the forward direction in the 3 different paces.

the speed. The handle was also free to rotate around the axis of the wireloop; the task thus imposed 5 spatial constraints. Since the human upper-limb is usually modelled as a 7-degree of freedom (DoF) system, participants could benefit from 2 DoF of redundancy when performing the task, which allowed for MV. Participants performed the tracking task both in backward and forward directions, in 3 pace conditions (5, 12 and 20 cm/s) with 20 trials each.

Participants' right upperlimb kinematics was recorded with a 3D motion capture system, and processed to extract joint angles. The RULA score (McAtamney & Corlett, 1993) was then computed along the path (defined by the curvilinear abscissa s) for each trial. Results show that, even within one condition (pace and direction), variability in participants' posture across trials leads to a distribution of RULA scores covering several levels of risk (Fig. 2). For instance, for $0.25 < s < 0.45$ in the fast pace, the RULA score varies from moderate to high risk. This finding highlights that neglecting MV may lead to underestimating occupational risk factors; in contrast, accounting for MV would improve MSD prevention.



◀ FIGURE 1
Experimental set-up. Participants moved a handle along a wireloop to match a reference pace given by the green light signal.

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KEY WORDS

Exoskeletons | Musculoskeletal disorders | Ergonomics | Human-centred design | Risk assessment

Industrial Exoskeletons: Technological Innovation and Integrated Strategy for the Reduction of Biomechanical Risks in the Workplace. Strength and Weaknesses



C. Vignola¹

Background

Work-related musculoskeletal disorders (MSDs) remain a leading driver of lost work ability and costs (EU-OSHA, 2019). Industrial exoskeletons can reduce biomechanical load and improve posture and productivity, but sustainable prevention demands integrated strategies rather than device-only fixes.

Objective

To present a pragmatic, human-centred framework that helps decide when and how to introduce occupational exoskeletons as part of MSD prevention, and to summarise the most robust benefits and limits reported in the last decade.

Methods

This synthesised peer-reviewed evidence and authority reports (e.g., UNI/TR 11950, 2024; De Looze *et al.*, 2016; Toxiri *et al.*, 2019) on device classes, task–user–environment fit, acceptance, and safety. It translates this corpus into a decision path comprising: task-level risk analysis; matching of device assistance to task biomechanics and user anthropometry; training that develops postural awareness; monitoring and maintenance; and an impact function $I(x)$ combining probability and severity to compare options.

Results

Evidence indicates meaningful reductions in back load during material handling and constrained postures, with reported sector-specific productivity gains, yet benefits are task-dependent and never a substitute for ergonomic redesign (De Looze *et al.*, 2016; Kim *et al.*, 2018; Schmalz *et al.*, 2019; Toxiri *et al.*, 2019). Acceptability hinges on comfort, correct configuration and gender/age anthropometrics; cognitive load and proprioception can be affected and must be managed by training and workflow design (EU-OSHA, 2019). We also highlight an intergenerational value proposition: early prevention in young workers can reduce the long-term MSD burden, supporting workforce resilience (EU-OSHA, 2019).

Conclusion

The framework operationalises sustainable adoption of exoskeletons as complementary measures, aligning prevention, productivity and worker well-being, and is ready to support pilots and evaluation in logistics, construction and healthcare.

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POSTER SESSION

Evaluation Concept for the Analysis of Shoulder Load in Over-Shoulder and Overhead Workstations in the Automotive Industry by Combining Optical Motion Capture and Force Measurements



M. Hinz and R. Hensel-Unger

Background

Musculoskeletal disorders are among the most common causes of work-related absences. Shoulder complaints occur particularly frequently in the manufacturing sector. Repetitive movements involving shoulder flexion or abduction above 60°, combined with exerted force, are considered key risk factors. The aim of this study was to analyze the duration during which shoulder load exceeded critical thresholds (see Methods) and to examine how various factors—such as shoulder angle, applied force, and body height—affect this duration.

Methods

Load intervals and their effects on the shoulder joint were examined during the task “*front hood opening*” in vehicle assembly. Increased load was defined as a shoulder angle > 60° and a hand force > 49 N. Only loads above these thresholds were included in the analysis. Fifteen participants performed the movement ten times under laboratory conditions. Kinematics were recorded using a motion capture system (ART) and modeled in the biomechanical software *Dynamicus* (ALASKA environment). Hand forces were calculated via inverse dynamics based on kinematic and ground reaction force data. Statistical analyses were conducted in R Studio using linear mixed models.

Results

No significant upward trend in load duration across repetitions was found ($\beta_1 = 0.0067s$; $p > 0.05$). Models accounting for interindividual effects showed a better fit (AIC = 109.28 vs. 144.99; $p < 0.05$). Larger shoulder angles ($\beta_1 = 0.012s$; $p < 0.05$), higher hand forces ($\beta_1 = 0.003s$; $p = 0.037$), and shorter body height ($\beta_1 = 0.03s$; $p < 0.05$) significantly increased load duration above the defined thresholds (range = 0–2.8s; median = 0.3s; mean = 0.4s). The shoulder moment during critical load intervals ranged from 21.3 to 50.6Nm (mean = 30.5Nm; median = 30.2Nm).

Discussion

Interindividual differences indicate varying movement strategies among participants. Increased shoulder angles, higher applied hand forces and shorter body height were linked to prolonged load durations, suggesting less favorable postures. These findings highlight the need for ergonomic adjustments in real-world assembly processes to reduce shoulder strain and promote sustainable working conditions.

KEY WORDS

Occupational exposure | Biomechanical | Job-exposure matrix | Occupational health services | Epidemiology

Exposure to biomechanical factors: how complementary are exposure reported by healthcare professionals and job-exposure matrices? Example of the Centre-Val de Loire County



M. Murcia-Clere¹, H. Willem¹, A. Descatha^{2,3}, Y. Roquelaure², J. Bodin² and M. Fadel²

Monitoring biomechanical occupational exposures is crucial for preventing musculoskeletal disorders (MSDs). While surveys and cohorts are valuable, their feasibility is limited. Occupational health services (OHS) routinely collect exposure data, but these are constrained by coding practices and data exhaustivity. Job-exposure matrices (JEMs) are widely used in research but rarely in clinical practice. This study compares biomechanical exposure assessments from OHS records (ACACIA database) and a biomechanical JEM (JEM CONSTANCES) to explore their complementarity and relevance for occupational health practice.

The study used the ACACIA database from the Centre-Val de Loire County (Gaillard J.F. *et al.*), an adjusted database covering 152,173 employees in 2023 who had appointments with occupational physician or nurses. Biomechanical exposures (e.g., standing, kneeling, carrying weights, repetitive actions) were extracted from OHS records and compared with JEM-CONSTANCES (Evanoff *et al.* 2019) after matching. Four methods were tested: (M1) Direct exposure percentages from ACACIA, (M2) Extension of exposures for jobs with >25% exposed workers from ACACIA, (M3) JEM assessed exposures applied to the ACACIA population and (M4) Combination of M2 and M3. Results were compared to national surveys percentages (SUMER 2016–2017, Evrest 2022–2023).

Exposure assessments varied significantly by method. (M1) often underreported exposures (e.g., <2% for arms above shoulder, arm abduction) compared to JEM-CON-

STANCES (7–38%). Conversely, physical intensity and load carrying were more frequently reported in ACACIA (33–64%) than in JEM (6–28%). Methods M2 and M4 yielded higher exposure rates than national surveys for some exposures. Computer use and repetitive work showed similar rates across methods, with increases in M2 and M4.

The study highlights the complementarity of OHS data and JEMs. OHS records reflect clinical expertise and local specifics but could be limited by coding heterogeneity and time constraints which limits exhaustive coding. JEMs provide systematic, occupation-based exposure estimates but lack intra-job variability. Combined use could enhance exposure assessment, supporting both clinical and epidemiological approaches in MSD prevention. Limitation included matching exposures between methods, the qualitative comparisons and the representativeness of the results. Workshop discussions with OHS professionals revealed that coding practices are influenced by perceived exposure, employee symptoms, and job knowledge.

The combined use of OHS data and JEMs offers a promising approach to improve biomechanical exposure assessment. Future research could explore other occupational risks (e.g., chemical agents) and expand to broader populations. This study highlights the potential of combining routinely collected data by OHS data with standardized tools to advance occupational health monitoring and prevention strategies.

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POSTER SESSION

KEY WORDS

Musculoskeletal disorders | Back pain | Absenteeism | Low | Sick leave

Musculoskeletal disorders as a major determinant of hospital absenteeism at the Ibn Rochd University Hospital in Casablanca

A. Hammal¹, S. Soltani¹, I. Mazroui¹, M. Es-Saadi¹, S. Lekbiri¹, A. Omali¹, F. Darid¹ and K. Wifaq¹

Introduction

Musculoskeletal disorders (MSDs) represent one of the leading causes of occupational morbidity worldwide, particularly in hospitals. They include a wide range of conditions affecting muscles, tendons, nerves, vessels, and joints [1]. MSDs often cause functional limitations, psychological strain, absenteeism, and can severely restrict mobility and dexterity, leading to reduced productivity, premature retirement, lower well-being, and decreased participation in daily life among workers [2]. These disorders significantly affect both individual health and quality of life. Moreover, they contribute to significant organizational and economic challenges, including disruption of work teams, increased turnover, and substantial costs related to sick leave, compensation, and medical care [3].

The objective of this study is to assess the impact of MSDs on absenteeism among hospital professionals at the University Hospital by determining the average number of workdays lost. This study also aims to identify the most frequently affected anatomical locations, as well as the main occupational risk factors associated with the occurrence of MSDs.

Methodology

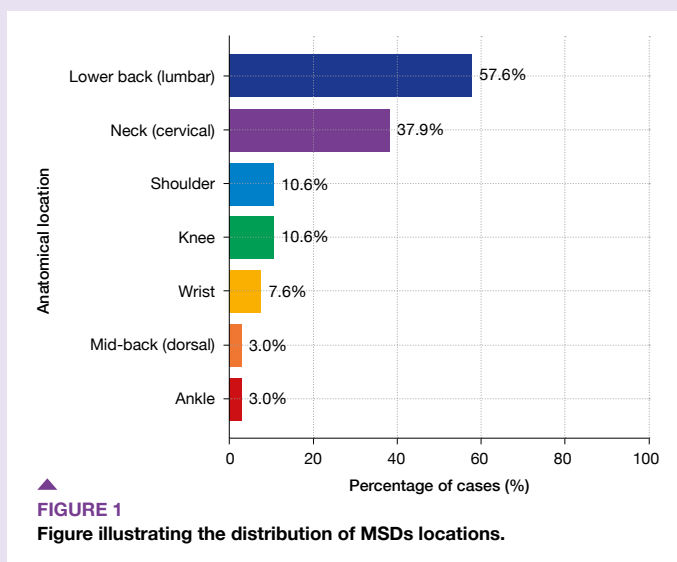
This descriptive cross-sectional study was conducted on 767 employees medical records from the Occupational Health Department of Ibn Rochd University Hospital, Casablanca, collected between January 2024 and October 2025.

These records corresponded to workers who attended medical examinations following sick leave. Among them, 66 cases of sick leave related to MSDs were identified. The variables examined included sociodemographic characteristics (age, gender, marital status, education level), absenteeism parameters (number and duration of absences, medical reasons, workplace accommodations), as well as key occupational risk factors (organizational and biomechanical). Data were extracted from medical files and analyzed using JAMOVI statistical software.

Results

The average age of the employees in our study was 34.1 years, with a marked female preponderance (86.4%). From a sociodemographic perspective, 47% were single, 44% married, and 9% divorced. The majority had completed higher education corresponding to Bachelor's or Master's degrees (Bac+3 to Bac+5). Most cases concerned paramedical staff (nurses, nurse assistants, and paramedical technicians). The average seniority is 9.4 years. Most employees (42%) had less than 5 years of experience at the hospital, while only 15% had more than 20 years of seniority. The most represented departments were Emergency Services (16.7%), Operating Rooms (15.2%), followed by Radiology (9.1%). The Body Mass Index (BMI) was calculated for 50 out of 66 cases (due to missing data for others), with a mean BMI of 24.3 kg/m². Only 10.3% of employees reported engaging in regular physical activity. Regarding organizational factors, 57.6% of employees worked more than 44 hours per week. In addition, 7.6% were assigned to permanent night shifts (one night every two days). Among the remaining 92.4%, most performed rotating night shift, with an average of two-night duties per month and a 12-hour recovery period after each duty, representing 97% of night-shift workers. Concerning the biomechanical factors identified, manual handling of heavy loads and prolonged standing were reported in 50% of cases, while constrained postures were observed in 54.5%. Repetitive movements were documented in 27.3% of cases. Among the 767 analyzed records, 66 cases of absenteeism were attributed MSDs, representing a rate of 8.6%. They predominantly affected the lumbar spine (57.6%) and cervical spine (37.9%). The shoulders were also frequently affected (10.6%), followed by the knees (10.6%), and wrists (7.6%). The mean duration of MSD-related sick leave was 18.1 days per person. On average, each worker submitted about 1.7 medical certificates per year, with values ranging from 1 to 15.

Low back pain and lumbosciatica were the leading causes of sick leave (38% of cases), followed by neck pain and cervico-brachial neuralgia (25%). Shoulder tendinopa-





thies represented the third most frequent cause (14%), while knee pain and other conditions were less frequent. A job adjustment was implemented in 7.6% of cases, primarily consisting of recommendations to avoid heavy lifting, constrained postures, and prolonged standing. Job transfers were necessary in 4.5% of cases. The majority of workers who benefited from a job adjustment or transfer did not experience further sick leaves following the modification of exposure conditions. However, three individuals experienced recurrent MSD-related absences.

Discussion

The mean age of participants (34.1 years) is consistent with findings from several African studies, which describe a young healthcare workforce aged between 30 and 40 years [4,5]. This reflects both a rejuvenation of hospital personnel and an early exposure to MSD risk factors within a context of staff shortages and intensified workloads. The female predominance (86.4%) observed aligns with the gender composition of most healthcare settings, where women represent more than two-thirds of paramedical staff [6]. This overrepresentation highlights the increased exposure of women to MSD-promoting conditions, due to the double burden of professional and domestic work, as well as physiological gender differences [7]. The high educational level (62.1% holding Bac+3 to Bac+5 degrees) reflects a well-qualified workforce. The average seniority of 9.4 years suggests chronic exposure to hospital physical constraints, including patient handling, prolonged standing, and repetitive movements. These factors — particularly static postures, load lifting, and trunk flexion — are recognized determinants of MSDs [8,9]. The mean BMI (24.3 kg/m²) indicates a trend toward mild overweight, a known risk factor for low back and joint pain [10,11]. The studies have demonstrated that excess body weight increases mechanical stress on the spine and peripheral joints, thereby exacerbating pain symptoms [9]. The most represented departments were Emergency Services (16.7%), Operating Rooms (15.2%), followed by Radiology (9.1%), reflecting a predominance of employees exposed to high physical workload environments such as surgical, imaging, and emergency units [3,5]. From an organizational standpoint, extended weekly working hours (>44 h for 57.6% of staff) and the frequency of night shifts act as aggravating factors. Shift work and insufficient recovery time are validated risk factors in both European and African reports, as they heighten muscular fatigue and the

likelihood of chronic MSDs [3,4]. In this study primarily they affected the lumbar spine, followed by the cervical spine and shoulders. This distribution differs slightly from international data, where MSDs typically affect the lumbar spine, shoulders, and then the neck region [3,4].

Low back pain and lumbosciatica were the most frequent causes of absence accounting for 38% [12,13], followed by neck pain (25%) and shoulder tendinopathies (14%). This distribution mirrors international trends, where low back pain remains the leading MSD, with an average prevalence of 57% in Africa [4,12]. The mean sick-leave duration in our population (18.1 days) was lower than that reported in international studies (32.1 days per worker) [3], but was relatively close to the period during which most workers (1–15 days) were absent from work due to ill health [14]. This discrepancy may be explained by earlier medical management of MSDs in our context or by institutional and organizational differences. Furthermore, the presence of 1.7 sick leaves per worker highlights the chronic and recurrent nature of MSDs, consistent with EU-OSHA findings describing these conditions as often relapsing and difficult to reverse [3]. However, the limited rate of job adjustments (7.6%) and transfers (4.5%), combined with the absence of recurrence in most adapted cases, confirms the effectiveness of ergonomic and organizational interventions.

Nevertheless, the persistence of recurrent cases underscores the need for continuous medical and ergonomic follow-up, as recommended by European occupational health guidelines [15].

Conclusion

MSDs constitute a major occupational health issue within the university hospital settings, with a direct impact on absenteeism.

The female predominance and young age of the workforce indicate early and prolonged exposure to risk factors in the absence of adequate preventive strategies.

It is therefore essential to strengthen preventive culture through regular ergonomics and posture training, periodic assessments of biomechanical and psychosocial risks, and the implementation of enhanced medical surveillance for exposed personnel.

A sustainable institutional prevention policy would reduce both the frequency of MSDs and the duration of sick leaves, thereby improving quality of work life and overall team performance.

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POSTER SESSION

KEY WORDS

Shoulder surgery | Return to work | Movement difficulty | Pain

Changes in movement difficulty and pain perception levels when returning to work/staying at work after shoulder surgery in an occupational context

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Context

Returning to work (RTW) after surgery for rotator cuff tendinopathy in an occupational context remains difficult and painful in a considerable proportion of cases. It is important to monitor movement difficulty and pain perception during the first few months after RTW in order to highlight both the benefits of surgery and the obstacles faced by salaried patients, especially in a context of heavy manual labour.

Methods

Individual and professional participants' characteristics were collected over five visits. Amongst the 96 participants followed-up from the preoperative stage until one year after RTW, 79 participants went back to work after rotator cuff surgery. They completed two monitoring notebooks; one just before RTW and during the first month, and one

during the fifth month after going back to work. Levels of perceived pain and functional discomfort in the operated shoulder were recorded using a visual analogue scale (pain) and a CR10 Borg scale (perception of movement difficulties). It was filled in twice a week at the end of the working day (one at the beginning (B) of the week and one at the end (E) of the week (W)). Participants' return to work/stay at work trajectory was categorized as being stable or unstable, based on the occurrence (or not) of sick leave(s) within one year of their initial return to work. Unstable trajectories concerned those that returned to work either temporarily or with one or more work stoppages during the follow-up period. Stable trajectories concerned those that returned to work until the end of the study, either full-time from the outset or by working part-time temporarily before returning to full-time work.

Results

Movement difficulty and pain levels in the operated shoulder decreased over time. The kinematics of stable and unstable trajectories were similar during the first and the fifth months. However, the movement difficulty and pain thresholds for unstable trajectories were significantly higher than for stable ones.

