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RESEARCH ARTICLE

Assessment and redesign proposals of musculoskeletal risks at work in an industrial packaging workstation

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Abstract – Work-related musculoskeletal disorders (WMSDs) remain a significant challenge in occupational health, particularly in industrial packaging environments characterised by prolonged standing, non-neutral body postures, and repetitive tasks. To address this issue, this study investigated the ergonomic hazards present at an industrial packaging station to propose redesign strategies aimed at mitigating physical strain on workers. A mixed-methods approach was used, integrating the Rapid Entire Body Assessment (REBA) tool with direct workplace observations and structured operator interviews. The acquired data revealed a baseline REBA score of 9, indicating a high risk of musculoskeletal injuries affecting the lower back, shoulders, and wrists. This elevated risk profile is primarily attributed to the physical demands of the operation, including long standing on hard surfaces, continuous arm movements, constant overhead stretching and excessive forward trunk flexion. Although ambient environmental parameters, such as temperature and lighting, passed basic ergonomic checks, employees still experienced localised pain daily. In addition, they pointed out structural problems with suboptimal tool organisation and general safety standards. Based on these diagnostic findings, a series of practical, low-to moderate-cost ergonomic interventions is proposed. Equipping the station with anti-fatigue mats, reorganising supplies for better accessibility, and utilising adjustable worktables should noticeably decrease the bodily strain. Implementing these specific changes is likely to reduce the overall number of WMSD cases in the industrial packaging sector.

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1. Introduction

Worker health is critical to the productivity and sustainability of any industrial operation, particularly in areas with high physical demand. Firms that fail to design ergonomically work environments expose workers to daily musculoskeletal strain, chronic fatigue, and reduced mental sharpness. This combination of factors lowers operational efficiency and increases the risk of accidents [1]. Design deficiencies are a significant cause of occupational accidents. Data from the Australian industrial sector shows that at least one root-cause design deficiency is present in over 50% of plant-related fatalities [2]. A large body of research has repeatedly shown that work-related musculoskeletal diseases (WMSDs) are a serious and pervasive problem for employee health, mostly due to poorly designed workstations that result in abnormal postures for long periods of time [3]-[4]. These musculoskeletal symptoms are strongly associated with long-term exposure to occupational risk factors, such as awkward postures, highly repetitive motions, strenuous manual material handling, and constant static loads. If sustained, these stressors disproportionately affect the lower back, shoulder, neck, and upper extremities. Beyond the direct physical discomfort they cause, WMSDs can lead to major productivity losses through increased absenteeism, reduced performance, and impairments. Therefore, preventing WMSD development remains a priority in occupational health and safety. This highlights the necessity of conducting detailed ergonomic risk assessments and implementing customised interventions tailored to each site [5].

However, the highly stressful environment of industrial packing can exacerbate these inherent ergonomic risks. Foam-in-place packaging machines are common in the industry for improving shipping procedures. However, the workstations constructed around these machines often require repetitive tasks, heavy physical demands, and extended non-neutral postures. Thus, the physiological load on the operator increases significantly when combined with local environmental stressors such as spatial layout constraints, poor lighting, and high ambient noise. The labour focuses on a specific packing workstation in an aviation components warehouse. Operators at this plant prepare packing materials, work with light aircraft parts, and seal outgoing packages; all these activities involve continuous standing and upper-extremity effort. Failure to consider these specific task characteristics leads to excessive biomechanical loading, greatly increasing the risk of developing work-related musculoskeletal disorders. This workstation is relevant for analysing ergonomic risks present in real work settings and assessing the effectiveness of the intervention techniques provided for the industrial packing sector.

Previous studies have demonstrated that certain work-related factors are highly correlated with upper-extremity fatigue and chronic low back pain. Design weaknesses in foam packaging stations are not new and pose immediate risks to occupational health and drastically reduce overall operational efficiency due to extended cycle durations, increased human error, and higher risks of product damage during transit. Therefore, a detailed assessment and reconstruction of these workstations is required to eliminate the identified hazards, safeguard employees' health, and optimise the overall workflow of the packing department. The main objective of this project is to assess in detail the ergonomic risk factors in an industrial packaging workstation and to determine their effect on work-related musculoskeletal disorders. The aim of this study was to provide a formal ergonomic analysis of high-risk postures and operational demands so that targeted and

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evidence-based remedial solutions can be developed. Finally, this approach has been designed to contribute to the avoidance of musculoskeletal injuries and safety improvement in daily work in the packaging industry.

1.1 Ergonomics in the Workplace

Ergonomics is a multidisciplinary scientific discipline concerned with understanding the interactions between humans and other elements of a system. It applies theory and data to enhance the well-being of people and the performance of systems [6]-[7]. This discipline requires that the worker be fit into the process, equipment, and physical environment, not that the worker be forced to fit poorly designed job requirements. This study was conducted in an industrial setting. Workplace ergonomics involves the gradual reduction of physical and mental stressors to increase safety, operational comfort, and throughput. In contrast, the lack of ergonomic design is responsible for a series of adverse effects, such as the massive spread of musculoskeletal disorders, reduction of productivity, high rate of absenteeism, and increase in the healthcare costs for companies [8]. However, properly implemented ergonomic interventions offer a proactive method to improve worker health and morale and increase profitability through fewer workplace injuries and smoother day-to-day operations. The application of WMSDs is evident in various manufacturing and administrative industries, and regular ergonomic assessment is vital for human health and long-term productivity [9].

An important feature is the attention paid to smooth human-system integration by the present industry. The significant influence of ergonomic compliance on process optimisation, quality control management, and larger strategic business goals has been proven by several studies [10]. A special area of need for intervention is manufacturing workplaces, where the combination of highly repetitive jobs and obligatory low posture is the major cause of significant deterioration of musculoskeletal health. The physical expenses of the job carried out at packing stations have direct and immediate effects on the safety of operators, often resulting in clinical symptoms directly related to poor postural needs [11]. In these high-risk environments, the rigorous application of ergonomic principles is necessary to mitigate risks and establish a sustainable labour paradigm. Hence, there is a need for detailed ergonomic evaluations and structural solutions to discover and remove the hazardous elements that cause physical and mental suffering in the industrial labour force.

1.2 Workstation Design Principles

The arrangement and functional design of a workstation are the main protections against occupational injuries and are essential for optimising human performance in complex activities. Three interdependent components are regularly highlighted as established ergonomic design principles: structural flexibility, operational accessibility, and physical comfort [12]. There is a baseline need for adjustability due to the extreme diversity of human anthropometry, muscular strength and desired functioning positions. Workstations need to easily support a wide variety of users. They also require broad height adjustability for major work surfaces and to allow operators to customise their immediate environment. This flexibility allows workers to maintain neutral body alignments, effectively avoiding awkward or static postures that cause acute musculoskeletal discomfort.

Simultaneously, the accessibility principle demands that all the necessary tools, common points of contact, and controls of the machinery be within the comfortable reach envelope of the operator, greatly restricting excessive stretching, extreme bending, and extended reaching that increase fatigue and invite structural damage [13]. Therefore, the physical layout of the workstation was carefully developed, and the major and secondary reach zones were determined so that the most critical components were placed close to the worker, no kinetic energy was wasted by misplacement, and the natural flow of the activity was optimised. Mechanical efficiency alone is not sufficient to make employment sustainable; physical comfort is also required. This involves providing ergonomic seats and standing platforms that offer sufficient lumbar support, distribute weight uniformly, and taking care to manage the wider physical environment. Lighting is carefully calibrated to avoid glare and precision light tasks; sophisticated noise reduction methods are employed to minimise cognitive distraction and prevent auditory damage; and rigorous and consistent temperature controls are maintained to ensure a highly conducive and supportive atmosphere [14]. An industrial designer may easily incorporate these simple ideas into an environment that automatically accommodates physical constraints, thereby vastly lowering the physical effort and mental stress and boosting the precision and efficiency of work execution.

