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INCLUSIVE WORKPLACE DESIGN USING MOCAP TECHNOLOGY

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Abstract
The integration of workers with disabilities into the labour market is a complex issue that requires an interdisciplinary approach. This study analyses barriers to employment for people with disabilities and highlights the role of ergonomics, modern technologies, and sustainability in creating an inclusive work environment. Through a literature review, surveys, and interviews, we examined the situation in Europe and in Slovenia, with particular attention to technologies such as an inertial motion capture (Mocap) system and Xsens sensor suit for improving workplace design. Although technological advances create opportunities, challenges remain, including low awareness of ergonomics, high implementation costs, and a shortage of qualified personnel. The study offers recommendations such as educational programmes, awareness campaigns, collaborative workshops, and practical solutions using simulation techniques. In particular, the use of motion-capture simulations such as Xsens sensor suit is emphasised as a valuable tool for ergonomic workplace design, enabling precise analysis and optimisation of tasks to better support an inclusive and sustainable work environment.
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Key Words: Ergonomics, Employment, Workplace Design, Workers with Disabilities, Motion Capture Systems

1. INTRODUCTION

Engagement in working life is one of the most important elements for participation in modern society as a whole and for an inclusive society. It plays a crucial role in shaping an individual's identity by providing psychological balance, facilitating social inclusion, providing opportunities for continuous learning and positively influencing a person's life [1]. This is particularly important for people with disabilities, as employment not only provides the benefits mentioned above, but also helps them to overcome prejudice. It can boost their self-esteem, improve their self-confidence, provide a sense of productivity and achieve equal integration into society [2-4]. In addition, the integration of people with disabilities into the workforce not only improves their quality of life but also enriches companies by contributing to greater diversity and innovation [5-7]. Despite numerous legal and financial incentives for companies and progress in adapting workplaces through assistive technologies, the integration of people with disabilities into the work environment remains a major challenge. Employment opportunities for people with disabilities are often lower compared to people without disabilities [1, 2, 8, 9]. This global trend is referred to as the disability employment gap (DEG) and serves as a key indicator of labour market inequality related to disability [2].

Job seekers with disabilities often face obstacles at every stage of the employment process, from finding a suitable job to successfully integrating into the workplace and maintaining employment. One is the lack of jobs tailored to their specific needs [10-12]. This is often due to a lack of ergonomic expertise [13], especially in small and medium-sized enterprises (SMEs), which are often unable to create an accessible working environment. Larger companies also face challenges related to the special needs of employees with disabilities. Often, employees with disabilities are assigned specific roles, which can lead to isolation and limited interaction with other colleagues [14]. In addition, large organizations may struggle to fully adapt to their large and complex workspaces, which can hinder the effectiveness of disability inclusion.

There is potential to improve employment opportunities for people with disabilities using assistive technologies [15-17]. In recent decades, these technologies have been widely adopted bringing numerous benefits to both people with disabilities and the general population. Although assistive technologies such as tools, equipment, devices and software [15, 18, 19] already provide essential workplace adaptations for people with disabilities, advanced systems like Xsens sensor suits are increasingly applied to optimize ergonomic design through motion sensing [20]. They provide precise motion analysis for better understanding of the needs of workers with disabilities and enable optimization of work processes. This technology could increase safety and efficiency in the workplace, which would ultimately increase productivity and create a more comfortable working environment for all employees.

Despite all progress, widespread stereotypes about people with disabilities continue to hinder their professional advancement and equal opportunities in the labour market [3]. To overcome these challenges, better access to ergonomic expertise is needed, especially for SMEs [21], through government programs and subsidies. Larger companies need to integrate people with disabilities into regular tasks and ensure equal opportunities for advancement, but it is also important to promote all positive attitudes through educational programs and awareness campaigns. Such initiatives help to break down prejudice and improve understanding of the real capabilities of people with disabilities, which can lead to a more inclusive and equitable working environment. This not only improves employment opportunities for people with disabilities but also strengthens the culture of acceptance and equality in the workplace.

The main objective of our study is to identify and analyse the complex barriers that people with disabilities face in finding and keeping employment. Various factors influencing their employability were examined, and solutions based on advanced technologies and best practices were proposed. Technological innovations can foster more inclusive workplaces, but integration remains limited by a lack of expertise, segregation, high costs, and persistent barriers. Coordinated action is therefore essential.

The inclusion of people with disabilities in the workplace is not only a legal and ethical responsibility but also a strategic investment that brings long-term value. A diverse workforce that includes people with disabilities offers numerous benefits to organisations, including innovative perspectives, increased productivity, and greater employee retention [22]. By removing barriers and ensuring equal opportunities, organisations contribute to greater social cohesion and lay the foundations for sustainable growth, benefiting both businesses and society.

