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Innovations in Ergonomic Risk Assessment and Intervention in Material Handling

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ABSTRACT

This review paper delves into the complex facets of ergonomic risk evaluation and reduction across various industrial sectors. The focus is on identifying the hazards linked to manual labor, especially those contributing to physical risks and musculoskeletal disorders among workers, and proposing inventive solutions to mitigate these threats. The review brings together insights from different studies, emphasizing the application of automation, virtual modeling, Kinect-based evaluations, and other innovative tools in repetitive tasks and material handling operations. It also explores the usage of back-support exoskeletons, observational checklists, and workspace redesigns to decrease risks in construction, manufacturing, vegetable transportation, clothing accessories, and other sectors. The development of risk assessment frameworks for specific roles such as container terminal operators and the examination of musculoskeletal disorders in diverse worker demographics, including older female farmers and factory workers, are also featured. The comprehensive approach of the journal sets the stage for future research, aiming to further reduce the prevalence of musculoskeletal disorders through continued innovation and cross-sector collaboration.

Keywords: Ergonomic Risk Assessment, Material Handling

1.0 INTRODUCTION

This review looks at the hazards from manual work. It mainly sees how ergonomic things lead to body harm and bone problems in workers from different places. It also talks about ways to lessen these dangers. Rocha and friends (2022) showed that using machines can make ergonomic dangers less. They say new methods for work that repeats a lot are important. In same thinking, Lunin and Glock (2021) talked about looking at manual work using Kinect things to see body dangers. Murugan and group (2023) did a study on manual work using things like NIOSH lift thing, RULA, and another thing called Strain index.

In building and making things, Abraham and friends (2022) talked about making bone problems less using computer models. Golabchi and group (2022) looked at how using a back-help thing can change posture in manual work. Chang and friends (2018) made a list to look at dangers of falling, and Rabbani and Ahmed (2020) looked at ergonomic things in building places. Also, Smallwood and Deacon (2019), Zhang and group (2019), and Kathiravan with Gunarani (2018) looked at ergonomic problems, tiredness checks, and how well ergonomic things work in building.

Some studies look at certain job types. Rao and friends (2023) made better carts for moving vegetables. Quiroz and friends (2021) changed work places to make bone problems less in clothes accessory jobs. Cimino and group (2023) made a plan to stop bone problems for people working with big containers, and Kamble and group (2022) looked at bone problems in cotton farmers.

1.1 PREVENTION OF MUSCULOSKELETAL DISORDERS IN INDUSTRIAL SETTINGS: ERGONOMIC TECHNIQUES IN HANDLING MATERIALS

In many industries, the tasks involving manual handling of materials come with their own sets of problems, often resulting in various musculoskeletal disorders (MSDs). The area of checking