1.3 Risk Factors in Packaging Workstations

Packing workplaces are physically demanding and dynamic; thus, there is a tremendous need for expert ergonomic oversight. Routine packing tasks, such as repetitive assembling, hand sealing, and mass labelling, involve rapid repetition, often leading to cumulative soft tissue and major joint damage [15]. A normal shift involves a standard sequence of work that includes preparing the plastic film, pouring the expanding foam, fastening the component locations, folding the structural flaps, sealing the cartons, and stacking the heavy boxes. It consists of thousands of micro-movements of the hands, wrists, arms, and shoulders. In addition, operators are often required to exert huge physical force, especially when lifting, transporting, and manoeuvring heavy and dimensionally problematic parcels, which leads to tremendous shock loads to the musculoskeletal system. Workers may be required to apply substantial downward manual force to seal and crush resilient cartons or to repeatedly lift a 5–10 kg box onto shipping pallets. Operators routinely state that they are forced into difficult anatomical positions, which is a huge source of baseline ergonomic risk [16]. Examples include unsafe positions, such as prolonged deep bending, twisting of the spine, or reaching the extreme to obtain raw materials, operate machine controls, or arrange finished stacks. Postural anomalies are especially apparent at the foam-in-place packaging stations, where workers must bend their trunk and cervical spine significantly to retrieve empty cartons from the floor or duck down under the main work table to operate the foam dispenser. In addition, the reloading method of film

rolls on high dispenser mounts requires the operators to lift their arms much beyond the shoulder line to hold this very fatiguing overhead position for longer periods of time.

Another unique negative postural deviation that adds to the soft tissue strain is the mechanical difficulty in twisting the wrist during the manual tape-sealing phase. Kinetic hazards increase when personnel are standing on hard concrete surfaces. Operators experience severe vascular pooling, muscular tiredness, and acute discomfort in the lower extremities due to the lack of suitable supportive footwear or anti-fatigue mats. No specific information was provided on exposure to mechanical vibration for this workstation, although it is a common hazard in similar industrial environments. Larger environmental problems, such as poor task lighting and localised temperature extremes (e.g. high heat around active packaging machinery), further increase ergonomic hazards and directly impact the health of workers. These risk factors have been extensively studied and are often the root causes of both acute upper limb strain and chronic lumbar degeneration. The combination of heavy physical demands, repetitive movements, awkward postures, and adverse environmental conditions subjects the workforce to extreme physiological strain and greatly increases the risk of developing disabling musculoskeletal disorders of the spine, shoulders, and wrists.

1.4 Ergonomic Assessment Methods

In highly dynamic environments, such as packaging lines, researchers have employed three evaluation approaches to systematically identify and quantify ergonomic hazards. These approaches include observational instruments, quantitative biomechanical measurements, and subjective qualitative assessments. Observational tools such as the Rapid Entire Body Assessment (REBA) and the Rapid Upper Limb Assessment (RULA) have some advantages, such as the ability of evaluators to visually see the working operator and quickly determine the postural strain and high-risk motions. For example, REBA is a highly valuable method for completely mapping whole-body postural dangers. It evaluates the mechanical force exerted on the musculoskeletal system by analysing specific joint angles, the volume of force exerted on tools or objects, and the total frequency of kinetic movements [17]. REBA connects the load and coupling factors to offer an action-level score for different anatomical segments, which suggests the area of ergonomic adjustment. Such an evaluation is useful for packaging stations, as it can precisely capture the physical strains to which workers are exposed daily. For example, it examines operators who are forced to stoop and crane their necks excessively to lift cartons off the floor, reach their arms above their shoulders to change film rolls, and twist their wrists painfully to tape boxes shut.

In previous field studies that have used the REBA framework to examine packing settings, the most prominent ergonomic concerns have been identified as unpleasant postures, high power needs, and repetitive motion. Haekal et al. [18] reported dangerously high REBA ratings of 11 in their study of pharmaceutical packaging material handling in Indonesia. High hazard levels were mainly attributed to operators pushing and hauling weights of over 100 kg, repetitive deep bending, and regularly reaching for objects kept well over safe working heights [18]. The authors recommended strict load weight restrictions, the use of step ladders to reach higher locations, redesigning the floor layout to prevent spatial congestion, and full training in safe handling to reduce these hazards. Similarly, [19] conducted a detailed multi-tool analysis in a Turkish logistics warehouse using RULA, REBA, and the NIOSH lifting equation to evaluate tasks such as picking, stacking, labelling, and loading [19]. The highest-risk postures were heavy trunk and neck flexion, unilateral weight bearing on a single leg, and manual lifting of loads > 10 kg. Suggested solutions ranged from engineering controls, such as adjustable lifting platforms and motorised manipulator arms, to administrative controls, such as equipment relocation and biomechanically specific training. A study was conducted in an electronic manufacturing company in Pekan, Pahang, Malaysia, to estimate the frequency of WMSDs faced by personnel based on the RULA and REBA assessments. Musculoskeletal degeneration was common in the data and was most prevalent in the shoulders, wrists, and lower back. Both unloading and pushing operations were associated with serious risk categories for both evaluation instruments [20].

Similarly, Lasota et al. [21] examined packers working at order fulfilment facilities, recording five different postures in Action Category (AC) 2, seven in AC3, and one in the critical threshold of AC4. The research findings showed that the greatest biomechanical risk occurred when workers carried large cartons with an arched back and arms above the trunk [21]. The study showed that urgent changes in workstations are important in preventing the development of MSD. The same result was found by Ahfriliandre et al. [13] in their research on a drug packaging line (PT. X) in Indonesia. The initial REBA analysis scored 4, indicating that the observed tasks were classified as medium risk. Although the risk was less than that in heavy warehouse conditions, the researchers found dangerous non-neutral postures, which were exacerbated by personnel shortages, and ultimately recommended targeted changes to manual handling methods. A study published in the International Journal of Environmental Research and Public Health demonstrated the effectiveness of technological intervention by studying the biomechanical profile of a packing tape workstation before and after automatic mechanisation. An example of successful and focused industrial automation is the introduction of an automatic tape machine which, by eliminating repetitive upper limb movements and awkward wrist postures, considerably reduced ergonomic risk factors [22].

Overall, the empirical investigations revealed that lengthy periods of manual packaging activity are invariably linked with a medium to very high REBA risk profile, mainly because of trunk hyperflexion, unsafe reach envelopes, and repetitive upper limb movements. These dangers can be controlled by proven engineering controls, such as height-adjustable work surfaces, mechanical aid hoists, and full systemic automation paired with an administrative strategy incorporating strategic layout rearrangement and comprehensive ergonomic training. However, as thoroughly reviewed for REBA applications [23]-[25], a significant portion of current research on packaging efforts is still limited to small-

scale case reports reliant solely on observational scoring, highlighting the urgent academic need for more robust data-driven pre- and post-intervention evaluations of packaging efforts.