Conclusion

It is thus understandable that unstable trajectories encountered more barriers during their return to work/ stay at work process, especially in contexts of manual labour. Nevertheless, remaining patient was important since improvement of these shoulder symptoms was indeed observed — regardless of the trajectory — during the fifth month after RTW. It is important that companies and occupational health services are aware of these dynamics of pain and discomfort in order to adapt employees' return-to-work plans.

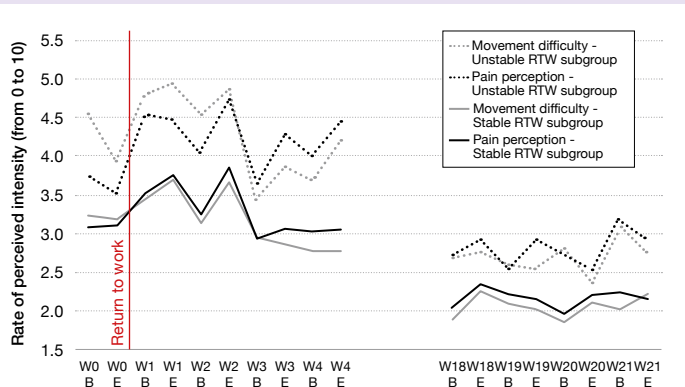


FIGURE 1
Perceived intensity of both movement difficulty and pain over time.

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KEY WORDS

Telework | Musculoskeletal disorders | Workstation | Ergonomics

Assessment of Ergonomic Conditions and Musculoskeletal Disorder Prevalence among teleworkers



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Introduction

The widespread adoption of telework, particularly accelerated by global events such as the COVID-19 pandemic, has fundamentally reshaped occupational landscapes (Gualano *et al.*, 2022). While telework offers advantages such as reduced commute times and increased flexibility, it also introduces unique challenges related to occupational health and safety. A prominent concern involves the potential for an elevated incidence of musculoskeletal disorders (MSDs) among remote workers (Milaković *et al.*, 2023). Office workers, in general, face a heightened risk for MSDs due to prolonged computer use. The transition to working from home often means individuals utilize non-ergonomic home environments, lacking appropriate furniture and equipment, leading to suboptimal postures and increased physical strain (Cruz-Ausejo *et al.*, 2022; Radulović *et al.*, 2021).

This investigation aims to identify the prevalence of musculoskeletal disorders among teleworkers and to characterize the ergonomic conditions present in their home working environments.

Methods

A cross-sectional study design was employed to assess the current prevalence of musculoskeletal disorders and associated ergonomic factors among teleworkers. This approach allowed for a snapshot analysis of the health status and working conditions within the target population at a specific point in time.

The population of this study comprised individuals engaged in telework activities who accepted to participate.

Data were collected using a self-administered online questionnaire structured into several sections, primarily utilizing two validated instruments: the Nordic Musculoskeletal Questionnaire (NMQ) to identify the occurrence of musculoskeletal symptoms, and the Maastricht Upper Extremity Questionnaire (MUEQ) to assess the participants' workstation and posture.

Key variables included demographic information (age, gender), profession, telework duration, self-reported MSD symptoms and characteristics of the physical workstation and postures.

Results

The sample consisted of 54 participants. The sex ratio was 0.69, indicating a predominance of females. The mean age was 31.4 years. Most participants were employed in the service sector, with a predominance of occupations in information technology (IT) and auditing. The average tenure in the current position was 3 years, while the mean total professional experience was 8 years. The mean duration of teleworking experience was 3.9 years. The majority (68.5%) reported teleworking 2 to 3 days per week, with an average of 7.4 hours per day. A total of 64.8% reported having a dedicated workspace for telework, whereas only 42.6% used ergonomic furniture. Regarding occupational accident coverage during telework hours, 46.3% were covered, 24.1% were not, and 29.6% were unsure.

As for the proportion of musculoskeletal problems in each body region, lower back, neck, shoulders and upper back were the regions with the most complaints both in the last 12 months and in the last seven days, causing limitation to perform tasks (Figure 1).

Regarding the workstation, the majority of participants (87.0%) reported having a desk at an appropriate height. However, only 59.3% were able to adjust the height of their chair, and 33.3% indicated that their seat provided adequate lumbar support. Furthermore, 75.9% stated that their keyboard was positioned directly in front of them, and 81.5% reported that their screen was properly aligned. Finally, 81.5% considered their workspace to be sufficiently spacious.

Concerning body posture during work, a significant proportion of teleworkers reported sitting in an uncomfortable position either "Often" (29.6%) or "Always" (5.6%). Nearly one-quarter of participants found their work to be physically exhausting ("Often" 13.0%; "Always" 9.3%), and 24.1% reported that their trunk was in a misaligned or awkward position ("Often" 18.5%; "Always" 5.6%). Lastly, 40.8% of respondents performed repetitive tasks "Often" (35.2%) or "Always" (5.6%). (Table 1).

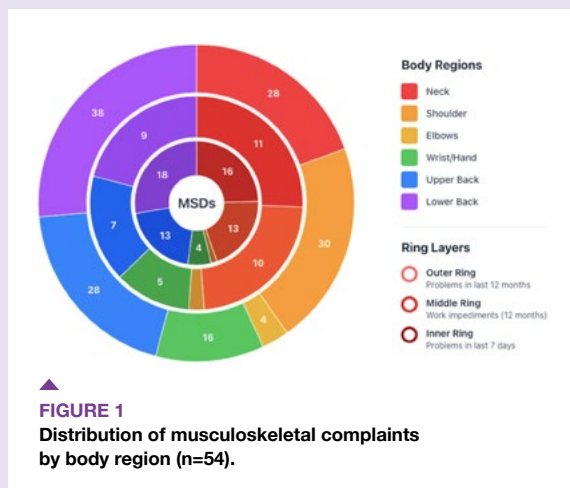


FIGURE 1
Distribution of musculoskeletal complaints by body region (n=54).

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WORKSTATION		
My desk (table) at work has suitable height.	Yes	87%
	No	13%
I can adjust my chair height.	Yes	59.3%
	No	40.7%
The chair I use during my work supports my lower back.	Yes	33.3%
	No	66.7%
My keyboard is placed directly in front of me.	Yes	75.9%
	No	24.1%
The screen is placed directly in front of me.	Yes	81.5%
	No	18.5%
I have enough space to work at my office.	Yes	81.5%
	No	18.5%
BODY POSTURE		
During my work, I sit in an awkward body posture.	Always	5.6%
	Often	29.6%
	Sometimes	46.3%
	Rarely	16.7%
	Never	1.9%
At work, I perform repetitive tasks.	Always	5.6%
	Often	35.2%
	Sometimes	44.4%
	Rarely	14.8%
	Never	0%
I find my job physically exhausting.	Always	9.3%
	Often	13.0%
	Sometimes	40.7%
	Rarely	27.8%
	Never	9.3%
My head is twisted towards the left or right.	Always	3.7%
	Often	18.5%
	Sometimes	37.0%
	Rarely	25.9%
	Never	14.8%
My trunk is twisted towards the left or right.	Always	1.9%
	Often	13.0%
	Sometimes	42.6%
	Rarely	25.9%
	Never	16.7%
My trunk is in a misaligned position.	Always	5.6%
	Often	18.5%
	Sometimes	44.4%
	Rarely	22.2%
	Never	9.3%

TABLE 1
Workstation conditions and body posture during telework.

Discussion

This study revealed a high prevalence of musculoskeletal disorders (MSDs) among teleworkers, predominantly affecting the lower back, neck, shoulders, and upper back. Similar findings were reported in Tunisia (Selma *et al.*, 2023), Ecuador (Larrea-Araujo *et al.*, 2021), and Brazil (Kadri Filho & de Lucca, 2022), where prolonged sitting and inadequate workstations were major contributors to pain. The predominance

of lower back symptoms in our study aligns with previous research describing the lumbar region as the most affected among teleworkers (Hong *et al.*, 2024; Santos *et al.*, 2021).

Regarding workstation ergonomics, despite most participants reporting a desk at an appropriate height, few had adjustable chairs or lumbar support. These findings are in line with previous studies showing that inadequate seating and non-adjustable furniture are major ergonomic deficits in home-based environments (Cruz-Ausejo *et al.*, 2022). A similar pattern was described by Kadri Filho and de Lucca (2022), who observed that many Brazilian teleworkers worked on non-ergonomic chairs or kitchen tables, leading to high ergonomic risk.

In contrast, most participants reported that their keyboard and screen were correctly positioned, suggesting partial ergonomic compliance. Similar results were found by Fadel *et al.* (2023), who noted that while many teleworkers respect certain ergonomic criteria, they often neglect key postural supports. Even minor misalignments, however, can exacerbate musculoskeletal strain over time (Baracho de Alencar *et al.*, 2025).

Our findings suggest that ergonomic interventions should prioritize adjustable furniture, adequate lumbar support, and postural education, as recommended across multiple international contexts (Hoe *et al.*, 2018; Radulović *et al.*, 2021).

Overall, the consistency between our results and those from diverse regions—including Latin America, North Africa, and Europe—supports the conclusion that telework poses universal ergonomic and musculoskeletal challenges. Targeted ergonomic training, coupled with psychosocial support and adequate workstation design, remains essential for sustainable telework practices.

Conclusion

This study confirms that musculoskeletal disorders remain highly prevalent among teleworkers. The persistence of these complaints across different professional and geographical contexts highlights the universal ergonomic challenges of remote work. To address these issues, preventive measures should prioritize the provision of ergonomic furniture, and ensure proper workstation setup through ergonomic assessments or self-evaluation tools. Occupational health professionals play a key role in identifying risk factors, raising awareness about proper posture and work practices, and implementing preventive interventions, thereby promoting the health and well-being of teleworkers.

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KEY WORDS

Climate change | Musculoskeletal disorders | Food processing | Socio-ecological challenges | Occupational health and safety

Climate change and musculoskeletal disorders: what are the links and challenges for food processing workers in Quebec?



C. Skrzypek¹, M.E. Major¹, N. Nicolakakis² and R. Lambert²

Rising temperatures and increased precipitation are among the most significant and plausible consequences of climate change in many countries, including Canada. These environmental changes and their associated phenomena can create hazardous situations and contribute to the onset or worsening of workers' health problems (e.g., respiratory, cardiovascular, and skin conditions) (Adam-Poupart *et al.*, 2013; ANSES, 2018). However, little is currently known about the links between climate change and hazardous situations for musculoskeletal disorders (MSDs). This is notably the case in the food processing sector, despite well-documented occupational health and safety (OHS) risks in this sector.

This study aimed to explore OHS risks pertaining to MSDs and work-related challenges experienced or anticipated in the context of current and projected climate change and related hazards (e.g., extreme weather events, ecosystem disruption, and socioeconomic shifts) among workers in meat and fruit and vegetable processing industries in the province of Quebec, Canada.

We aim to recruit ten companies from the meat processing (slaughtering and packaging) and fruit and vegetable processing sectors across three regions of Quebec. Semi-structured individual interviews (45–60 minutes) were conducted with employer representatives and employees (n expected = 45). Data were analyzed using an inductive qualitative approach and thematic analysis.

Preliminary findings suggest that participants find it difficult to identify the impacts of climate change in their daily work. Despite limited awareness of climate-related issues, their accounts reveal emerging challenges that may create or exacerbate risk situations for MSD development. For instance, variability in fruit quality due to prolonged droughts and heatwaves can lead to modifications in work practices, while the need to maintain product quality under time pressure may influence psychosocial and biomechanical exposures and the risk of MSDs.

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WEDNESDAY, 6 MAY 2026

KEYNOTE PRESENTATION (PM)

13:30 - 14:30 – AUDITORIUM 300, LEVEL 1

Research challenges in developing sustainable intervention strategies for the prevention of musculoskeletal disorders



F. Coutarel and M.-E. Major



Fabien Coutarel is full professor in Ergonomics at Clermont Auvergne University, in France. His research on the prevention of musculoskeletal disorders focuses primarily on the design and evaluation of ergonomic interventions, as well as methods for supporting technological innovations in the workplace.

Marie-Eve Major is full professor at Département des Relations Industrielles, at the University Laval (Quebec, Canada). She is a member of the Centre de recherche interdisciplinaire sur le bien-être, la santé, la société et l'environnement (CINBIOSE), the Réseau Communautés rurales et éloignées en santé (CARES-FRQS), and the research team Santé-Genre-Egalité (SAGE-FRQSC). She holds recognized expertise in ergonomics intervention-research on the prevention of musculoskeletal disorders (MSDs). Her work aims to better understand the various constraints – organizational, physical, psychosocial, temporal, and environmental – related to working and employment conditions. Anchored in an interdisciplinary and collaborative approach, her research supports the design, implementation, and evaluation of occupational health interventions aimed at fostering healthy work environments and enhance organizational efficiency. A central objective of her work on MSD prevention is to address and reduce social and sex/gender-related health inequalities in workplaces, with particular attention to populations employed in rural and remote regions and in sectors where prevention efforts face significant challenges.

Her projects on MSD prevention, conducted in collaboration with the different workplaces and partners from the sectors, are intended to support both workers and employers in developing and establishing working conditions that promote a healthy and sustainable workplace environment.

Musculoskeletal Disorders (MSDs) are a significant source of pain and limitation for many workers and one of the leading causes of work-related disability. In the European Union, MSDs are most often reported as the main work-related health problem, and in approximately three-quarters of those who work or have worked previously, MSDs result in some or considerable limitations in day-to-day activities at or outside of work (Eurostat, 2010). This issue is also prevalent elsewhere in the world. MSDs represent considerable economic costs and are associated with productivity losses for businesses. These human and economic costs will increase: the digitalization of work could lead to new combinations of constraints. For example, upper limb overload combined with sedentary postures, and fewer psychosocial and organizational resources. Given these repercussions, it is essential to examine the prevention interventions implemented in the workplace and to work with stakeholders to promote an informed approach to MSD prevention. Research on ergonomic intervention practice is needed.

To date, the scientific literature on ergonomic intervention is dominated by studies that do not examine intervention strategies, processes and contexts. Most of the literature reviews conclude that there is no evidence on effectiveness of ergonomic interventions, but the studies considered focus mainly on technical changes. Scientific

articles on interventions describe little to nothing about the context and processes of intervention. Also, several tools and grids exist for measuring exposure to MSD risks or for evaluating work-related constraints associated with MSDs. However, existing tools tend to blur the distinction between MSD risk assessment and ergonomic analysis of work activity. In addition, knowledge and tools specifically related to interventions and their implementation in the workplace remain limited.

A growing body of ergonomic literature focuses on the evaluation of complex interventions, namely interventions that are, among other things, closely linked to the context in which they take place, involve several interacting components, and in which various groups at different hierarchical levels are involved and may be motivated by conflicting rationales. Very few tools exist to specifically support and guide the implementation of interventions aimed at preventing MSDs in the workplace. Still, there is a greater acceptance that the implementation of MSD prevention interventions takes place within a socio-organizational context, with different actors that have their own issues which must be considered to engage significant changes in work. Understanding the contexts and processes of interventions is essential for informing interventions that produce the desired effects of MSD prevention.

PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (1)

14:30 - 15:30 – AUDITORIUM 300, LEVEL 1

Musculoskeletal disorders as an opportunity to foster a global approach to prevention

N. Balthazard, A. Perny.....P.69

MSDs in primary prevention: Reflective approach in inter-company occupational health and safety service

C. Zind, R. Codron.....P.70

Skill development of WMSDs ambassadors within member companies of an intercompany occupational health and prevention service in Lyon

M. Limoges, B. Rouzé.....P.71

02. ORAL COMMUNICATIONS NEW TECHNOLOGIES – *HUMAN ROBOT INTERACTIONS*

14:30 - 15:10 – ROOM 103, LEVEL 1

Biomechanical assessment of human-robot collaboration in virtual reality and on a real workstation

G. Personeni, D. Danilovskii, A. Savescu.....P.72

Measuring the Cognitive and Psychosocial Dimensions of Professional Gestures: A Method for designing Human-Robot Collaboration to reduce WMSD exposure

M. Krausz, A. Landry, A. Cherubini, M. Nstame Sima.....P.73

03. ORAL COMMUNICATIONS POPULATION AND SECTOR SPECIFIC APPROACHES – *DESCRIPTIVE STUDIES*

14:30 - 15:30 – ROOM 104, LEVEL 1

Evaluation of musculoskeletal disorders in a meat-processing plant: results of a cross-sectional study

N. Roger, T. Lelard, F. Telliez.....P.74

Typology of musculoskeletal occupational wear and tear: a latent class analysis in the CONSTANCES cohort

G. Morvan, J. Bodin, N. Fouquet, H. Bouziri, M.E. Major, Y. Roquelaure.....P.75

Return-to-work and retention of health and social care workers with MSDs: from research to practice

L. Munar, P. Berastegui.....P.76

03. ORAL COMMUNICATIONS SOCIO-ECOLOGICAL CHALLENGES

14:30 - 15:10 – ROOM 105, LEVEL 1

Agroecological transition and prevention of musculoskeletal disorders: a case study among organic vegetable farmers

S. Caroly, M.E. Major.....P.77

Cars dismantling in the context of ecological transition. An opportunity to design sustainable work?

W. Buchmann, O. Richal, B. Daille-Lefevre, A. Savescu, F. Barcellini.....P.78

PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (1)

14:30 - 14:50 – AUDITORIUM 300, LEVEL 1 – #56

KEY WORDS

Musculoskeletal disorders | Global approach | Organization | Work-based training | Occupational risks

Musculoskeletal disorders as an opportunity to foster a global approach to prevention

N. Balthazard¹ and A. Perny²

According to the French National Health Insurance (2023), risks related to physical activity, which may lead to Musculoskeletal Disorders (MSDs), are the main cause of work-related health problems. Although the multifactorial nature of these disorders is well established (Armstrong *et al.*, 1993; Da Costa & Vieira, 2010), their understanding within companies remains heterogeneous and limited. A report by the French Directorate General of Labour (Caroly *et al.*, 2007) highlights that etiological models are still mainly biomechanical and physiological. Moreover, new forms of work organization and increasing demands for individual performance have fostered the development of psychosocial risk factors (DARES, 2024). A DARES study (2023) shows that enhancing autonomy and social support helps reduce perceived work unsustainability, unlike conventional safety training. In addition, Yves Clot (2010) promotes a “clinical approach focused on work activity and the development of psychological and social resources”, which combines health and performance rather than opposing them (Salman, 2022).

This openness to a holistic approach led us to support two companies through a global prevention strategy addressing MSD risks. Management sought to improve working conditions based on a risk mapping of their organ-

ization. The proposed intervention began with a workshop involving members of the Steering Committees, focusing on their history, priorities, and prevention culture. It was also an opportunity to develop an approach adapted to their context, including skills transfer in physical activity risk assessment through Project Groups, field observations, and group interviews. Periodic summaries were presented to the Steering Committees, responsible for defining and monitoring the implementation of actions.

