# WORKLOAD COMPARISON OF PERSONS WITH DISABILITIES AND HEALTHY INDIVIDUALS ON A PREDEFINED COURSE USING XSENS

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***Abstract:***

*This study compares the physical workload of people with disabilities and healthy individuals performing tasks on a predefined course using the Xsens motion capture system. Motion data from 56 participants were used to create digital human models for ergonomic assessment with the Ovako Working Posture Analysis System (OWAS). The results reveal significant workload differences, highlighting increased ergonomic risks for people with disabilities during specific tasks. The findings were validated in rehabilitation and employment settings. The study confirms that combining wearable motion capture with established ergonomic methods effectively assesses workload and supports workplace adaptations.*

## 1 Introduction

Physical workload during daily and occupational tasks is closely linked to movement patterns, postural strategies, and an individual's ability to adapt to specific environmental demands. For people with disabilities, these factors are particularly significant, as physical limitations often lead to compensatory movement patterns. Although these patterns enable functional task execution, they also result in uneven force distribution and increased mechanical strain on certain components of the musculoskeletal system. Understanding these biomechanical specifics is crucial for reliable assessment of physical workload and for moving from subjective approaches to objective risk evaluation. Detailed analysis of changes in posture and movement enables identification of critical loads that are not always detectable through observation. This forms a basis for developing professionally grounded adaptations of work tasks and living environments. Such adaptations enhance safety, reduce injury risk, and support the long-term, sustainable, and ergonomically efficient inclusion of people with disabilities in active social and work environments. Collectively, these challenges highlight the need for more precise and objective approaches to physical workload assessment that go beyond conventional observational methods, particularly for populations with physical impairments.

In the field of physical workload assessment, ergonomists have long used a range of established methods that rely primarily on observational protocols and standardized questionnaires. Among the most frequently used are the postural load assessment methods such as Rapid Entire Body Assessment (REBA) [1], Rapid Upper Limb Assessment (RULA) [2], Ovako Working Posture Analysis System (OWAS) [3], the Occupational Repetitive Action (OCRA) method for assessing repetitive movements, the National Institute for Occupational Safety and Health (NIOSH) equation for load handling and many others. Although these methods are widely used for their simplicity and practicality – several reviews and comparisons were made in the past [4] - they often depend on subjective judgement or self-assessment and may fail to detect short-term, yet biomechanically critical, peak loads [5]. This is particularly problematic for individuals with physical disabilities, where compensatory movements may occur inconsistently, situationally, and within brief time intervals. As a result, important biomechanical risks may remain undetected, despite the apparent functional

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success of task execution. Modern ergonomics guidelines emphasize the need to update observational methods and to develop and implement new, objective ergonomic assessment techniques. Consequently, there is growing interest in reliable, rapid, automated tools for motion capture and analysis across a wide range of environments - not only in industrial settings, but also in medicine, sport and rehabilitation [6] – [8]. While motion capture (Mocap) systems are gaining prominence for their ability to provide precise and repeatable digitization of human movement in real time [9] – [11], there remains a lack of studies that systematically integrate this objective data with established ergonomic methods for evaluating populations with disabilities. This technology is particularly relevant for such groups, as it reveals nuances and specific biomechanical adaptations that conventional observational protocols often fail to capture. Systematic reviews show that wearable inertial and sEMG sensors, as well as non-/optical motion capture suits and depth-camera systems, provide objective kinematic and kinetic measures, enabling more reliable risk categorization than purely visual methods while still often mapping to established tools [6] – [8]. Therefore, leveraging the high precision of Mocap systems to enhance musculoskeletal risk assessment forms the core focus of this research.