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lessening ergonomic risks has many studies, and these studies look into these risks in different sectors like labs, cloth-making, farming, building, and health services. In these checks, they look at many things, especially MSDs, how people stand and work, discomfort related to work and how different tasks make muscles work hard. For these kinds of checks, tools such as Rapid Entire Body Assessment (REBA), Ergonomic Checkpoints tool, Rodgers muscle tiredness check, and RULA are used much (Rocha et al., 2022; Lunin & Glock, 2021; Murugan et al., 2023; Abraham et al., 2022; Golabchi et al., 2022) In the area of industries and making things, many plans are there to make ergonomic methods that make people safe, healthy, and work better. These plans are mostly about making MSDs less, changing how work areas look, making ergonomic designs, finding out ergonomic risks, and starting ergonomic methods (Murugan et al., 2023; Abraham et al., 2022; Golabchi et al., 2022). New technology has brought new ways to check and make ergonomic risks less in many work areas, like farming, building, health services, and cloth-making. Some ergonomic tools, like REBA and the Ergonomic Checkpoints tool, are used to make MSDs less, make people's work stands better, and make work discomfort less (Zhang et al., 2019; Kathiravan & Gunarani, 2018). In many work areas, like farming, building, health services, and cloth-making, checking and making ergonomic risks less is very important. Many studies in this topic try to know and make MSDs less, look at how people work and stand, and see how tasks make muscles work. Many tools like REBA, Ergonomic Checkpoints tool, Rodgers muscle tiredness check, and RULA are used for these studies (Kamble et al., 2022; Shin & Jeong, 2022; Chen & Luo, 2023; Kamble & Pandit, 2022; Yusof & Shahida, 2021; Kotadiya et al., 2021; Patel & Ghosh, 2023; Syafei et al., 2023; Fischer et al., 2021). Work areas see a big increase in checking and making ergonomic risks less. Mainly, tasks of manual material handling have big ergonomic risks. This has been studied a lot in areas like labs, cloth-making, farming, building, health services, and more. Main points of these studies are to know and make MSDs less, look at how people work, and see how tasks affect muscles. For these, many tools like REBA, Ergonomic Checkpoints tool, Rodgers muscle tiredness check, and RULA are used (Johnen et al., 2022; Saptari et al., 2023; Rodrigues Ferreira Faisting & de Oliveira Sato, 2019; Das, 2020; Karimi et al., 2020; Yadi & Kurniawidjaja, 2019). In many work sectors, tasks of manual material handling have ergonomic risks (Susihono et al., 2018; Ibrahim et al., 2020; Yusof & Shalahim, 2020; Marak et al., 2020; Qureshi et al., 2019; Cai et al., 2020; Hemati et al., 2020; Curbano, 2018; Nabil & Dahda, 2022). Workers often say they have MSDs in parts like the back, neck, knees, and legs (Susihono et al., 2018; Ibrahim et al., 2020; Yusof & Shalahim, 2020; Marak et al., 2020; Qureshi et al., 2019; Curbano, 2018). Work to check and make ergonomic risks in handling materials less is a big area of study in many sectors like labs, cloth-making, farming, building, and health services. The main idea is to know and make MSDs less, make work stands better, and make work discomfort less (Rizkya et al., 2018). For these, tools like REBA, Ergonomic Checkpoints tool, and Rodgers muscle tiredness check are often used. One study shows work that checked ergonomic problems in repeating scrap handling work in car industries. This found that workers use much force, have safety issues, and risk of MSDs (Dasari & Balasubramanian, 2021). What the study found says that starting ergonomic methods, like using digital human modeling and making simulations, might solve these problems (Dasari & Balasubramanian, 2021). Handling materials has many manual tasks in areas like labs, farming, cloth-making, building, health services, and more. Here, ergonomics is very important. Many studies are there to check and make ergonomic risks less. These look at MSDs, how people work, and how tasks affect muscles. Many used tools for these are the REBA, Ergonomic Checkpoints tool, Rodgers muscle tiredness check, and RULA (Tirloni, Reis, & Moro, 2020; Wurzelbacher et al., 2020). With time, more studies try to explore ergonomics, check, and make dangers less from manual material handling tasks in areas like labs, cloth-making, farming, building, and health services (Vu L.Q., Kim K.H., Rajulu S.L., 2021). A big part of this work is to understand and fix MSDs, see how people work, and look at how tasks affect muscles. Using ergonomic tools like REBA and Rodgers muscle tiredness check, these studies help much in efforts to make risks less (Abdol Rahman M.N., Ahmad Zuhaidi M.F., 2018).

1.2 ADDRESSING MUSCULOSKELETAL DISCOMFORT IN MATERIAL HANDLING: ERGONOMIC RISKS AND INTERVENTIONS ACROSS DIVERSE SECTORS

Handling materials in different work areas shows many dangers linked to ergonomics, needing a close look and steps to solve. Sectors like laboratory works, cloth-making, farming, building, health

