SMART DIGITAL SYSTEMS FOR IMPROVING WORKERS' SAFETY AND HEALTH

WEARABLES TO MONITOR & IMPROVE POSTURE ERGONOMICS

1 Introduction

Smart digital systems and technologies entering EU workplaces are reshaping work environments for workers and employers alike. Innovations in smart wearables, exoskeletons, artificial intelligence (AI), machine learning (ML), internet of things (IoT), virtual and augmented reality (VR and AR), among others, are giving new opportunities for preventing and responding to workplace risks.

As part of EU-OSHA's occupational safety and health (OSH) overview programme (2020-2023)[1], EU-OSHA has examined the challenges and opportunities of smart digital tools and monitoring systems for improving workers' safety and health. These systems, leverage digital technology to collect and analyse data in order to identify and assess risks, prevent and/or minimise harm and promote OSH.[2] EU-OSHA has categorised such systems into proactive (preventive) and reactive, albeit acknowledging the potential overlap between the two.[3] EU-OSHA further provided an overview of the risks and opportunities associated with these systems[4] and explored the workplace resources that could ensure their safe and healthy use.[5]

In order to investigate the practical implementation of smart digital tools and new OSH monitoring systems for improving workers' safety and health, EU-OSHA has developed a number of case studies. This set of case studies includes both cases of smart digital systems at the level of design/development and cases of companies implementing the systems. The case studies accordingly investigate aspects related to the design/development stage and to the implementation stage. OSH aspects including worker's involvement was considered in all case studies taking into account the type of case study. Further all case studies look at possible drivers, barriers and success factors for safe and effective implementation.

To develop these case studies, apart from desk research, a number of interviews with key informants were conducted, including workers' representatives, safety officers, employers and representatives of industry associations. In addition, at company level, up to five interviews were conducted with operators, data protection officers, health and safety engineers, managers, work councillors and technology officers. The interviews had a duration of 1-1.5 hours each and were performed in the participants' native language, if possible, or alternatively in English, an interview guide, while the results of the interviews were anonymised. The case studies referring to designers' results do not contain detailed information on workplace implementation, as there has been collection of information from companies in which the systems are installed.

In total 15 cases were identified, and preliminary information was collected for these through a questionnaire, hereafter, nine of them were further developed into case studies.

[1] For more information, see: osha.europa.eu (n.d.) Digitalisation of work. Available at: https://osha.europa.eu/en/themes/digitalisation-work

[2] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: uses and challenges, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-uses-and-challenges

[3] Ibid.

[4] Ibid.

[5] EU-OSHA (2023). Smart digital monitoring systems for occupational safety and health: workplace resources for design, implementation and use, https://osha.europa.eu/en/publications/smart-digital-monitoring-systems-occupational-safety-and-health-workplace-resources-design-implementation-and-use

2 Description of the smart digital system

2.1 General company description (developer)

The company started its activities in 2015 as a startup, and since then has developed into a small enterprise having an international portfolio with a strong presence in European countries and in the United States. It specialises in innovative safety-monitoring solutions such as wearable devices, sensor-free video analysis, and data analysis that its customers use to enhance health and safety in their respective workplaces. The products are individual health-focused monitoring systems. They solely focus on **monitoring workers' movements on an individual scale**, and do not monitor company-wide macro indicators (for instance the level of pollution onsite). In this sense, they allow companies to improve their efficiency, productivity, and overall awareness concerning health and safety-related topics. The company has developed and employs several types of technology, including wearable technology, ML AI, vision recognition, and information and communication technologies. Currently, they are used in various sectors, such as warehousing, retail and manufacturing, with a focus on activities that involve a high level of hazardous and repetitive movements.

2.2 System description

2.2.1 What is the system about?

The company's ergonomics improvement system consists of 3 major components, which together functions as a **wearable-based AI training programme to improve workers' ergonomic safety.** It delivers **personalised coaching** for workers by first identifying the most at-risk tasks and movements, and then offers the worker corrective guidance. First, the **wearable device** monitors workers' movements whilst providing biofeedback in the form of audible and vibrotactile alerts, to inform workers about hazardous motions in real time and helps them to self-correct their movements. This wearable technology measures the following 10 at-risk back and shoulder movements in real time:

1. lifting movements with poor technique and overreaching (sagittal flexion),
2. back twisting (rotation of the trunk),
3. high and sudden impact forces,
4. sustained arm elevation,
5. hazardous pushing and pulling of the shoulder,
6. sustained awkward static postures (including sagittal flexion and rotation of the trunk),
7. arm elevation (with or without load),
8. shoulder overexertion,
9. repetitive shoulder movements,
10. repetitive back movements.