The performed study involves a comparative analysis of physical workload between individuals with disabilities and a control group, conducted on a custom-designed course simulating typical daily and occupational tasks. By using Mocap technology together with the established OWAS method, which is widely applied in occupational ergonomics and enables standardized comparison of postural loads, we aim to accurately evaluate the differences in postural strategies and actual loads between the groups. In addition to identifying critical loads, the study aims to uncover specific compensatory mechanisms that individuals with physical impairments develop to perform tasks successfully. The results therefore provide an important basis for a deeper understanding of movement limitations in a functional environment and serve as an empirical foundation for developing practical guidelines for ergonomic design and individual workplace adaptation. Ultimately, the goal of this integrated approach is to ensure a safer working environment, reduce the risk of injuries, and promote the long-term vocational inclusion of people with disabilities.



## 2 Methodology

### *2.1 Participants*

The study included 56 participants, divided into two groups: an experimental group (people with disabilities) and a control group (people without disabilities), allowing a comparative evaluation of physical workload and strain between the groups during the course. The group with disabilities comprised individuals with various physical limitations affecting mobility and task execution, while the control group consisted of participants without reported disabilities. All participants were informed of the study's purpose and procedures and provided written informed consent before participating. For detailed analysis and presentation of results, five participants were selected as the most representative of the experimental and control groups in terms of movement characteristics and task performance. The key characteristics of these participants, including participant ID, gender, year of birth, height, weight, disability status, and baseline physiological measurements (blood pressure and heart rate), are summarized in Table 1.

*Table 1. Anthropometric and physiological characteristics of the participants.*

| P No. | Gender | Year of birth | Blood pressure, mmHg | Heart rate, bpm | Body height, cm | Body weight, kg | Disability status |
|---|---|---|---|---|---|---|---|
| P 1 | Male | 1965 | 148/88 | 71 | 178 | 157 | Yes |
| P 2 | Male | 1968 | 147/83 | 74 | 176 | 80 | Yes |
| P 3 | Female | 1981 | 122/72 | 52 | 170 | 72 | Yes |
| P 4 | Male | 1999 | 140/85 | 88 | 180 | 100 | No |
| P 5 | Female | 2000 | 188/78 | 93 | 165 | 55 | No |

### *2.2 Experimental Course Setup and Tasks*

A predefined movement course was developed to simulate typical dynamic and static activities found in rehabilitation and work-related environments. Before performing the movements on the predefined course, the participants were not exposed to any other loads. The course was set up in an indoor space measuring 6 × 5 meters and included various elements to challenge mobility and balance. The main tasks performed on the course were:

- Forward and backward walking
- Obstacle negotiation (over low hurdles - sticks)
- Squatting
- Sit-to-stand transitions from a chair
- Arm elevation
- Balance maintenance on one leg

To ensure consistent execution, the course featured clearly marked zones for each task, with simple and safe obstacles. The layout was designed to allow smooth transitions between activities, effectively representing common movements in everyday and occupational contexts. A schematic overview of the spatial layout and task sequence is shown in Figure 1.