2. MATERIALS AND METHODS

The overall research methodology, shown in Fig. 1, consists of four phases, namely: *Phase 1*: Desk research; extensive literature review, *Phase 2*: Filed research; conducting focus group interviews and surveys of employees with disabilities, *Phase 3*: Data analysis; analysing the data from Phases 1 and 2, and *Phase 4*: Ergonomic options and solutions; Mocap testing for different groups of people (with and without disabilities) on a polygon circle with a sequence of simple actions, three dynamic and four static, using the Mocap system.

In our study, we followed a mixed methods approach, using both qualitative and quantitative data collection methods. The literature review and data analysis fell primarily under the qualitative methods, while the interviews, surveys and Mocap tests contained elements of both methods. Since we conducted the research among individuals with various types of disabilities, who are considered vulnerable groups, we first submitted all materials used later for interviews and survey research for review and approval to the university ethics committee. The committee reviewed and approved all the materials. The presented multi-faceted approach allowed us to gain a comprehensive and nuanced understanding of the research topic, with each stage building on the findings of the previous one.

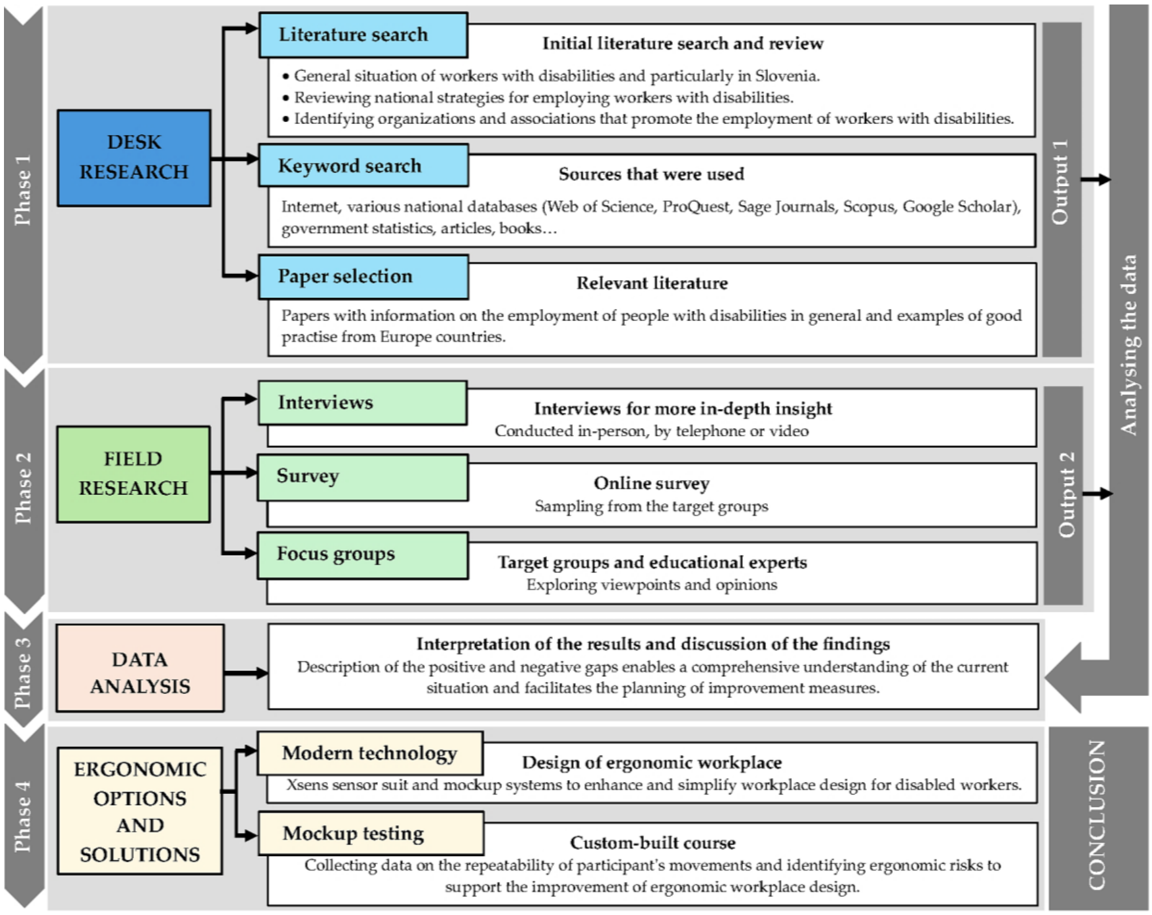
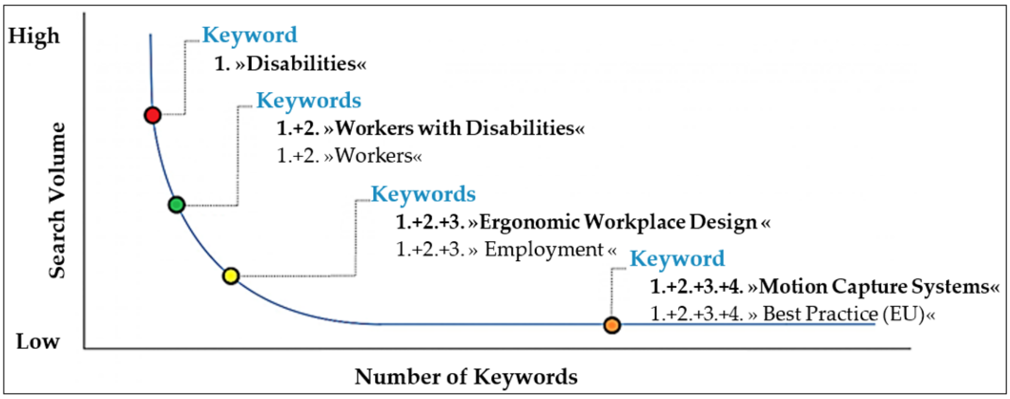