Quantitative measurement methods, instead of visual estimation, use advanced instrumentation, such as electromyography, digital goniometers, and multi-axis force plates, to quantify physiological parameters, applied forces, exact joint articulation angles, and localised muscle activation. Although these empirical methods provide a very high level of accuracy, objectivity, and resolution of internal biomechanical loads, they are inherently more time-consuming and costly and require specialised operator training and laboratory-grade equipment [24]. This can lead to the perception that they are not appropriate for large-scale facility screening or routine daily checks in typical industrial settings. However, when used for additional analysis of specific problematic behaviours, initially identified by observational tools, these quantitative tools provide invaluable and complementary biomechanical data.

Finally, subjective assessments obtain qualitative data from employees through standardised interviews and formal surveys. These participatory methods are crucial for capturing the lived human experience of physical discomfort, acute pain, perceived environmental stressors, and practical operator-generated ideas for structural improvement, which are rarely captured through rigid visual observation or purely quantitative biomechanical assessments alone [25]. The Environmental Checklist is a key component of this overall strategy. It routinely asks operators about specific features of the physical environment of their workspace which are direct determinants of their day-to-day comfort and long-term health, including the quality of ambient lighting, control of temperature, efficacy of ventilation, and levels of acoustic noise. Such a checklist is especially important at packaging workstations, where obscure environmental factors, such as localised heat buildup around operating machinery and the profound vascular effects of prolonged standing on unyielding surfaces, are major contributors to increased worker fatigue and localised discomfort. Finally, it offers a qualitative systematic tool for the correct recognition of latent environmental variables which significantly improve the baseline physical requirements of industrial labour.

1.5 Assessing Current Approaches in Packaging Workstations

Contemporary ergonomic literature has focused on the effect of workstation architecture on the occurrence of work-related musculoskeletal diseases, especially in industrial situations that call for repetitive motion and persistent non-neutral body mechanics. Although general risk factors for the overall manufacturing and logistics industries are well established, highly specialised activities such as foam-in-place packaging present particular biomechanical issues. This encompasses prolonged forward trunk flexion, excessive overhead reaching to get to elevated film dispensers, and simultaneous manual material handling, which have not been extensively studied in the literature. Observational studies, such as the Rapid Entire Body Assessment, have indicated serious postural risks in packaging operations for pharmaceuticals and electronic components [20]-[21]. However, a major shortcoming of many of these empirical studies is the lack of triangulation of biomechanical data with subjective operator input and localised environmental stress factors. Therefore, a clear gap exists in the methodology of the holistic assessment and purposeful structural redesign of foam packing workstations. To fill this gap, the current study employs a robust mixed-methods approach by integrating REBA analysis, standardised environmental checklists, and structured operator surveys to systematically map and mitigate ergonomic vulnerabilities at a specialised aerospace component packaging workstation.

2. Materials and Methods

The methodology provided here is a systematic approach for a full ergonomic assessment and subsequent redesign of a foam packing workstation in an aerospace component distribution warehouse. This analytical method was designed to offer a multidimensional understanding of current postural dangers, objective measures of biomechanical risk, and the integration of subjective experiential information from the operational staff. The use of a mixed approach is expected to lead to reliable and actionable data, which can aid in building successful design solutions for a safer, more comfortable, and highly productive industrial environment. Although this project was a non-interventional workplace assessment, it was carried out in accordance with the institutional ethics guidelines of Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). The researchers obtained verbal informed consent from the operators involved before any interview or photographs were taken. All collected materials and survey responses were fully anonymised prior to analysis to ensure workers' privacy.

2.1 Ergonomic Assessment Tools

The ergonomic analysis was based on a selected set of proven diagnostic tools to ensure a high degree of reliability, impartiality, and functional comprehensiveness. The tools were selected carefully to extract quantitative and qualitative data streams in an organised manner. The REBA framework was used as the research diagnostic base. This investigation was based on a robust and widely used observational tool. Foam dispensing, and carton sealing require highly variable and dynamic postures, making REBA an ideal tool for identifying the exact ergonomic risks present within the workforce. The assessment focused mainly on high-risk kinematic behaviours, such as extreme bending and reaching, to prepare the film rolls in the shipping cartons. Notably, the overhead arm used to activate the foam dispenser was thoroughly examined in its elevated position, as overhead reaching is recognised clinically as a precursor to chronic cervical and shoulder strain, and this factor is directly weighted in the REBA scoring matrix. In addition, the examination allowed us to pinpoint the minor postural abnormalities occurring during foam expansion, that is, the constant forward tilt of the trunk which leads to a permanent static strain on the lumbar spine. In addition, the last working procedures of bimanual carton sealing and manual lifting of packages of 6-8 kilograms into a staging stack were analysed. These motions include vigorous effort

and combined trunk movements, which are key determinants of the final REBA risk levels. Finally, to ensure inter-rater reliability and transparency in observational scoring, the assessments focused on the most extreme postures during physically demanding parts of the workflow. Two qualified ergonomic researchers independently reviewed and rated the digital photographic evidence of these high-risk activities.

Inter-rater reliability was assessed using rigorous testing, and initial disagreements over specific joint articulation angles were systematically resolved through collaborative review and professional consensus. This analytical approach allows investigators to estimate the mechanical forces applied to the musculoskeletal system by analysing the physical posture of the operator, force coupling for specific tools, and the number of times kinetic movements are required to generate an action level score, which determines the level of urgency for intervention [26]. A specific Environmental Checklist was used to rigorously audit the surrounding physical parameters in an industrial warehouse scenario, in addition to posture analysis. The extensive inventory considered key facility parameters, namely localised illumination (to assess both the presence of glare and general task visibility), thermal regulation (to assess localised heat build-up around machinery and general thermal comfort), facility ventilation (to assess the presence of adequate air circulation and the dispersion of chemical fumes), and ambient acoustic noise. Rigorous qualitative auditing is crucial for detecting secondary physical stressors that can cause worker exhaustion or impair cognitive attention.

A standard Worker Survey Template was also administered to the active workforce to obtain important subjective insights. The survey consisted of 12 well-designed questions to capture the lived experiences of operators, document localised physical pain, measure overall happiness with the workplace, and include open-ended questions to create practical, worker-generated recommendations for workstation improvement. This human dimension adds a qualitative layer that is often missing from strictly observational approaches. Digital photography is an important supplementary tool that allows for detailed high-fidelity postural evaluation. The operators were videotaped at all times while performing their usual work duties. The visual records provided basic empirical data that "froze" complex kinetic movements in time and enabled accurate retrospective calculation of specific joint angles and body segment deviations, which supported the accuracy of the REBA scoring. Finally, the important spatial parameters of the workstation and manipulated inventory were measured using conventional physical measuring equipment, that is, industrial tape measures and calibrated weighing scales. The devices recorded the precise size of the workstations and the necessary vertical and horizontal reach characteristics, as well as the actual weight of the boxes handled, which was always between 5 and 10 kg. This objective geographical data was critical in the analysis of static loads, depiction of optimal ergonomic reach zones, and complete knowledge of the real physical toll of the material handling requirements.

2.2 Field observation methodology

The observational phase of the study was methodically designed to include all operational duties and associated biomechanical problems at the foam packing station. Long observation periods and varying daily workloads were used to acquire highly representative data, and the researchers were able to account for the normal variability in the operator posture and speed of job performance. The technique involved closely watching and annotating the anatomical position assumed at each important phase of the sequence: foam dispensing, carton folding, hand sealing, and final pallet stacking. The evaluators focused on extreme trunk flexion and cervical bending, which occurred most often when the operators retrieved empty boxes from the floor or reached beneath the primary worktable to turn foam dispensers on and off.

