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Integrating Cultural Insight into Ergonomic Design: Enhancing Material Handling for Disabled Individuals in Plastic Bottled Water Production

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Abstract

This study explored how integrating cultural sensitivity into ergonomic design enhanced material handling for disabled workers in a plastic bottled water production facility. Initial resistance from workers—stemming from fears of job loss and the devaluation of human labor—highlighted the need for an inclusive design approach. Using the Rapid Entire Body Assessment (REBA), the study identified high-risk postures, particularly during the transition between the bottle printing and packaging processes. The researchers co-designed material handling equipment that maintained human involvement while reducing physical strain. After implementation, REBA scores decreased from 11 to 2 and from 11 to 5 at two key points. The required force for bottle handling was also reduced from 12.96 newtons to 3.6 newtons. The findings demonstrated that ergonomics, when informed by cultural understanding, not only improved physical safety but also supported worker dignity and acceptance of technological change. Integrating human control into the design process was crucial for worker acceptance, ensuring that technology was seen as a tool to enhance, rather than replace, their labor.

Keywords: *Cultural Insight, Disability Labor, Material Handling Equipment, Ergonomic Design, Plastic Bottled Water Production, Risk Assessment*

Introduction

In modern industrial sectors, rapid technological advancement had led to increasing automation, which often marginalized vulnerable populations such as individuals with disabilities. While industries had strived to optimize productivity, equal opportunities for disabled workers remained limited (International Labour Organization, 2015). Disabled workers frequently faced ergonomic risks due to repetitive motions and heavy lifting (Herzog et al., 2019). Cultural resistance to automation further complicated technology adoption, as workers feared job displacement (McClure, 2018). In response to this disparity, inclusive employment and universal

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design emerged as essential frameworks for ensuring that individuals with varying physical and cognitive abilities could participate meaningfully in the workforce.

This study focused on a small-scale drinking water production center operated by a career development center for people with disabilities in Thailand. The facility integrated both machinery and manual labor, employing individuals with visual, intellectual, and physical impairments. Although such initiatives promoted inclusion, challenges remained—particularly in ergonomics, where improper working postures, heavy lifting, and inefficient workflows imposed health risks and reduced efficiency. Preliminary observations revealed that some employees were initially hesitant to cooperate with the research due to fears of job replacement by automation, reflecting a deeper concern over the erosion of human value and dignity.

Existing research in ergonomic intervention had primarily addressed the general workforce, often overlooking the specific limitations and needs of disabled individuals (Kroemer et al., 2001). While studies on assistive equipment design existed, users were frequently treated as passive recipients rather than as active participants. Moreover, universal design principles had seen limited integration in small-scale production settings, especially in developing countries (Steinfeld & Maisel, 2012). This gap highlighted the need for context-sensitive, participatory design processes that empowered disabled workers to co-create tools and systems that enhanced task performance while preserving individual autonomy and identity (Spinuzzi, 2005).

The objective of this research was to analyze and improve the material handling process in the water bottling line through ergonomic design tailored to disabled workers. A participatory approach was adopted, ensuring that the final design supported existing roles and retained human labor while reducing physical strain and improving efficiency.

The findings and recommendations in this article aimed to contribute to inclusive industrial design practices. The subsequent sections outlined the literature review, research methodology—including REBA assessment—results of ergonomic redesign, and implications for future ergonomic interventions in socially responsible production environments.

Literature Review

Ergonomic Design and Assessment:

Ergonomic design focuses on the interaction between humans and technology, with the goal of optimizing the working environment. Key considerations include task structure, body movement, work frequency, and the configuration of tools and equipment (Elbert et al., 2018). A well-executed ergonomic design aims to reduce occupational stress arising from poor posture—such as prolonged standing or heavy lifting—which can lead to musculoskeletal injuries. At its core, ergonomic design enhances both user comfort and functional performance (Grandjean & Kroemer, 1997).

Ergonomic risk assessment is a critical component of the design process. It provides a systematic approach to evaluating the probability and severity of potential injuries, helping to identify hazards associated with specific postures or repetitive tasks within the workplace (Cox et al., 1996). Several standardized methods have been developed for the rapid evaluation of physical workload and postural risk.

The Rapid Upper Limb Assessment (RULA), for instance, focuses on postures involving the neck, shoulders, arms, wrists, and upper back, while also considering the force exerted and the frequency of movements (McAtamney & Corlett, 1993). In contrast, the Rapid Entire Body

Assessment (REBA) evaluates full-body postures and is particularly suitable for tasks involving dynamic or complex movements (Hignett & McAtamney, 2000).