Figure 1: Research methodology phases.

2.1 Phase 1: Desk research

The first phase of our methodology involved a comprehensive literature review to gain an overview of the current situation of workers with disabilities, with a focus on Slovenia.



	Web of Science		ProQuest		Sage Journals		Scopus		Google Scholar	
1	226,267		447,019		217,088		265,641		1.160,000	
2	182	5,403	1,357	12,364	4,300	26,155	6,824	6,976	9,130	336,000
3	0	1,060	5	1,234	3	2,453	19	1,242	798	81,900
4	0	5	0	26	0	22	0	17	2	42

Figure 2: Summary of the database search results, showing the number of articles found and search curve.

In this phase, national strategies for the employment of workers with disabilities were analysed, associations promoting their employment were identified and examples of good practice in the employment of people with disabilities were examined. International databases were then systematically searched for relevant articles using a set of carefully selected keywords related to the employment of people with disabilities, workplace integration, ergonomic design of workplaces and the use of modern technologies such as motion capture systems to adapt workplaces (Fig. 2). The literature review covered various studies and research, conducted primarily in the period from 2015 to 2024 in Slovenia and Europe. The findings indicate that the employment of people with disabilities is well documented in the scientific literature. The number of identified cases suggests that the issue is actively addressed and that numerous successful approaches exist for integrating people with disabilities into the work environment. However, certain databases yield only a limited number of results, particularly when the keyword “motion capture systems” is included, indicating a potential gap in the literature regarding the application of advanced technologies in this area.

2.2 Phase 2: Field research

The second phase of our methodology consisted of field research. We conducted focus group interviews and an online survey among employees with disabilities.

The aim of the focus group interviews was to gain a deeper understanding of the topic addressed and to shed light on additional reasons that could be responsible for the current situation. We conducted 19 in-depth interviews with employers and 10 with employees. These employers and employees were selected based on their years of experience managing and working in inclusive work environments to ensure diverse perspectives and comprehensive insights into the challenges and best practices related to employing people with disabilities. Interview questions were determined based on information from the literature review, input from practitioners and preliminary discussions with stakeholders. The interviews were conducted in person, by telephone or by video conference.

The survey of employees with disabilities allowed us to reach a larger number of participants with specific questions that gave us a quantitative insight into the topic under discussion. A total of 40 participants took part, with a balanced gender distribution. When formulating the questions for the survey, we used data gathered from a literature review and an in-depth analysis of the interviews, and focused on identifying the main challenges, barriers and potential solutions for employing people with disabilities. The survey targeted workers with disabilities employed in companies of different sizes. Most of these workers were employed in the primary and manufacturing industries, as well as in the retail and service sectors.

In focus groups, the target groups shared their perspectives directly with education experts. This exchange of life experience and expert knowledge provided valuable insights into the complex nature and contextual challenges of the topic.

2.3 Phase 3: Data analysis

Various methods were used to analyse data from both desk and field research. Qualitative and quantitative findings were visualised with diagrams to ensure clear data interpretation.