The folding and hand tape-sealing manoeuvres were highly repeated, and the arms and shoulders were kinematically tracked in detail. Researchers [18] have also reviewed forceful, prolonged, or mechanically difficult postures that can result in acute musculoskeletal injuries, in light of the specific body mechanics used to move and stack finished cartons onto pallets. The vertical and horizontal reach distances were also physically tested and compared with the observational data. Researchers have found that high overhead arm elevations are necessary to change depleted film rolls on high-mounted dispensers and that severe spinal flexion angles are necessary for material handling at the floor level. The specific postural demands in the preliminary problem description, including persistent upward arm extension and severe bending at the waist and neck, were immediately confirmed by direct field observations.

Finally, the observational methodology was extended to monitor dynamic environmental changes associated with operational shifts. In addition to describing the static state of facilities, researchers have actively monitored transient environmental variables that may affect operator comfort. These include localised thermal radiation produced around active foam machinery during continuous operation and sudden surges in ambient warehouse noise. Simultaneously, operators consistently cited the constant threat of long-term standing in a static position on hard concrete floors as a major cause of systemic fatigue and lower body pain.

2.3 Subjective Data Gathering Process

The study included seven employees (n=7) who represented the full staff of this foam packing station across all shifts. The workers' personal experiences were collected using a custom survey. Although this measure has not been formally psychometrically validated, it is similar to the well-established Nordic Musculoskeletal Questionnaire (NMQ) in its approach to identifying specific areas of body discomfort. Objective biomechanical metrics and topographical data were supplemented with relevant direct feedback from the workforce throughout the organised interview procedure. Personnel from the Repair, Packaging, Asset Control, and Inventory Unit, which is the typical personnel for the workstation, were questioned. The cohort had varying experiences with the specific foam equipment. Two employees had less than six months of experience, two had between six months and one year, two had between one and three years, and one operator had more than three years of experience. The distribution showed that the overwhelming majority of the workforce had

only been running the machines for less than three years, suggesting a reasonable baseline familiarity with the specialised task needs. All responses were anonymous to allow complete candour and safeguard the privacy of the operators.

Thus, the questionnaire was carefully loaded with question types designed to elicit numerical scales and rich qualitative narratives. Closed-ended scale queries with a standard 1-5 rating range were used to quantify daily physical discomfort severity perception, baseline satisfaction with workstation characteristics, and frequency of operational dangers. These measurements offer measurable and subjective data points. Instead, open-ended questions were added to encourage operators to describe their everyday physical experience, point out the exact anatomical areas where they felt pain, report the ambient variables that disrupted their activities, and explicitly propose practical engineering solutions that could be applied at the floor level. By combining these multiple data-gathering methodologies, a richly textured dataset was produced which properly represented the lived experience of the operators and provided vital qualitative context to the study's rigorous numerical conclusions.

2.4 Data Synthesis and Analysis Strategy

The data collection phases were completed, and the numerous metrics received from the different instruments were systematically organised and thoroughly examined using a pre-established assessment framework. The analytical architecture was designed to enable a multidimensional evaluation of the workstation ergonomic profile by combining objective biomechanical risk indicators with the qualitative reality of the operator experience. The collected data were divided into four independent evaluation groups. A quantitative model of postural stress was developed. Then, the researchers could provide objective values for the total postural stress using the REBA ratings they generated and the digital picture evidence. These metrics are effective tools for quantifying the overall injury risk of specific body movements performed during critical tasks and provide hard empirical data to confirm the severe trunk flexion, excessive neck bending, prolonged overhead arm elevation, and repetitive wrist twisting identified during preliminary scoping. Second, Environmental Stressors were assessed using Environmental Checklist data. This made it possible to carry out a full audit of the workstation physical environment, including a full assessment of the ambient lighting performance, local thermal stability, ventilation efficiency, and baseline noise levels. This category provides key context for non-postural environmental factors that may degrade operator well-being.

Third, a deep-dive study of the Worker Survey transcripts was conducted to analyse the Subjective Experience. The current study was conducted to accurately report the operator-reported frequencies of acute physical discomfort, systemic tiredness, and overall satisfaction with the prevailing workstation architecture. This direct feedback from the users was vital in understanding the dynamics between the physical machinery and the operator in terms of physiological health and psychological morale, including the negative effects of standing for long periods. Finally, the Tool and Layout were validated for appropriateness by comparing the direct observations of the protocol and the exact physical measurements taken on the floor. This called for a detailed structural study of the entire layout of the workstation and the ergonomic feasibility of the tools supplied. Access to the control module, spatial height of the primary foam dispensing nozzle, and functional mechanics of the manual sealing mechanism were rigorously evaluated against recognised ergonomic design principles. This full mixed-methods synthesis worked very well, providing strong quantitative assessments of hazards and rich qualitative insights into the behaviour. Together, these datasets provided a scientifically sound basis for the evidence-based, highly practical redesign ideas presented in the following sections of this publication.

Table 1. Poster assessment and scoring

Body Region	Observed Posture	Score	Comment
Trunk	Bent forward ~30°	2	During foam insertion into the box
Neck	Tilted forward	2	Watching foam position during expansion
Legs	Standing, knees slightly bent	1	No foot support or anti-fatigue mat
Upper Arms	Raised above shoulder level	3	Reaching overhead to pull film
Lower Arms	Extended forward	1	Holding carton edges
Wrist	Twisted during sealing	2	Wrist strain from taping
Coupling	Fair grip	1	Handles nozzle with moderate control
Load/Force	~6–8 kg carton lifted manually	1	Light to moderate weight

3. Results and Discussion

3.1 Assessment of Existing Workstation

A baseline ergonomic analysis was performed using the Rapid Entire Body Assessment to quantify the major postural hazards involved in significant packing activity. The final REBA score was 9. This score is well into the high-risk category tier, indicating an absolute requirement for immediate structural intervention to avoid injury to the operator. The unique body postures recorded, the individual hazard scores associated with them, and the contextual task variables included in the scores are shown in Table 1. The upper arms of the divided anatomical segments were given the highest individual penalty (score of 3), which was directly proportional to the continual overhead reaching required to remove the protective film from high dispenser mounts. The trunk was docked 2 points for the 30° forward bending of the spine required to inject expanding foam into deep shipping containers. At the same time, the operators were required to keep their cervical spine forward so that they could witness the chemical expansion process at all times; therefore, they scored 2 for the neck. The wrist posture also received a 2, reflecting the high repetition and severe twisting mechanics in the hand tap step. The

lower arm extension was scored as 1 for physically handling and gripping the carton flaps during sealing. Lower extremities (legs) 1 Need for long periods of static standing without anti-fatigue matting or ergonomic footrests Also, the load/force variable was scored 1 because of the physical lifting and moving of finished boxes that weighed 6 to 8 kilos. The coupling was finally scored as 1, meaning that the physical coupling was not adequate, although the operators had good control of the foam pouring nozzle.

The packaging operation is a step-by-step process to maximise the security of the product with the throughput of the warehouse. Operators prepare raw foam materials for further mechanical dispensing through fill-roll preparation. Next, a film roll is prepared. The empty carton has a plastic liner that is physically inserted into it. The liner acts as a barrier to protect the aircraft components during the volatile foam expansion process. The operators then have to check the display module and must do so before they can actuate the foam. This is an important quality control step to ensure that the part is in the right place and has no defects before it is permanently encased. The liquid foam was then poured directly into the housing. Operators visually monitor the expansion to ensure optimum product cushioning. When the foam is cured, the carton is folded by hand, taped up, and stacked for outbound products. This completes the operation cycle. This sequence is shown step-by-step in Figure 1. This analysis of the workflow highlights the physical and repetitive nature of the packing cycle, with frequent cycles of bending, overreaching, and vigorous manual material handling. The visual documentation of these discrete procedures offers crucial context for the ergonomic audit and experimentally confirms the high-risk REBA scores derived from foam dispensing and hand sealing operations.