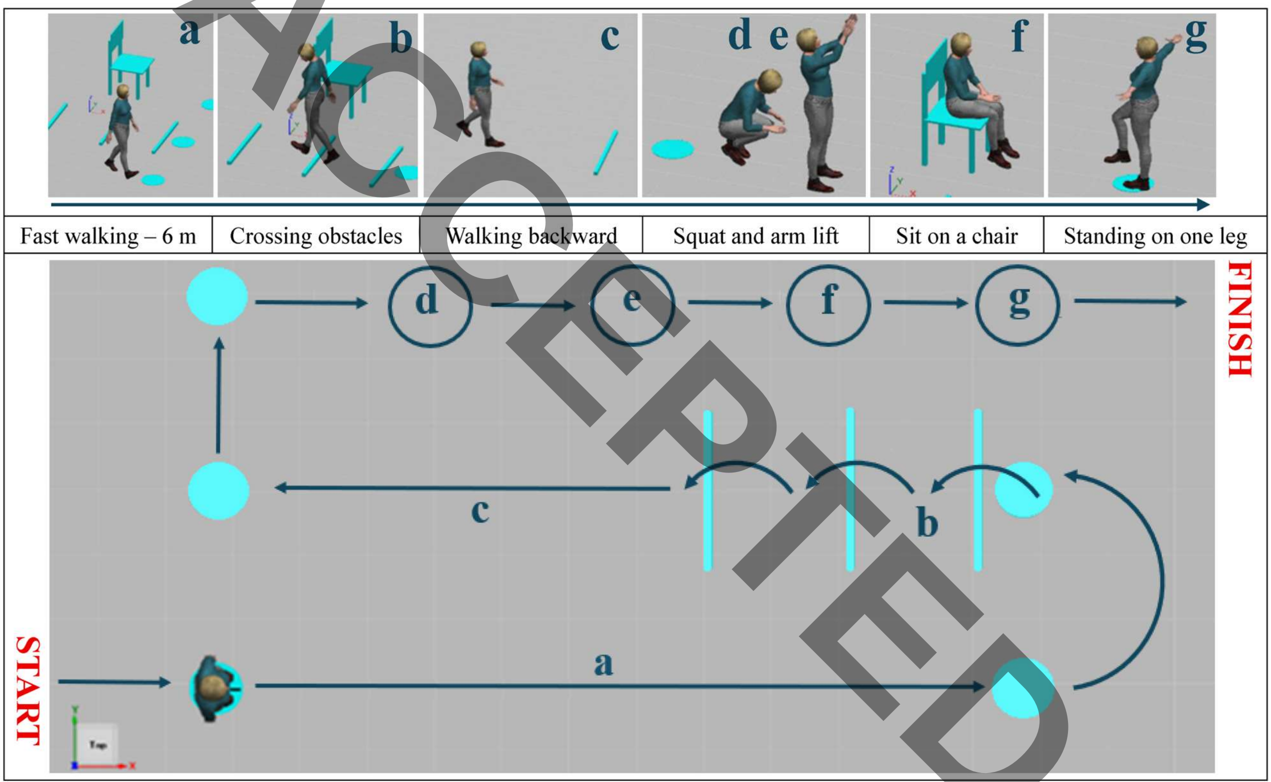




*Figure 1. Schematic representation of the experimental course, including the spatial layout and the sequence of movement tasks (a - g)*

### *2.3 Motion Capture System and Data Collection*

Participants were equipped with a wearable motion capture system to record full-body kinematics during the experimental tasks. A Mocap system is a technology used to track and record the movement of individuals and objects in real time and has been widely applied in ergonomic research [6], [7], [11], [12]. These systems are particularly useful for workplace and task assessment, as they enable faster data acquisition and more objective, precise movement analysis compared to traditional observational methods performed manually by an ergonomist [12]. In this study, the Xsens MVN Awinda motion capture system was used. The system consists of 17 wireless inertial sensors, which were securely attached to participants using a dedicated Lycra suit and adjustable straps to ensure stable fixation and accurate signal acquisition. The sensors were positioned on specific body segments to capture whole-body movement data. The placement of the sensors and the body segments monitored by the system are shown in Figure 2.

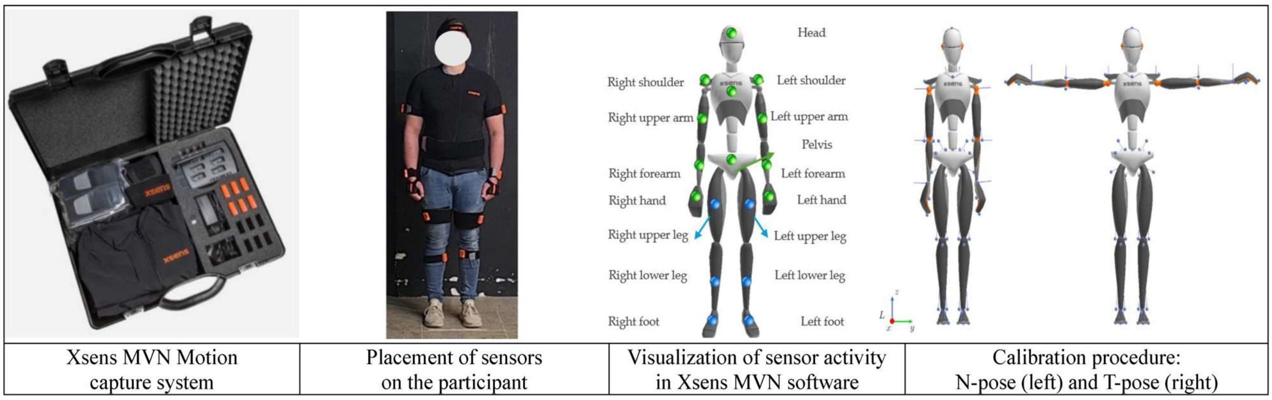


*Figure 2. Inertial Mocap system components, sensor configuration, and calibration poses*