In the first phase, qualitative data were summarised in tables and a flow chart based on keyword searches, while in the second phase, quantitative data were processed in Excel and presented as percentage-based charts. This approach enabled an in-depth discussion of the employment and inclusion of people with disabilities in the workplace. The analysis focused on identifying key strengths and weaknesses to support the planning of ergonomic improvements and the development of further solutions.

2.4 Phase 4: Ergonomic options and solution

The final phase of the research cycle involves Mocap tests for different groups of people (with and without disabilities) on a training ground (polygon) using the Mocap system.

The Xsens sensor suit was used to explore the potential of modern technologies for the assessment of disability-related abilities. The Xsens sensor suit provides detailed motion detection capabilities [23] that can be used to design workplaces tailored to the physical requirements of workers with disabilities. Mocap systems enable simulation of real tasks in a controlled environment, allowing employers to test and refine ergonomic solutions before they are implemented [18, 24, 25]. By integrating these technologies, the process of creating an accessible and efficient workplace could be simplified [26].

A special test environment was set up for our research, designed in collaboration with a kinesiologist (Fig. 3, left part).

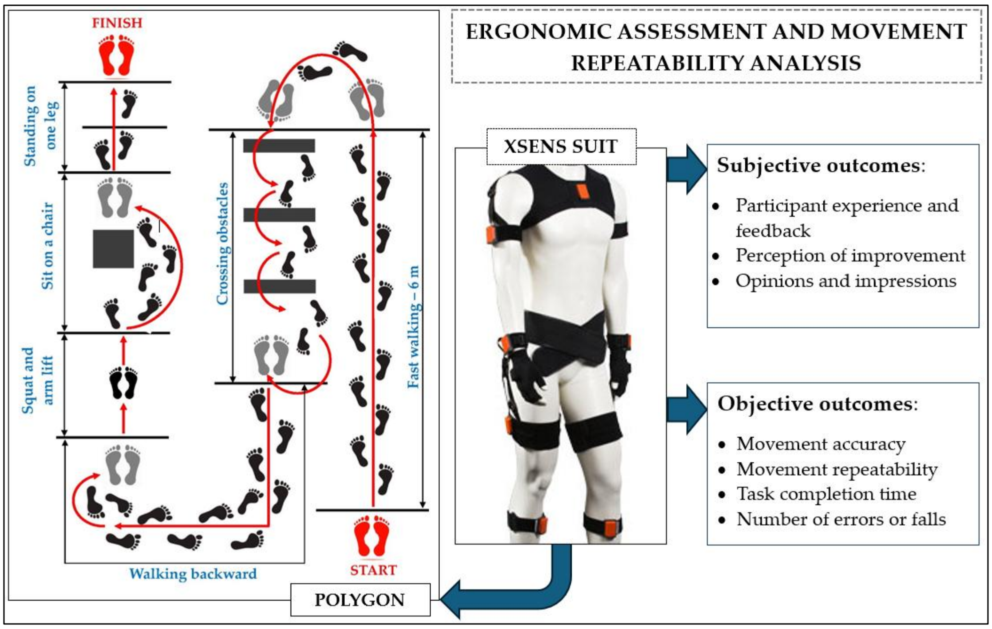


Figure 3: Diagram of the testing course /polygon and expected objective and subjective outcomes.

The Xsens sensor suit with the Process Simulate software (Siemens PLM) was used to carry out the tests. This suit was procured as part of the RIUM project, which was co-financed by the Slovenian Ministry of Education, Science and Sport and the European Union from the European Regional Development Fund. The Xsens MVN Awinda system with 17 wireless motion sensors (Fig. 3, right part) attached to a special Lycra suit was used for our research.

The Xsens MVN Awinda system uses 23 segments: 17 sensors attached to specific body parts, e.g. pelvis, spine (T8), head, shoulders, upper arms, forearms, hands, thighs, lower legs and feet; for other body parts, e.g. the neck and the spine (L5, L3, T12), the movements are estimated by integrating the data from the neighbouring segments and the biomechanical model. To achieve high accuracy, the sensors were calibrated using the N-Pose and the human movements were recorded and later analysed using the Process Simulate software.

3. RESULTS

This chapter presents the results of the studies on the occupational integration of workers with disabilities. The focus is first on summarizing the results of the literature review, which provides a comprehensive overview of the existing research and relevant legislation in this area. It then discusses the data from the interviews with employers and employees with disabilities and the results of a broad online survey. Finally, the results of the initial testing of the Xsens sensor suit on a custom-built polygon for testing people with and without disabilities (see Fig. 4) will be discussed to evaluate its effectiveness as a tool for assessing and improving workplace ergonomics for people with disabilities.