help, and others see dangers from manual handling of things. They worry about muscle and bone problems (MSDs), different ways of standing while working, soreness from work, and muscles working too hard. To look at these closely, tools named Rapid Entire Body Assessment (REBA), Ergonomic Checkpoints tool, Rodgers muscle getting tired check, and RULA are used (Rocha et al., 2022; Lunin & Glock, 2021; Murugan et al., 2023; Abraham et al., 2022; Golabchi et al., 2022). In some work areas, special dangers from manual handling of things are there. Cloth-making area, for example, has many dangers, and people studying, like Murugan et al. (2023), used different ergonomic look-tools to understand these dangers and make plans to solve. Building work also has these risks. Abraham et al. (2022) used computer modeling to see problems warehouse workers face. Golabchi et al. (2022) thought that wearing back-helping things can help building workers, mainly helping with lower back and other sore places.New tech tools bring new ways to look at and make less the ergonomic dangers in work areas like farming, building, health help, and cloth-making. Ergonomic tools like REBA and the Ergonomic Checkpoints tool are used to make MSDs less, make better ways of working, and make work soreness less (Zhang et al., 2019; Kathiravan & Gunarani, 2018). Looking closely at ergonomic dangers and how they hurt worker health can guide in making good steps to solve. Sett et al. (2022) used a future guessing bones method to see soreness in female workers making bricks in India, showing these workers are easy to hurt from work. In the same way, Rao et al. (2023) made a better push cart for selling vegetables in Hyderabad to make MSDs less, showing the good sides of making work things fit better with ergonomics.

Chen and Luo (2023) studied health of people working in tape-making factory and found that workers from Taiwan said more pain in shoulders, lower back, neck, and knees than workers from Thailand who said pain in hands, wrists, shoulders, and thighs. Their study showed work tasks connect with where the soreness is and that lifting heavy things is a big danger for both groups. Yusof and Shahida (2021) did a study in a medicine making place, finding workers felt most sore in lower back, shoulders, and top back. These results give good info for managers and safety officers in work places to stop MSDs in medicine-making work. Working together in different study areas is needed to know and solve work dangers. For example, Kotadiya et al. (2021) talked about how bones study and ergonomics should work together. In another look, Patel and Ghosh (2023) found many body parts, mainly neck and lower back, feel sore in people processing fish. Syafei et al. (2023) used ergonomic looking-tools like the Nordic Body Map and REBA to see current ways of plastic wrapping work. They gave ideas to make the ergonomic danger less and work more. Fischer et al. (2021) asked people fixing wind turbines on the ground about muscle problems and soreness they feel, showing need for thinking of ergonomics in designing wind turbines. Gathering all these studies tells about why we must know ergonomic dangers and take steps to make muscle soreness less in work areas. Karimi et al. (2020) did a special study in a milk factory, showing that starting ergonomic steps and manager decisions together made better ways of working and less muscle soreness. In making things, farming, health help, and building work areas, moving things many times don't think of ergonomics, causing MSDs (Susihono et al., 2018; Yusof & Shalahim, 2020; Marak et al., 2020; Qureshi et al., 2019; Curbano, 2018). Yusof & Shalahim (2020) saw that workers making things felt a lot of lower back MSDs, with lifting heavy things being a big danger. In farming, women picking tea leaves felt a lot of pain because old work ways don't think of ergonomics (Marak et al., 2020). Studies focus on making and starting ergonomic steps to solve these dangers. Hemati et al. (2020) started ergonomic steps in a flour factory, leading to less MSDs. In the same way, Curbano (2018) made an ergonomic step for manual moving of things, showing how important it is to train and understand personal ability to make soreness less. Checking and solving ergonomic dangers in tasks of moving materials is big study area covering many sectors, like labs, cloth-making, farming, building, and health help. The big goal is to understand and make MSDs less, find best ways of working, and make work-related soreness less (Rizkya et al., 2018). Many tools, including REBA, Ergonomic Checkpoints tool, and Rodgers muscle getting tired check, are used in these works. Understanding these dangers deeply and making good steps are very important for worker health, safety, and doing work well.