In office settings, the Rapid Office Strain Assessment (ROSA) is used to evaluate the ergonomic risks associated with workstation configurations—including the positioning of chairs, desks, monitors, and keyboards—relative to user posture (Sonne et al., 2012). Another widely adopted tool, the Ovako Working Posture Analysis System (OWAS), is designed to assess postures related to standing, walking, lifting, and bending, helping identify biomechanical stress particularly affecting the back and lower limbs (Karhu et al., 1977).

Other assessment tools address more specific ergonomic risks. The NIOSH Lifting Equation evaluates the safety of manual lifting tasks, especially those involving heavy loads, and determines whether such tasks exceed safe thresholds (Waters et al., 1993). The Job Strain Index (JSI) analyzes muscular stress resulting from repetitive hand-intensive tasks, such as those found in assembly-line work (Steven Moore & Garg, 1995). Similarly, the Manual Handling Assessment Chart (MAC Tool), developed by the UK Health and Safety Executive (HSE), offers a practical framework for evaluating risks associated with lifting, pushing, and pulling tasks common in manual labor (Carter & Banister, 1994).

Most recently, Sirikasemsuk et al. (2024) conducted a comparative analysis of RULA and REBA within a metal coating facility. The study found that while both methods effectively identified postural risks in standing tasks, RULA consistently indicated higher levels of risk. This discrepancy highlights how the choice of assessment tool can influence the perceived severity of ergonomic hazards. The authors further emphasized the value of examining both the mean and variability of assessment scores to ensure accurate and nuanced interpretation of ergonomic risks.

Cultural Insight in Design:

The integration of technology into workplaces is frequently celebrated for its potential to improve efficiency and reduce physical strain. However, for marginalized groups—particularly individuals with disabilities—technology adoption is not always perceived as wholly beneficial. Instead, it may evoke fear, uncertainty, and resistance. These emotional and psychological responses arise not only from unfamiliarity with technology, but also from deeper concerns about job security, personal autonomy, and the erosion of human dignity (Kozak-Holland et al., 2020; Kane, 2019).

A widely recognized framework for understanding how individuals adopt new technologies is the Technology Acceptance Model (TAM), developed by Davis (1989). This model identifies perceived usefulness and perceived ease of use as the primary determinants of technology acceptance. Yet, when applied to marginalized populations—such as workers with disabilities—TAM may prove insufficient. Several studies have shown that perceived threats, such as fear of job displacement by automation, can outweigh perceived benefits, especially among those who have historically experienced systemic exclusion or devaluation in the labor market (Wajcman, 2017; Cozzens & Thakur, 2014).

Cultural and socioeconomic contexts further influenced these attitudes. In developing countries, for instance, labor-saving technologies have often been perceived as threats to job security—particularly in settings where employment served not only an economic function but also a social one, such as inclusive employment centers for individuals with disabilities (Meager & Higgins, 2011). In such environments, the lack of user involvement in design and decision-making processes intensified concerns about diminishing relevance and autonomy.

To address these challenges, recent scholarship has emphasized the importance of participatory approaches to technology integration, wherein marginalized users are actively engaged in the design and implementation of tools that affect their work. This approach not only enhances usability but also fosters trust, a sense of ownership, and dignity among participants (Björgvinsson et al., 2010). When disabled workers have been engaged in the co-design of ergonomic tools, studies have shown that concerns about technological displacement were alleviated, and technology was reframed as a supportive element that complemented—rather than replaced—human labor (Shinohara & Wobbrock, 2011).

Recently, Sirikasemsuk et al. (2025) showed that integrating cultural lean practices with innovations—such as SMED techniques and locally adapted tools—significantly reduced changeover time in compressor manufacturing. Beyond efficiency, the study highlighted how involving workers in solution development fostered ownership and trust. This culturally informed approach demonstrated that respecting local practices enhances both productivity and worker engagement. In a study applying the Karakuri Kaizen principle, Kittipanya-ngam et al. (2024) developed material handling equipment that significantly reduced both transport distance and time without relying on external energy sources. By emphasizing low-cost, mechanically driven design tailored to local factory contexts, the research highlighted how culturally rooted innovation—based on simplicity, sustainability, and worker familiarity—can enhance efficiency while preserving human-centered design values.