Before the experimental tasks, a standardized calibration procedure (Figure 2) was performed for each participant in accordance with the manufacturer's guidelines to ensure accurate alignment of the sensor coordinate systems with the participant's anatomical reference frames.

To ensure consistent execution of the experimental protocol, the repeatability of the movement course was evaluated in a previous study [10]. In that assessment, the course was performed repeatedly under identical conditions, confirming stable movement patterns across trials. These findings support the reliability of the motion capture data used in the present study and confirm the suitability of the experimental setup for ergonomic and biomechanical analysis.

### *2.4 Ergonomic Assessment Using OWAS*

The recorded movement data were imported into the Process Simulate digital human modeling software, where ergonomic analyses were conducted. Digital human modelling tools enable the integration of motion capture data with ergonomic assessment methods and are widely used to evaluate physical workload and postural risk in occupational and rehabilitation contexts. Several established ergonomic assessment methods (e.g., OWAS, REBA, RULA) can be applied in such environments to evaluate working postures and movement-related risks. In this study, OWAS was selected for the ergonomic assessment of human movements.

The OWAS method [1], [13] is a posture-based ergonomic assessment technique used to evaluate the risk associated with working postures by analyzing the position of the back, upper limbs, and lower limbs, as well as the external load or force applied. Each observed posture is classified into one of four risk categories, indicating the urgency of corrective measures (Table 2).

*Table 2. Classification of OWAS risk levels.*

| Action Category | Color Code | Risk Level | Description and Necessary Actions |
|---|---|---|---|
| 1 | Green | Acceptable | Normal posture<br>No corrective action required |
| 2 | Yellow | Low risk | Slightly harmful posture<br>Corrective actions required shortly |
| 3 | Orange | Moderate risk | Distinctly harmful posture<br>Corrective actions should be done as soon as possible |
| 4 | Red | High risk | Extremely harmful posture<br>Corrective actions for improvement are required immediately |

This classification enables the identification of postures associated with increased ergonomic risk and supports comparison of physical workload between different tasks and participant groups. Green indicates acceptable postures (category 1), requiring no intervention, while yellow, orange, and red indicate increasing levels of postural risk, with category 4 requiring immediate corrective action.

## 3 Results and discussion

The results are presented in two main sections. Section 3.1 provides an ergonomic evaluation of all five participants using the OWAS method to determine postural risk levels during the experimental course. Section 3.2 compares kinematic data between the experimental and control groups to identify significant differences in functional mobility.

### *3.1 Ergonomic Evaluation: Results of the OWAS Method*

Figures 3 and 4 show the ergonomic risk levels identified for each participant during the experimental course. The results are presented for two groups: Participants 1 - 3 (Figure 3), representing the experimental group and Participants 4 - 5 (Figure 4), representing the control group. The color-coded bars in the charts correspond to the risk levels previously defined in Table 2.

A detailed analysis of the OWAS action categories reveals significant behavioural and ergonomic differences between the groups. The temporal distribution of ergonomic risk for the experimental group (P1 - P3) shows a sustained moderate postural load throughout the tasks (Figure 3). Participants in this group mainly operated within OWAS action category 2 (yellow), indicating that most of the course was performed in non-ideal postures requiring long-term monitoring.