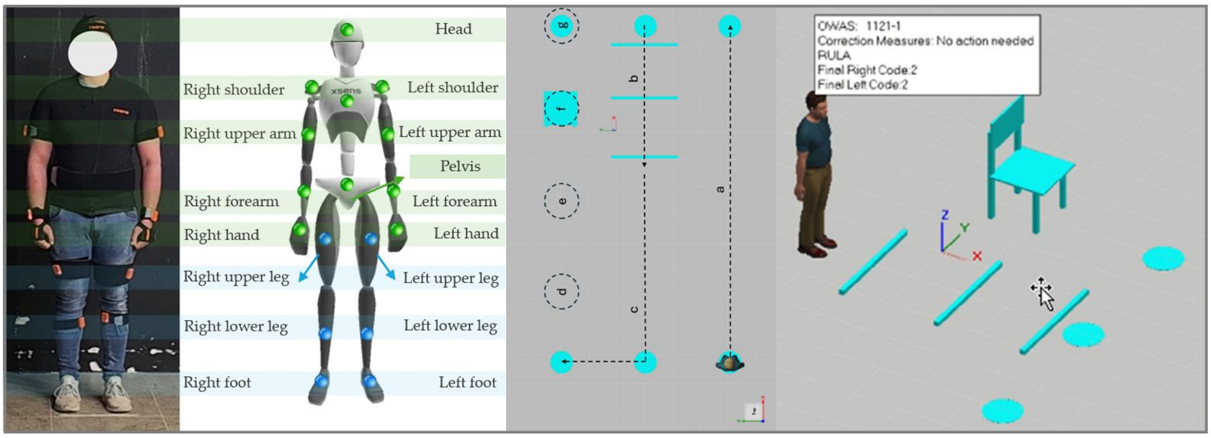


Figure 4: Testing polygon and human movements created with Process simulate.

3.1 Findings from the field research

According to the Statistical Office of the Republic of Slovenia, people with disabilities make up around 12–13 % of the total population of Slovenia [27], which corresponds to an estimated number of 160.000 to 170.000 people. Of these, 36.000 are of working age [28]. An analysis of employment trends from 2017 to 2024 shows that the unemployment rate for people with disabilities is between 15.2 % (in 2020) and 18.2 % (in 2019). This is around three times higher than the aver-age unemployment rate for the general population. Although this trend has improved somewhat in recent years, the employment rate for people with disabilities remains very low at just 4 %. The detailed data is shown in the graph in Fig. 5.

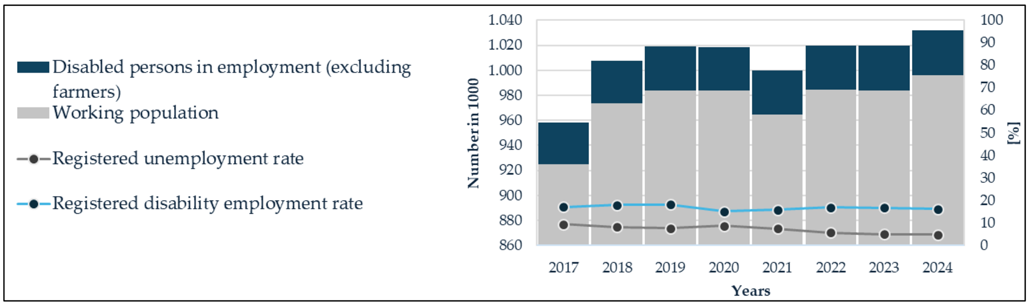


Figure 5: The employment situation in Slovenia over the last eight years.

The statistical data show that there is a large gap between the employability of people with disabilities and the rest of the population, although Slovenia has an active policy in this area and has introduced a quota system to promote the employment of people with disabilities since 2004. Apart from the specifics of the quota system, the country has a comprehensive legal framework comprising numerous laws and regulations, including the Employment Relations Act, the Act on Vocational Rehabilitation and Employment of Persons with Disabilities, the Act on Equal Opportunities for Persons with Disabilities and the Act on Equal Opportunities for Women and Men. In addition to the existing laws, there are also practical strategies that contribute to increasing the employment of people with disabilities. These include the Union for Equality: Strategy for the Rights of Persons with Disabilities (2021–2030), Action Program for Persons with Disabilities (2022–2030), Strategic Plan of the Association of Disabled Workers of Slovenia (2022–2026). There are also several important organizations in Slovenia that support and promote the employment of people with disabilities. The identified organizations include government agencies (offices, centres) and non-governmental organizations (associations, foundations, funds, chambers, municipalities) as well as other institutions. These institutions are the most important actors in promoting equal opportunities for the inclusion of people with disabilities in the workplace. Among the most important are the Slovenian Employment Service, the Slovenian National Council of Disability Organizations, the Slovenian Association of Disabled Workers, the Slovenian Association of Vocational Rehabilitation Providers, the Slovenian Association of the Deaf and Hard of Hearing and others.