Next, via the **mobile app** (through their mobile phones or a communal tablet built-in to the charging hub), workers can access the data on the 10 movement types outlined above in. This allows workers to **visualise their working days, highlighting dangerous positions and the time spent in each during a specific shift**. For instance, a worker can view exactly how much time they spent twisting their back and "track" (identify) the tasks and times of day when this hazardous movement occurs most frequently. Accordingly, the core indicator that the app shows is the number of hazardous movements for the spine and shoulder per hour. This indicator is used later to classify workers by the risk level of their tasks. In addition, the app provides a **20-day personalised training programme** for workers' individual movements and injury risks by enabling workers to visualise hotspots while also providing recommendations on how to correct these. The training includes short daily tutorials to encourage workers to change their behaviour in a sustainable way.

Last, the coach system makes use of an **analytics dashboard** which displays aggregated data on workers' movements. The dashboard enables managers and OSH officers to view and manage workers' progress regarding their posture and movement. The dashboard allows the visualisation of objective risk **data to analyse and reduce workplace risk through multiple solutions** such as training, workplace redesign, or a change of equipment. Moreover, there is a possibility of sorting data **by job role, department, or task** to accurately distinguish **hotspots** and map where interventions and

improvements are required. The two figures below summarise the company's coach system function, with the three main phases from the perspective of both the worker and employer.

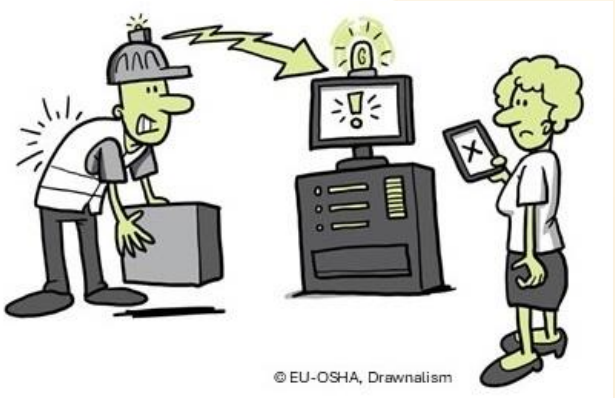
2.2.2 How does the system work?

The first component of the system is the wearable device already described. The second component of the system is a cloud-based **video recognition and analysis tool** that combines video captures through the app with AI-driven data analysis, to measure risk movements in the workplace accurately. With the help of a **data analysis tool** rapid interpretation of ergonomic risks will be provided. This helps workers and managers identify which tasks and movements are the riskiest. The app displays overall improvement as well as specific progress in individual body parts, which is crucial for enhancing workers' posture and movement. The **risk level of tasks and movements** is divided into **three categories**, and a **colour code** is assigned, which corresponds to the degree of danger that a task may carry. Green means that the task/movement in question is low risk, referring to motions with angles below 30°. Orange signifies that the task/movement is of medium risk with angles that range from 30° to 60° degrees. Red refers to a high-risk task/movement with angles above 60°. Workers are classified in one of the three categories depending on the number of risks in their tasks per hour. Further, an important functionality of the system is the **video comparison tool**, which evaluates various intervention options and **helps managers choose the best practices** based on the efficiency of each implemented practice. The comparison feature also enables **an assessment** of the measures put in place by workers and/or managers.

The third component of the company's system is an **analytics dashboard.** Thanks to the data collected by the wearable coach device and the video recognition and analysis functions, simple and intuitive reports on worker job activities and ergonomic hazards are generated as well as details of physical demands. This show the degree of physical load and strength required for a specific role. Collected data indicates how many **risks and movements** there are **on an organisational level** and clearly points out which tasks/roles exhibit problems. Data displayed in the dashboard can be viewed by all people involved in the company's programme (workers, safety managers, operations managers) and can be shared between them, but remain anonymous. Furthermore, each worker can view and track their personal performance exclusively.

To ensure the system's proper functioning, several senior managers of the system developer reported that they are always involved in implementations at the workplace level, overseeing and constantly improving or updating the system, taking into account both employer's (client) and workers' feedback as well as technological developments. The system is proactive as it assesses a worker's posture and takes immediate steps to improve it before injury occurs.

Figure 1: Cartoon-style representation of the system



3 Drivers and barriers for the implementation of the system

3.1 Motivators and goals

Interviewees expressed two main factors that were and are still driving the design and development phase: **the high number of work-related injuries** and the cost associated with this, as well as the **general lack of digitalisation of OSH departments in certain companies – especially in medium-sized enterprises.** While designing and developing the system, the company closely **collaborated**

with OSH and technical representatives to ensure that they had a thorough understanding of the OSH context, as well as all the dimensions of the technology they wanted to develop.