1.3 IMPROVING ERGONOMICS IN MATERIAL HANDLING: A FOCUS ON WORK POSTURE AND ITS IMPLICATIONS ACROSS INDUSTRIES

In the study area of ergonomic risk check and lessen, many research papers are found looking deeply at many risks linked with handling materials by hand in varied sectors. This covers places like labs, clothing making, farming, building works, healthcare, and more places. These looks into study many parts like problems in muscles and bones (MSDs), how workers stand and move, pain in muscles and bones because of work, and how certain works put stress on muscles. Important tools used here are Rapid Entire Body Assessment (REBA), Ergonomic Checkpoints tool, Rodgers analysis for muscle tiredness, and RULA. These tools are very helpful for this study (Rocha et al., 2022; Lunin & Glock, 2021; Murugan et al., 2023; Abraham et al., 2022; Golabchi et al., 2022). In industry for building big electricity towers, there are many ergonomic problems, mostly about falling dangers. Chang et al. (2018) made a list to see this danger, pointing out that changing position is the work with most danger of falling. The ergonomic problems also touch workers in construction who don't have much training. Research found that being very tired is a big reason for less good work and less safe work (Lee et al., 2020). Also, when looking at house building sites, bad standing and moving, and not right handling of materials harm workers (Rabbani & Ahmed, 2020). New technologies help in creating new ways to check and make less ergonomic dangers in many sectors like farming, building, health care, clothing making, and others. Many tools for ergonomics, like REBA and Ergonomic Checkpoints tool, are used to make MSDs less, make better work positions, and lessen pain from work (Zhang et al., 2019; Kathiravan & Gunarani, 2018). On the other side, research by Kathiravan and Gunarani (2018) used RULA and REBA tools to look at how ergonomics is in house building in Tamil Nadu place. The results show bad effects of not good work positions and talk about needing deep checks for ergonomic dangers to find ways to make them less. Checking and making less ergonomic dangers is big matter in many industries like farming, building, health care, and clothing making. The main goals of these research works are to understand and lower MSDs, see work positions, and study how different works stress muscles. Many tools like REBA, Ergonomic Checkpoints tool, Rodgers analysis for muscle tiredness, and RULA are used in these looks into (Kamble et al., 2022; Shin & Jeong, 2022; Chen & Luo, 2023; Kamble & Pandit, 2022; Yusof & Shahida, 2021; Kotadiya et al., 2021; Patel & Ghosh, 2023; Syafei et al., 2023; Fischer et al., 2021). Handling materials by hand has ergonomic dangers which many sectors like labs, clothing making, farming, building, and health care have studied. Main point of these studies is to understand and lessen MSDs, see work positions, and know effects of varied works on muscle stress. Many tools like REBA, Ergonomic Checkpoints tool, Rodgers analysis for muscle tiredness, and RULA are used for this (Johnen et al., 2022; Saptari et al., 2023; Rodrigues Ferreira Faisting & de Oliveira Sato, 2019; Das, 2020; Karimi et al., 2020; Yadi & Kurniawidjaja, 2019). Special research by Karimi et al. (2020) looked at what happens when ergonomic changes and manager choices are done at the same time in milk factory. This made work positions much better and less pain in muscles and bones for workers. Ergonomics is very important for handling materials which has many manual works in sectors like labs, farming, clothing making, building, and health care. More and more studies want to check and make less ergonomic dangers, understand MSDs fully, see work positions, and know effects of different works on muscles. Tools like REBA, Ergonomic Checkpoints tool, Rodgers analysis for muscle tiredness, and RULA are mostly used in these checks (Tirloni et al., 2020; Wurzelbacher et al., 2020). Valverde, Diaz, and Chavarri (2022) made a model to make less workers not coming to work by changing workspaces. This model tried to make less workers not coming by making better work positions and less physical hard work. More and more studies look at ergonomics to check and make less dangers from handling materials by hand in many sectors like labs, clothing making, farming, building, and health care (Vu L.Q., Kim K.H., Rajulu S.L., 2021). Important part of this study area is to understand and solve MSDs, look at work positions, and see how different works affect muscles. With tools like REBA and Rodgers muscle tiredness check, these studies give much help to lessen dangers (Abdol Rahman M.N., Ahmad Zuhaidi M.F., 2018). Another important research by Rodriguez Diez-Caballero B., Alfonso-Beltrán J., Bautista I.J., Barrios C. (2020) looked closely at what causes long time muscle problems in shoulder in car making workers in Spain. They found many reasons like using hand tools, not good positions, and mind problems. So, next research can see how ergonomic and mind dangers work together in making these problems and find ways to stop them in work places.