Moreover, numerous examples of good practice demonstrate the potential for equal inclusion of people with disabilities in the workplace. Although Slovenia has developed valuable knowledge and successful initiatives in this area, these remain insufficiently recognised. Promoting such practices strengthens professional cooperation and raises public awareness. Analysis of interview results further confirms that workplace inclusion enhances the social participation, self-esteem, and well-being of people with disabilities. Employers generally express willingness to invest in workplace adaptations, training, and awareness activities, recognising that supported employees with disabilities often perform as well as, or better than, their peers. Nevertheless, challenges remain, including longer training periods, limited resources for adaptations, and health-related constraints.

On the other hand, employees with disabilities emphasized that the key factors for successful employment are desire, willingness, initiative, employer support, effective communication and good interpersonal relationships. Flexible workplaces and ergonomic adjustments are important elements for the successful inclusion of people with disabilities. However, they have difficulties integrating into a new work environment. These include limited social skills, sensory issues, adjustment and training at the start of employment, longer time to adapt to new jobs and colleagues, inflexibility of managers and rapid burnout.

To complement the interview findings and gain a broader overview of the current situation, a survey was conducted among employees with disabilities and their employers.

The results of the survey (Table I) show that in most cases (81 %), adjustments to the workplace were necessary before starting work (Q1). Likewise, 81 % believed their work tools (Q2) are adapted to their needs, while 40 % said the same about the adapted workplace as a whole (Q3). This suggests that workplace adaptation can be a limiting factor in employment and that respondents may been selected for jobs that require minimal adjustments.

It is clear that employers are successfully adapting to the needs of people with disabilities. More than 80 % of respondents say that the current ergonomics of their workplace are suitable for their disability (Q4) and that they have been trained or informed about hazards and their impact on the working environment (Q5). Similarly, more than 80 % are satisfied with their current job situation in terms of the support they receive in relation to their disability (Q6). However, satisfaction with the opportunities for self-development and career progression decreases slightly (Q7).

Table I: Results of the online survey.

Share Chart		**RESPONSE** (%)				
		I totally agree / Very large impact	I agree / Large impact	Neutral / Moderate impact	I don't agree / Small impact	I don't agree at all / Very small impact
QUESTION	Q1	42	39	13	3	3
	Q2	42	39	11	5	3
	Q3	16	24	18	18	24
	Q4	32	55	11	3	0
	Q5	18	61	21	0	0
	Q6	34	47	11	5	3
	Q7	21	42	13	8	16
	Q8	23	48	20	8	3
	Q9	25	25	40	8	3
	Q10	25	35	28	13	0

The analysis of the responses on the availability of accessible workplaces shows that around 70 % of participants believe that the lack of adapted workplaces (Q8) has a major to very major impact on the employment of people with disabilities. Half of the respondents (around 50 %) also stated that employers' lack of knowledge about appropriate measures and strategies (Q9) has a significant (very large or large) impact. Unfortunately, prejudices and misconceptions about people with disabilities (Q10) continue to be a significant barrier to employment. 60 % of respondents hold this view. This shows that the public perception of people with disabilities is still extremely negative.

3.2 The potential of modern Xsens technology to eliminate gaps in ergonomic workplace design for people with disabilities

In the search for innovative solutions, we have investigated the potential of modern technologies such as the Xsens sensor suit and Mocap systems in connection with the ergonomic design of workplaces for people with disabilities using the Process simulate software.

A total of 30 participants took part, 9 with various physical disabilities (mobility impairment, spine problems, lifting limitations, knee pain, shoulder pain, deaf, one eye vision loss) and 21 without disabilities. Before conducting the study, we measured the blood pressure and heart rate of each participant in advance. We also collected data on height, weight, year of birth, gender and the type of disability, if any. Participants were fitted with an Xsens sensor suit, the calibration procedure was performed, and then they completed the movements through the polygon. Prior to the main study, a repeatability test was conducted, in which the polygon was performed seven times in succession to assess the consistency of movement execution. The polygon was designed to include three dynamic and four static activities. The movements of the polygon included:

1. walking straight ahead for approximately 6 metres,
2. walking over obstacles,
3. walking backwards,
4. squatting down,
5. standing up from a squat and raising your arms above your head,
6. sit down and stand up from a chair without using your hands, and
7. standing on one leg with arms outstretched for 30 seconds to maintain balance.