Another crucial element of the design and development phase was to introduce a **long-term behavioural change within organisations**, that is, to push companies in taking actions in a proactive manner. In fact, interviewees reported that many companies seek assistance in critical situations only after damage has occurred rather than focusing on preventing incidents in the first place. The final rationale for designing and developing the system was the company's goal to enhance organisations' **awareness of smart solutions and their efficiency and practicality in addressing OSH challenges compared to traditional methods** (such as excel or spreadsheets).

The design and development phase started with the concept of preventing injuries before they happen using wearable coaching technology. The achievement of this concept was possible with the help of companies (potential future implementers) adhered to this vision. With funds raised from these companies, the system developer start building its product. Workers were involved from the first (testing) phases. Interviewees highlighted that the design and development process was composed of many prototypes, tests, first versions, and minimum viable products.

For the system developer**, OSH was and continues to be the primary consideration when designing and developing the system**. At the time of the company's inception, the objective was to prevent risks associated with hazardous movements by proposing an innovative, technological OSH solution, thereby establishing itself as a key player in the market. At the moment the company is successful in an international field with a strong involvement for addressing customers' needs and concerns while taking into account any societal differences between countries.

3.2 Drivers

Prior to setting up the system, the developers need to understand each implementing company's context, needs and expectations. They have to understand the way that implementing company is working, their OSH policies, rules and networks, and the tools they are using. It is only by understanding the implementing company's context that the system developer can best adjusts its solution to its needs.

The company's head of development explained that initial consultations and discussions with OSH and high-tech representatives held **at the beginning of the design and development process** were very insightful and allowed the enterprise to understand the whole spectrum of OSH smart-monitoring systems. The company organised **monthly meetings with OSH/ergonomics professionals** to assess the main risks and safety needs in organisations. Furthermore, during the onsite testing phase, the enterprise received a high volume of **feedback and suggestions from the implementing company and its end users,** which enabled it to determine the direction in which to develop the system.

Developer- and implementer's collaboration is most evident during the **onsite implementation phase.** During this phase, workers who will wear the device and selected workers (for instance OSH representative) are testing and familiarise themselves with the system for approximately two weeks. During the proof-of-concept period, workers can ask questions about the system and raise concerns. In response, the solution developer addresses these concerns by increasing awareness of both the system and general OSH practices through video materials, short training on the ecosystem functionalities, objectives, and expected impact. After the testing phase, if no problems are reported, the system is deployed throughout the organisation.

From the beginning of the implementation process, it has been important to encourage workers to use the technology as a supplementary tool rather than a replacement for fundamental safety practices. Moreover, the system needs to be integrated into broader safety programmes to reinforce its use and benefits.

Another driver within the developer's close collaboration with the implementing companies, is to **jointly define goals and measurable KPIs** and identify the appropriate solution to achieve the implementing company's objectives. This **adaptability and flexibility allow it to be replicated and applied to different contexts,** in industries ranging from logistics and retail to manufacturing, and c company structures from start-ups to global corporations. **Technological progress and awareness** have also facilitated the implementation of the company's product, as noted above.

However, engaging end users/workers in the design and development phase is complex and it is necessarily to allow time for testing the solution. The company invited OSH and workers representatives to engage in discussions on the optimal way to design and develop the solution.

3.3 Barriers

Building worker engagement is the hardest and longest part. But once workers are on board, the implementation phase is smoother, at least from the human perspective. However, **technical issues** may persist, and before implementing the system, the company must wait and collect a high number of approvals and confirmations from operational managers of implementing companies. Many stakeholders are involved in this process, and the system developer must consult with all of them, which can be time-consuming. Moreover, in some organisations, issues with **data protection legislation** may come up Some companies use the full names of workers, whereas others opt for non-disclosure agreements. The system developer and its client -the deployer- must be GDPR compliant and guarantee that data is stored and secured properly. In other cases, the system developer has also faced restrictions in terms **of IT infrastructure,** (e.g. difficulties with the hub implementation and restrictions on workers using their personal phones). In some locations, it is not possible to record videos because of sensitive information and products. These regulations differ between companies but are found globally. In addition, implementing the system in larger companies usually entails a higher volume of **paperwork**.

Another barrier is **cost related, which particularly concerns SMEs**. Indeed, since health and safety are long-term investments, sometimes, companies are impatient to wait for results. In some cases, results are only visible several months after implementation. The system developer tries to convince partners that the initial investment is worthwhile. Another issue with the initial investment is maintaining and upgrading the OSH system; for example, training new workers. Nevertheless, in the majority of cases these costs are low.