Disability Labor:

Persons with disabilities are integral members of society who deserve equal protection of rights and opportunities, no less than other citizens. Rather than being viewed solely as individuals requiring medical care, each person with a disability should be recognized as an active participant in society, entitled to social and economic inclusion (Morris, 2005).

Despite increasing awareness, many people with disabilities continued to live in poverty due to limited access to equitable employment opportunities. This challenge has been further exacerbated by persistent societal doubts about their capabilities. Consequently, both individuals with disabilities and their families have historically faced systemic neglect and marginalization. Moreover, many were unaware of the legal protections and social policies intended to support their rights and participation (Sanchez, 2015).

In light of the challenges faced by people with disabilities, assistive technologies play a crucial role in enhancing their quality of life. These tools not only improve physical functioning and confidence but also foster emotional and educational development. Well-designed assistive technology promotes social participation and enables access to the labor market. Medical rehabilitation, social support, and accessible infrastructure are all key to building inclusive work environments (Mahmoudi-Dehaki et al, 2025).

However, physical disabilities vary widely in nature and severity. This diversity requires that assistive tools be carefully designed and evaluated to prevent unintended health risks (Tsai et al., 2012). Inappropriate designs may cause further strain or injury, underscoring the need for user-centered evaluations (Cheng et al., 2011). Designers must consider not only the user's capabilities but also the environment and the specific tasks the individual performs (Chen, 2011).

For instance, the design of a hair-washing station for individuals with different degrees of shoulder immobility had to accommodate this variation (Wu et al., 2009).

To ensure relevance and sustainability, innovation in assistive technology should be guided by thorough impact assessments that account for both benefits and drawbacks. Particularly for aging and disabled populations, adaptive strategies must align with their real-life needs and capabilities (Campopiano & Bassani, 2021). Efforts should also emphasize empowering these populations to participate fully in society through inclusive innovation and personalized care models (Martwangsaeng et al., 2020).

Ultimately, it is imperative for researchers and policymakers to recognize the importance of designing inclusive systems that promote social justice and equity. Such efforts are foundational to achieving sustainable development that benefits everyone (Dias & Partidário, 2019).

Analysis of Research Gaps:

While existing literature provides robust frameworks for ergonomic assessment and design—such as REBA, RULA, OWAS, and other task-specific tools—most studies have focused primarily on physical risk mitigation without fully addressing the socio-cultural dimensions of workplace design. Research on disability labor has highlighted the systemic barriers faced by disabled workers, including limited access to ergonomically optimized environments. However, few ergonomic interventions have been tailored specifically for disabled individuals working in physically demanding, small-scale production facilities. Additionally, although inclusive design principles have gained traction in broader design disciplines, there remains a significant gap in integrating cultural insight—such as worker values, fears, and resistance to change—into ergonomic decision-making processes.

Furthermore, the intersection of disability, dignity, and labor remains underexplored within the context of industrial ergonomics. Most participatory design approaches tend to overlook the nuanced cultural and emotional responses that influence how new equipment and workflow adjustments are perceived by workers. This gap is particularly critical in settings where automation or redesign efforts may unintentionally threaten job identity or human involvement.

This study seeks to fill these gaps by integrating cultural sensitivity into ergonomic design, with a focus on enhancing the material handling process for disabled workers in a plastic bottled water production facility. By combining biomechanical assessments with participatory design rooted in cultural understanding, the research aims to support both physical well-being and socio-emotional acceptance, thus advancing a more inclusive and contextually responsive approach to ergonomic design.

Research Methodology

The Disability Vocational Development Center was established in 1983 as a model institution for promoting career development among individuals with disabilities. Its primary objective was to enhance job-related skills and provide vocational training for rehabilitated individuals, enabling them to achieve self-reliance and support their families through employment in sheltered workshops. Guided by the vision of becoming a leader in disability employment promotion, the center operated under four core missions: (1) promoting vocational and social skills, (2) developing standardized products, (3) managing the organization efficiently through risk management tools and staff development, and (4) building collaborative networks with government agencies, private sectors, and local communities to support production, design, and fundraising efforts. These initiatives were grounded in the philosophy of "Creating Value through Quality."