Figure 1. Step and procedure to operate foam packaging machine

Table 2. REBA score calculation

Step	Description	Score
A	Trunk + Neck + Legs (from REBA Table A)	5
B	Upper arm + Lower arm + Wrist + Coupling (Table B)	4
C	Combined Score A + B (REBA Table C)	7
D	+ Activity Score (1) + Load/Force Score (1)	+2
REBA Final Score	C + D	9

A detailed environmental assessment and postural audit were performed in the immediate packing zone. Special consideration was given to ambient lighting, temperature regulation, mechanical ventilation, and acoustic noise because of their significant impact on operator comfort, cognitive performance, and general injury prevention. Data collection showed that the lighting infrastructure of the workstation was well-designed; the strong overhead lighting system provided a very uniform distribution of light, efficiently eliminated shadows, and decreased visual glare. Operators verified that "Visual clarity was still very good when doing precision tasks such as putting down foam and taping things shut" and that it was a very nice operational environment. The results are consistent with the international ergonomic guidelines for the required illumination (lux) levels for manual industrial labour (ISO 6385:2016). Furthermore, the ambient temperature was maintained in the optimum range of 23 °C to 26 °C using highly efficient air circulation. The industrial foam apparatus generated a localised thermal output. However, the surrounding space was sufficiently well-ventilated to prevent the accumulation of dangerous heat. The operators reported full thermal comfort with no signs of heat stress or physical overheating. The building is equipped with strong, fully functional mechanical ventilation systems complemented by natural air currents. The expanding polyurethane foam gives off soft chemical vapours, which are dispersed quickly by the infrastructure, so that the work area does not have a lingering smell or stuffiness in the air. The operators confirmed that there were no reports of respiratory discomfort, indicating excellent indoor air quality. Finally, the noise environment was determined to be low to moderate. Noise from foam expansion and hand sealing of the carton was kept low and non-disruptive. Operator comments suggest that noise from adjacent warehouse operations was not excessively loud and did not adversely affect cognitive attention or productivity. In simple terms, the environmental audit indicated that all ambient physical elements were within acceptable ergonomic limits and positively influenced workers. The elevated hazards

identified at this workstation are therefore mainly explained by the significant postural risks evaluated by the REBA assessment.

3.2 Major Ergonomic Deficiencies

The foam packaging workstation was found to be working at a critically high level of ergonomic risk, with a final score of 9, necessitating immediate structural adjustment based on the empirical conclusions acquired from the REBA analysis [26]. The high-risk profile was mostly attributable to extended static standing on hard surfaces without anti-fatigue support, continued overhead reaching, and sustained flexion of the trunk in the anterior direction, all of which are known initiators of debilitating musculoskeletal illnesses (MSDs). The findings are consistent with the large body of scientific literature on present logistics and packaging environments, where similar physical dangers are frequently described. For example, Haekal et al. [18] reported extreme REBA scores of 11 in pharmaceutical packing facilities owing to extreme weight handling, repetitive spinal flexion, and extreme spatial constraints, forcing operators to operate in awkward reaching envelopes. Similarly, Kirci et al. [19] reported severely high-risk postures in Turkish logistics warehouses when handling and taping heavy cartons and recommended targeted engineering interventions, such as height-adjustable lifting platforms and mechanised handling aids.

The results obtained in the present study clearly demonstrate high cumulative strain on the upper extremities of the operators. Upper arms were awarded a worry score for the repetitive overhead actions required to obtain packaging film from high mounts. This particular kinetic movement not only causes rapid muscular fatigue, but also considerably increases the chance of an acute shoulder joint injury. Lasota [21] described similar order fulfilment situations with similar dangers. The REBA Action Categories were always AC3 or AC4, requiring immediate restructuring of the facility due to excessive overhead work and trunk postures beyond the limits. In addition, the hand taping method included repetitive wrist twisting which posed a specific danger level of 2. Previous studies have shown that the use of automated tape applicators greatly reduces localised ergonomic pressure on the wrist and forearm. The stress on the upper body is compounded by the complete lack of anti-fatigue flooring or footrests to support the worker, a condition that greatly increases vascular pooling and mechanical strain in the lower limb. This is a major source of lower extremity pain when faced with prolonged standing demands and a proven initiator of decreased productivity during a shift.

The analysis of these combined metrics allows for the recommendation of a very targeted, multi-levelled ergonomic intervention strategy. The first line of defense is the use of engineering controls, particularly adjustable-height worktables, scissor-lift pallet positioners, and rotating work turntables to bring operational jobs back to a neutral physiological posture. In addition, the film dispensing units need to be spatially redesigned or lowered vertically to effectively minimise the high shoulder elevation. Prolonged standing causes considerable physiological discomfort, and a high-quality anti-fatigue mat is vital for mitigating this discomfort. In addition, the use of semi-automated or ergonomically optimised tape dispensers would immediately remove the numerous wrist deviations that hamper the sealing stage. Such individual structural solutions are in direct alignment with empirical suggestions from earlier research that revealed substantial reductions in baseline REBA ratings after deliberate workstation redesign and localised job automation [20]-[21]. To enhance efficacy, engineering solutions should be closely paired with strategic administrative measures, such as the enforcement of worker rotation matrices and the scheduling of micro-breaks to uniformly divide physical stress and further delay the onset of MSDs. In contrast, the overall environmental assessment indicated that the ambient light, localised temperature, mechanical ventilation, and acoustic noise levels of the facility were all within optimal ergonomic requirements, thereby allowing for a physically comfortable and safe environment. The lighting system provided good visual clarity with no glare. The thermal regulation was very constant (23-26 °C), and the ventilation design of the solid avoided the accumulation of heat and efficiently dissipated the mild chemical vapours without any respiratory distress. Ambient noise levels were low to moderate, and the operators were able to concentrate without interruption. The results of these tests show that ambient environmental factors are not a true hazard to the workforce but are performance enhancers. The only association with high postural risks (trunk flexion, overhead reaching, and fast repetitive motion) is the critical REBA score 9. The remaining ergonomic capital should be heavily weighted toward physical workstation reconstruction and kinetic task modification, rather than ambient facility upgrades.

The qualitative results from the structured study with the seven packaging operators provided significant insight into the floor-level reality of the workspace. Interestingly, the physical effort required for these jobs was quite low. Four operators rated the daily work as “not demanding” (1 out of 5) and only one operator rated it as “very demanding” (5 out of 5). In addition, the group only experienced sporadic episodes of acute physical discomfort, with only one operator officially reporting localised pain radiating through the neck, shoulders, and lower lumbar region. This implies that the cardiovascular and physical demands of the work alone are probably within the capacity of most workers, but the very repetitive and mechanically uncomfortable position may result in serious localised musculoskeletal injury over time. When asked, only one operator identified foam spraying as the most stressful procedure. No single task was reported as too tiring by the rest of the workforce, indicating that, at baseline, the pace of tasks was generally sustainable. The preliminary REBA analysis indicated that the workers more often had minor, localised pain in their neck, shoulders, and lower back, as shown in the qualitative results in Table 3.