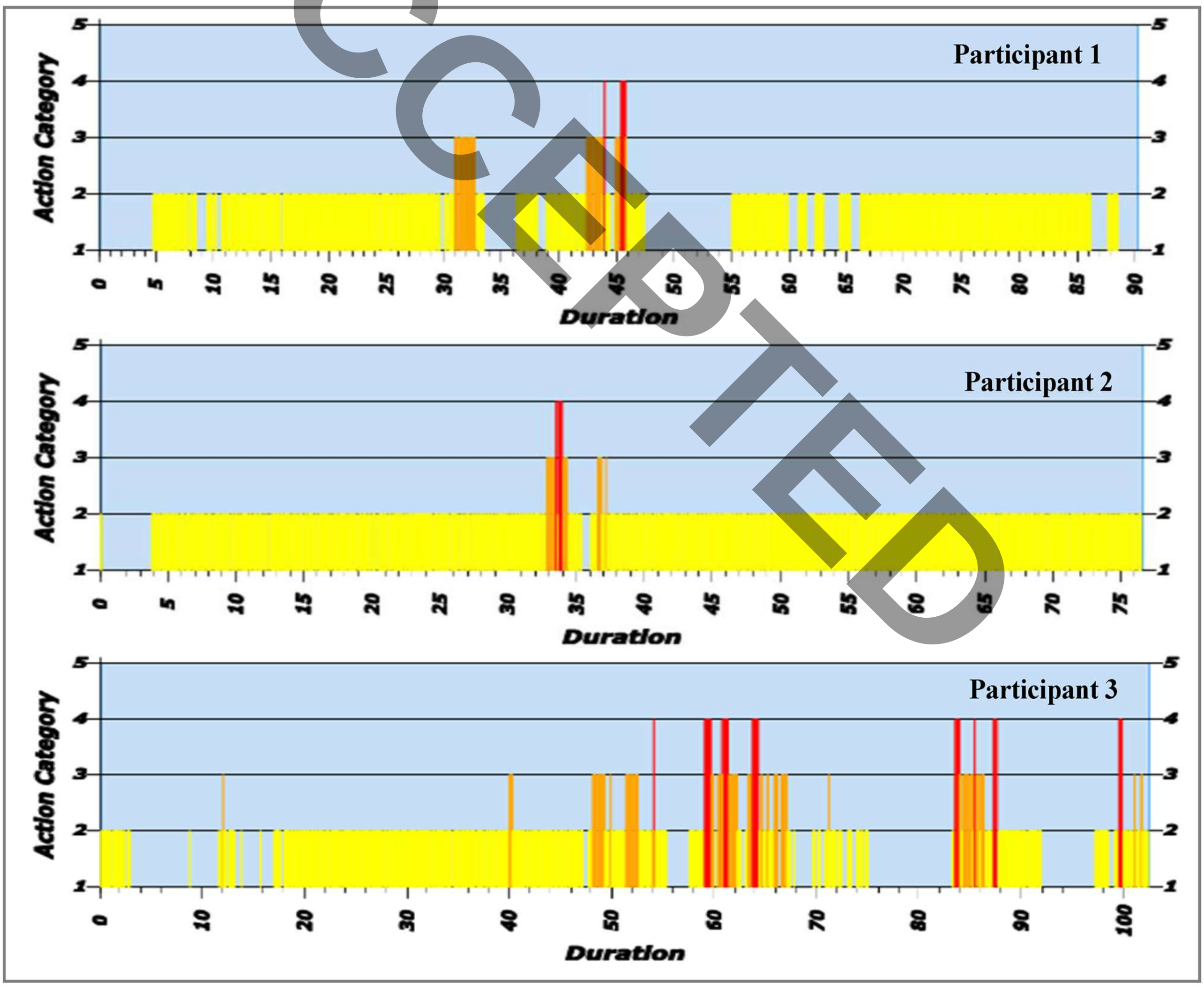


*Figure 3. Temporal distribution of OWAS action categories for the experimental group participants during tasks execution.*