After two years, 31% of workstations have been analyzed, 14 actions implemented, and 15 are currently being deployed by the Steering Committees. Finally, 19% of major MSD risk situations have been improved.

Beyond the issue of MSDs, psychosocial risks were gradually integrated into the process. This included awareness sessions for one company's Executive Committee, on-site coordination with dedicated resources, the creation of dialogue spaces involving employees and employee representatives, and the management of urgent situations. The main outcome lies in the shift from a risk-specific approach, initially expected by the employer and occupational physician, to a global approach to prevention, promoted by the intervention team.

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (1)

14:50 - 15:10 – AUDITORIUM 300, LEVEL 1 – #46

KEY WORDS

Primary prevention | Job retention | Financial aspect | Work organization | Inter-company occupational health and safety service

MSDs in primary prevention: Reflective approach in inter-company occupational health and safety service



R. Codron¹ and C. Zind¹

Occupational health and safety activities focus on three areas: individual health monitoring, workplace initiatives, and job retention in various sectors and often small companies. Individual situations are most often the gateway to workplace interventions related to MSDs, whether it be the need for job retention, requests for equipment, PPE, etc.

Examples of ergonomic studies conducted for:

- Lower back pain attributed to the weight of cables among electricians,
- Request for suitable safety shoes for a cleaning agent,
- Search for redeployment for a driver suffering from a shoulder injury (occupational illness),
- Request for knee pads for a cosmetics manufacturing agent,
- Workstation adjustments for a bus exterior cleaner.

The same method is used: observations, interviews, metrology where applicable, reporting, and joint development of action plans.

All of our findings led us to reflect on the organization of work :

- Problems with site preparation,
- Incorrect assessment of workload,
- Poorly anticipated loading and routes,
- Poorly designed machine installed in unsuitable premises,
- Poor distribution of workload.

Feedback raises issues which, once resolved, have benefited the group as a whole.

Analysis of our experience leads us to question best practices for moving from individual to primary prevention action and implementing regulations.

What is needed to gain acceptance for an ergonomic intervention in the face of limited demand?

- A good knowledge of the company, made possible by the expertise and presence in the field of the prevention service, is essential
- A relationship of trust is built in particular by confronting the reality of the business and understanding the challenges facing the company and its employees.

How should we approach the restitution and co-construction of an action plan for the prevention of MSDs?

MSDs are multifactorial and their prevention is often complex in constrained work contexts. All these studies have shown us that organizational inconsistencies are detrimental to this risk but also a source of additional costs for the company. The financial aspect, rarely mentioned in occupational health, nevertheless attracted the attention of managers during the presentations. They recognized the value of working on the organization in light of our findings. And once the company takes up the issue, it becomes receptive to our support.

Thus, taking advantage of every opportunity to intervene, observing the reality of work in the field, analyzing the organization, and engaging in dialogue with the company to test an action plan that benefits both the company and its employees are the keys to sustainable primary prevention of MSDs. And for the SPSTI's multidisciplinary teams, these actions are in line with our mission of collectively preventing professional exclusion.

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (1)

15:10 - 15:30 – AUDITORIUM 300, LEVEL 1 – #98

KEY WORDS

Training | Participatory approach | Practical learning | Field support | Activity analysis

Skill development of WMSDs ambassadors within member companies of an intercompany occupational health and prevention service in Lyon

B. Rouzé¹ and M. Limoges¹

The current context of Intercompany Occupational Health and Prevention Services in France is leading health and prevention professionals to rethink their intervention approaches in order to better support member companies, in particular regarding work-related musculoskeletal disorders (WMSDs), which accounted for 86% of all reported occupational diseases in France in 2022 (CARSAT Rhône-Alpes, n.d.).

Skill Development of ambassadors first aims to strengthen companies' ability to act and promote a culture of prevention, as required by the French Labour Code (French Parliament, 2021). It also helps optimizing the contribution of occupational health teams in a context of limited resources relative to the number of member companies.

The WMSDs Ambassador Skill Development program targets employees within member companies and aims to train them on WMSDs, their contributing factors, a prevention approach (inspired by INRS guidelines), and how to lead this process.

The training includes three main stages:

- Creation of a steering committee within the company, responsible for identifying risks related to WMSDs factors and leading prevention initiatives. The committee is first educated about the basics of WMSDs prevention through an interactive board game.
- Theoretical and practical training for ambassadors, providing foundational knowledge, key skills, and tools necessary to lead a WMSDs prevention initiative.

- Field implementation, following the INRS intervention methodology, allowing ambassadors to apply their learning in real company situation. Ambassadors are supported by an ergonomist throughout the process: identifying work situations with the steering committee, conducting pre-observation interviews, performing activity analysis and diagnostic assessment, leading working groups, and developing an action plan.

Given the scope and complexity of WMSDs, a playful training format is used, combining simulations and case studies to help ambassadors:

- Understand the multifactorial nature of WMSDs and their physical impact in relation to work tasks (role-playing activities);
- Learn to identify determinants contributing to observed risk factors in various work situations (video analysis and story);
- Practice each step of the WMSDs prevention process using supporting tools (interview guides, activity analysis framework, task prioritization aids, and action plan templates).

A pilot phase was conducted in 2025 within Promeom, in collaboration with seven occupational physicians and their multidisciplinary teams experienced in ergonomic intervention approaches. The positive outcomes of this pilot encourage us to propose several training sessions to our member companies in 2026.

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KEY WORDS

Virtual reality | Motion capture | Collaborative robotics

Biomechanical assessment of human-robot collaboration in virtual reality and on a real workstation

G. Personeni¹, D. Danilovskii¹ and A. Savescu¹

In human-centered design, the intersection of ergonomics with immersive technologies presents particularly promising opportunities, as virtual reality (VR) technologies can further enhance safety prevention including musculoskeletal disorders (MSD) (Singh, 2025). These technologies enable detailed simulations of real-world environments, and allow for comprehensive biomechanical risk assessments early in the iterative design processes. Following this perspective, an experiment was designed to assess the ecological validity of a VR simulation with respect to the real manufacturing task assisted with a collaborative robot. We designed a virtual environment reproducing the real workstation (see *Figure 1*), and simulated the robot using the ROS framework (Robot Operating System). It allows to execute the real robot program with input from the virtual environment. In this collaborative workstation, the operator performs a task that involving assembling 5 different gears on a base piece and then bolting a cover on top. The robot can either work independently on a different piece, perform the first part of the assembly for the operator or hold the piece as the operator assembles the cover. The goal was to analyse how operator's postures, distance to the robot and task performance differ between real and virtual conditions. For that, a motion capture system was required that could be used in both conditions and synchronize with a capture of the real and virtual robot.

The Python OpenCV library was used for the calibration of cameras and video capture. Subsequently, we used Mediapipe, a computer vision framework built on machine learning, to process each video stream separately to pinpoint estimated joint centers as image coordinates on each



FIGURE 2
Camera frame with 3D joint centers and body segments overlaid.

frame. Using the projection matrices of each camera, image coordinates from a set of time-congruent frames were triangulated to obtain joint centers coordinates in 3D space (see *Figure 2* for an example). These coordinates could then be used to compute joint angles and the associated RULA score (McAtamney, 1993) frame-by-frame. In the real situation, the camera system is calibrated with respect to a fixed point of the robotic cell, allowing to locate the operator relative to the robot and workstation. In the virtual situation, the visual calibration pattern is fixed to VR trackers to align the coordinates system of the real cameras and virtual environment.

In a preliminary validation of the system, the activity of two operators in different collaboration modes and in virtual and real conditions was analyzed. It was found that RULA scores remain consistent across our different experimental conditions, hinting that our virtual environment is suitable simulation of the workstation and warrants further investigation. However, we identified several challenges and limitations while designing the virtual environment. In particular, while robotic simulation tools exist, we found no off the shelf solution that allows to accurately simulate the robot in VR and have it interact with the environment, sensors, workpieces and operator. Our task also involves workpieces and tool with negligible mass, further investigation with force-feedback and heavier parts would be required to assess how validity is affected. Considering the intersection of current limits of VR systems and the wide diversity of tasks, validation of the biomechanical assessment on the real workstation remains necessary.

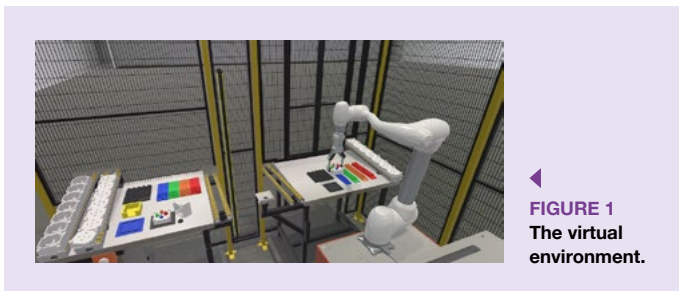


FIGURE 1
The virtual environment.

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PARALLEL SESSIONS (PM)

02. ORAL COMMUNICATIONS: NEW TECHNOLOGIES – HUMAN ROBOT INTERACTIONS

14:50 - 15:10 – ROOM 103, LEVEL 1 – #67

KEY WORDS

WMSD | Professional gestures | Collaborative robotics | Car bodywork

Measuring the Cognitive and Psychosocial Dimensions of Professional Gestures: A Method for designing Human–Robot Collaboration to reduce WMSD exposure

M. Krausz¹, A. Landry¹, A. Cherubini² and M. Nstame Sima³

Since 2021, with the emergence of 5.0 industry, questions surrounding new forms of work have become central. This paradigm seeks to redefine human–machine interactions through the introduction of new technologies such as collaborative robots. These machines, designed to interact directly with human operators (Knudsen & Kaivo-Oja, 2020), can increase productivity and quality but also lead to changes in work practices, task distribution, and operator safety. Consequently, they have a significant impact on professional gestures. These gestures, defined as meaningful, goal-directed movements (Leplat, 2013), are structured around three dimensions: biomechanical, cognitive, and psychosocial (Bourgeois & Hubault, 2005; Schoose, 2022). An imbalance between these dimensions can lead to development of musculoskeletal disorders (Buchmann & Landry, 2010). This raises a key question: how can the professional gesture and its dimensions be considered in the design of an appropriate robotic assistance solution?

This study proposes a method to assess the cognitive and psychosocial dimensions of professional gestures in order to complement approaches traditionally focused solely on physical strain. Self-assessment scales were developed to measure cognitive load (attention/accuracy, decision-making, and working memory) and psychosocial factors (satisfaction, perceived usefulness, quality of exe-

cution, speed of execution, and autonomy/freedom in task performance). A pre-questionnaire was also integrated to assess experts' perceptions of psychosocial factors and weigh their responses accordingly.

To test this method, the analysis focused on car bodywork tasks, a sector historically rooted in craftsmanship and known for its high prevalence of upper limb musculoskeletal disorders (8.7 ± 1.1 % of compensated injuries; IRSST, Marchand & Giguère, 2012). The work was segmented into three levels: tasks (goals to be achieved), professional gestures (sets of meaningful actions or movements), and movements (trajectories of body segments). A detailed activity analysis was conducted to identify processes and structure the segmentation. Subsequently, interviews were carried out to collect the subjective experience of each participant regarding each professional gesture performed during task execution.

This study highlights the importance of analyzing professional gestures across all their dimensions in robotic assistance contexts to adapt task distribution to individual operators. Relying solely on objective physical strain is insufficient, as it does not reflect individual assistance needs (Cippelletti *et al.*, 2023). A biomechanically demanding gesture may be meaningful to the operator and contribute to professional identity, and its removal can negatively affect technology acceptance (Schoose, 2022).

ACKNOWLEDGEMENTS

The authors would like to thank the company for participating in this study, as well as the employees who agreed to be observed and interviewed. This work has received funding from the ANR Project HERCULES (Grant ANR-23-CE33-0010).

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PARALLEL SESSIONS (PM)

03. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES – DESCRIPTIVE STUDIES

14:30 - 14:50 – ROOM 104, LEVEL 1 – #83

KEY WORDS

Occupational health | Musculoskeletal disorders | Meat-processing industry | Workplace risk factors | Health Monitoring

Evaluation of musculoskeletal disorders in a meat-processing plant: results of a cross-sectional study



N. Roger^{1,2,3}, T. Lelard¹ and F. Telliez²

Introduction

Work-related musculoskeletal disorders (WRMSDs) are a leading occupational health concern, particularly in sectors involving repetitive tasks, postural strain, manual handling, and cold environments. The meat-processing industry is especially exposed, yet no study has quantified the prevalence or severity of MSDs among French workers in this field, nor related symptoms to specific workplace risks. This study aims to assess current MSD prevalence and intensity, and to identify associated occupational factors using an adapted analytical framework at a factory scale.

Methods

This 6-month study was conducted in a meat-processing plant where all 300 employees were invited to participate. Each underwent a 5–20-minute individual interview using the Nordic Musculoskeletal Questionnaire and a numeric rating scale to assess pain by body region and intensity. Quantitative data were expressed as mean (\pm SD), qualitative data as percentages. MSD prevalence was compared across sectors using Chi-squared tests, and logistic regression identified associated risk factors.

Results

Among the 300 employees, 78% ($n=235$) participated in the survey (48% women, 53% men). Median age was 40 ± 12 years, with 13 ± 11 years of experience in the

plant and 6 ± 7 years at the workstation. Overall, 86% reported at least one musculoskeletal complaint in the past 12 months. Low back pain was most frequent (56%, intensity $5.4 \pm 1.8/10$), followed by shoulder (33%, 5.6 ± 1.6), wrist (23%, 4.8 ± 2.2), and neck pain (21%, 5.8 ± 1.6). Analyses were conducted across 13 industrial sectors. Chi-squared tests revealed significant sector effects on neck ($p = 0.01$), shoulder ($p < 0.001$), and wrist pain ($p < 0.001$). ANOVA showed sector influence on the number of complaints per worker ($p < 0.001$). Regression models identified sex as associated with neck pain ($p = 0.001$) and number of complaints ($p = 0.014$), and age with upper-back pain ($p = 0.029$) and low back pain ($p = 0.021$). No significant associations were found for tenure at workstation or in the company.

Discussion and Conclusion

This study provides the first mapping of musculoskeletal pain levels and associated factors among French meat-processing workers. The high prevalence of MSDs and sector-specific differences highlight the influence of task organization on pain distribution. Identifying factors such as age and sex supports more targeted prevention efforts. These findings encourage sector-specific preventive actions rather than generic approaches, and confirm the feasibility of simple on-site screening tools for sustainable workplace health management.

ACKNOWLEDGEMENTS

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PARALLEL SESSIONS (PM)

03. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES – DESCRIPTIVE STUDIES

14:50 - 15:10 – ROOM 104, LEVEL 1 – #97

KEY WORDS

Latent class analysis | occupational wear and tear | musculoskeletal disorders | biomechanical risk factors

Typology of musculoskeletal occupational wear and tear: a latent class analysis in the CONSTANCES cohort

G. Morvan¹, J. Bodin¹, N. Fouquet², H. Bouziri³, M.E. Major⁴ and Y. Roquelaure⁵

Occupational wear and tear (OWT) is defined as a process of deterioration in health resulting from prolonged exposure to work constraints. The 2023 pension reform in France created a fund (*Fonds d'investissement pour la prévention de l'usure professionnelle* - FIPU) to prevent OWT and related disability. The FIPU targets exposure to manual handling of loads, strenuous postures and mechanical vibrations, all three of which are risk factors of musculoskeletal disorders (MSDs). The concept of OWT, a major issue in a context of career lengthening, is poorly documented in the literature. This study aimed to identify a typology of musculoskeletal OWT among CONSTANCES, a large French population-based cohort.

We used data from the cross-sectional French CONSTANCES cohort, restricting our analysis to participants aged 45 years and older. MSDs (in six body regions), functional limitations (three items: limitations in routine activities, difficulty climbing up or down a flight of stairs, or carrying a 5 kg object over 10 meters) and work ability (two items: change job or position, or cessation of activity before the official retirement age due to any musculoskeletal problem) were assessed, using self-reported data. Latent class analysis was performed to identify musculoskeletal OWT typology at inclusion, separately for men and women.

A total of 74,581 adults (35,919 men and 38,662 women) were included in the analysis. Four classes were identified for men and women. All profiles were consistent between sexes: class 1 "Absence of MSDs" (men = 52.0%; women = 42.7%), class 2 "Subacute MSDs" (men = 24.9%; women = 27.1%), class 3 "Chronic MSDs, with moderate functional impairment" (men = 13.3%; women = 16.1%), and class 4 "Occupational wear and tear" (men = 9.8%; women = 14.1%). The latter was characterized by individuals reporting permanent symptoms of MSDs, severe functional impairment, and a significantly reduced work ability.

The identified typology provide relevant information to characterize musculoskeletal OWT in the French population. This highlights the importance of early detection of individuals at risk of musculoskeletal OWT and better targeting the development of appropriate preventive measures. Further studies are underway to examine the association between these classes and trajectories of occupational biomechanical exposure over the course of a career.

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PARALLEL SESSIONS (PM)

03. ORAL COMMUNICATIONS: POPULATION AND SECTOR SPECIFIC APPROACHES – DESCRIPTIVE STUDIES

15:10 - 15:30 – ROOM 104, LEVEL 1 – #111

KEY WORDS

Health and social care sector | Musculoskeletal health | Psychosocial risks | Retention of workers with MSDs | Return-to-work

Return-to-work and retention of health and social care workers with MSDs: from research to practice



L. Munar¹ and P. Berastegui¹

EU-OSHA is conducting a multi-year research activity on the health and social care (HeSCare) sector, running from 2022 to 2026. The overall aim is to provide evidence-based knowledge on the diverse challenges faced by the sector regarding the safety and health of its workers, in order to increase awareness and guide the policy-making process.

Return-to-work processes and musculoskeletal disorders (MSDs) are major OSH challenges in the HeSCare sector. Psychosocial and organisational factors often act as barriers or resources in these processes, influencing outcomes for affected workers. Data from the ESENER survey shows wide differences between countries in the implementation of procedures to support employees returning to work after long-term sickness absence, often reflecting national legal or policy frameworks (Table 1).

The present communication is based on three of the most recent publications produced within the framework of this research activity. The findings will be used to:

- Highlight the multifactorial nature of MSDs, with a focus on how PSRs contribute to their onset and chronic progression.
- Underline the role of psychosocial and organisational factors as barriers or resources in return-to-work and job retention.
- Illustrate cross-country differences in how companies implement return-to-work procedures.
- Identify success factors and effective approaches that support sustainable return-to-work and retention for HeSCare workers with MSDs.