The center employed a total of 60 staff members, comprising 24 non-disabled administrative personnel and 36 disabled workers in the production department. Of the disabled workers, nine were assigned to the bottled water production unit—one with a visual impairment, six with intellectual disabilities, and two with physical or mobility impairments. The production process for 350 ml, 600 ml, and 1,500 ml bottled water was divided into four main stages:

Stage 1: Bottle Cleaning and Water Filling Department

Two workers with physical or mobility impairments carried out the initial stage. The process involved rinsing empty bottles using a faucet, arranging 24 bottles per tray, filling the bottles, and capping each bottle manually under visual supervision. The trays were then transported to the date-printing section using a cart.

Stage 2: Date Printing Department

Two workers with intellectual disabilities placed the bottles on a conveyor belt for automatic date stamping. After the printing process, the bottles were collected into plastic crates and transferred to the packaging section.

Stage 3: Bottle Packaging Department

Another two workers with intellectual disabilities packaged the bottles into plastic bags based on their sizes—12 bottles per bag for the 350 ml and 600 ml sizes, and 6 bottles per bag for the 1,500 ml size.

Stage 4: Sealing and Storage Department

Four workers with intellectual disabilities sealed the packaged bottles using a plastic sealing machine and stacked the sealed bottles on pallets for transport to the storage facility.

Workflow diagrams and movement charts from each production section revealed the presence of awkward and potentially harmful working postures. In response, the research team conducted a risk assessment to identify which work stages posed the highest ergonomic risk. The Rapid Entire Body Assessment (REBA) method was selected for this analysis.

An illustrative REBA assessment was conducted at the transition point between Stage 2 (date printing) and Stage 3 (bottle packaging), where the workers exhibited the postures shown in Figures 1 and 2. The REBA method assessed ergonomic risk in two groups: Group A evaluated the neck, trunk, and legs, while Group B focused on the upper limbs, including arms and wrists. This comprehensive assessment informed the development of ergonomic interventions aimed at reducing physical strain while maintaining the workers' involvement.

Figure 1. Illustrative Posture of a Worker Assessed Under REBA Group A, Focusing on the Neck, Trunk, And Legs.

Figure 2. Illustrative Posture of a Worker Assessed Under REBA Group B, Focusing on the Upper Limbs Including Arms and Wrists.

REBA Assessment: Group A (Neck, Trunk, and Legs)

As illustrated in Figure 1, the assessment was divided into three components: the neck, trunk, and legs, each indicated by a different color—pink, blue, and orange, respectively. For the neck, the worker's head was tilted approximately 17 degrees relative to the vertical body axis. This posture received a base score of 1. Due to the observed neck twisting, an additional point was added, resulting in a total neck score of 2. For the trunk, the worker bent forward at an angle of approximately 75 degrees. This posture received a base score of 4. A lateral trunk bend was also present, which added another point, resulting in a total trunk score of 5. For the legs, the worker stood in an unbalanced posture. The left leg, which displayed a more awkward position, was selected for evaluation. This posture received a score of 2. Additionally, the worker bent the knee beyond 60 degrees, adding 2 more points, for a total leg score of 4. Combining the scores from the neck, trunk, and legs yielded a Group A score of 9. It should be noted that no additional points were added for load/force, as the task involved handling loads weighing less than 5 kilograms.

REBA Assessment: Group B (Upper Arms, Lower Arms, and Wrists)

As shown in Figure 2, this assessment was also divided into three components: the upper arms, lower arms, and wrists, represented by yellow, purple, and green lines, respectively. For the upper arms, the worker's arm was extended forward at less than 20 degrees from the vertical axis, which resulted in a score of 1. For the lower arms, the forearm angled downward at less than 60 degrees, receiving a score of 2. For the wrists, the wrist was flexed downward more than 15 degrees relative to the forearm. This posture received a score of 2. An additional point was added due to lateral wrist deviation, resulting in a total wrist score of 3. Combining the scores from the upper arms, lower arms, and wrists resulted in a Group B score of 4. No further points were added for coupling, as the worker was able to grip objects comfortably and securely.

Overall REBA Score

The combined scores from Group A and Group B were referenced using the REBA final scoring table, which yielded an initial score of 10. Because the task involved repetitive movement of one or more body parts more than four times per minute, one additional point was added. Therefore, the final REBA score for this task was 11, indicating a very high risk level that warranted immediate ergonomic intervention.

A summary of REBA risk levels across all evaluated tasks is presented in Table 1.