In 2014-2015, at the beginning of the design and development of the company's product, potential implementing companies were not well informed about wearable technology and had little interest in adopting this type of product. In fact, company representatives pointed out that OSH departments of organisations were **reluctant to digitalise OSH-related matters.** Thanks to technological progress and the company's early successes and outreach, more organisations began adopting the product and automating OSH processes. Despite recognising the benefits of digitalisation, such as fewer accidents and sick days, as well as increased efficiency, which in turn generates additional savings – OSH still lags behind other sectors in terms of digitalisation. One reason for this relatively slow progress was offered by an interviewee:

> *"There is still a long way to go and effort to make in explaining to companies/workers that the technology is not there to replace humans but to help them".*

Complex collaboration with end users during the design and development phase was also cited as a challenge. It is necessarily to allow workers to spend time on testing the system. Testing means that workers maybe need to devote supplementary time to this and, therefore, have less time to complete other (safe and healthy) work duties. The management of work time and workload must be considered. One possibility might be to carry out the **test phase during workers' regular working hours** and reduce their other workload during the test period.

When asked about challenges for the near future, respondents noted that in the European context, the most pressing issues would revolve around **ensuring data security and compliance**. Moreover, according to the prevailing emphasis in Europe for companies to adapt the workplace rather than workers to change their behaviour, the introduction of technology could be seen as weakening this **employer's responsibility.** Finally, the system might have an impact on the workflow that could occur in the form of disruptions. Audible and vibrotactile alerts could potentially **disrupt productivity and concentration**, particularly in high-stress or high-focus environments.

4 OSH impact

4.1 Opportunities

According to the developing company's representatives, the primary feedback about this product concerns **the reduction of risks and work-related injuries.** Companies using the system reported on average a 30-70% reduction in work-related injuries and accidents in their workplaces. In parallel, they noted **increased productivity and efficiency in OSH-related issues and other operations.** Indeed, data collected by the wearable allows companies to resolve matters, such as musculoskeletal disorders (MSDs). It also indirectly leads to positive changes in general. For example, it was reported that worker turnover and worker compensation costs has been reduced, and therefore better financial results and growth. The system's immediate feedback allows for **early intervention** enabling quick reactions and prevention of OSH hazards such as MSDs. Moreover, the use of the systems also have an impact outside of the work context, with managers explaining that workers are changing their behaviour related to ergonomics and posture in the long term and outside of their workplace (e.g. whilst gardening or lifting heavy items).

The quantifiable impacts highlighted above also lead to **increased cohesion and overall OSH culture in companies**. After using this OSH monitoring system, workers usually understand the importance and value of such a system, as well an improvement in worker relations and management regarding OSH topics in general. The system also enhances **continuous learning** since workers receive ongoing training and reinforcement of safe practices, leading to sustained improvements in ergonomics.

Another opportunity the OSH system provides is thorough task analysis. The analytics dashboard provides valuable data on which tasks and movements are the riskiest, enabling targeted interventions. With **data-driven insights,** managers can use the data to make informed decisions about workplace design, training programmes, and resource allocation.