Some of the case studies already published—and others to be released by EU-OSHA in the coming months—will be used to illustrate how these findings can be translated into concrete actions at both sectoral and workplace levels.

	2014	2019	2024
at	42	53	61
be	60	71	81
bg	49	45	44
cy	48	39	56
de	84	88	88
dk	73	84	77
ee	12	22	24
el	39	40	56
es	53	50	62
fi	90	90	89
fr	61	60	58
hr	36	35	43
hu	33	34	35
ie	81	88	87
it	48	47	56
lt	15	15	27
lu	51	50	53
lv	34	34	42
mt	47	59	48
nl	92	92	94
pl	33	36	29
pt	59	56	66
ro	57	68	67
se	93	95	94
si	48	48	56
sk	31	41	43
Eu-27	61	64	66

TABLE 1

Procedure to support employees returning to work after a long-term sickness absence (% establishments, 2014-2019-2024) – ESENER data. Source: EU-OSHA, forthcoming

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PARALLEL SESSIONS (PM)

04. ORAL COMMUNICATIONS: SOCIO-ECOLOGICAL CHALLENGES

14:30 - 14:50 – ROOM 103, LEVEL 1 – #110

KEY WORDS

Agroecology | Musculoskeletal disorders | Ergonomics intervention | Sustainability

Agroecological transition and prevention of musculoskeletal disorders: a case study among organic vegetable farmers



S. Caroly¹ and M.E. Major²

Introduction

In response to environmental concerns and climate change, agroecology is an emerging trend in the context of ecological transition (Wezel *et al.*, 2018). In order to promote a sustainable transition, the role of the human and protecting farmers' health must be considered. Therefore, addressing occupational health issues in this context, in terms of work organization and working systems, should be considered (Thatcher *et al.*, 2022). The objectives of this study were to investigate occupational constraints that may contribute to the development of musculoskeletal disorders (MSDs) among vegetable farmers on a small-scale organic vegetable farm and to document individual and collective strategies employed by workers to mitigate health risks and promote occupational well-being.

Methodology

An ergonomic analysis of work activity was conducted through a case study in the organic vegetable production sector. Semi-structured interviews with workers and managers, observations of the work activity and production, as well as collaborative workshops to experiment solutions were conducted.

Results

Four situations that may create or exacerbate risks for MSD development were identified in partnership with workers and stakeholders: (i) field work; (ii) washing crops; (iii) plant nursery work; (iv) maintenance of the tomato and cucumber greenhouse. For each of these situations, MSD risk factors and their technical and organizational determinants were identified. For example, maintaining an uncomfortable posture when weeding due to manual methods and tools to minimize soil disturbance. An action plan for experimentation and transformation was then implemented with the different stakeholders. For example, to reduce the workload and the musculoskeletal constraints associated with weeding, an experimentation was carried out using a tiller for manual weed control operations conducted along the field edges.

Discussion

This ergonomic intervention yielded valuable insights into sustainable strategies for preventing MSDs among agricultural workers. These promising findings underscore the relevance of ergonomics as a lever for supporting work system transformations in the context of ecological transitions.

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KEY WORDS

Dismantling | Circular economy | Algorithmic management | Industry 6.0

Cars dismantling in the context of ecological transition. An opportunity to design sustainable work?



W. Buchmann¹, O. Richal¹, B. Daille-Lefevre², A. Savescu² and F. Barcellini¹

Every year in France, approximately 1.3 million end-of-life vehicles (ELVs) must be dismantled and recycled. To cope with quantitative and qualitative changes in dismantling work, specialised companies are transforming their processes to industrialise them and are questioning the 'old-fashioned' design of car scrapyards. Furthermore, data on reported workplace accidents and occupational illnesses collected by the French National Health Insurance Fund (CNAM) place the waste collection and treatment sector among the most accident-prone professional sectors at the national level, particularly for lower back pain and musculoskeletal disorders (Ameli.fr). In this context, research is being conducted to document and model the work involved in dismantling end-of-life vehicles with the aim of designing a tool to assist in the design of dismantling lines.

The research field is a french factory (250 employees) that dismantles around 100 end-of-life vehicles per day. Dismantling is mainly carried out on two lines operating in parallel. Each line is divided into seven specific stations, each manned by one or two operators. Following a precise order imposed by a production management algorithm, the operators' main task is to dismantle and check the quality of the various components.

The research is in the field of constructive ergonomics (Falzon, 2013) aimed at the design of sustainable work (Delgoulet, 2023) and understands MSDs as an organizational problem, limiting workers' room for manoeuvre (Bourgeois et al. 2000). Data collection took place between January and September 2024: collection of company documents, 15 non-consecutive days of observations of the work of 12 dismantling operators, and 9 semi-structured interviews

with workshop management and production operators.

We highlight 3 main results: The model of human at work limited to biomechanical aspects is considered 'poor and a source of errors' by the designers interviewed. As a result, designers tend to design simple, repetitive workstations and tasks, without any useful leeway to deal with industrial, inter- and intra-individual variability.

There are many sources of musculoskeletal strain associated with dismantling processes: (1) the seven stations on the line operate at an 'average' takt time, with no buffer stock between stations, which limits the time available to deal with unforeseen events; (2) the resources made available to operators do not always enable them to efficiently find solutions for dismantling unknown or rare vehicles; (3) some dismantling operations are complex due to a lack of ad hoc tools (e.g. dismantling wheels fitted with anti-theft nuts).

However, there are also factors that can help prevent MSDs and should be maximised: collective flexibility (an operator can leave their post to help another operator who is running late or experiencing difficulties) and initial and ongoing training in dismantling skills (versatility) and health.

The development of ELV dismantling centres is booming, yet documentation and reference cases for the design of these work systems are still scarce and difficult to access. These initial investigations encourage us to pursue three avenues: analyses of dismantling activities to refine our initial results, collaborations with the designers of these work systems to understand their constraints and design logic, and the production of tools and guides useful to designers in order to integrate MSD prevention into the design of ELV dismantling workshops.

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS

IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)

16:00 - 17:30 – AUDITORIUM 300, LEVEL 1

From cocoa dust exposure to sustainable MSD prevention: professional dialogue as a resource for work transformation in a chocolate factory

Y. Lestrade, D. Cromer, A. Bonnemain, F. Coutarel..... P.80

Air France x Axomove Innovating Musculoskeletal Disorder Prevention for Employees

T. Davergne, S. Sutter..... P.82

New Belgian regulations (2024) to better prevent musculoskeletal disorders (MSD), supplementing the European directives of the 1990s

A. Piette, N. Cock..... P.83

One Year After the Implementation of the New Belgian Decree on Ergonomics and MSD Prevention: Observations and Field Realities

N. Cock, A. Piette..... P.84

02. ORAL COMMUNICATIONS

RISK ASSESSMENT AND HEALTH EFFECTS – CO-EXPOSURE

16:00 - 17:30 – ROOM 103, LEVEL 1

Carpal tunnel release surgery and occupational co-exposure to biomechanical factors and neurotoxic chemicals: findings from the Constances cohort

J. Bodin, C. Rapicault, A. Descatha, M. Fadel, F. Gilbert, B. Evanoff, N. Bonvallot, M. Goldberg, M. Zins, Y. Roquelaure..... P.85

Analysis of data on multiple exposure to biomechanical factors and neurotoxic substances

F. Clerc, L. Claudon..... P.86

Between Dust and MSD: Worker Trade-Offs in Sustainable Prevention Strategies

B. Langard, E.S. Mariko..... P.87

Prevalence and psychosocial determinants of musculoskeletal disorders among workers in a tire manufacturing plant: a cross-sectional study

T. Capet, A. Nourry, P. Crozet, F. Telliez..... P.88

03. SYMPOSIUM

“ASSISTIVE TECHNOLOGY OR PERSONAL PROTECTIVE EQUIPMENT? IMPLEMENTATION QUESTIONS FOR EXOSKELETON SOLUTION”

16:00 - 17:30 – ROOM 104, LEVEL 1

Laboratory study evaluating a series of exoskeletons for repeated lifting and overhead torque wrench use

K. O’Keefe, M. Fray, A. Lloyd, S. Bassford..... P.90

The Toyota Motor Europe approach for preparing the company for exoskeleton implementation

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Exploration of the implementation of exoskeletons in 3 EU manufacturing locations

K. O’Keefe, M. Fray, A. Lloyd, S. Bassford..... P.92

Laboratory study to explore the benefits of exoskeletons on varied activities in healthcare

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Between Assistive Technology and Personal Protective Equipment: Understanding Exoskeletons in Nursing Practice

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04. SYMPOSIUM

“PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL, ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW ?”

16:00 - 17:30 – ROOM 105, LEVEL 1

Contribution of socio-technical, organizational and situational leeway into msds prevention

A. Cuny-Guerrier, A. Aublet-Cuvelier, Y. Roquelaure, F. Coutarel..... P.96

Developing operational leeway to prevent musculoskeletal disorders among care assistants in nursing homes for the elderly

S. Poncet, S. Caroly, Y. Roquelaure..... P.97

How professional gesture analysis promote the development of employees’ empowerment and socio-technical organisational leeway in professional training? The case of gravediggers

P. Simonet, A. Savescu..... P.98

Training to operational leeway for MSD prevention with an educational video

A. Vasselin, L. Querelle, A. Cuny-Guerrier..... P.99

PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)

16:00 - 16:20 – AUDITORIUM 300, LEVEL 1 – #63

KEY WORDS

Prevention | Musculoskeletal disorders | Intervention | Professional dialogue | Development

From cocoa dust exposure to sustainable msd prevention: professional dialogue as a resource for work transformation in a chocolate factory



Y. Lestrade¹, D. Cromer¹, A. Bonnemain¹ and F. Coutarel¹

This communication examines how an ergonomic intervention based on professional dialogue can contribute to transforming work representations and supporting the sustainable prevention of musculoskeletal disorders (MSDs). It is guided by a dual research question: how can ergonomics interventions foster ambitious work transformations, and how can professional dialogue serve as a developmental resource for this process?

Grounded in the intersection between activity ergonomics and the clinic of activity, this work draws on approaches where dialogue—through professional dispute, by means of cross self-confrontation (Bonnemain & Clot, 2017; Clot, 2005)—is used as a tool for analysing and developing work. These dialogical processes make it possible to articulate issues of health, efficiency, and work quality, approaching prevention not as a technical fix but as a lever for activity transformation within a systemic perspective.



FIGURE 1
In-situ analysis by operators of the turntable rebalancing gesture during praline coating, through comparison of different ways of doing it, following cross self-confrontation interviews.



FIGURE 2
Simulation (Béguin, 2013; Daniellou, 2007; Van Belleghem, 2018) of a sifting device and reduced turntable speed, eliminating the rebalancing gesture, co-designed by/with operators.

The intervention was conducted during a master's internship in ergonomics within a chocolate factory seeking to reduce operators' exposure to fine cocoa dust during the production of cocoa-coated pralines. Upon arrival, the company had already proposed a technical solution—an extraction hood—seen as the obvious answer. The ergonomic intervention questioned this assumption by initiating professional dialogue, first among chocolatiers, then between them and management, focusing on real work activity and quality criteria (Bonnemain & Clot, 2022).

Through cross self-confrontation interviews, operators compared their ways of working and collectively analysed the determinants of particle suspension (turntable speed, cocoa fat content, ambient temperature, professional gestures, etc.). This broadened the scope of the toxicological issue, revealing not only the mechanisms

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of particle suspension but also the risks of MSDs already reported by operators. Creating conditions for the collective and reflective construction of professional gestures proved essential for MSD prevention (Coutarel *et al.*, 2022). Here, the development of dialogical capacities fostered the shaping of professional gestures, directly contributing to prevention (Clot & Fernandez, 2005; Savescu *et al.*, 2020; Simonet & Caroly, 2020; Tomàs & Bonnemain, 2019).

In conclusion, this case illustrates the transformative potential of an ergonomic approach grounded in professional dialogue. Encouraged by these results, the company extended the process within a CIFRE PhD project,

aimed at implementing structured collective dialogue for the design of a new production site. The ongoing work seeks to progressively expand frontline operators' scope of deliberation—from their daily activity to decision-making processes involving a specific form of social dialogue and other institutional actors (Prot, Bonnefond & Clot, 2021; Saily, Johansen, Tengblad & van Klaversen, 2022). The collective that has developed its power to act on daily activity is gradually becoming an instrument for analysing and shaping leeway at multiple organizational levels, including those related to potential MSD emergence (Cromer, Bonnemain & Coutarel, 2023), as exemplified by the cocoa powder coating process.

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)

16:20 - 16:40 – AUDITORIUM 300, LEVEL 1 – #36

KEY WORDS

MSK | Physical activity | Physiotherapy | Empowerment | Absenteeism

Air France x Axomove: Innovating Musculoskeletal Disorder Prevention for Employees



Sonia Sutter¹ and Thomas Davergne²

Context

Air France has been committed to preventing musculoskeletal disorders (MSKs) for more than 20 years, focusing on gesture and posture economy training in professions with high physical exposure. While appreciated by employees, existing measures have shown limits: they require employees to be absent from production, depend on the availability and motivation of managers, and place a heavy organizational burden on internal prevention networks. Moreover, tertiary and sedentary professions have been largely excluded from these programs.

Seeking innovative and more inclusive solutions, Air France identified Axomove, a certified digital clinic dedicated to physical health and MSK prevention. Axomove Selfcare delivers personalized, video-guided exercise programs with daily monitoring under Physiotherapists (PTs) supervision, empowering employees to manage pain, prevent chronicity, and sustain long-term health. A proof of concept was launched with both high-risk professions and a representative panel of support functions.

Deployment

The pilot project was initiated in December 2022 to evaluate Axomove's relevance for 1,000 employees across several business units. The deployment relied on the Health, Safety & Environment (EHS) network and, depending on the sector, support from occupational health physicians. The program was officially introduced during a corporate webinar led by the Head of Physical Risks and an occupational physician. Employees voluntarily enrolled on the platform, benefiting from personalized follow-up either independently or under physiotherapist supervision.

First Results

Since 2022, 855 Air France employees have used the Axomove digital clinic at least once. In October 2024, a satisfaction survey gathered 68 employee responses. Of the 43 participants who engaged in physiotherapist-supervised follow-up, 36 were seeking to reduce existing pain. Among them, 72% reported a significant decrease in their symptoms. Overall satisfaction with the service reached an average score of 8/10, and the recommendation score was 4/5. These results confirm Axomove's complementarity with traditional MSD prevention measures and highlight its potential for wide adoption.

Future Opportunities

Building on these first outcomes, Air France and Axomove have set a joint roadmap for 2026–2029. Two main priorities have been identified: (1) consolidating evidence by linking usage and self-reported outcomes with HR data such as absenteeism; and (2) strengthening the partnership through broader awareness campaigns, improved targeting of high-risk employees, and securing sustainable engagement across a complex, global organization.

A progressive post-pilot rollout to all 40,000 Air France employees is under preparation, with strong potential for extension to subsidiaries Hop and Transavia, which began using Axomove in 2025.

Conclusion

The Air France–Axomove collaboration demonstrates how digital health solutions can complement established prevention strategies, improve employee engagement, and generate measurable benefits in MSD prevention. This partnership illustrates a scalable, innovative model for integrating digital clinics into occupational health ecosystems.

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)

16:40 - 17:00 – AUDITORIUM 300, LEVEL 1 – #35

KEY WORDS

MSD | Ergonomics | Musculoskeletal risks | Legislation | Prevention

New Belgian regulations (2024) to better prevent musculoskeletal disorders (MSD), supplementing the European directives of the 1990s

A. Piette¹ and N. Cock²

As in most European countries, Belgian legislation on occupational risks related to musculoskeletal disorders (MSD) was based on two European directives (working with display screens, manual handling of loads) that were written in the early 1990s. Although the European Commission has set up working groups in recent years to update these directives, they remain in force.

Along with psychosocial risks (PSR), MSD are the main occupational health and safety issues affecting all companies. Both surveys on working conditions and figures on incapacity and invalidity at work show the significant impact of MSD on workers (more than 50% of workers affected in the last 12 months), on companies (PSR and MSD responsible for 60% of absenteeism) and on society (for example, one third of the 500,000 invalid persons, at a cost of more than €8 billion per year).

After developing specific Belgian legislation on the prevention of psychosocial risks, facilitating the link between PSR and MSD, and given the scale of the MSD problem, it was necessary to improve Belgian legislation on MSD without waiting for the European directives to be updated.

New regulations relating to ergonomics at work and the prevention of musculoskeletal disorders (MSD) at work were published in the *Moniteur Belge* on 15 May 2024, namely the Royal Decree (RD) of 19 March 2024 amending Book VIII of the Code of Well-being at Work with regard to ergonomics at work and the prevention of musculoskeletal disorders at work.

The urgent need to focus more on preventing these MSD and on improving workplace ergonomics in general require a comprehensive approach immediately apparent in the new title of Book VIII of the Code 'Ergonomics at work and prevention of musculoskeletal disorders'.

The RD first introduces 4 concepts that will henceforth be defined in the Code, namely the ergonomist prevention advisor, ergonomics at work, musculoskeletal disorders and musculoskeletal risks at work.

The Royal Decree (RD) then adds certain general principles relating to ergonomics at work and the prevention of MSD to Book VIII of the Code, which are included in the new Title 1:

- The employer must take account of ergonomics at work when designing and fitting out new workstations, as well as when adapting existing workstations.
- The employer must therefore implement a policy of preventing MSD or other health problems caused or aggravated by musculoskeletal risks at work by means of a global approach which takes into account the various risk factors, such as biomechanical risk factors, other risk factors linked to the workstation and the results of risk analyses carried out in other areas of well-being which may have an impact on musculoskeletal risks at work (e.g. vibrations). The RD also lists a number of biomechanical risk factors to be taken into account in the risk analysis, such as the use of force, repetitive movements, duration and frequency of movements or tasks, working postures, gestures at work and contact force. Appropriate preventive measures must then be taken to deal as effectively as possible with these musculoskeletal risks in the workplace. This prevention policy must also be regularly evaluated and updated.
- The various actors who play a role in this prevention policy are specified, in particular the prevention advisor from the internal occupational health and safety service, the ergonomic prevention advisor and the prevention advisor/occupational physician. Finally, workers and the committee for prevention and protection at work must be informed and trained about musculoskeletal risks at work and the various preventive measures.

This new legislation finally defines ergonomics in the Code of Well-being at Work, not only to prevent MSD but to prevent ALL occupational risks. It also helps companies to better prevent MSD while covering all work activities, no longer limited to workers sitting in front of a screen or those who handle heavy loads.