Stage of Process		REBA Scores			
		Bottle Entering Process	In Process	Bottle Exiting Process	Between Departments (Stages)
1	Bottle Cleaning and Water Filling	3	10	5	4
2	Bottle Date Printing	7	Machine in Operation		11
3	Bottle Packaging	11	4	4	-
4	Sealing and Storage	9	Machine in Operation	5	-

Table 1: Results of the REBA Risk Assessment

Identification of Problem Statements and Indicators

Table 1 illustrated the REBA risk assessment scores for abnormal working postures in each process step that might negatively affect health. The highest risk assessment scores, based on the REBA method, were found in two areas, both with a score of 11. The first area was the transition from the Date Printing Department to the Packaging Department, while the second area involved the process of feeding bottles into the Packaging Department. These results indicated a very high risk, requiring immediate improvements. Therefore, the research team focused on studying and addressing the areas with the highest health risks first. In fact, both areas exhibited abnormal working postures, including bending, stretching, and exerting considerable effort during the tasks.

It should be noted that these two areas, which were to be studied, represented continuous activities. At times, this research could consider these activities in parallel.

In addition to the high REBA risk assessment scores, other factors were also considered, such as height, time, and the force exerted during the work process. The bottles were printed with dates by a machine in the Date Printing Department (Stage 2) and then dropped into a plastic crate. The crate remained in place until it was full, at which point it was moved to the next department.

Afterward, a plastic crate filled with bottles was moved from the Date Printing Department (Stage 2) to the Packaging Department (Stage 3). This process took 12 seconds per plastic crate, covering a distance of 1.65 meters, with a force of 12.96 newtons, as shown in Figure 3.

Bottles were subsequently transferred from the plastic crate to the designated packaging area. This task required 4 seconds per bottle, with a transport distance of 0.75 meters, as shown in Figure 4.

Figure 3: Transportation of the plastic crate from the Date Printing Department to the Packaging Department

Figure 4: Transfer Of Bottled Water from the Plastic Crate to the Packaging Position

The analysis identified two primary causes, as outlined below:

Cause 1: Abnormal working postures. Employees frequently adopted incorrect postures, such as bending and tilting their bodies to pick up water bottles. Additionally, significant physical effort was required for tasks such as dragging heavy objects, which increased the risk of injury, particularly to the back.

Cause 2: Inadequate material handling equipment. The use of plastic crates for transporting materials was found to be inefficient, as it hindered the workflow. Employees were required to exert excessive force when moving the heavy crates between departments. Furthermore, the height of the crates was not suitable for the tasks in the packaging department, forcing employees to bend down to retrieve the bottles.

Based on these issues, it was concluded that the working conditions posed a significant health risk to employees.

Following brainstorming sessions between the research team, operations supervisors, and workers, it was determined that adjusting the height of the work areas was not feasible, as the tables could not be moved or modified. As a result, the team, in collaboration with the workers, designed a new material handling device specifically for bottle transport in the production process. This equipment was intended to address both of the primary causes simultaneously, offering a comprehensive solution to the identified problems.

The design concept for the equipment used to transport water bottles was based on the principles of ECRS (Eliminate, Combine, Rearrange, and Simplify), aiming to simplify tasks and apply universal design principles to ensure accessibility for all workers. ECRS focuses on eliminating unnecessary steps, combining tasks where possible, rearranging processes for greater efficiency, and simplifying tasks or equipment design to reduce physical strain. These principles guided the creation of a design that not only enhances efficiency but also supports ergonomic considerations, ensuring that the equipment could be used effectively by all workers, regardless of their abilities. Three models were considered:

Model 1: Conventional Cart

This device was designed to assist with transportation, consisting of a rectangular base with rubber wheels that could rotate 360 degrees, and a handle for pushing. The disadvantage of this model was that it did not address the need to reduce bending and stretching during the task. However, it facilitated the convenient transportation of plastic crates. Therefore, the research team decided not to proceed with this approach.

Model 2: Cart with Spring Mechanism

This model incorporated a spring mechanism to assist with vertical movement, helping to reduce bending and stretching during the task. The device was designed as a container for holding water bottles waiting to be packaged. Springs were placed at the base of the container, allowing the height of the container to adjust as the number of bottles inside decreased, thereby reducing the need for workers to bend. However, the device’s height adjustment was not controlled by the worker, which led to a lack of worker involvement in the process. Consequently, the research team decided not to choose this model.