2.0 METHODOLOGIES

The study of ergonomic risks in tasks related to material handling involves various approaches to prevent and mitigate musculoskeletal disorders (MSDs) and to enhance productivity across

industries. The Rapid Entire Body Assessment (REBA) stands out as a primary tool for evaluating such risks. Observing and recording activities, behaviors, and events in their actual settings is crucial, rooted in hands-on scientific principles. Tools called Ergonomic Checkpoints, developed by international organizations like the IEA and ILO, offer guidance on how to identify, analyze, and mitigate workplace risks. This guidance covers aspects such as material handling, workstation design, tool safety, and work organization. Cameras, meanwhile, offer a practical means of documenting tasks or actions for later review, enabling researchers to obtain sequential data over time. Techniques like Motion Capture (MoCap) are noteworthy in this domain, aiding in the identification and reduction of MSDs, evaluating work postures, and understanding the impact of various tasks on muscles. When combined, these techniques offer a comprehensive perspective on the ergonomic risks associated with material handling.

2.1 USING REBA TO CHANGE HOW ERGONOMIC RISK GETS LOOKED AT IN MATERIAL MOVING ACROSS DIFFERENT WORKPLACES

In many industries, the job of moving materials carries ergonomic dangers. These dangers can make health problems and can lead to conditions in the bones and muscles known as MSDs. Because of these dangers, it's very important to have good ways to look at them and try to lessen them. There's this one way called Rapid Entire Body Assessment, or REBA for short. REBA is a special way to look at how the body is positioned, how different parts of the body move, and how much force they use during a job. It helps find out what things in the job can make the worker get MSDs. Using REBA is pretty simple. It involves watching how a person's body is positioned, how much force they use, how they handle things, and if they do the same movements over and over, as well as other things they do in their job. When someone uses REBA to see how materials are moved, they follow certain steps. First, the person watching will look at the worker doing their job. Then, they will use a kind of picture with codes and a way to give scores to what they see. Each part of the body like the neck, middle part, legs, and arms get a score. If the score is high, it means there's a lot of danger. Many times, people have studied how good REBA is in different jobs. For example, Nabil and Dahda (2022) looked at how things were packed at PT. XYZ's place where they organize stuff to be shipped. They used REBA to see problems with how workers stand and the dangers in moving things by hand. What they found out was that there was a lot of danger, so they said it's important to make changes to how people stand and work to avoid hurt in the bones and muscles. Then, Rao, Prakesh, and Pandit (2023) used REBA to make better carts for moving vegetables in a city called Hyderabad. With REBA, they saw problems with the bones and muscles and then thought of a new design for the carts. This new design is based on good practices for the body, which makes the job safer. Adhaye and Jolhe (2023) also used REBA when they wanted to plan how to move things in a food storage place in India. In their study, they looked at many ways to find out where it hurts, where there's pain, and what dangers there are in moving things. Using REBA, they saw what needed to be better, like how things are held, how often they're moved, standing in strange ways, and the paths they follow. In another kind of job, Cuautle Gutiérrez, Uribe Pacheco, and García Tepox (2021) looked at risks when finishing parts for cars using REBA. They and some other good ways found things that could be made better. They even thought of a new tool to reduce chances of getting hurt. REBA is also used for people working on train tracks. Das (2020) used REBA to look at injuries and problems in bones and muscles among those who keep train tracks in good shape in India. Many of them had these problems. This study showed that REBA is very useful to see what's wrong and think of how to fix it.