4.2 Challenges

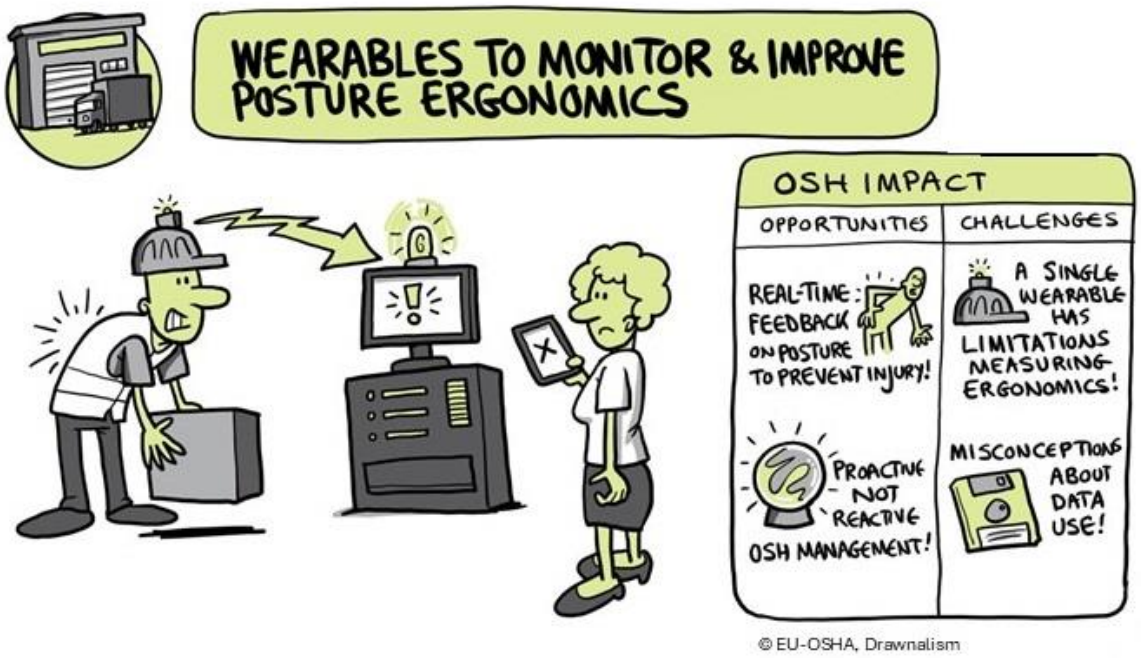
During our research, several interviewees emphasised the fact that data collected by the employer is **strictly related to job activities only and thus, no personal information is compiled or processed.** The employer *should commit that only the number of hazardous movements is tracked and worker's location or productivity is not recorded.* For each worker, the system collects ergonomic-related data, analyses movements and tries to detect either positive or negative emerging trends. In terms of legislative compliance, the wearable complies with data protection regulations as well as with the company's own internal data processing policy. In this context, the national situation of the implementation company comes into play. Interviewees from the US based developing company noted the different legislative contexts in terms of data protection to consider. Consequently, in several European companies, collected data has been entirely anonymised, which does ensure the protection of worker privacy but can, at the same time, alter the results of implementation in a work site. This aspect has been further developed in the earlier section on barriers.

Another challenge for Europe is the change due to demographics and an **ageing workforce**. The interviews touched upon how older workers can be wary of using digitalised OSH solutions. In parallel, **young workers** are less likely to be concerned about the long-term benefits of these solutions and, therefore, maybe are less likely to want to use OSH systems. However, as they most likely feel more comfortable with technology and applications, may be further engaged and use the system more effectively. **Trade unions** could be involved and provided with evidence about the purpose and consequences of adopting such technological solutions.

Representatives of the company developing the system also reported a tense relationship between the implementing company (client)'s workers and managers regarding the adoption of OSH solutions. For instance, some workers may resist using the wearables due to **discomfort, scepticism, or lack of familiarity with the technology.**

Another challenge can be a dependence on technology, that is, **over-reliance.** Workers might become overly reliant on the system, potentially neglecting basic safety practices when the technology is not in use. Also digitalised OSH systems can be subjected to **technical failures or malfunctions** which can disrupt the monitoring and feedback process, leading to lapses in safety. A form of technical malfunction can be linked to **false alarms and feedback accuracy**. Inappropriate alerts can lead to annoyance and eventual disregard for the warnings, reducing the effectiveness of the system.

Figure 2: Cartoon-style representation of opportunities and challenges for OSH



5 Takeaways for development and implementation

Both the developing company and the implementing companies emphasised the fact that successful implementation heavily depends on worker engagement.

The implementing company, the employer needs to:

- create a system to ensure that workers are using the system in the appropriate way, consistently wearing and returning the device, that data is uploaded and that the hardware is functioning properly,
- ensure that workers use the technology as a supplementary tool rather than a replacement for fundamental safety practices.
- take care that the system is integrated into broader safety programmes to reinforce its use and benefits.

The system developer needs to:

- understand each implementing company's context, needs and expectations, prior to setting up the system, as well as their OSH policies, rules and networks, including the tools they use – by the involvement of manager, OSH representatives and workers. Equipped with this information, the system developer can tailor the system to the end user 's needs.
- provide training material/tutorials regarding hazardous movements during design and implementation thereby increasing employer and workers' awareness about OSH. The developer can even be an intermediary by disseminating useful OSH practices. For instance, if a logistics company can automatise manual handling, the studied company can share this process with other companies within the same sector, which is useful at the industry level. In this way, the studied company builds a catalogue of good practices to share.
- provide transparent communication with implementing companies about the usage of their data as this is crucial to ensure smooth implementation. The company developing the OSH system needs to specify and explain confidential data protection policies to its customers to avoid any misunderstandings.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
IoT	Internet of things
ML	Machine learning
OSH	Occupational safety and health
QM	Quality management
VR	Virtual reality

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