Table 3. Summary of worker survey responses (n=7)

Survey Metric	Measurement / Scale	Summary of Findings
Perceived Physical Demand	1 (Low) to 5 (High)	Average: 1.57 (Four rated '1', one rated '5')
Most Tiring Task	Open-ended	Foam spraying (n=1), None/Manageable (n=6)
Discomfort Locations	Multiple Choice / Map	Neck, Shoulders, Lower Back (Reported by 1 worker)
Environmental Satisfaction	Qualitative / 1-5 scale	100% reported adequate lighting, acceptable noise/temp
Key Worker Suggestions	Open-ended Themes	Need for tool tray/rack, 5S layout, better PPE for foam

All operators had high opinions of the physical surroundings. All respondents agreed that the task lighting was more than adequate, the acoustic noise was easily tolerated, and the localised temperature was comfortable. One operator did mention a faint smell of chemical foam but was careful to describe it as non-intrusive. This direct subjective feedback supports the empirical findings of the environmental evaluation, which shows that the main hazard to the workforce is the physical geometry of the workstation, not the ambient warehouse environment. The workers also offered extremely practical suggestions for adjustments at the floor level in grading the existing system of waste management. The desire of the workforce for a dedicated tool tray or storage rack, a more streamlined workstation setup, and the installation of stringent post-shift cleaning measures all point to a clear need for increased spatial organisation to speed up the workflow and eliminate physical clutter. Finally, workers highlighted real safety concerns regarding the risk of thermal burns from expanding foam and the difficulty in removing cured foam residue from normal clothing and identified an urgent need for improved PPE regulations and specific chemical handling training. In conclusion, the survey data indicate good management of the ambient environment and acceptable cardiovascular workload, but a complete ergonomic redesign should focus on the elimination of awkward body postures, improvement of the spatial layout of tools, and rigorous enforcement of chemical safety procedures to reduce localised physical discomfort and exposure to hazardous substances.

3.3 Ergonomic Interventions

Based on the detected ergonomic deficiencies, a package of targeted redesign choices is proposed, with all actions having a sound biomechanical rationale to increase operator comfort, safety, and system efficiency. The use of an adjustable-height industrial worktable completely alleviates the primary problem of excessive forward trunk bending during foam application. This structural improvement is biomechanically logical because the main working surface can be adjusted to the individual user's resting elbow height (ensuring the correct 90° arm angle). This in turn physically prevents the operator from extending his trunk beyond the hazardous limit of 20° and is in full accordance with the international ergonomic regulations (ISO 6385 section 5.4.3). Similarly, the excessive physiological strain of extreme overhead reaching can be negated by transferring the heavy film rolls to a variable-height waist-to-shoulder-level glide track. This unique spatial accommodation prevents the upper arm from rising above 90°, immediately eliminating the mechanical catalyst for chronic shoulder fatigue and repetitive strain injuries, guaranteeing compliance with both the NIOSH lifting zone standards and ISO 6385 Section 5.4.4. In addition, the installation of high-density anti-fatigue matting on the operational floor is a very cost-efficient and instantly impactful solution to the tremendous physiological toll of static standing. These mats actively promote vascular circulation by micro-movements of lower extremities, greatly diminishing muscle fatigue of legs and feet during long hours and meeting the strict standards of both ISO 6385 Section 5.5 and OSHA 3123 regulations. Figure 2 provides a graphical depiction of the proposed redesign concept with these structural enhancements.

The predictive REBA assessment suggests that these ergonomic changes, which are still in the planning stages, are expected to significantly reduce physical strain. The variable-height desk with a lowered film roll addresses the most extreme postures, avoiding excessive forward leaning (lowering the trunk score from 2 to 1) and overhead stretching (reducing the upper arm score from 3 to 1). With these changes, the predicted REBA score would drop from 9 (high risk) to an acceptable 4 (low/medium risk). The 5S organisation and basic tool storage are cheap and acceptable approaches from the perspective of implementation possibilities. The cost of adjustable workstations is a relatively small capital investment, but it is far outweighed by the predicted fall in injury-related worker absences in the long term. All tools and tape dispensers required to handle foam and seal cartons must be relocated to a special tray or rack securely mounted in the operator's main near-reach area to minimise the dangerous wrist twisting required to do this. An effective approach for combating excessive wrist deviation and dangerous arm overextension is to keep these frequent contact points within a 40–50 cm horizontal reach envelope and meet the spatial design recommendations of ISO 6385 Section 5.6 and the NIOSH ergonomic reach envelope guidelines. In addition, the facility will mandate the use and specific provision of special Personal Protective Equipment (PPE), namely chemical-resistant industrial gloves and protective aprons, to reduce the risk of volatile foam pouring onto exposed flesh or regular clothing. Using this intervention greatly reduces the incidence of acute chemical contact injuries, is compliant with the PPE standards of the Occupational Safety and OSHA and is compatible with the hazard control guidelines of ISO 6385 Section 6.3.

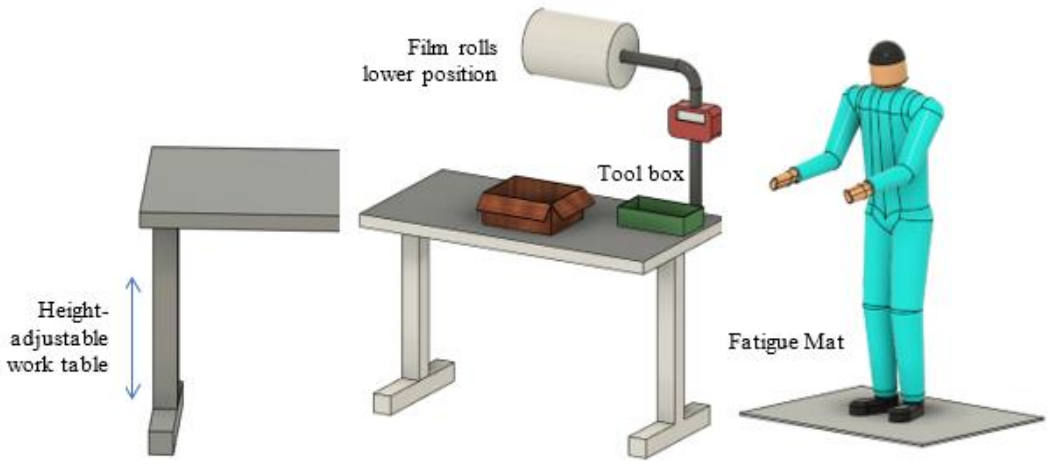


Figure 2. A redesign proposal according to identified issues

Additionally, the random placement and storage of hand tools has been a concern for the operators; therefore, the layout of the work area has been completely reorganised using the 5S approach to create highly visual, dedicated work areas for the tools. This lean manufacturing strategy reduces wasted movement and search time by ensuring consistent tool placement and meeting functional workplace design standards, as defined in ISO 6385 Section 5.6. Finally, it is important to have a strict and formalised Standard Operating Procedure (SOP) for the daily post-shift cleaning of the foam nozzles and work surfaces. This administrative control addresses basic facility cleanliness and significantly reduces secondary contact hazards from hardened residual foam, directly meeting the ISO 6385 Section 7 work system maintenance criteria. This composite matrix of proposed engineering and administrative improvements is precision-engineered to promote a fundamentally safer, highly efficient, and deeply comfortable industrial work environment. The final architectural layout of the optimised workstation is shown in Figure 3.