The analysis of movement repeatability, shown in Fig. 6, shows that most movements were performed with high consistency. The standard deviation (*SD*) values for the back, arms, and head were generally between 0.0 and 0.5, confirming stable execution across all repetitions. Greater variability was observed for the legs and trunk, particularly between 25–29 seconds (*SD* for legs up to 0.9, arms up to 0.9, and head 1.0) and between 33–35 seconds (trunk *SD* between 1.0 and 1.3). These results indicate that movements requiring increased use of the lower extremities and trunk, such as walking over obstacles and backwards, bending down or standing up, were less consistent. In contrast, other actions, such as walking or simple reaching movements, remained highly repeatable.

The participant's posture analysis was evaluated using the OWAS method, which helps to determine the load on the musculoskeletal system, identify system-related incorrect postures and repetitions, and define optimal work tasks. The analysis revealed that most postures during the task were categorised as action category 1 (normal positions that do not require special caution), indicating that the working postures were generally safe. Occasional instances of category 2 (postures requiring correction in the near future) were observed, particularly between 25–28 seconds and 33–35 seconds, where ratings ranged from 2.0 to 2.9. These results suggest that, although most postures were ergonomically acceptable, less favourable postures were adopted at certain phases of the task and should be corrected to avoid potential long-term musculoskeletal strain. Importantly, none of the postures were categorised as 3 or 4, which would require critical action.

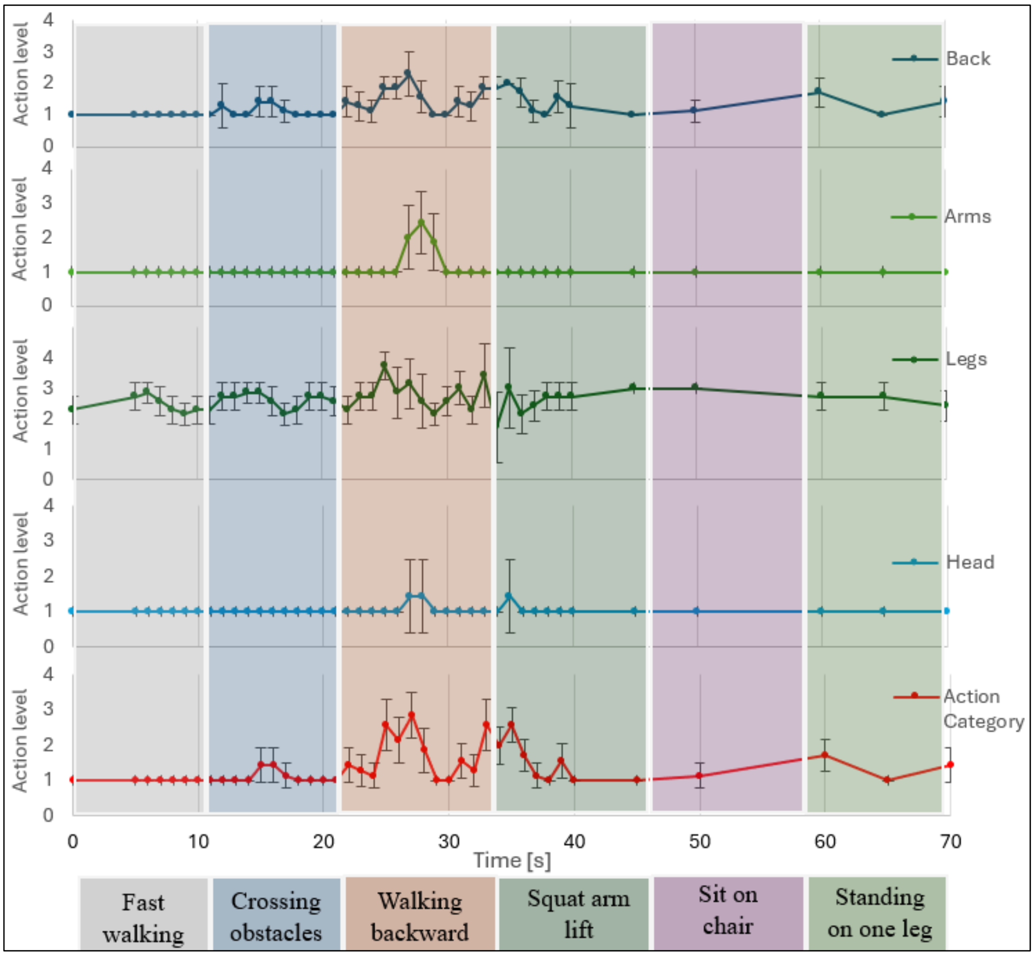


Figure 6: Graphical analysis of postural load using the OWAS method.