Model 3: Cart with Linear Actuator Motor

This model was designed as a lift, utilizing a linear actuator motor to control the vertical movement of the lift's legs. The purpose was to raise the plastic crate to a convenient height for the worker, allowing for easier access to the bottles for packaging. Additionally, the cart was equipped with rubber wheels at its base to facilitate movement between workstations. The device operated on a 12-volt DC power supply, capable of pressing 75 kilograms, pulling 75 kilograms, and achieving a speed of 10 millimeters per second when unloaded.

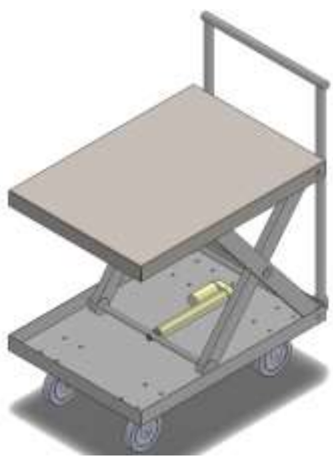

Figure 5: Model 3 - A Trolley Utilizing a Linear Actuator Motor for Movement

During the early stages of field data collection, the researchers encountered specific obstacles that reflected a form of "cultural resistance" from the disabled workers. This resistance manifested in their reluctance to provide detailed information, especially regarding the difficulties and risks associated with their working postures. The workers often responded to questions with vague or generalized statements such as, "There's nothing, I can do everything," or "Everything is fine," avoiding any mention of the physical challenges or strain caused by their tasks.

In addition to these evasive responses, some workers exhibited avoidance behavior during interviews, feigning busyness or engaging in other activities while qualitative data was being collected. Some workers even expressed a mistrust of the research process, with comments like, "Will this research result in machines replacing us?" These reactions highlighted a deeply rooted concern about the potential for technological changes to replace human labor, particularly among disabled workers who feared that their roles would become obsolete.

Through observations and in-depth conversations, it became clear that these behaviors stemmed from a fear that identifying work-related difficulties could lead to the development of technology that would reduce the need for human labor, thereby putting workers at risk of losing their jobs. The workers' concerns were not unfounded; there was a cultural context within the workplace where technological advancement had historically been associated with job displacement, particularly for vulnerable groups such as those with disabilities.

To address these concerns and build trust, the researchers took proactive steps to clarify the purpose of the project. They explained the concept of co-design, emphasizing that the development of new equipment was not aimed at reducing the workforce, but rather at making the work environment safer, more efficient, and more suitable for the physical capabilities of disabled workers. The researchers reassured the workers that the newly designed material handling equipment would not function autonomously but would require human involvement for operation. The equipment was designed to aid workers in their tasks, not replace them, and the workers would still play an essential role in its effective use.

Furthermore, the researchers stressed that the equipment would require skill, process understanding, and experience to operate effectively. This clarification aimed to emphasize that the workers' expertise and experience would remain central to the production process, and their involvement in the work would continue to be vital. This effort to involve workers in the design process, listen to their concerns, and address their fears helped foster a sense of ownership and participation. It ensured that the workers did not feel alienated by the technological changes and that their voices were heard throughout the design process.

By engaging in these conversations and fostering an open, transparent dialogue, the researchers were able to mitigate the cultural resistance that had initially hindered the data collection process. As a result, the workers began to view the co-design process as an opportunity for empowerment rather than a threat to their employment. This shift in perspective allowed the researchers to move forward with their work while maintaining a collaborative, culturally sensitive approach that respected the concerns and dignity of all involved.

Result

The design approach for Model 3 was based on a structure resembling an elevator, with the frame constructed from steel square tubing for the four legs of the device. The upper and lower sections of the device were made from folded steel sheets, and all components were assembled using steel bolts to form a functional lift. Four caster wheels were mounted at each of the four corners of the lower folded steel section, and a linear actuator motor was installed with a switch to control its operation, enabling the device to move vertically. Additionally, steel tubing was used to create the handles, which were intended for manual pushing.

The overall height of the device was 69 centimeters, with a width of 50 centimeters and a length of 70 centimeters. When combined with the plastic crate used in the work process, the total height reached 117 centimeters. The assembly of all parts together resulted in enhanced stability during operation, as shown in Model 3. Furthermore, the entire device was constructed using steel to emphasize durability, as depicted in Figure 6.

Figure 6: Trolley Utilizing a Linear Actuator Motor for Movement

Upon completion of the construction, the research team conducted practical tests to confirm the device's weight capacity. A comparison of performance before and after the modifications is presented in Figures 7 and 8. The Key Performance Indicators (KPIs) for both Area 1 and Area 2 were summarized as follows:

KPI 1: Risk assessment using the REBA method. The current score for Area 1 was 11, and after the improvements, it decreased to 2. In Area 2, the current score was 11, and after the improvements, it dropped to 5. These results indicate a reduction in risk assessment scores for both areas.