2.2 HOW MOTION CAPTURE HELPS IN LOOKING AT MOVING MATERIALS

Looking into Ergonomic Risk when handling materials and making things safer at the workplace is really important. The main aim here is to find out and reduce problems in bones and muscles, see how people stand and work, and see how different tasks make the muscles work hard in many industries. There are many ways to do these checks, but a very special one is Motion Capture, which many people shorten to MoCap. Motion Capture, or MoCap, is a cool system that sees and saves how humans move. People use it in making cartoons, in virtual games, and in studying how humans and machines work together. For this method, small shiny spots are put on a person, and cameras that see

infrared light watch these spots. This way, the movement of the person can be turned into a 3D picture on a computer. In studying how the body moves and how one stands, MoCap is often used. It helps see how hard the body works in different tasks and checks for possible dangers to the body. MoCap can really show if there's a wrong way of moving or standing that might cause harm to bones and muscles. In a study by Ghaneh-Ezabadi et al. (2022), these people wanted to check a tool called posture-matching load assessment tool (PLAT). This tool tries to understand the heavy feeling on the lower back when moving materials. They used MoCap and PLAT together with some prediction methods. They found out that PLAT is a good tool, showing that MoCap helps in checking ergonomic tools. Zhao et al. (2022) also used MoCap with marks on the body in their study. They looked at the dangers in warehouses. They saw how different it was when putting things on high shelves compared to low ones. This shows MoCap can give good details about how people move and the dangers in different jobs. Then, Muller et al. (2022) made and checked a new way using MoCap to guess the heavy feeling on the back when moving materials. What they found is that MoCap can really help guess some physical facts, and it's good for checking ergonomic stuff at work. Iranzo et al. (2022) mixed MoCap and a way to measure muscle activity to see how a back-supporting tool helps reduce muscle tiredness when moving materials. Their results showed that MoCap is good at checking if things like back supports help in making jobs easier. Bortolini et al. (2020) added MoCap to a system named Motion Analysis System (MAS) to watch and study human movements in making and putting together things. This showed how MoCap can help do the job better but still think of the health of the worker. Feldmann et al. (2019) also used MoCap to turn the ergonomic tool Key Indicator Method (KIM) into a digital version. They checked how people stand in order picking jobs. This study showed how MoCap is useful in real job settings.

Finally, McDonald et al. (2020) combined MoCap and a way to measure muscle activity to guess the work in shoulder muscles during pushing and pulling. They found out that where the hands are and how force is used can change shoulder muscle work, showing the detailed things MoCap can find about muscles.

2.3 USING ERGONOMIC CHECKPOINTS METHOD TO LOOK AT AND MAKE BETTER MOVING MATERIAL JOBS

Ergonomic Checkpoints are ideas made by big global groups, like the International Ergonomics Association (IEA) and the International Labour Office (ILO). These ideas help people see, understand, and fix problems related to jobs. These checkpoints look at many places where people work, such as places where people get medical care, factories, and outdoor work sites. In these checkpoints, they talk about important things: moving materials, how the workspace looks, safety of machines and tools, the surrounding environment, places to rest, talking at work, and how work is planned. Using these checkpoints is simple. They tell people step by step how to see and make better the problems at work. First, the ones who use this method pick the right checkpoints for their job place. After that, they look at how things are at their work using the checkpoints. From what they see, they suggest how to make things better. They always think about what is possible and what isn't in their specific work setting. Many studies have used this method to look at and make better the working conditions. One study in a place in Colombia where they cut meat used this Ergonomic Checkpoints method. They found out things they needed to fix about storing materials, moving things by hand, safety of machines, the design of workspaces, and how work is planned (Pérez, Rodríguez, Salazar, & Trujillo, 2021). In places where people get medical care, this tool also showed its worth. In one hospital in Colombia, they saw things to make better about storing materials, moving patients safely, workspaces, stopping infections, and how work is set up (Torres, Rodríguez, & Buitrago, 2021). This study showed how important it is that everyone involved gets a say in using the checkpoints. The group called Southeast Asian Network of Ergonomics Societies (SEANES) made their version of the Ergonomic Checkpoints for inside and outside workplaces. They wanted to make the same ergonomic rules for different job places and to make workers want to have safer and better job places (Khalid, Kogi, & Helander, 2019). There was another study where they made ergonomic checkpoints just for medical jobs. They made 60 checkpoints that covered ten big technical areas. They found these checkpoints good for making different professionals talk together and for making better places for healthcare (Kogi, Sano, Yoshikawa, & Yoshikawa, 2019).