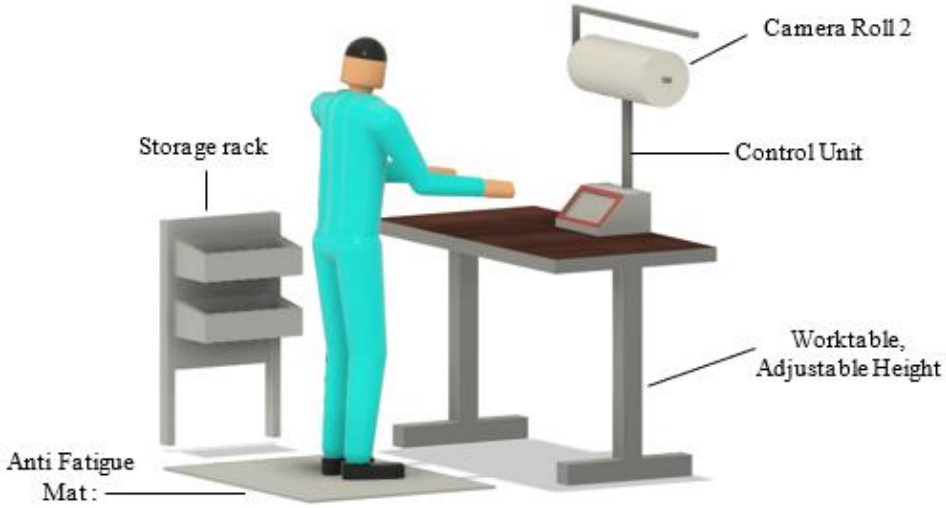


Figure 3. Redesign workstation layout with ergonomic enhancements

We expect that the deliberate introduction of these science-based ergonomic changes will have profound, measurable benefits for the larger enterprise, well beyond simple regulatory compliance, and will lead to tangible improvements in human health and raw throughput. The optimised architecture of the packaging sequence is illustrated in Figure 3. The main advantage of this structural change is a significant reduction in the likelihood of operators suffering from serious musculoskeletal disorders, particularly those affecting the lower lumbar spine, shoulder joints, and wrists, which were identified as critical risk areas in the baseline REBA assessment. Furthermore, the entire redesign should result in a dramatic increase in labour morale by systematically removing the particular physical pressures which currently characterise the shift. The company will demonstrate a real financial commitment to the physical complaints documented by the workforce. This will improve overall job satisfaction and build a highly favourable company culture. Operationally, better spatial accessibility and less localised muscle fatigue directly translate into faster task execution and better quality control. Therefore, mathematically, the greater morale of the operators and the drastically reduced physical strain should result in higher daily yields of output. Moreover, such a highly proactive strategy for injury prevention through ergonomic capital investments will greatly minimise organisational absenteeism. As the rate of chronic strain injury decreases, so too will the expense of sick leave payouts and employee turnover rates that disturb the workplace. Ultimately, these focused re-engineering efforts culminate in stringent compliance of the facility with the most comprehensive international regulatory standards, such as the all-encompassing ISO 6385 paradigm and rigorous OSHA advisories, thereby

confirming the organisation's perpetual audit-readiness and reaffirming its perpetual dedication to superior occupational health and safety practices. A considerable amount of epidemiological and industrial engineering evidence supports the projected outcomes and has repeatedly shown that purposeful, data-driven ergonomic investments can completely offset the huge long-term financial liabilities of occupational trauma and ongoing worker replacement [28]. This study has some key limitations that need to be recognised. The qualitative results are not generalisable because the experiment was conducted at one foam packing station with seven operators (n=7). The physical environment was assessed using basic checklists, and no reliable instrument monitoring of noise and lightening was performed. Finally, the planned workstation enhancements are still only on paper. The hoped-for reductions in postural strain are only forecasts until structural improvements are implemented on the shop floor. In an ideal world, future research would take the next step in physically testing these medicines and measuring their actual and long-term success.

4. Conclusions

This study provides a complete ergonomic evaluation of a specific foam-packing workstation in an industrial warehousing setting. The primary purpose of this study was to discover and measure in-depth the deeply embedded ergonomic dangers that are slowly eroding the physical safety, everyday comfort, and general productivity of the active working force. The technique is quite robust, encompassing the concept of Rapid Entire Body Assessment, detailed environmental audits, and direct structured operator interviews. This combined diagnostic approach provided highly actionable data and key areas of structural breakdown. Most notably, the workstation scored a high 9 on REBA, putting the operation at the highest risk level for musculoskeletal damage. The disturbing measure required an immediate comprehensive ergonomic intervention to correct extremely dangerous physical behaviours, such as constant forward bending of the operator's trunk, excessive overhead reaching under load, and prolonged static standing on hard concrete surfaces. Extreme deviations in posture and physical friction involved in manual material handling were unequivocally established as the main factors contributing to acute physiological strain on the workforce, thereby increasing the risk of developing disabling work-related musculoskeletal illnesses.

Based on these empirically confirmed risks, a systematic recommendation of a complete matrix of targeted ergonomic changes was provided. The main technical recommendation was the rapid installation of an industrial worktable with height adjustment to accommodate the very different anthropometric statures of the workforce in an effort to neutralise awkward, injury-inducing trunk postures. Operators who must stand constantly must also employ high-density anti-fatigue matting to actively increase vascular circulation and greatly reduce lower extremity discomfort. It is recommended that very specific ergonomic training modules be used in parallel to increase the workforce's conscious understanding of safe biomechanics and good kinetic work practices. Other key interventions included spatially lowering elevated film rolls, strict enforcement of chemical-resistant PPE during foam application, and rigorous spatial reorganisation of hand tools to permanently eliminate severe wrist strain and wasted kinetic movement. These suggested structural and administrative solutions have been developed to comply with elite global ergonomic standards and industry best practices, closely referencing the ISO 6385:2016 framework, NIOSH biomechanical recommendations, and OSHA safety laws. Compliance with this regulation implies that the forthcoming plant re-layout will significantly improve the daily working conditions, ensure long-term organisational compliance, and secure the ultimate operational sustainability of the packing line. The proposed improvements are in line with well-known ergonomic standards, such as ISO 6385 and NIOSH. However, this study is essentially the first step in quantifying baseline risks and identifying potential corrective actions. The actual construction of the new setup, experimental tests, and calculation of the subsequent REBA scores were not included in the scope of this first phase. Researchers will now test these interventions on the actual manufacturing floor to determine whether they improve productivity, reduce absenteeism, and minimise verifiable physical pain.

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Declaration of Competing Interest

The author declares no conflicts of interest

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N.M. Yahya: Conceptualisation; Methodology; Validation; Resources; Investigation; Writing – original draft
M.A. Shahabudin: Methodology; Validation; Writing; Visualization; Supervision; Writing - review & revise
M. Mohd Ali: Validation; Resources; Investigation; Resources; Writing - review & revise
M.N. Osman Zahid: Validation; Resources; Resources; Writing - review & revise

Availability of Data and Materials
The data supporting the findings of this study are available from the corresponding author upon request.

Ethics Statement
This study did not involve human participants or animal subjects. Therefore, ethical approval was not required.

Generative Artificial Intelligence Declarations
The authors claim that artificial intelligence-assisted technologies, such as generative AI, were not used to generate content, ideas, or theories. We have used AI to enhance readability and refine the language. This was used with extreme human control and supervision. The authors take full responsibility for reviewing and approving the content of this manuscript.

References

[1] V. Vijayakumar, F. Sgarbossa, W. P. Neumann, and A. Sobhani, "Framework for incorporating human factors into production and logistics systems," *International Journal of Production Research*, vol. 60, no. 2, pp. 1–18, 2021. https://doi.org/10.1080/00207543.2021.1983225.