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Service public fédéral Emploi, Travail et Concertation sociale (2025), outils pour informer et sensibiliser à la prévention des TMS et à l'ergonomie : www.beswic.be et via www.preventiondestms.be.

Service public fédéral Emploi, Travail et Concertation sociale (2024), le 27 mai 2024, la Direction générale Humanisation du Travail (DG HUT) du SPF Emploi a organisé un webinaire concernant la nouvelle législation sur l'ergonomie et les troubles musculosquelettiques (TMS), qui est entrée en vigueur le 25 mai 2024. [Revivez le webinaire sur la nouvelle réglementation sur l'ergonomie et la prévention des TMS | Beswic](#).

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PARALLEL SESSIONS (PM)

01. ORAL COMMUNICATIONS: IMPLEMENTATION AND EVALUATION OF PREVENTIVE INTERVENTIONS (2)

17:00 - 17:20 – AUDITORIUM 300, LEVEL 1 – #37

KEY WORDS

MSD | Ergonomics | Musculoskeletal risks | Prevention

One Year After the Implementation of the New Belgian Decree on Ergonomics and MSD Prevention: Observations and Field Realities



N. Cock¹ and A. Piette²

It has now been a year since the new decree (May 15, 2024) on the prevention of musculoskeletal disorders (MSDs) came into force in Belgium. Yet many companies—small, medium, or large—still struggle with its implementation. MSD prevention remains a complex issue. The expectations of the labor inspection (Well-being Control - CBE), which hoped to see companies initiate autonomous actions, have turned out to be difficult to put into practice.

In reality, many companies turn to their External Service for Prevention and Protection at work (SEPP) from the very first steps of the prevention process, specifically to the ergonomics prevention advisors within these SEPPs. This early reliance—effectively outsourcing the entire process—can be explained by a lack of internal skills, time, or resources. Inspectors, for their part, struggle to enforce the legislation, due to their limited numbers, the absence of a universally recognized method for risk analysis, and a certain lack of understanding of field realities. These challenges apply to all occupational risks (psychosocial risks, chemical risks, vibrations, etc.), not just MSDs. The emergence of MSDs alongside psychosocial risks within companies, and the multifactorial causes of MSDs, highlight the complexity of this issue.

The interpretation of the legal text varies among stakeholders, creating discrepancies between regulatory expectations and actual practices.

Inspectors are tasked with verifying the implementation of an MSD prevention policy, checking for musculoskeletal risk analyses, and most importantly, ensuring the implementation of preventive measures.

Several key questions arise that require consultation between the FPS Employment (inspectors, legal experts from the Federal Public Service) and field actors: What does “risk assessment” concretely mean? Should risks be quantified? The law emphasizes the importance of achieving results rather than focusing on the means or methods used. However, in practice, SEPPs are often involved from the beginning of the process, which alters their role compared to what the inspection expects. The latter would prefer their expertise to be used only for complex or specific cases. But what should be done when a small company with five employees asks for help? What if the internal prevention advisor lacks the time or resources to initiate an MSD risk analysis? What if tasks are not repetitive and quantitative methods are not applicable? What if there are more than 80 job functions in a company?

Faced with these realities, SEPPs like CESI are developing their own approach, aiming to involve companies as much as possible and offering support at various levels, as proposed in the brochure developed by the FPS Employment. The steps include: needs analysis, pre-diagnosis, diagnosis, co-design/construction of solutions, implementation of solutions, and follow-up.

Practical cases will be presented at the congress, ranging from approaches in very small SMEs to larger institutions.

For prevention advisors specialized in ergonomics, mainly working within SEPPs, the focus is on the proposed preventive measures and their implementation, far more than on the method used to identify and assess risks.

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PARALLEL SESSIONS (PM)

02. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS – CO-EXPOSURE

16:00 - 16:20 – ROOM 103, LEVEL 1 – #106

KEY WORDS

Carpal tunnel release | Biomechanical risk factors | Chemicals | Co-exposure | Job-exposure matrix

Carpal tunnel release surgery and occupational co-exposure to biomechanical factors and neurotoxic chemicals: findings from the Constances cohort



J. Bodin¹, C. Rapicault¹, A. Descatha^{1,2}, M. Fadel¹, F. Gilbert³, B. Evanoff⁴, N. Bonvallo⁵, M. Goldberg³, M. Zins³ and Y. Roquelaure¹

Objective

In previous studies, we have shown an association between self-reported carpal tunnel syndrome and occupational co-exposure to biomechanical risk factors and chemicals in a cohort of French workers and in a cross-sectional study of French farmers and agricultural workers. The aim of the present study was to study the association between occupational co-exposure to biomechanical risk factors and chemicals and carpal tunnel release (CTR) surgery in a large cohort of French workers.

Methods

Data from Constances, a French national population-based cohort, were analyzed. Participants were enrolled between 2012 and 2018. CTR was obtained from the French national health insurance information system (Système national des données de santé – SNDS) after inclusion in the cohort. Five biomechanical risk factors in the 12 months period preceding inclusion were assessed using a self-administered questionnaire: high perceived exertion (>12 on the Borg rating of Perceived Exertion scale), repetitive hand movements (≥4h/day), hand-transmitted vibrations (≥2h/day), awkward wrist postures (≥2h/day), holding tools/objects in a pinch grip (≥4h/day). Lifetime occupational exposure to chemicals was assessed using job-exposure matrices: chlorinated solvents and formaldehyde. Cox models were used to evaluate the association between the occupational co-exposure and CTR, adjusted for personal and medical factors (age, BMI, diabetes mellitus and/or rheumatoid arthritis, current alcohol consumption and effort-reward imbalance) and stratified by gender.

Results

The sample comprised 71,558 workers (32,915 men and 38,643 women). During a median follow-up of 33 months (interquartile range, 19.0–51.0), 170 men and 350 women underwent CTR surgery. At baseline, women were more exposed to biomechanical risk factors than men (35.9% vs. 31.8% respectively, $p<0.001$). Men were more exposed to chemicals during their working life than women (15.8% vs. 12.9% respectively, $p<0.001$). Co-exposure to biomechanical risk factors and chemicals occurred in 8.4% of men and 7.9% of women ($p<0.001$). In both men and women, exposure to chemicals (HR=1.43 [0.82-2.50] and 1.49 [0.95-2.33], respectively) or biomechanical factors (HR=2.06 [1.42-2.97] and 1.71 [1.34-2.17]) was associated with a higher risk for CTR; while exposure to both chemicals and biomechanical factors showed a higher risk (HR=3.12 [2.08-4.70] and 2.34 [1.71-3.21]).

Discussion

This large prospective study showed an association between CTR and co-exposure to both occupational biomechanical risk factors and chemicals, using JEM method for chemical exposure. These results are consistent with those of our previous studies in the same cohort with self-reported carpal tunnel syndrome, and in a cohort of French farmers. Although, we lack mechanistic evidence, this provides further support for the potential effects of chemical exposure on the risk of carpal tunnel syndrome in workers exposed to biomechanical risk factors.

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Analysis of data on multiple exposure to biomechanical factors and neurotoxic substances



F. Clerc et L. Claudon

Introduction

Strong links are now well established between musculo-skeletal disorders (MSDs) and both biomechanical and psychosocial risk factors. Furthermore, several studies have focused on the association between exposure to biomechanical constraints and to substances toxic to the nervous system, in order to explain the risk of developing certain MSDs (Bodin *et al.*, 2018). Since the causes of MSDs are by nature multifactorial, it is therefore important to characterize the potential for cumulative exposure to multiple hazards—known as multiple or combined exposures. In this context, populations of workers facing such multiple exposures are not always well identified. The aim of this work is to use existing data to produce a profile of workers simultaneously exposed to both biomechanical risks and neurotoxic chemical substances.

Materials and Methods

Two data sources were used: the INRS Colchic and Scola databases, which provide information on exposure levels to chemical substances, and the three most recent Sumer surveys (2003, 2010, and 2017), which provide information on the number of exposed workers. All chemical substances bearing hazard statements under the European CLP regulation (Classification, Labelling, Packaging) related to neurotoxicity were selected. The corresponding work situations were extracted from Colchic and Scola. Among those presenting high exposure levels, the numbers of workers simultaneously exposed to these substances and to manual handling of loads or people, awkward postures, and repetitive movements were calculated.

Results

Over the period 2002–2021, 166 work situations were identified in the Colchic and Scola databases where at least one neurotoxic substance exceeded its occupational exposure limit value. Twenty of these situations were cross-referenced with Sumer survey data, as they contained a sufficient quantity of information. The results show that the sectors concerned with such multiple exposures are mostly industrial: chemistry, automotive, rubber and plastics, etc. The construction and social work sectors are also represented. Only low-skilled or unskilled occupations were identified—mainly manual workers, and employees in the social work sector.

Discussion and Conclusion

Low-skilled occupations in the industrial sector are those most affected by combined exposure to biomechanical constraints and neurotoxic substances. For these specific occupational groups, special attention should be paid to identifying this type of multiple exposure during risk assessment. The goal is, on the one hand, to identify possible links between such combined exposures and the occurrence of certain musculoskeletal disorders (for example, the hypothesis of a combined multiple exposure to “neurotoxic agents and wrist joint strain” in the development of carpal tunnel syndrome, Bodin *et al.*, 2018), and, on the other hand, to prioritize prevention actions by taking these potential interactions into account.

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PARALLEL SESSIONS (PM)

02. ORAL COMMUNICATIONS: RISK ASSESSMENT AND HEALTH EFFECTS – CO-EXPOSURE

16:40 - 17:00 – ROOM 103, LEVEL 1 – #105

KEY WORDS

MSD | Silica dust | Trade-Offs | Finishing masons | Construction sector

Between Dust and MSD: Worker Trade-Offs in Sustainable Prevention Strategies

E.S. Mariko^{1,2} and B. Langard²

Crystalline silica is a hazardous chemical and a major prevention challenge for the construction sector because it is present in numerous rocks and building materials and also because many workers are exposed (12.3% exposed) (Anses, 2019; DARES, 2017). Tasks such as sanding, cutting, drilling concrete and sweeping generate silica dust and also expose workers to physical hazards and musculoskeletal disorder (MSD) risks including falls, cuts, sustained static postures, heat, cold, noise, vibration and heavy lifting.

Despite its impact on health, few studies examine workers' actual activity from an ergonomic perspective (Faverge & Ombredane, 1955; Guérin *et al.*, 2006; Teiger, 1993). This study of finishing masons' work activity, initiated by Professional Organization for Prevention in the Construction and Public Works Industry (OPPBTB), aimed to understand exposures and propose effective prevention. We applied ergotoxicology (Sznalwar, 1992), an ergonomic approach that develops operant models (Wisner, 1972) and prevention tools for chemical hazards, treating exposure as a "puzzle" to be solved by activity analysis (Garrigou, 2011).

Dust exposures extend beyond single tasks or individuals: technical, human and organizational determinants contribute, and multiple concurrent exposures require fine-grained analysis. The Occupational Health Plan 2016–2020 identifies five constraint categories encountered across careers: physical, chemical, biological, organizational and relational (Fourneau *et al.*, 2021).

Our ergotoxicological methodology comprised five phases: participatory study construction with stakeholders; global analysis of work situations; systematic observation plus metrology (in real time and integrated); self-confronta-

tion interviews; and restitution with stakeholders (Mariko *et al.*, 2024; Mariko *et al.*, 2023).

Results reveal multiple exposure situations and risk representations. Activity analysis highlighted trade-offs between protection and production logics: finishing masons face a dual demand to deliver quality under time pressure while managing production contingencies, often compromising protective measures such as mask use or vacuum extraction. For example, finishers may choose not to use a vacuum cleaner when sanding in order to protect themselves from the risk of musculoskeletal disorders that carrying it up and down several floors of stairs would generate. Conversely, protecting oneself from the risk of dust with a vacuum cleaner creates a risk of musculoskeletal disorders. Trade-offs also occur within protective logics. For example, between preventing MSDs (shoulder injury, etc.) and preventing long-term diseases (silicosis). During silica exposure, operators face concurrent risks (cuts, vibration, heavy loads, falls, constrained postures such as kneeling or bent backs) that influence protective choices. Consequently, workers often prioritize mitigation of immediate, visible risks over protection against dusts whose harms are diffuse and normalized. Variable risk representations among operators supports this finding (Mariko *et al.*, forthcoming).

Situations involving exposure to silica dust are part of complex systems involving various hazards to which workers may be simultaneously exposed (Garrigou, 2023). Indeed, exposure to crystalline silica among finishing masons therefore involves a combination of various hazards that must be understood together in order to inform prevention measures. A broader view based on multiple exposures can clarify the choices and compromises made by workers and support prevention strategies that incorporate several levels of activity analysis.

ACKNOWLEDGEMENTS

The authors would like to thank OPPBTB, Bordeaux University and ÉPICÈNE, as well as the companies that hosted the field study.

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KEY WORDS

Musculoskeletal disorders | Psychosocial factors | Tire manufacturing | Occupational health

Prevalence and psychosocial determinants of musculoskeletal disorders among workers in a tire manufacturing plant: a cross-sectional study

T. Capet¹, A. Nourry², P. Crozet¹ and F. Telliez³

Introduction

Musculoskeletal disorders (MSDs) are the leading cause of occupational disease in France and remain a major concern in physically demanding sectors. Their development is multifactorial, arising from the interaction of biomechanical loads, organizational constraints, and psychosocial stressors. The tire manufacturing industry, characterized by repetitive material handling, prolonged standing, and sustained production rates, has been relatively underexplored beyond ergonomic studies. This study aimed to estimate MSD prevalence among production workers and to examine associations with psychosocial factors, perceived work overload, anxiety, and sleep disturbances, while accounting for individual and occupational characteristics.

Methods

An anonymous cross-sectional survey was carried out between February and May 2023 in a tire manufacturing plant employing 560 production workers. A random sample of 300 operators was invited, and 244 completed the questionnaire. The Standardized Nordic Questionnaire (Kuorinka *et al.*, 1987) captured self-reported pain during the previous 12 months across anatomical regions. Additional variables included self-rated mental health (0–10), perceived work overload and anxiety at work, nocturnal sleep disruption, smoking status, and regular physical activity. Age, body mass index (BMI), job tenure, company tenure, and production sector/line were also recorded. Associations between pain by body region and psychosocial or occupational factors were examined using logistic regression, with p-values indicating statistical significance.

Results

Participants had a mean age of 43.8 years (IQR 37–51); 97.7% were men, and mean BMI was 27.1 kg/m². Average job tenure was 10.4 years (IQR 3–16.3) and company tenure 15.9 years (IQR 5–23). Mean pain intensity reached 4.8/10 (IQR 3–7), while self-rated mental health was relatively high (7.6/10; IQR 7–9). Overall, 91.4% reported at least one MSD during the past 12 months, with an average

of 2.9 painful regions per worker (IQR 1–4); 35.8% reported three or more painful sites, indicating frequent multisite involvement. The most affected areas were the lower back (66%), neck (35%), and shoulders (32–37%), followed by wrists (22–29%) and knees (18–20%), with ankles (18%) and upper back (19%) also reported.

Psychosocial correlates were consistent across several regions. Perceived work overload was found to act on pain occurrence, being significantly associated with pain in the neck ($p = 0.034$), hips/thighs ($p = 0.022$), knees ($p = 0.022$), and ankles ($p = 0.029$). Anxiety at work was associated with hip ($p = 0.007$) and knee pain ($p = 0.020$). Age was related to neck ($p = 0.032$) and upper back pain ($p = 0.032$). Job tenure correlated with knee ($p = 0.001$) and elbow pain ($p = 0.050$), while company tenure was associated with low back pain ($p = 0.050$) and nocturnal awakenings ($p = 0.004$). Regular physical activity was associated with shoulder pain ($p = 0.038$), and no significant associations were found with smoking.

Discussion and Conclusion

This study reveals a very high frequency of MSDs with multisite distribution in tire production workers. The associations between work overload, anxiety, and pain in highly exposed regions support a biopsychosocial interpretation, where organizational and mental demands contribute to or amplify symptoms alongside biomechanical exposure. Associations with sleep disturbances and seniority suggest cumulative effects over time, as more tenured workers reported both low back pain and nocturnal awakenings. From a prevention standpoint, these findings call for integrated strategies combining ergonomic improvements (posture optimization, handling aids, task rotation, cycle design) with workload management (adequate staffing, pacing, recovery opportunities), targeted mental health support (screening and brief interventions for anxiety), and sleep-friendly scheduling and recovery practices. This cross-sectional analysis provides recent, sector-specific data for tire manufacturing and offers practical guidance for multidimensional MSD prevention in physically demanding environments.

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WEDNESDAY, 6 MAY 2026

SYMPOSIUM (PM)

16:00 - 17:30 – ROOM 104, LEVEL 1

KEY WORDS*Exoskeletons | Manufacturing | PPE | Assistive Technology | Healthcare*

Assistive Technology or Personal Protective Equipment? Implementation questions for Exoskeleton Solutions

M. Fray¹ and S. Bassford²

This symposium is created to explore the real-world challenges of the selection and implementation of exoskeletons in complex work tasks. Repeatedly safety officers are shown laboratory trial data that proves the physiological benefit of exoskeletons in controlled scenarios.

The reality of implementation into a workplace with lasting effect is however much more challenging. This symposium is created following a collaboration between a university and an international motor manufacturer. The symposium will discuss the implementation of exoskeletons into both motor manufacturing and healthcare work. The focus is on the management of workers that do not do simple repetitive tasks with other workplace factors that challenge the implementation process. Toyota H&S Dept reviewed available study papers and exoskeleton manufacturer reports but could not find practical data to quantify upper limb exoskeleton use in a like for like manufacturing environment to Toyota. An internal review in Toyota North America had purchased upper limb exoskeletons but had not conducted a detailed study and most were no longer being used. This created the idea at Toyota Motor Europe (TME) for Toyota engineering division and Toyota H&S dept for support on clarifying whether upper limb exoskeleton technology could be utilised as substitute for lifting aid equipment.

This collection of papers explores the various aspects of the use and implementation of exoskeleton solutions in a variety of application areas. The main focus is a collaboration between a university and a motor manufacturer which reviewed a number of exoskeletons against specific

automotive manufacturing tasks and tried to implement those devices in a range of EU settings. In this project new task specific data was collected to prove the benefits of a range of exoskeletons for two specific workplace tasks. The successful exoskeletons from the laboratory trial were then taken out to a range of manufacturing locations with varying results. Three of Toyota Motor Europe's manufacturing plants were identified as sites for the trials 1) Portugal slow takt 32 minute, very manual processes in a hot working environment, 2) Turkey fast paced takt 72 second takt, less manual but hot working environment, 3) UK plant fast paced takt 85 seconds, less manual processes, cooler climate.