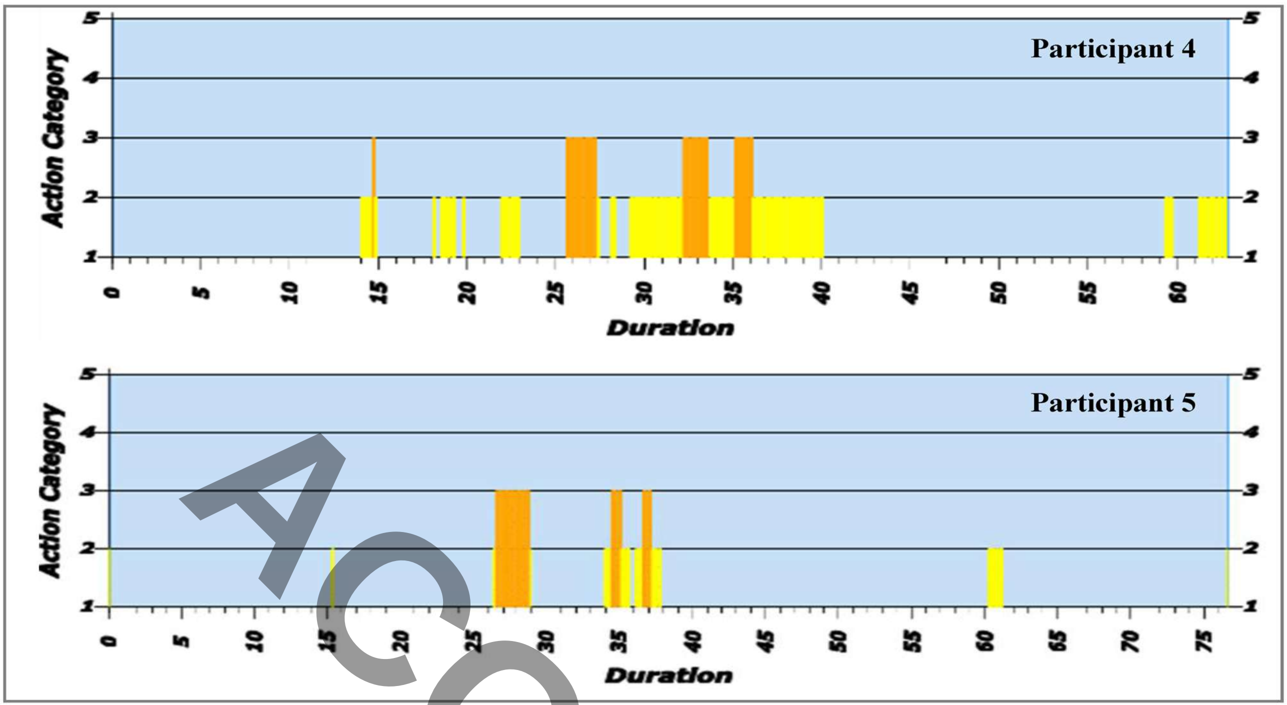


*Figure 4. Temporal distribution of OWAS action categories for control group participants during tasks execution.*



As shown in the individual profiles, the experimental group frequently moved into higher risk zones during specific activities. The presence of action category 4 (red) spikes, most prominent in P3, suggests that certain segments of the course - specifically squatting, arm lifting, sitting and standing up from a chair, and standing on one leg - forced participants into critically stressful postures. These peak loads indicate moments when participants had to adopt extreme body positions to compensate for their physical limitations.

In contrast, the control group (Figure 4) exhibited a more stable ergonomic profile. Although occasional transitions to action category 3 (orange) occurred, these were brief and transient. The absence of action category 4 spikes in this group further highlights the difference in ergonomic risk between the groups.

### *3.2 Comparison Between Groups of Participants*

A comparative analysis of the ergonomic burden, highlighting the differences between the experimental and control groups, is presented in Table 3. While the previous analysis focused on the temporal distribution of postures during the task, the following results provide a quantitative summary of the percentage of total time spent in each OWAS action category.