[2] T. Horberry and R. Burgess-Limerick, "Applying a human-centred process to re-design equipment and work environments," *Safety*, vol. 1, no. 1, pp. 7–15, 2015. https://doi.org/10.3390/safety1010007.

[3] M. G. Kibria, M. S. Parvez, P. Saha, and S. Talapatra, "Evaluating the ergonomic deficiencies in computer workstations and investigating their correlation with reported musculoskeletal disorders and visual symptoms among computer users in Bangladeshi university," *Heliyon*, vol. 9, no. 11, Art. no. e22179, 2023. https://doi.org/10.1016/j.heliyon.2023.e22179.

[4] W. Sukania, S. Ariyanti, M. Jayusman, and S. R. Nasution, "Risk assessment of working posture and implementation of new workstation to increase productivity," *IOP Conference Series: Materials Science and Engineering*, vol. 852, no. 1, Art. no. 012116, 2020. https://doi.org/10.1088/1757-899X/852/1/012116.

[5] N. Larson, H. Wick, S. Hallbeck, and P. Vink, "Corporate ergonomics programs: Identifying value through a company award process," *IIE Transactions on Occupational Ergonomics and Human Factors*, vol. 3, no. 1, pp. 9–23, 2015. https://doi.org/10.1080/21577323.2014.1001042.

[6] B. Hasanain, "The role of ergonomic and human factors in sustainable manufacturing: A review," *Machines*, vol. 12, no. 3, Art. no. 159, 2024. https://doi.org/10.3390/machines12030159.

[7] M. Lorenzini, M. Lagomarsino, L. Fortini, S. Gholami, and A. Ajoudani, "Ergonomic human-robot collaboration in industry: A review," *Frontiers in Robotics and AI*, vol. 9, Art. no. 813907, 2023. https://doi.org/10.3389/frobt.2022.813907.

[8] O. Bazaluk, V. Tsopa, S. Cheberiachko, *et al.*, "Ergonomic risk management process for safety and health at work," *Frontiers in Public Health*, vol. 11, Art. no. 1253141, 2023. https://doi.org/10.3389/fpubh.2023.1253141.

[9] F. Jusoh and M. N. O. Zahid, "Ergonomics risk assessment among support staff in Universiti Malaysia Pahang," *IOP Conference Series: Materials Science and Engineering*, vol. 319, no. 1, Art. no. 012059, 2018. https://doi.org/10.1088/1757-899X/319/1/012059.

[10] M. García, A. Sánchez, R. Domingo, and M. Á. Sebastián, "A cost-benefit ergonomics methodology applied to service industry with digital human modelling," *European Journal of Industrial Engineering*, vol. 8, no. 4, p. 533, 2014. https://doi.org/10.1504/ejie.2014.064757.

[11] R. Ginting, D. Nurhadi, and A. F. Malik, "Designing a lifting tool work using SNQ and anthropometry," *IOP Conference Series: Earth and Environmental Science*, vol. 452, no. 1, Art. no. 012091, 2020. https://doi.org/10.1088/1755-1315/452/1/012091.

[12] D. O. Odebiyi and A. C. U. Okafor, "Musculoskeletal disorders, workplace ergonomics and injury prevention," in *Ergonomics — New Insights*. London, U.K.: IntechOpen, 2023. https://doi.org/10.5772/intechopen.106031.

[13] A. Esmaeel, "An ergonomic design of workplace layout based on anthropometric measurements: A literature review," *Journal of Ergonomics*, vol. 12, no. 6, Art. no. 323, 2022. https://doi.org/10.35248/2165-7556.22.12.323.

[14] H. Jain, "Critical insights into thermal comfort optimization and heat resilience in indoor spaces," *City and Built Environment*, vol. 2, no. 1, Art. no. 38, 2024. https://doi.org/10.1007/s44213-024-00038-z.

[15] S. Javanmardi, L. Rappelt, C. Baumgart, D. Niederer, L. Heinke, and J. Freiwald, "Work conditions and determinants of health status among industrial shift workers: A cross-sectional study," *Frontiers in Public Health*, vol. 12, Art. no. 1489178, 2025. https://doi.org/10.3389/fpubh.2024.1489178.

[16] L. Silva, N. Costa, C. Schutz Rosa, *et al.*, "Ergonomic assessment of postal workers' pain symptoms and musculoskeletal risks related to parcel processing activity for delivery," *EXCLI Journal*, vol. 21, pp. 744–756, 2022. https://doi.org/10.17179/excli2022-4857.

[17] M. Hita-Gutiérrez, M. Gómez-Galán, M. Díaz-Pérez, and Á.-J. Callejón-Ferre, "An overview of REBA method applications in the world," *International Journal of Environmental Research and Public Health*, vol. 17, no. 8, Art. no. 2635, 2020. https://doi.org/10.3390/ijerph17082635.

[18] J. Haekal, B. Hanum, and D. E. Prasetio, "Analysis of operator body posture packaging using Rapid Entire Body Assessment (REBA) method: A case study of pharmaceutical company in Bogor, Indonesia," *International Journal of Engineering Research and Advanced Technology*, vol. 6, no. 7, pp. 27–36, 2020. https://doi.org/10.31695/ijerat.2020.3620.

[19] B. K. Kirci, M. E. Ozay, and R. Ucan, "A case study in ergonomics by using REBA, RULA and NIOSH methods: Logistics warehouse sector in Turkey," *Hittite Journal of Science & Engineering*, vol. 7, no. 4, pp. 257–264, 2020. https://doi.org/10.17350/hjse19030000194.

[20] N. M. Yahya and M. N. O. Zahid, "Work-related musculoskeletal disorders (WMDs) risk assessment at core assembly production of electronic components manufacturing company," *IOP Conference Series: Materials Science and Engineering*, vol. 319, no. 1, Art. no. 012036, 2018. https://doi.org/10.1088/1757-899X/319/1/012036.

[21] A. Lasota, "A REBA-based analysis of packers workload: A case study," *LogForum*, vol. 10, no. 1, p. 87, 2014. http://www.logforum.net/vol10/issue1/no9.

[22] R. C. M. Teixeira, W. P. S. Guimarães, J. G. Ribeiro, *et al.*, "Analysis of the reduction of ergonomic risks through the implementation of an automatic tape packaging machine," *International Journal of Environmental Research and Public Health*, vol. 19, no. 22, Art. no. 15193, 2022. https://doi.org/10.3390/ijerph192215193.

[23] S. Hignett and L. McAtamney, "Rapid Entire Body Assessment (REBA)," *Applied Ergonomics*, vol. 31, no. 2, pp. 201–205, 2000. https://doi.org/10.1016/S0003-6870(99)00039-3.

[24] C. Tripathi, M. Arora, and A. Chakrabarti, "Occupational safety within non-routine manufacturing processes: Evaluating the validity of task-based ergonomic assessments," arXiv preprint arXiv:2507.20261, 2025. https://doi.org/10.48550/arXiv.2507.20261.

[25] E. Cippelletti, S. Azouaghe, D. Pellier, and A. Landry, "Assessing MSDs before introduction of a cobot: Psychosocial aspects and employee's subjective experience," *Relations industrielles/Industrial Relations*, vol. 70, no. 1, 2023. https://doi.org/10.7202/1101311ar.

[26] C. Gungor and M. F. Oguz, "Manual material handling risk assessment in furniture industry: REBA method," *World Journal of Advanced Research and Reviews*, vol. 21, no. 3, pp. 1760–1765, 2024. https://doi.org/10.30574/wjarr.2024.21.3.0934.