This is supported by a study investigating varies work postures and tasks in healthcare. The final paper asks questions about the design and use of exoskeletons and how their design and introduction leaves questions for the implementation company, safety advisors and the makers of exoskeletons. The symposium will provide a series of different views of the data regularly seen in academic studies and its contradictory evidence from real users in various workplace settings. The discussion format will target these different data sources to explore whether the wider safety network has clarity on the evidence and the routes to selection and or implementation.

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KEY WORDS

Exoskeletons | Manufacturing | PPE | Assistive Technology

Laboratory study evaluating a series of exoskeletons for repeated lifting and overhead torque wrench use



K. O'Keefe¹, M. Fray¹, A. Lloyd¹ and S. Bassford²

Introduction

15 Toyota members from the Burnaston Plant were recruited for the trial. Each participant completed the work tasks with each exoskeleton and un-aided, the exposure to all conditions (n=4) was in a squared order to avoid order bias. The effects of the exoskeletons were measured objectively by heart rate and electromyography (EMG) in Erector Spinae, Extensor Digitorum, Trapezius, Triceps Brachii, Flexor Carpi Radialis, Biceps Brachii, Vastus Medialis and Vastus Lateralis.

The worker perception was recorded by a range of subjective evaluation tools. Force and effort were reported with; Perceived Fatigue – (Borg CR-10 scale), Perceived Muscle Effort – (Borg CR-10 Scale), Rating of Perceived Exertion (Borg 6-20). Physical and thermal comfort/discomfort by the Arm Discomfort – (Borg CR-10 scale, Thermal Comfort and Thermal Sensation Likert scales.

Results

- During both tasks there were no significant difference between the heart rates between any exoskeleton device and the unaided task.
- When reviewing the EMG data for changes in fatigue and effort small differences were observed but again no significant effects were seen. In the upper body, there was no significant difference ($P \geq 0.35$, $\eta p^2 \leq 0.23$) between the unaided and exoskeleton conditions in this study.
- When comparing the EMG in the individual muscle groups a similar observation was found. EMG traces were examined, indicating little or no objective improvement in 'effort' (rectified and average EMG amplitude) or fatigue (decline in median EMG frequency) provided by the three exoskeleton suits, when compared to an unaided condition.
- Contrary to the objective parameters, the subjective responses suggested that both perceived force and arm discomfort were marginally reduced ($P < 0.05$, $\eta p^2 \geq 0.22$) by the use of an upper body exoskeletons.
- There were also no differences ($P > 0.06$) between wearing an exoskeleton and unaided work for thermal sensation and/or thermal comfort in either task 1 (lifting) or task 2 (power wrench).

- The strongest effects were seen in the Measure for Rate of Perceived Exertion where there were significant differences between unaided and all exoskeleton tasks for task 1 ($p=0.02$) and task 2 ($p=0.03$)

After wearing all devices the participants were asked to compare the devices. The participants showed a preference for the Ottobock device above the others. The Levitate device was the least preferred and created issues related to fit and comfort specifically. All 15 participants stated that they would like to use an exoskeleton to aid the delivery of their work.

Conclusion

There was some evidence that the exoskeletons improved the perceived effort required to complete these two tasks though no effect was seen across some of the measures recorded. The Toyota Members were generally in favour of the devices and reported that they considered them beneficial to the activities completed. The Member perception and the physiological evidence did not entirely match. This study was taken forward by Toyota to paper 2 and 3 in the symposium.

	Most Preferred	Least Preferred
Skelex	5	5
Levitate	1	9
Ottobock	9	1

▲ **TABLE 1**
Most Preferred and Least Preferred Exoskeleton (n=15).

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PARALLEL SESSIONS (PM)

03. SYMPOSIUM: ASSISTIVE TECHNOLOGY OR PERSONAL PROTECTIVE EQUIPMENT?
IMPLEMENTATION QUESTIONS FOR EXOSKELETON SOLUTIONS

The Toyota Motor Europe approach for preparing the company for exoskeleton implementation



S. Bassford¹

Introduction

The manufacturing plants across Toyota Motor Europe have a strong safety and human performance focus that supports the wellbeing of all members in the workplace and the drive for high levels of efficiency and effectiveness across all areas. The question about the use of assistive devices is regularly explored in these complex and varied work situations. The manufacture of automotive vehicles is supported by high levels of automation, assisted devices (powered hand tools, lifting equipment, etc), and the collaboration between those designing the work and factory processes is very clear. The complex tasks at each assembly position and the fixed time for each assembly station are key in the complexity of the production line performance. The company considers each worker as an industrial athlete and supports their health and well-being accordingly. This paper reports on the considerations of exoskeleton implementation from the company perspective and how the collaboration was intended to improve the understanding of the comparative benefits of the devices.

Context and creation of the collaboration project

- Trigger for proof-of-concept trials at Toyota Motor Europe (TME) - Toyota engineering division made request to Toyota H&S dept for support on clarifying whether upper limb exoskeleton technology could be utilised as substitute for lifting aid equipment.
- Toyota H&S Dept reviewed available study papers and exoskeleton manufacturer reports but could not find practical data to quantify Upper limb exoskeleton use in a like for like manufacturing environment to Toyota. Internal review Toyota North America had purchased upper limb exoskeletons but had not conducted a detailed study and most were no longer being used.
- Based on the lack of solid evidence supporting the benefits of upper limb exoskeletons, Toyota Motor Europe's H&S Senior Specialist Stuart Bassford started to look at conducting a study with the support from Dr Mike Fray of Loughborough University's School for Design, to clarify the benefit or not of passive upper limb exoskeletons

- Five of Toyota Motor Europe's Manufacturing plants were identified as sites for the trials – this was eventually narrowed down to three plants 1) Portugal slow takt 32 minute, very manual processes in a hot working environment 2) Turkey fast paced takt 72 second takt, less manual but hot working environment 3) UK plant fast paced takt 85 seconds, less manual processes, cooler climate, close location to Loughborough Uni for lab studies. Total users for the shop floor trial 57, Lab study 15.

Specific activities and considerations from the Manufacturers perspective

- Scope of the project, reason for study presented to TME Manufacturing VP to gain agreement for the study to begin. This triggered Funding, legal contracts, timeline objectives all of which was agreed between Toyota Motor Europe & Loughborough University.
- Planning of project included, contacting Exoskeleton manufacturers who would like to support this Toyota trail, permission to conduct trials in the selected Toyota Plants, reviews with unions to gain permission to use shop floor workers in the trials, development of questionnaires to support Loughborough Uni data collection/evidence, clarification on specific tasks task areas to provide suitable upper body burden linked to exo suit performance, individual Process safety risk assessments, Health and wellbeing checks of the Toyota shop floor workers, volunteer disclaimers / participation agreements x 3 languages, medical check confirmations prior to trials and post trials.
- Exo manufacturer fitment training to TME Stuart Bassford or onsite support was confirmed.
- Trial Planner across the three plants
- Project Co-ordinator, Stuart Bassford, travelled to each site with the same exoskeletons to conduct the Trials, support training, and oversee each trial at the shop floor for testing consistency.
- Planning and preparation for feedback to Plant and TME top management of post-trial results.

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Exploration of the implementation of exoskeletons in 3 EU manufacturing locations



K. OKeefe¹, M. Fray¹, A. Lloyd¹ and S. Bassford²

Introduction

The laboratory trial created positive evidence that the exoskeletons assisted with the two tasks. This evidence was shared across various EU locations, and a formal user trial was developed. The process was controlled by the H&S team within the Toyota group. All interventions were supported by the team to ensure all products were fitted correctly and the data was collected in a uniform manner. Every opportunity was taken to standardize the different delivery points. The study introduced the exoskeletons to a range of job types and included Logistics (manual lifting) tasks and the QA (overhead) tasks and the regular assembly line positions.

Methods

The field trial was completed in 3 locations. Data were collected from Turkey, Portugal and UK. 57 wear tests were recorded. Each trial was evaluated with a 19-point questionnaire translated into the local language and piloted for users. All questions were scored on a 9-point Likert scale (1=Extremely Bad 9=Extremely Good). The questionnaire required users to consider 3 qualities of the exoskeleton devices a) Donning/doffing adjusting (n=5 questions) b) Comfort and fit (n=7) c) Performance factors (n=7).

Results

There were differences between the locations, the job types and between the exoskeleton types. All combinations showed the Levitate as the least preferred device. The

Logistics (manual lifting) tasks and the QA (overhead) tasks scored a full point above the Assembly workers. The preference over all tasks was consistently with the Skelex device but Ottobock was preferred by both Logistics and QA.

Field trials showed differences between job types, locations and the exoskeletons. There were more notable benefits for the devices for the logistics and the QA roles. The assembly roles showed lower overall scores for all devices. The laboratory trials showed less clarity as the objective physical measures of fatigue and effort showed little benefit when using an exoskeleton. Whereas the subjective evaluations showed that workers did suggest there was an effect. The combination of the two studies has revealed a clearer understanding of the safety management methods in place and possible opportunities for the use of these assistive devices in automotive production:

- The physical controls in place in the Toyota locations successfully reduce the possible MSD risks for workers. The effects seen in many other exoskeleton trials were reduced here due to lower overall demand.
- The workers used in the laboratory trials were recognised as highly skilled and high levels of worker fitness. Their mobility between stations and in their range of motion indicated that the devices were hindering their efficient movement patterns.
- Workers liked the concept of exoskeletons and voted favourably for their use in both trials.
- When asked to wear the devices many could not or would not wear them for a full shift suggesting that they did not match their expectations.
- Logistics and QA roles showed more positive effects than assembly. The speed and range of movements required for the assembly tasks could not be supported as effectively by the exoskeleton.
- Participant feedback from both laboratory and field trials suggest issues related to comfort, fit, chaffing and thermal effects need to be addressed for better acceptance with the workers.
- The results suggested that for some staff and some tasks there could be opportunities for use for specific worker support.

Conclusion

The evidence collected in these two trials (papers 1,2,3) have not produced a convincing argument for the widespread introduction of exoskeletons. The objective improvements were small and though the subjective evaluations were in favour of the concept of an assistive device the wearability and comfort were not suitable. Further collaboration with the manufacturers to improve the design and usability could deliver a better level of acceptance.

	Levitate (n = 20)	Skellex (n = 15)	Ottobock (n = 22)	Mean
Turkey (n = 21)	2.76	5.10	4.12	3.72
UK (n = 12)	4.76	5.11	5.49	5.21
Portugal (n = 24)	5.61	6.31	6.31	6.08
Mean	4.20	5.75	5.29	

TABLE 1
Mean Scores by Location for all exoskeletons.

	Levitate (n = 20)	Skellex (n = 15)	Ottobock (n = 22)	Mean
Don, Doff and Adjust	4.97	5.77	5.83	5.51
Comfort and Fit	3.97	5.56	5.16	4.85
Performance	3.86	5.91	5.01	4.85

TABLE 2
Mean Scores by Questionnaire Sections.

	Levitate	Skellex	Ottobock	Mean
Assembly	3.66	5.68	4.84	4.71
Logistics	5.45	6.02	6.28	5.88
QA	5.11		6.18	5.64
Total mean	4.20	5.75	5.23	

TABLE 3
Mean scores by Job Type.

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PARALLEL SESSIONS (PM)

03. SYMPOSIUM: ASSISTIVE TECHNOLOGY OR PERSONAL PROTECTIVE EQUIPMENT?
IMPLEMENTATION QUESTIONS FOR EXOSKELETON SOLUTIONS

Laboratory study to explore the benefits of exoskeletons on varied activities in healthcare

A. Yangsap¹, M. Fray¹ and A. Lloyd¹

Introduction

Two contextual studies explored the needs and opportunities for the use and implementation of exoskeletons in care home work. These studies focused on the roles and activities of the care support workers so often excluded from academic study. These previous studies created a formal laboratory to explore the possible benefits of two Back Support Exoskeletons (BSE).

The study posed clear research questions: Can a BSE reduce the physical workloads when performing caregiving activities? Can a BSE reduce muscle activities when performing caregiving tasks? Can a BSE reduce work metabolism, heart rate, perceived physical exertion when performing caregiving tasks? Is participants' body kinematic different between wearing and not wearing a BSE?

Methods

The two exoskeleton devices and a device free activity were compared. Each evaluation included a timed exposure to activities representative of bathing, repositioning a patient in bed and the preparation for hoisting actions. All participants (n=20) were fit and healthy and all completed all activities with all conditions.

Muscle activity was measured using wireless surface EMGs (Biometrics Ltd, UK). Kinematic data was measured and recorded by wireless electronic goniometers (Biometrics Ltd, UK).

Heart rate (HR) during the caregiving simulation was measured using a chest-strap HR monitor (Polar Vantage, Kempele, Finland). Incremental standing arm crank tests were performed on an electrical braked arm crank ergometer (Lodge Anglo BV, Groningen, the Netherlands). Oxygen consumption (VO₂) was measured using a breathing gas analysis system (COSMED Srl, Quark CPET, Rome, Italy).

The caregiving simulation was recording by a camera (Sony HDR-XR200). Two types of manikins were used in the study: a heavy and a light manikin. The heavy manikin was 91.6 kg used in the bathing and repositioning task. The light manikin weighed 50.2 kg used in the hoisting task. The room temperature was set at 22°C (± 1.5°C). The subjects were asked to rate the physical exertion (RPE) using the Borg CR-20 scale (Table 2) after completing each task; bathing, repositioning, and hoisting a manikin.

Results Summary

The primary research question explored whether BSEs could reduce the physical workload of caregiving activities by lowering muscle activation, work metabolism, heart rate, and perceived physical exertion. The findings indicated that both BSE models significantly reduced back muscle activity dur-

ing bathing and repositioning tasks. The secondary research question examined whether BSEs could help prevent musculoskeletal disorders (MSDs) among caregivers by reducing the time spent in hazardous working postures. The results showed that during activities such as hoisting, participants wearing the BSEs spent significantly less time in postures involving trunk bending over 40°, indicating a reduction in hazardous posture duration.

Muscle activity of lumbar erector spinae (LES) was significantly reduced with BSEs model AC and S in bathing task and repositioning task. LES muscle is a group of muscles in the lower back that run vertically up the length of the back along both sides of the spine. LES plays an important role in stabilising spine, maintaining posture and generate movements such as trunk forward flexion and extension (Aspden RM., 1992).

A trunk inclination between 0°–20° is considered an optimal working posture. Participants wearing both models of BSEs spent more than 70% of the time in this optimal range during bathing and repositioning tasks, and over 65% during hoisting tasks. In contrast, participants without BSEs remained in this optimal range for less than half the time across all tasks. This suggests that wearing BSEs encourages a safer trunk inclination range, reducing the risk of harmful postures.

Heart rate, VO₂, EE levels did not show significant changes across all conditions and caregiving tasks, suggesting that wearing exoskeletons in a controlled environment (22°C) does not increase the physiological workload for workers.

Conclusion

This study assessed the effectiveness of industrial BSEs during caregiving activities, focusing on three physically demanding tasks: bathing, repositioning, and hoisting. The results demonstrate that both BSE models significantly reduced back muscle activity during bathing and repositioning tasks, with differences between models. Additionally, BSEs improved participants posture during the caregiving simulations. In the hoisting task, participants wearing BSEs spent significantly less time in the hazardous over 40° trunk bending range compared to participants without BSEs. During bathing and repositioning tasks, participants wearing BSEs maintained an optimal trunk inclination (0°–20°) for more than 70% of the time. Importantly, wearing BSEs did not significantly change physiological workload. The reduction in back muscle activation and protection against excessive trunk bending, without increasing physiological demand, highlights the potential of BSEs as assistive devices for caregiving tasks.

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Between Assistive Technology and Personal Protective Equipment: Understanding Exoskeletons in Nursing Practice



X. Lin¹, M. Fray¹ and S. Hodder¹

Healthcare workers, especially nurses, continue to face high rates of work-related musculoskeletal disorders (WMSDs), mainly due to demanding patient-handling tasks. Current assistive technologies, which are regarded as interventions for nursing 's WMSDs, such as hoists and slide sheets, are effective in reducing physical strain. However, largely due to issues of environmental fit, efficiency, and the time pressures of real care settings, their adoption in clinical practice remains limited. Exoskeletons, as wearable support devices, offer new possibilities by overcoming some of these limitations and may help prevent WMSDs in nursing.

A raised question is how exoskeletons should be classified: should they be considered assistive technology (AT) or personal protective equipment (PPE)? This unclear status has important consequences for policy, organizations, and individuals. From a legal and policy perspective, PPE usually requires mandatory use, while AT is optional for employees. These two categories also follow different rules and responsibilities. For organizations, classification influences budgeting strategies as well as training needs. It also affects how accident responsibility and workloads are managed. At the individual level, it impacts how nurses experience the device, how they view their job demands, and their expectations at work.

We conducted a preliminary study with ten experts in patient-handling area. Seven experts categorized exoskeletons as PPE, while three classified them as AT. When

asked whether they were worried about being assigned more heavy patient-handling tasks after wearing exoskeletons, all three in the AT group reported such concerns, compared with only two of the seven in the PPE group. The two groups also differed in their preferences regarding usability priorities. The PPE group highlighted weight and size, staffing needs, and whether the device could be unobtrusive. The AT group focused more on pressure, heat, and compatibility with other equipment. In addition, several experts expressed concern that when nurses feel a strong sense of support from the device, they might be more willing to take risks or perform non-standard handling under time pressure. These results suggest that classification can shape how usability is judged as well as users' perceptions, acceptance, and satisfaction.

In conclusion, exoskeletons are a special type of wearable device with both supportive and protective functions. Enhancement is their approach, similar to AT; protection is their aim, as with PPE. They cross the traditional boundary between AT and PPE and therefore have dual attributes. Instead of focusing only on the question of "what they are," it may be more useful to ask, "how they work in different situations, who they affect, and what the consequences are." Future research should examine these contextual roles in more depth. Such work will support policy and management decisions, guide the future development of exoskeletons, and provide essential evidence for reducing WMSDs among nursing staff.

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WEDNESDAY, 6 MAY 2026

SYMPOSIUM (PM)

16:00 - 17:30 – ROOM 105, LEVEL 1

KEY WORDS*Socio-Technical Organizational Leeway | Situational Operational leeway | Musculoskeletal disorders prevention | Training*

Prevent MSDs by the development of socio-technical, organisational and situational operational leeway: Why and how?

A. Cuny-Guerrier¹ and S. Caroly²

Socio-Technical Organizational Leeway (STOL) and Situational Operational leeway (SOL) are widely used in etiological models of MSDs and interventional approaches derived from the field of activity ergonomics.