*Table 3. Percentage distribution of OWAS action categories across participants.*

| Participant / Action Cat. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| P1 (Experimental) | 31 % | 64 % | 4 % | 2 % |
| P2 (Experimental) | 2 % | 93 % | 3 % | 2 % |
| P3 (Experimental) | 19 % | 68 % | 8 % | 6 % |
| P4 (Control) | 59 % | 34 % | 7 % | 0 % |
| P5 (Control) | 84 % | 11 % | 5 % | 0 % |

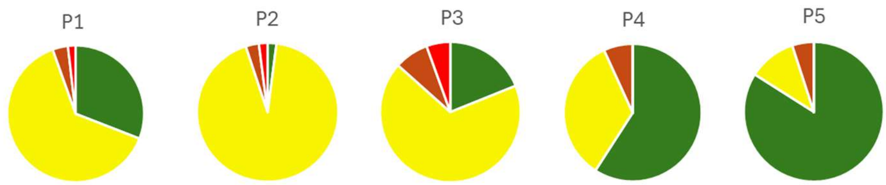

Table 3, including the pie charts, shows the relative distribution of postural risk for each participant. A clear distinction can be observed between the two groups:

- Experimental group: Participants in this group exhibited a higher prevalence of non-neutral postures. For example, P2 spent 93 % of the time in action category 2, while P3 had the highest cumulative exposure to high-risk postures, spending 14 % of the time in categories 3 and 4 combined.

- Control group: This group demonstrated significantly better ergonomic outcomes. Participant P5 maintained acceptable postures (category 1) for 84 % of the experimental course. Notably, neither participant in the control group reached action category 4 (red), indicating a more stable and ergonomically efficient movement pattern.

These findings suggest that physical limitations in the experimental group led to more frequent compensatory movements, resulting in sustained moderate-to-high ergonomic risk throughout the tasks.

## 4 Discussion

The results of the study confirm that participants' physical limitations directly influence their choice of postural strategies, leading to increased ergonomic workload during functional tasks. The OWAS-based analysis reveals a clear distinction between the two groups: the control group (P4 and P5) spent most of their time on the course in neutral and ergonomically acceptable postures (category 1), while the experimental group predominantly operated within an elevated risk range (category 2). This indicates that, for people with disabilities, even basic movement along the course involves sustained postural strain, preventing the body from returning to a fully neutral posture.

Particularly critical are the moments when peak loads in category 4 were observed in the experimental group, especially during tasks such as squatting, transitioning from sitting to standing, and standing on one leg. These spikes into the highest risk category, which are entirely absent in the control group, highlight situations in which people with disabilities must adopt extreme body postures to accomplish task objectives. Such postures serve as compensatory mechanisms to overcome physical limitations; however, in the long term, they pose a high risk of musculoskeletal injury. The case of participant P2, who spent up to 93% of the time in risk category 2, demonstrates markedly limited movement variability, with the body constrained to a rigid and biomechanically unfavourable posture.

In contrast to the experimental group, the control group's transitions into higher categories (e.g., category 3) were brief and transient, reflecting dynamic and efficient postural control. These findings suggest that standard ergonomic assessments in workplace or rehabilitation settings often underestimate risks for people with disabilities when relying solely on average values rather than the temporal distribution of extreme loads. Although 56 individuals participated in the broader study, the present detailed analysis of five selected participants provides precise insight into specific biomechanical adaptations. The results clearly justify the need to design adapted work and living environments that reduce the necessity for extreme compensatory movements, thereby enabling safe and ergonomically efficient inclusion of people with disabilities.

## 5 Conclusion

This study confirms that integrating Mocap technology with OWAS analysis offers a practical and effective method for assessing physical workload in individuals with physical limitations. By moving beyond static averages and focusing on the temporal distribution of postural risks, the proposed approach identifies critical biomechanical strain that standard ergonomic assessments often overlook. The findings were presented in various rehabilitation and occupational settings, where the methodology received strong validation and support for integration into professional practice. The study demonstrates that such an objective evaluation tool is essential for supporting task adaptation and workplace customization. Ultimately, this approach provides a scientific basis for reducing extreme compensatory movements, thereby fostering safer and more inclusive environments for people with disabilities in both every day and occupational contexts.

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