Subjective feedback from participants, both with and without disabilities, revealed several insights and barriers. Participants without disabilities reported that the course was easy, while participants with special needs acknowledged the complexity of the tasks. In particular, they highlighted some difficulties with tasks such as squatting and standing on one leg. They emphasised that tailored support and training could significantly improve their performance. There were also differences in the duration of the tests. Both groups shared the view that such tests could make an important contribution to the ergonomic design of workplaces for people with disabilities, as they would provide a better understanding of their specific needs.

The first tests carried out with the Xsens sensor suit have shown that it is possible to recognise and distinguish differences in the movements of people with and without limitations. This indicates that the equipment is precise enough for differentiation. In addition, a detailed analysis of movement repeatability was conducted, focussing on how consistently a person performed the polygon tasks while wearing the suit. These results confirmed that the system can reliably capture even subtle variations in posture and movement, which is essential for assessing ergonomic risks and work performance. The results are encouraging, so we will continue the research. The objective results of these tests are currently being further analysed and will be presented in the future to provide a comprehensive understanding of the movement abilities and needs of people with disabilities in a work environment. We are also planning further tests for different groups of people, such as men, women, younger and older people, with and without disabilities.

4. DISCUSSION

The results presented in the previous chapter provide several important insights into the occupational inclusion of workers with disabilities and the effectiveness of current practices and tools. The analysis of these results highlights both the strengths and limitations of existing approaches and points to future improvements.

The literature review shows that there is extensive research and comprehensive legal framework to promote the employment of people with disabilities, both generally in Europe and specifically in Slovenia. However, it also reveals gaps in the practical implementation of these measures. While the legal measures are thorough, their application in practice often varies depending on the company's commitment and available resources. This discrepancy suggests that more consistent application of these measures is needed to bridge the gap between legislative intent and actual practice.

The interviews with employers and employees with disabilities provided in-depth qualitative insights into the benefits and challenges associated with workplace accommodations. Employers generally recognize the importance of including employees with disabilities and are willing to invest in the necessary adjustments and supports. However, they often lack sufficient knowledge about ergonomic design or the necessary resources to hire and support suitable employees. This knowledge gap can hinder the successful implementation of adaptation measures and reduce the overall effectiveness of inclusion strategies. To close this gap and improve employment opportunities for people with disabilities, better training and access to expertise on ergonomic workplace design and support systems are needed. On the other hand, workers with disabilities emphasized the need for individualized support, especially in terms of ergonomic adjustments and flexibility in the workplace. These results underline the need for ongoing support and tailored measures to ensure effective integration.

The survey results also highlight a significant perception gap between the overall satisfaction of employees with disabilities and the actual implementation of support measures. Although many respondents were satisfied with their current job situation, problems such as prejudice, misconceptions and inadequate workplace adjustments were cited. This suggests that raising awareness among employers and addressing these misconceptions could increase the effectiveness of inclusion strategies and contribute to a supportive work environment.

The Mocap tests with the Xsens sensor suit provided initial insights into how advanced technologies can help with ergonomic design. Although these tests are still ongoing, the initial results suggest that such technologies have the potential to significantly improve the adaptation of the work environment for people with disabilities. Feedback from participants underlined the promise of tailored support and the need for further refinement of these tools to better address specific needs.

In summary, despite the progress that has been made in the inclusion of people with disabilities, the integration of the findings from the literature review, field research and pilot projects shows that further efforts are needed to find comprehensive and effective solutions.

Employers and policy makers should focus on bridging the gap between the legal framework and the practical approach by investing in training, raising awareness and utilizing advanced technologies.

5. CONCLUSIONS

The analysis of the literature and examples of good practice confirm significant progress in integrating people with disabilities into the labour market. However, despite these improvements, notable gaps remain, particularly in adapting workplaces to diverse individual needs. Advancing technological solutions and ergonomic workplace design are therefore key steps towards bridging these gaps. Preliminary research on the use of the Xsens motion capture suit in workplace design has shown strong potential for accurately assessing and improving the movement of people with disabilities. With this technology and complementary ergonomic tools, it is possible to collect essential data quickly to adapt workplaces to individual needs. Future research will build on these findings and expand to include various groups of people with and without disabilities to develop more inclusive and sustainable workplace solutions.

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