However, these concepts remain little known outside the field of activity ergonomics and are insufficiently operational to allow for wider dissemination. This symposium will seek to address these limitations. Objectives are, from 4 contributions, (1) to introduce the concept of the Socio-Technical Organizational Leeway (STOL) and Situational Operational leeway (SOL) and interest for the prevention of MSDs from a comprehensive and

interventional perspective, (2) to show how support their development through two cases studies, one with care assistants in nursing home and one with gravediggers, and (3) to present an initiative which try to overcome the limitations associated with its lack of dissemination by proposing an educational video developed for prevention specialists. Benefits, limitations and difficulties will be discussed.

THE CONTRIBUTIONS TO THE SESSION ARE

Contribution of socio-technical, organizational and situational leeway into MSDs prevention: A. Cuny-Guerrier, A. Aublet-Cuvellier, Y. Roquelaure and F. Coutarel. **Developing operational leeway to prevent musculoskeletal disorders among care assistants in nursing homes for the elderly:** S. Poncet, S. Caroly and Y. Roquelaure. **How professional gesture analysis promote the development of employees- empowerment and socio-technical organisational leeway in professional training? The case of gravediggers:** P. Simonet, A. Savescu. **Training to operational leeway for MSD prevention with an educational vide:** A.Vasselin, L.Querelle, A. Cuny-Guerrier.

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PARALLEL SESSIONS (PM)

04. SYMPOSIUM: PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL, ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW?

KEY WORDS

Socio-Technical Organizational Leeway | Situational Operational leeway | Musculoskeletal disorders prevention

Contribution of socio-technical, organizational and situational leeway into msds prevention



A. Cuny-Guerrier¹, A. Aublet-Cuvelier², Y. Roquelaure³ and F. Coutarel⁴

The occurrence of MSDs can be analyzed in the light of the organization inability to provide Socio-Technical Organizational Leeway (STOL) for developing situational operational leeway (SOL) of a set of actors: the workers concerned but also the different levels of management.

The STOL are organizational, material and technical resources allocated by the environment. The SOL corresponds to the possibility of developing different ways of working with a good balance between health and performance. The SOL depends on the existence of STOL “but also on workers’ ability to make use of them at the right point in their activities” (Roquelaure *et al.*, 2012) in a specific working situation, or even to create new ones (Coutarel *et al.*, 2024).

After having presented and defined STOL and SOL, the objective of this communication will be to discuss benefits and challenges associated with their use at each stage of an intervention to prevent MSDs: for commitment of stakeholders, identification of priority risk situations, analysis, transformation and evaluation, as well as at the

level of the different actors: decision-makers, managers, workers directly concerned by the risk. We will refer to recent literature as well as examples of interventions in the field. Thus, we will defend the idea that STOL/SOL can be mobilized at each stage of the prevention process. They can support the commitment of the stakeholders and promote the coordination of actions between different levels of actors, identify new indicators to characterize risk situations, deepen the analysis of the activity by revealing the (im)possibilities of actors’ real actions, explaining risky strategies or by making unsuspected or unimagined-resources visible. These concepts can thus redefine the MSD prevention approach in its interventional dynamics. However, these proposals still face certain difficulties. Their operational character depends on the knowledge, skills, and representations of the various actors involved in MSDs prevention. Better appropriation and dissemination of these concepts thus requires methodological developments supporting a better integration into the MSD prevention approach.

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Fabien Coutarel, Mohsen Zare, Sandrine Caroly, Agnès Aublet-Cuvelier, Nicole Vézina, Alain Garrigou et Yves Roquelaure. (2024). *Marge.s de manoeuvre: des concepts à la transformation du travail*. Editions Octarès, 350 p.

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PARALLEL SESSIONS (PM)

04. SYMPOSIUM: PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL, ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW?

KEY WORDS

Socio-Technical Organizational Leeway | Situational Operational leeway | Musculoskeletal disorders prevention | Care assistant | Nursing home

Developing operational leeway to prevent musculoskeletal disorders among care assistants in nursing homes for the elderly

S. Poncet¹, S. Caroly¹ and Y. Roquelaure²

Work-related Musculoskeletal disorders (MSDs) represent a major health issue. Care assistants in nursing home for the elderly are particularly affected (Marquier *and al.*, 2016). In a developmental approach to risk prevention, the goal is not only to reduce constraints but also to develop resources to design a work environment that supports regulation (Aublet-Cuvelier *and al.*, 2019; Caroly *and al.*, 2015). Thus, this research focuses on the activity of care assistants in nursing home through two types of leeway, from a perspective of MSD prevention: the Socio-Technical Organizational Leeway (STOL) as preconditions for activity and the Situational Operational leeway (SOL) as a scope for activity regulation (Coutarel *and al.*, 2024). We argue that the STOL offered by the work environment, and its mobilization in work situations through the care assistant's skills, enables the development of SOL that limits exposure to MSD risk factors. By understanding the relationships between STOL and SOL, ergonomic intervention aims to create new leeway.

The methodology combines a mixed-methods approach to characterize the STOL provided to care assistants, a case study to identify the links between offered STOL, SOL, and MSDs, and an evaluation of the effects of a participatory method based on simulating a difficult hygiene care situation on both types of leeway.

The results show that STOL is provided by the organization, the work collective, and the resident. In care

activities, the care assistant develops her SOL around this offered STOL and her skills. The more leeway the resident offers by cooperating during care, the more the care assistant is able to develop sufficient SOL, allowing her to protect her health and deliver quality care. However, mobilizing this leeway is possible only if the care assistant perceives it and/or is able to use it, particularly based on her knowledge of the resident and caregiving experience. Additional STOL is also necessary, such as autonomy, time, appropriate equipment, opportunities for teamwork, and a cohesive work collective. Discussions about work within the work collective (peers and supervisors) and the repeated development of SOL during care promote the development of efficient care strategies and lead to the creation of leeway provided by the resident. A training program based on simulating a challenging hygiene care operation relies on this process of developing offered STOL and SOL through dialogue and action. Its implementation helps to formalize and to construct STOL promoting future SOL development. Care assistants also report a transformation in their practices, involving an enhancement of their SOL in certain situations.

We conclude that intervening in MSD prevention by exploring the dynamic construction between offered STOL and SOL appears to be an effective model, opening up avenues for developmental intervention and research (Arnoud *and al.*, 2022).

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PARALLEL SESSIONS (PM)

04. SYMPOSIUM: PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL, ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW?

KEY WORDS

Training, MSD | Situational operational leeway | Empowerment | Socio-Technical Organizational Leeway

How professional gesture analysis promote the development of employees' empowerment and socio-technical organisational leeway in professional training? The case of gravediggers



P. Simonet¹ and A. Savescu²

It is well known that in France, the recognition of MSDs as occupational diseases is based on examining the links between these diseases and repetitive movements at work (Bourgeois & Hubault, 2005; Hatzfeld, 2008). Jacques Leplat (2005, 2011) has consistently advocated the need to study movements in work analysis. This analysis allows us to examine the conditions under which the action is carried out and to identify areas for improvement in working conditions. This is what we did in an intervention-based research project focused on the profession of gravedigger, conducted in an interdisciplinary manner combining ergonomic (Simonet, Caroly, Clot, 2011), biomechanical (Savescu *et al.*, 2018, 2020) and clinical activity (Simonet, 2011) approaches. The contribution to this symposium will focus on interdisciplinary action between biomechanics and clinical activity framework. The aim is to show how biomechanical analysis (objective) of movements has become an analytical tool within the methodological framework of self-confrontation in clinical activity practice (Clot *et al.*, 2000) and has undermined the discourse of fatalism among gravediggers ('it's normal to have shoulder and back pain'). We will also explain how the dissemination and collective discussion of intra-individual and inter-individual movement variability enabled gravediggers to experiment with other ways of performing the professional gesture under study through professional gesture controversies, thereby developing their empower-

ment in the use of tools and their entire body in the activity. In this way, the research intervention contributed to the development of the gravediggers' capacity for action.

In the municipality that employs gravediggers, several actors are responsible for defining MSD prevention measures: occupational physician, department head, prevention engineer. They met regularly within a steering committee, where the analyses produced with the gravediggers were presented. After several months of discussions among themselves, fuelled by analyses of gravediggers' movements, they requested that the traditional 'movements and postures' training be supplemented by the creation of a new training tool, more specific and closely aligned with the realities of the gravedigger's profession. A reference guide to movements in the activity (Poussin & Simonet, 2017) was thus designed with the participation of gravediggers, based on analyses of their movements in this study. Some of them became co-facilitators of training courses for their colleagues. This new tool has therefore increased the socio-technical organizational leeway of prevention officers and supervisors in organising the prevention of MSDs.

Finally, we will discuss this training tool and the evolutions we have proposed (Simonet & Savescu, 2024) to increase its effectiveness in developing empowerment and socio-technical organizational leeway in MSD prevention by training.

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PARALLEL SESSIONS (PM)

04. SYMPOSIUM: PREVENT MSDS BY THE DEVELOPMENT OF SOCIO-TECHNICAL, ORGANISATIONAL AND SITUATIONAL OPERATIONAL LEEWAY: WHY AND HOW?

KEY WORDS

Operational leeway | Training | Educational video

Training to operational leeway for MSD prevention with an educational video

A. Vasselin¹, L. Querelle² and A. Cuny-Guerrier³

The concept of socio-technical and organizational leeway (STOL) and situational operational leeway (SOL) are introduced in activity-centered approach to prevent MSD for a better understanding of risk exposure and to support the rollout of interventions by prevention specialists (Roquelaure, 2016). Despite the expected benefits, some authors warn of the difficulty of transferring this concept on a larger scale in the absence of satisfactory educational tools (Cuny-Guerrier *et al.*, 2024).

The aim of this presentation will be to present the collective work and theoretical principles that underpinned the development of an educational video on the concept of STOL/SOL for French prevention specialists.

This educational video aims to raise learners' awareness of the STOL/SOL in order to facilitate its use in understanding MSD risk situations and the MSD preven-

tion process. It encourages learners to (1) identify the different types of STOL in the workplace: organizational, collective, spatial, temporal, and material, and (2) to analyze their impact on the more or less risky strategies employed. To do this, learners are presented with the same work situation, one with sufficient STOL and the other with limited. Thus, when STOL are reduced or non-existent, the development of SOL is complicated, managing variability of work becomes difficult, and workers may deploy strategies that expose them to MSD risk factors in an attempt to achieve the expected performance. An educational exercise validates the correct understanding of all these concepts.

The video currently used in the training of prevention specialists and ergonomists in training shows encouraging results.

ACKNOWLEDGEMENTS

The authors acknowledge contributors of the project: Alexandra Gendre for her support, Laurent Kerangueven and Virginie Govaere for their expertise.

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THURSDAY, 7 MAY 2026

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MSDs and the future of work: risk factors and prevention opportunities

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Motor Strategies in Human–Robot Interaction:

A Muscle Synergy Approach Risk assessment and health effects

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Field assessment of a passive back exoskeleton in the aeronautics industry: effects on muscle activity and perceived discomfort

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Measurement-based assessment of the load on the distal upper extremity during manual therapy techniques in physical therapy

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Physical exercises at work in the construction industry; from analysis to co-design of sessions to open up to a global approach to MSD prevention

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THURSDAY, 7 MAY 2026

PROSPECTIVE VIEW

09:00 - 10:00 – AUDITORIUM 300, LEVEL 1

MSDs and the future of work: risk factors and prevention strategies



A. Hauke and M. Malenfer



Angelika Hauke is a research officer at the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA) in Sankt Augustin, Germany. She is project manager for the German Social Accident Insurance's Risk Observatory and leads the IFA's Competence Centre for Climate Change and Occupational Safety and Health (OSH). Her work focuses on trend analyses, evaluation and the effects of climate change and decarbonization on OSH

Marc Malenfer is in charge of the watch and foresight unit of INRS. He has a dual background in History and Risk management. He joined INRS in 2005, there he worked in communication and in a mission for occupational risk prevention in small and medium-sized enterprises. He's member of the watch and foresight unit since 2017 where he dealt with various topics : uberization, circular economy, artificial intelligence...

The German Social Accident Insurance's (DGUV) Risk Observatory is a mechanism for the early detection of major trends, i.e. trends that will have a particularly significant impact on the world of work, education, and the safety and health of insured persons within the next five to ten years¹.

For the past fifteen years, the INRS has had a Watch and Foresight Unit which conducts thematic studies on certain topics with significant OSH implications and seeks to identify changes in the world of work likely to affect occupational risks and their prevention in the future².

Both activities yield highly consistent findings and, in particular, help identify the main drivers of change in the workplace, such as digitalisation, demographics, and decarbonisation. These drivers are often referred to as the "3 Ds" and were selected by the authors to analyze their potential impact—both protective and exacerbating—on the future development of musculoskeletal disorders.

- Digitalisation encompasses several trends related to the growing use of digital tools in the workplace: connected work equipment, the use of artificial intelligence systems, the use of big data, algorithmic management, robotisation/drone use, cybersecurity, and more.

- In this context, decarbonisation encompasses both the transformation of production models to reduce environmental impacts (renewable energy, the circular economy, etc.) and the adaptation to climate change and its consequences (extreme heat, natural disasters, etc.)

- Demographics primarily concern ageing and its implications for workers' health (chronic diseases, etc.), but also address issues of migration and the increasing diversity of the workforce in terms of age, gender, background, vulnerability, and health status.

The inventory and categorisation of MSD risk factors proposed by Y. Roquelaure³ provides a framework against which these drivers of workplace transformation can be assessed in order to identify their potential effects on the incidence of MSDs and possible prevention strategies, for anticipatory purposes. This exercise has already been carried out by Y. Roquelaure with regard to digitalisation⁴. This paper revisits and expands upon that analysis, then explores the dimensions of decarbonisation and demographics.

Finally, to illustrate these analyses more concretely, two fictional case studies of workers in 2040 incorporating the various dimensions will be presented, highlighting the potential impacts on their exposure to MSD risk factors.

¹ Être préparés : identification de tendances, priorisation et analyse à l'IFA (Allemagne), Angelika Hauke, Ruth Klüser, HST n°280, sept 2025. ² www.inrs.fr/prospective.

³ Musculoskeletal disorders and psychosocial factors at work, Y. Roquelaure, ETUI, 2018. ⁴ New forms of work in the digital era: implications for psychosocial risks and musculoskeletal disorders, Y. Roquelaure, EU-OSHA, 2021.

KEY WORDS

Human-robot interaction | Muscle synergies | Motor control strategies | Ergonomics

Motor Strategies in Human-Robot Interaction: A Muscle Synergy Approach

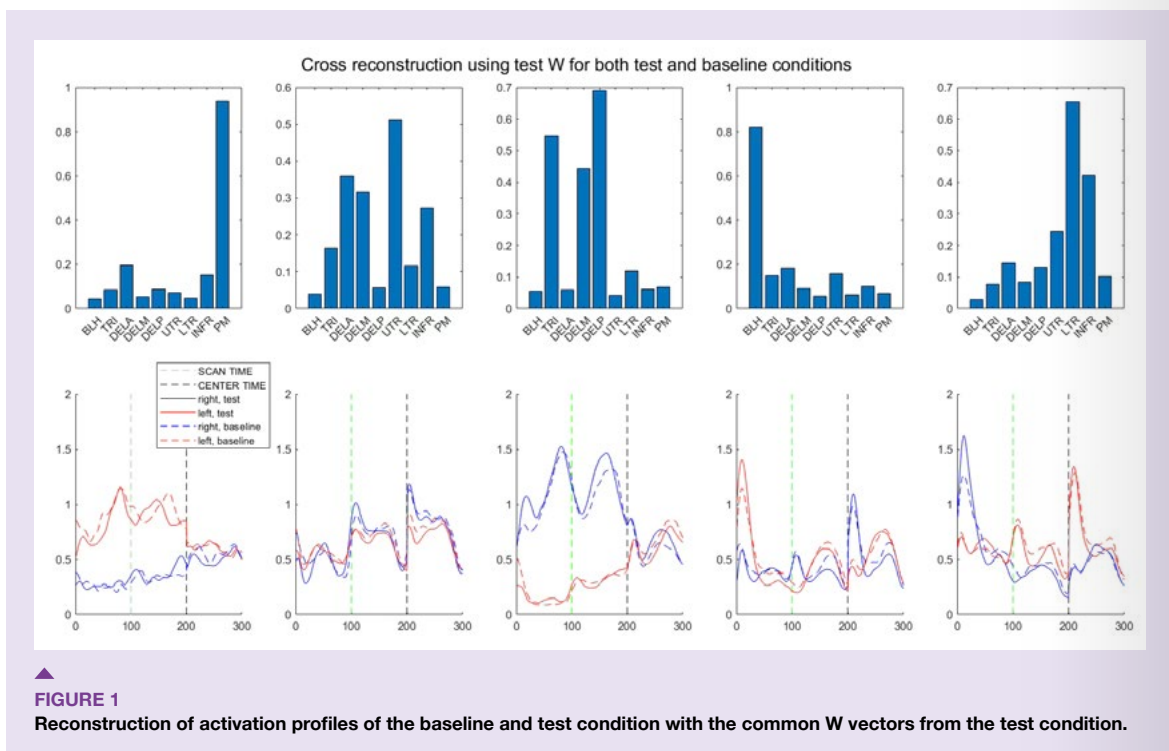


E. M. Fiorino¹, D. Bibbo¹, S. Conforto¹, A. de Nobile¹, S. Ranaldi¹ and M. Schmid¹

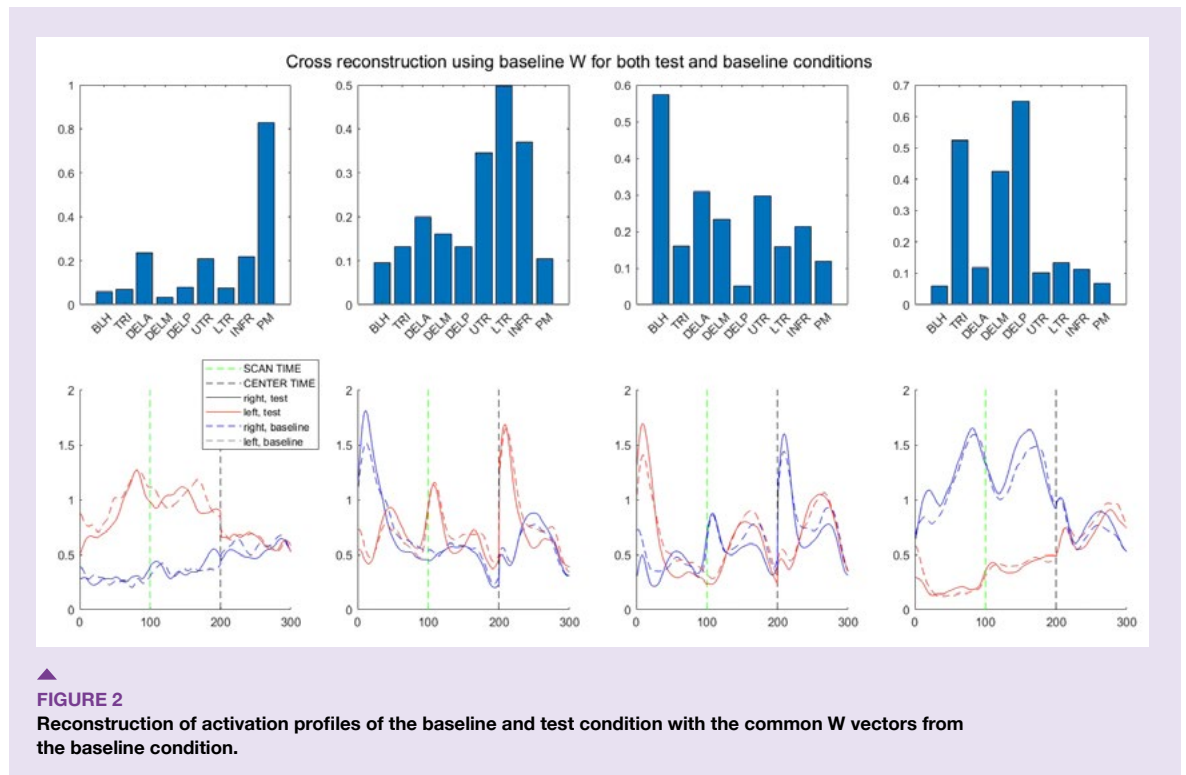
Human-Robot Interaction (HRI) is expanding across workplaces to also support repetitive manual handling, potentially reducing the risk of work-related musculoskeletal disorders (WMSDs). Understanding how HRI influences human motor control is essential to optimize ergonomic design and prevent injury. Muscle synergy analysis (MSA) from surface electromyography (EMG) provides a quantitative framework to investigate these adaptations and to identify early indicators of WMSD risk (Madeleine, 2010). In this work, MSA was applied to a simple unconstrained HRI task, to test whether the presence of a collaborative robot influences motor coordination.