3.0 ADVANCING ERGONOMIC RESEARCH: EMERGING STRATEGIES, TECHNOLOGIES, AND CHALLENGES FOR WORKER WELL-BEING

In the study of ergonomics, understanding and addressing the challenges is ever-evolving. The prevention of musculoskeletal disorders in industrial settings is a critical area where continuous efforts are directed towards devising new methodologies and strategies. This not only aims to secure the safety of workers but also ensures the reduction of musculoskeletal problems, enhancing overall productivity across varied industries. Alongside, when addressing musculoskeletal discomfort in material handling, it becomes imperative to emphasize the effectiveness of ergonomic interventions. These interventions, applied across sectors like healthcare, construction, and manufacturing, are crucial in understanding the broader implications of ergonomic designs. Such designs, incorporating tools such as trolleys or modifying work environments like pharmacies, underline the importance of design and usability evaluations. Additionally, while the focus on work posture and its implications across industries remains paramount, it is also essential to compare various ergonomic tools and strategies through comparative studies. These studies give a comprehensive view of the lasting effects of ergonomic measures, shedding light on their long-term benefits. At the same juncture, technological advances, including robotics, augmented reality, and IoT, are progressively becoming pivotal in redefining ergonomic practices. To conclude, with industries having their distinct challenges, industry-specific ergonomic studies become crucial. These not only highlight unique issues but also spotlight the requirement for tailor-made ergonomic solutions, thus paving the path for a deeper understanding of worker fatigue and stress. This introductory note serves as a foundation, guiding researchers towards the myriad dimensions of ergonomics, each contributing to the holistic well-being of workers across sectors.

3.1 FUTURE RESEARCH DIRECTIONS FOR "PREVENTION OF MUSCULOSKELETAL DISORDERS IN INDUSTRIAL SETTINGS"

In the realm of musculoskeletal disorder prevention within industrial settings, several notable research areas are emerging. Studies propose to incorporate and measure the results of ergonomic measures especially within the residential construction sector. The intent is to identify the most efficient ergonomic methods by comparing different strategies and understanding their influence on workers' health and productivity. Parallelly, research on manual cotton harvesting places emphasis on devising and applying measures that curtail Musculoskeletal Disorders (MSDs) and allergy incidences among farmers. This involves the endorsement of safety equipment usage, teaching the right working techniques, and spreading awareness of the health hazards linked to pesticide contact. The ultimate aim is to evaluate the ergonomic measures' impact over a prolonged period on health, safety, and productivity of workers. There's also an ambition to recognize the extended effectiveness of ergonomic interventions across various domains, like healthcare, automotive, and manufacturing. By conducting extended studies, the objective is to comprehend these measures' effect on mitigating musculoskeletal disorders and elevating worker security and output. An additional layer to this is the assessment of how ergonomic factors interplay with psychosocial risks and their combined consequences on job-related health and safety. Moreover, the long-standing utility of passive back-support exoskeletons in genuine work situations is being explored. The goal is to discern their efficacy across diverse manual tasks and industries, and also to see if sensor technologies can be integrated to deliver immediate feedback and adjustable support according to the unique requirements of each task and individual. Investigations in dairy factories are striving to reaffirm the findings, by emphasizing on the enduring sustainability and result of ergonomic solutions, considering organizational and psychosocial elements to enhance musculoskeletal health and working postures. Lastly, when considering manual material handling methods, research is zeroing in on the creation and execution of ergonomic solutions. The purpose here is to discern their lasting impact in minimizing physical grievances, workload, and musculoskeletal hazards. The eventual intention is to assess the benefits of suitable material handling equipment and tools on the safety and health of workers, maybe by conducting comparative studies to pinpoint the best methods and most efficacious measures.