KPI 2: Height. The current height for Area 2 was 75 centimeters, and after the improvement, it decreased to 20 centimeters. This reduction in height was evident in Area 2.

KPI 3: Time. The current time for Area 1 was 12 seconds per plastic crate, and after the improvements, it was reduced to 10 seconds per plastic crate. For Area 2, the current time was 4 seconds per bottle, and after the improvements, it decreased to 2 seconds per bottle. These results showed a reduction in time for both areas.

KPI 4: Force. The current force for Area 1 was 12.96 newtons, and after the improvements, it was reduced to 3.6 newtons.

a) Before the improvement b) After the improvement

Figure 7: Before And After Intervention at Area 1 - Transition from the Date Printing Department to the Packaging Department

a) Before the improvement b) After the improvement

Figure 8: Before And After Intervention at Area 2 - Feeding Bottled Water into the Packaging Process

After the researchers had built trust and consistently clarified the objectives of the study, the disabled workers gradually began to open up and provide candid feedback regarding the challenges they encountered in their work. They started to actively participate in the design process once they realized that the designed equipment was not intended to replace human labor, but rather to assist in making the work process more efficient, requiring human control to function effectively. The material handling equipment that was designed could not operate autonomously and required the understanding and experience of the workers to use it effectively.

The material handling equipment necessitated full control by the operators; otherwise, it would not function correctly. The workers were required to push and adjust the height of the equipment independently. They also had to control the direction of the push and exert physical force to move the equipment as needed. This highlighted the pivotal role of the operators in controlling and operating the equipment.

Additionally, the workers began to recognize their role as "co-owners of the concept," able to define the equipment's specifications to accommodate their physical limitations and work environment. Their awareness of their involvement in the design process fostered a sense of ownership, which enhanced their pride and alleviated concerns about the newly designed technology. This sense of ownership led them to feel more accepted and to value the technology that had been developed to meet their specific needs.

These changes in attitudes not only facilitated stronger relationships with the new technology but also promoted cultural acceptance and value within the workplace. The workers began to perceive themselves as integral to the development and design of their working environment, which contributed to both personal dignity and the acceptance of the implemented technology. The integration of cultural insights into the design process proved to be crucial in generating positive changes, both in the effectiveness of the equipment and in the workers' acceptance of the newly introduced technology.

Conclusion

This study demonstrated the critical importance of integrating cultural sensitivity and participatory design into ergonomic interventions aimed at improving material handling for disabled workers in a plastic bottled water production facility. By addressing the high ergonomic risks identified through the Rapid Entire Body Assessment (REBA)—which initially revealed scores of 11 in key areas—the co-designed material handling equipment (Model 3) significantly reduced physical strain. Following implementation, REBA scores dropped to 2 and 5, the required force for bottle handling decreased from 12.96 newtons to 3.6 newtons, and task completion times were reduced, resulting in improved overall efficiency. These improvements not only mitigated health risks associated with awkward working postures but also enhanced workplace safety and productivity.

Equally significant was the cultural dimension of the intervention. Initial resistance from disabled workers—driven by fears of job displacement and the perceived devaluation of their labor—highlighted the need for a human-centered approach. Through transparent communication, sustained trust-building, and active involvement in the co-design process, researchers successfully reframed the role of technology as supportive rather than substitutive. Workers came to see themselves as co-owners of the design process, which fostered a sense of pride, autonomy, and acceptance of the new equipment—tools that required their expertise and manual control to operate effectively. This shift in perception transformed initial skepticism into meaningful collaboration and reaffirmed the workers' value within the production environment.

The findings underscore that ergonomic design, when informed by cultural insight and participatory methods, can yield both physical and socio-emotional benefits. By prioritizing universal design principles and adhering to the ECRS (Eliminate, Combine, Rearrange, Simplify) framework, the intervention ensured accessibility and efficiency while preserving the dignity and agency of disabled workers. These results have broader implications for inclusive industrial design, particularly in small-scale production contexts within developing countries. Future research should further investigate the intersection of cultural context, disability labor, and ergonomic innovation to foster equitable, sustainable, and empowering work environments for all.

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Conflict of Interest Statement

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