Seventeen healthy right-handed young adults performed a manual handling task consisting of moving a box from a central position to two lateral targets, under two conditions: a baseline (self-paced rhythm) and a test condition where a collaborative robot provided timing and directional cues.

Surface EMG signals were collected from nine muscles of the right upper limb: biceps long head (BLH), triceps lateral (TRI), anterior deltoid (DELA), medial deltoid (DELM), posterior deltoid (DELP), upper trapezius (UTR), lower trapezius (LTR), infraspinatus (INFR), and pectoralis major (PM). MSA was performed using a synchronous



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model (Chiovetto *et al.*, 2022) and non-negative matrix factorization, with the optimization based on Ranaldi *et al.*, 2021.

Four synergies emerged in the baseline and five in the robot-guided condition. Average synergy matrices W were computed for both conditions and used for self- and cross-reconstruction validation. The modules extracted (Figure 1 and Figure 2 from test and baseline W , respectively) revealed consistent spatial structures across participants:

- W1: mainly pectoralis major, active during the first two phases of leftward movements.
- W2: anterior deltoid and upper trapezius, showing tonic activation in later phases. Only present in robot-guided conditions, for postural adjustments during pauses.
- W3: triceps and posterior deltoid, mainly active during early phases of rightward movements.

- W4: biceps, active in early leftward and late rightward phases.
- W5: lower trapezius and infraspinatus, exhibiting mirrored activation relative to W4.

Muscle coordination during both conditions was efficiently represented by a small number of synergies, reflecting consistent biomechanical functions across individuals. The temporally structured test condition enhanced the emergence of individual muscle contributions. Both W vector sets correctly explained muscle activation in both conditions, suggesting that motor strategy patterns are shared, with an additional module required only for the realization of time coordination functions.

Overall, the findings demonstrate that MSA offers a robust, interpretable feature space for EMG data, supporting the quantitative assessment of motor adaptations and potentially enabling early detection of WMSD risk in collaborative work environments.

ACKNOWLEDGEMENTS

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CONFERENCE SESSION YOUNG RESEARCHER NOMINEES

10:50 - 11:10 – AUDITORIUM 300, LEVEL 1 – #89

KEY WORDS

Biomechanics | Exoskeleton | Industry | Field study

Field assessment of a passive back exoskeleton in the aeronautics industry: effects on muscle activity and perceived discomfort



T. Albouy^{1,2,3}, M. Zare³, E. Chin² and G. Mornieux¹

In the aeronautics industry, operations such as material handling, maintenance, repair, and aircraft assembly expose workers to high risks of low-back disorders (Asadi *et al.*, 2019). Preventive strategies such as workstation redesign and organizational improvements are not always sufficient, as some tasks remain difficult to modify due to their complexity and operational constraints (De Looze *et al.*, 2016; Govaerts *et al.*, 2024). In particular, polishing tasks involve back-straining postures, with low-back pain being frequently reported among operators. One preventive strategy could be the use of passive back exoskeletons, which have shown benefits during manual material handling and trunk-bending activities (De Looze *et al.*,

2016; Kermavnar *et al.*, 2021). Although laboratory studies provide encouraging evidence, only a limited number of investigations have been carried out in real work environments (Theurel & Desbrosses, 2019), and these have reported mixed results, emphasizing the need for further field evaluations.

The present study aimed to assess the biomechanical effects of a rigid passive back exoskeleton during real industrial polishing tasks. Ten male employees from an aeronautics manufacturer performed seven representative polishing tasks under two conditions: without the exoskeleton (FREE) and with the Laevo FLEX (EXO). Tasks were selected based on sample size, operational goal (round-



▲
FIGURE 1

Examples of two of the seven polishing tasks: external barrel brushing (BRSH-EXT-BAR) and internal barrel inspection (INSP-INT-BAR).

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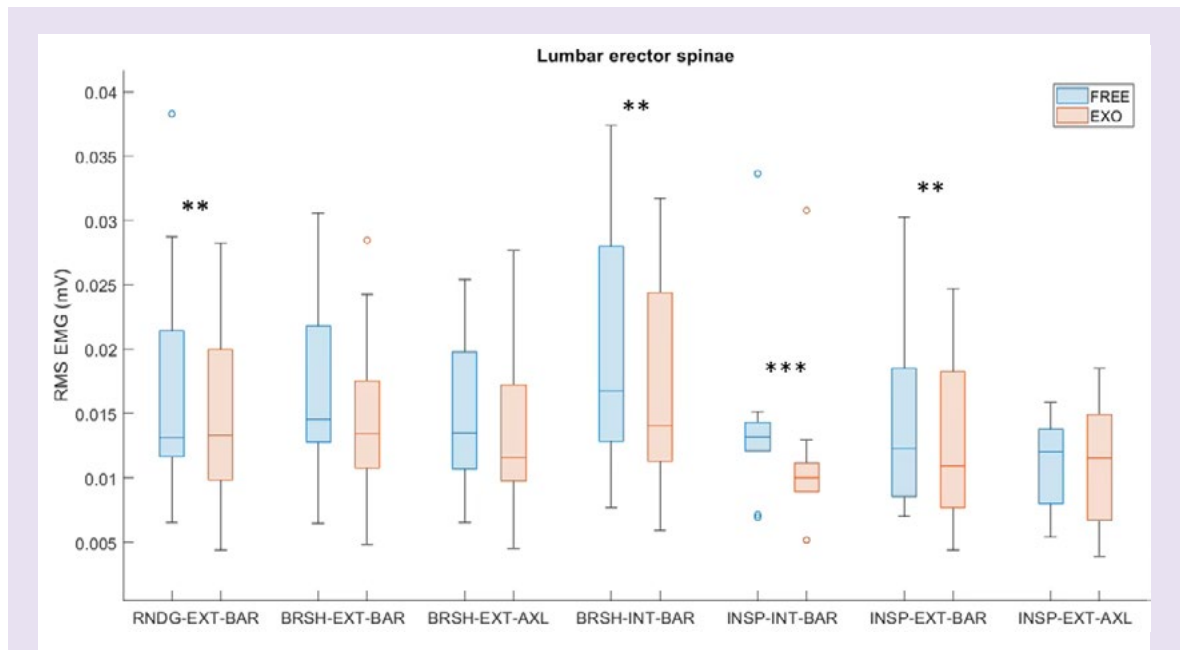


FIGURE 2
EMG amplitude values (mV) of lumbar erector spinae in the FREE (blue) and EXO (red) conditions, for each of the seven tasks. In the boxplot, the central mark is the median (horizontal colored bar), the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points to be not outliers, and the outliers (o) are plotted individually. Asterisks indicated significant differences between conditions (*: $p < .05$; **: $p < .01$; ***: $p < .001$).

ing, brushing, inspection), part location (interior/exterior, barrel/axle), and trunk posture characteristics (degree of flexion, static or dynamic...).

Surface electromyography was used to record bilateral thoracic (TES) and lumbar (LES) erector spinae activity. Perceived discomfort was rated using the Borg CR10 scale (Borg, 1982) on the lower limbs, torso, and back.

LES muscle activity was significantly reduced by the exoskeleton in four of the seven tasks ($p < .05$), with median reductions across participants ranging from -7.3% to -24.8%. TES activity also decreased significantly in two of these tasks. Perceived back discomfort showed a non-significant trend toward reduction (median from "low" to "very low"; $p = .091$), while no significant

effects were found for discomfort in the lower limbs ($p = .526$) or torso ($p = .588$).

These findings are consistent with laboratory studies reporting 6–61% reductions in erector spinae activation (De Looze et al., 2016; Kermavnar et al., 2021; Theurel & Desbrosses, 2019) and demonstrate even greater decreases than those observed in laboratory-based polishing simulations (Albouy et al., 2025). This supports the exoskeleton's beneficial impact on spinal muscle activity in real industrial conditions.

Overall, the study provides field-based evidence of their ergonomic benefit during complex aeronautical polishing tasks and highlights the importance of task-specific evaluation for effective workplace integration.

ACKNOWLEDGEMENTS

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CONFERENCE SESSION YOUNG RESEARCHER NOMINEES

11:10 - 11:30 – AUDITORIUM 300, LEVEL 1 – #80

KEY WORDS

Physical therapy | Distal upper extremity | Work related musculoskeletal disorders | Sensor based | Risk assessment

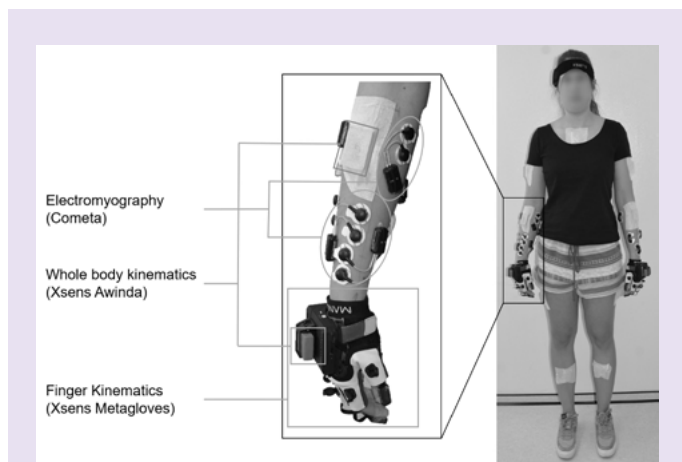
Measurement-based assessment of the load on the distal upper extremity during manual therapy techniques in physical therapy



T. Braun¹, S. Campos¹, U. Glitsch¹, O. El-Edrissi¹, D. Gräßle¹, M. Wanstrath², A. Nienhaus^{2,3} and K. Heinrich¹

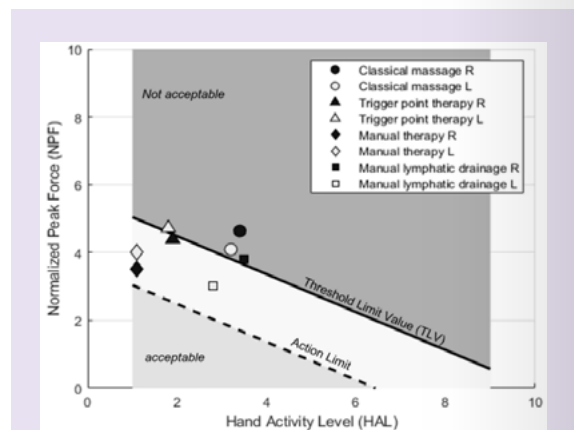
Introduction

Physical therapists are frequently affected by work-related musculoskeletal disorders (WMSDs) affecting the wrist and thumb, which can considerably impair their ability to work (Waller *et al.*, 2022). However, sensor-based investigations assessing the physical load on these anatomical structures during manual physical therapy tasks are lacking. The aim of this study was to develop a methodological approach and to evaluate the load on the distal upper extremity during manual physical therapy techniques, first under controlled laboratory conditions and subsequently in field settings.



▲ FIGURE 1

Overview of the measurement systems attached to the subject: the Xsens Metagloves for capturing the kinematics of the hand and fingers, the Awinda System for capturing full-body kinematics, and the Cometa System for capturing forearm muscle activation.



▲ FIGURE 2

Muscular load (y-axis) and the degree of repetition (x-axis) for the left and right wrists across four therapy techniques evaluated using the Threshold Limit Value for Hand Activity Level (TLV-HAL) established by the American Conference of Governmental Industrial Hygienists (2018).

Methods

15 physical therapists (11 female, 4 male; 35.6 ± 12.7 years) performed four manual therapy techniques—classical massage, manual lymphatic drainage, trigger point therapy, and spinal mobilization—on healthy test patients in a controlled laboratory setting. As illustrated in Figure 1, full-body kinematics were captured using two compatible inertial measurement systems (Xsens Awinda and Xsens Metagloves). Bilateral forearm muscle activity was recorded with a 14-channel electromyography system (Cometa WavePlus). Applied

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forces were quantified by simulating physical therapy tasks on a portable force measurement setup. Wrist load was evaluated according to the Threshold Limit Value (TLV) for Hand Activity Level (HAL) established by the American Conference of Governmental Industrial Hygienists (ACGIH, 2018).

Results

All manual therapy techniques exceeded the HAL Action Limit, while massage (right, left), manual lymphatic drainage (right), and trigger point therapy (left) also surpassed the TLV (Figure 2). The highest mean thumb range of motion (CMC joint) was observed during manual lymphatic drainage in flexion ($45 \pm 11^\circ$) and during trigger point therapy in abduction ($34 \pm 6^\circ$). Thumb muscle activity (90th percentile) varied between 29% during manual lymphatic drainage and 42% of maximal voluntary activation during classical massage. The highest peak forces were recorded during spinal mobilization (male = 153.5 N; female = 94.1 N).

Discussion

The TLV-HAL findings indicate that physical therapists are exposed to hand activity levels greater than recommended thresholds. Exceeding the Action Limit underscores the need for monitoring and training interventions, while surpassing the TLV indicates an increased risk of WMSDs. The measured thumb ROM during physical therapy tasks approached the passive limits, suggesting potentially unfavorable joint loading. Thumb muscle activity was up to four times higher than during a transport task involving 2.5–3.0 kg objects (Roda-Sales *et al.*, 2023). Consistent with previous reports (Gagnon *et al.*, 2016), the highest exerted forces were observed during spinal mobilization.

Conclusion

The sensor-based measurement approach was successfully implemented in the laboratory setting and provides initial insights into the physical workload of physical therapists. Field studies encompassing complete work shifts are needed for a more comprehensive assessment.

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CONFERENCE SESSION YOUNG RESEARCHER NOMINEES

11:30 - 11:50 – AUDITORIUM 300, LEVEL 1 – #59

KEY WORDS

Physical exercises | Musculoskeletal disorders | Construction industry | Prevention

Physical exercises at work in the construction industry; from analysis to co-design of sessions to open up to a global approach to MSD prevention



C. Troussier-Thevenot^{1,2}, B. Langard², P. Girardot², Y. Roquelaure¹ and F. Coutarel³

In France, work-related musculoskeletal disorders (MSDs) are the main cause of occupational diseases in construction, representing over 88% of recognised cases (CNAM, 2025). Preventing these disorders remains a major challenge. One growing strategy is workplace physical exercise sessions, often called “warm-ups” or “muscle awakening” with the aim of preventing MSDs. While some studies suggest benefits for team atmosphere (Choi & Rajendran, 2014; Goldenhar & Stafford, 2015), there is currently no evidence to support their effectiveness in preventing MSDs (Claudon *et al.*, 2018; Larinier, 2024).

This communication presents the accompaniment of one of the case studies (case C) from doctoral research in ergonomics. In this study, we consider these sessions as work situations in their own right, analysed within their organisational and social context (St-Vincent *et al.*, 2011).

Case C concerns a major renovation site in Paris where daily physical exercises were implemented. Based on the literature and previous cases, we developed a model that defines the conditions for the effective contri-

bution of such sessions in the face of MSDs. These conditions are organised into three dimensions: the organisation and facilitation of the sessions, their articulation with site organisation, and their integration within the company's overall prevention policy. The intervention in this case was conducted in several phases: initial contact, field analysis, construction of research materials, and accompaniment. It combined observations, interviews with workers and team leaders (acting as facilitators), and self-confrontation interviews. Initial analyses revealed that sessions only partially met the identified conditions: for example, they were poorly adapted to the real work organisation, exercises were not suitable and practicable for everyone, and preventive actions on MSDs remained limited (Troussier-Thevenot *et al.*, 2024).

A restitution phase was then organised to collectively review the results with the company's workers. This resulted in the creation of “prevention workshops,” which are participatory spaces where health and the safety manager and workers collaboratively design new physical

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exercise sessions in an attempt to fulfil the conditions of the thesis template. The company then launched working groups to make progress on the conditions identified, as part of a participatory approach involving the workers. Two orientations were given: (1) redesign sessions based on identified conditions, involving workers, facilitators, and the health and safety manager; (2) analyse other critical work situations to improve them.

One test phase evaluated the redesigned sessions. Workers and facilitators adapted exercises for all participants, including those with pain, and encouraged subcontractor participation to strengthen cohesion. Despite strong engagement, site constraints limited the full implementation of the identified conditions. However,

the “prevention workshop” created a valuable opportunity to discuss and exchange on other critical work situations and explore ways to improve them.

The co-design process showed that involving workers in developing sessions transforms them into opportunities for autonomy, reinforces the legitimacy of facilitators, and supports a collective, participatory approach to MSD prevention. Overall, this case highlights the need to design physical exercise sessions as integral parts of work organisation and prevention strategies rather than isolated initiatives. Their effectiveness depends on their integration within a comprehensive, participatory prevention approach that promotes dialogue (Cromer *et al.*, 2024) and action on MSD-related situations.

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