3.2 FUTURE RESEARCH DIRECTIONS FOR "MUSCULOSKELETAL DISCOMFORT IN MATERIAL HANDLING"

Research directions are steering towards evaluating ergonomic trolley designs in real-world manual material handling scenarios through usability studies and field tests. There's keen interest in understanding how these trolleys compare in terms of worker safety, efficiency, and productivity against traditional ones. Moreover, there's anticipation around refining material layouts in manual picking tasks and choosing protective glove materials for cold surroundings. This considers worker body shapes, job details, ergonomic designs, and how gloves work with various surfaces. Designing and validating ergonomic devices, such as trolleys and handle designs for industries, is also being prioritized, with a focus on their role in decreasing physical stress and increasing worker productivity. Emphasis is also being placed on creating and introducing ergonomic adjustments in manual material handling, ensuring the use of ideal tools to decrease complaints and risks. Another promising direction is the adoption of a digitized tool for ergonomic evaluations in order picking processes, which may revolutionize conventional methods in many sectors. The gap in understanding ergonomic solutions across different industries is also being addressed, particularly regarding their efficiency in manual material handling. On another front, deep insights are being sought on the significant concern of occupational injuries in material handling, focusing on the reasons behind such injuries and how ergonomics can mitigate them. Lastly, the exploration of robotic solutions, especially for the food sector, is being eyed, with the intention of optimizing human-robot interactions for material handling tasks.

3.3 FUTURE RESEARCH DIRECTIONS FOR "WORK POSTURE AND ITS IMPLICATIONS ACROSS INDUSTRIES"

Research is turning its attention to implementing ergonomic interventions within genuine manufacturing systems, emphasizing bi-objective mathematical models and the role of job rotations. One important goal is understanding the benefits of these interventions, particularly for older workers, in terms of satisfaction and overall well-being. Long-term methodologies will be a key to track the lasting impacts. Another key area of interest is the real-world performance and acceptance of ergonomically designed wheelbarrows. Through comparative examinations, this study will dig deep into the differences between various wheelbarrow designs, considering elements like load capabilities and user contentment. Exploring advanced ergonomic risk evaluation tools is also on the horizon, with a focus on wearable technology for real-time monitoring. The primary aim is to gauge the long-term benefits of ergonomics in preventing work-related musculoskeletal issues. Moreover, the introduction of ergonomic benches in real settings to enhance posture and minimize musculoskeletal problems is also under scrutiny. The effectiveness of job rotation strategies, especially for older workers, in genuine manufacturing scenarios will be evaluated using a bi-objective mathematical approach. The long-term effects on satisfaction and well-being form the crux of this research direction. Lastly, the potential of Internet of Things (IoT) wearables is being pursued, with the aim of refining their capabilities and understanding their role in diverse work situations. Combining IoT with other digital technologies to craft holistic ergonomic strategies is a notable endeavor, aiming to significantly minimize musculoskeletal ailments and uplift the overall state of workers.

4.0 CONCLUSION

The discussion presented elucidates the considerable advancements made in the realm of assessing and addressing ergonomic concerns, especially those linked to manual material handling tasks across a spectrum of diverse industries. These efforts, which are underpinned by a myriad of unique and varied methods, have been instrumental in enhancing our understanding and consequently reducing the incidence of musculoskeletal disorders (MSDs). Furthermore, these endeavors have significantly improved working postures and have provided relief from job-related discomfort. Evaluation tools and methodologies, including but not limited to instruments such as REBA and Ergonomic Checkpoints, have enriched the knowledge base on ergonomic risks, facilitating a comprehensive and holistic approach to their mitigation. An introspection into potential future

pathways uncovers a vast expanse for further exploration and innovation within the field of ergonomics. This vastness encompasses areas like design assessments, a multitude of investigative studies, the inclusion of cutting-edge technological advancements in ergonomics, and specialized ergonomic studies specific to various industries. The success and fruition of these ambitious undertakings will largely be contingent upon the continuous embrace of emerging technologies and innovative methodologies. This, when combined with rigorous, dedicated long-term research, ensures persistent improvements and advancements. To encapsulate, even though there have been commendable achievements in the domain of ergonomic risk detection and amelioration, there's a vast horizon that remains unexplored. The trajectory of future ergonomic research is poised to provide more profound insights into MSDs, enable further refinement in research methodologies, and harness the power of state-of-the-art technology to amplify worker safety and productivity. All these strides in progress are geared to pave the way for creating more bespoke, efficacious, and contextually apt ergonomic solutions that cater to a myriad of industrial needs.

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