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Prevention of MSD by Assessing Psychosocial Factors in Manual Handling Tasks in the Workplace

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Table of Contents

Summary in Hungarian Language

Ez a disszertáció a pszichoszociális tényezők hatását vizsgálja a kézi anyagmozgatási tevékenységekre ipari munkakörnyezetben, azzal a céllal, hogy megelőzze a mozgásszervi megbetegedéseket (MSD-k). A kutatást az egészségvédelem és munkabiztonság területén felmerülő pszichoszociális kockázatok kezelésével kapcsolatos kérdések befolyásolták.

A vizsgálat három fő módszertani szakaszra oszlott, amelyek mindegyike külön fejezetben került bemutatásra. Az 1. fejezet bemutatja a kutatási kontextust, célkitűzéseket és hipotéziseket, valamint a tudományos problémát. A 2. fejezet egy szisztematikus irodalmi áttekintést tartalmaz, amelyet a PRISMA módszerrel végeztek el, hogy azonosítsák a mozgásszervi megbetegedésekkel összefüggő kulcsfontosságú pszichoszociális kockázati tényezőket. Ezután egy meta-analízist végeztek 40 releváns tanulmány finomított kiválasztásán, a Comprehensive Meta-Analysis (CMA) szoftver segítségével. Az eredmények szignifikáns statisztikai összefüggést mutattak ki a pszichoszociális stresszorok és az izomaktivitás csökkenése között ($r = 0{,}480$, $p < 0{,}001$).

A 3. fejezetben egy többkritériumos döntéshozatali (MCDM) módszert alkalmaztak a munkavállalók pszichoszociális kockázatérzékelésének elemzésére. Összesen 283 ipari dolgozó vett részt egy felmérésben, amelyet az Analytic Hierarchy Process (AHP) és a Best Worst Method (BWM) módszerekkel elemeztek. Ezek a módszerek rangsorolták az azonosított stresszor kategóriákat. Az eredmények megerősítették a stresszt kiváltó tényezők azonosításának megbízhatóságát és konzisztenciáját.

A 4. fejezet egy kísérleti tanulmányt mutat be, amely során 13 résztvevő hajtott végre általános kézi feladatokat, miközben galvanikus bőrreakciós (GSR) és szívritmus (HR) érzékelők mérték élettani válaszaikat. Összesen 39 000 élettani adatminta lett begyűjtve és elemezve. Az eredmények 38,8%-os izomaktivitás-csökkenést mutattak ismételt feladatciklusok során, amely korrelált a stresszterheléssel. Ezeket a jeleket gépi tanulási modellekkel osztályozták, például K-legközelebbi szomszéd (KNN), konvolúciós neurális hálók (CNN) és mélytanulási algoritmusok segítségével. A modellek nagy pontossággal azonosították a stresszállapotokat élettani jelzők alapján.

Antecedents of the Research

To earn a living. With the emergence of occupational health, the concept of work and our perception of the workplace have evolved in recent years and are now the subject of continuous research [1], [2]. From that point, and throughout history, the concept of "work" has evolved dramatically as a result of globalisation as a unique economic trend [3]. Approximately 1848, the Industrial Revolution's focus on industrial hygiene enabled the first steps towards what is now recognised as occupational health. [4].

The next step was to start 'Working for a suitable life'. The realisation that just producing money without considering workers' health could harm not only the workers but also the owners of these businesses was the impetus that propelled the concept of occupational safety forward [5]. Work has evolved from "simply making money" to today, when the concept of decent work is recognised as a human right. [4], [6], [7].

As the ILO (International Labour Organisation) points out in its agenda, the main difficulty in making a comprehensive environment safe is a recurring case study [8]. The analysis and assessment of safety risks are specific, but the principle must be applied to all workplaces. Continuous research into safety issues has led to the emergence of new risk elements in the workplace [9], ranging from those that are visible (physical factors) to those that are hidden but deeply present, and some of which can be more harmful (psychological factors) [10], [11]. Physical and psychological risk factors are both directly linked to the development of work-related disorders.

Two categories define the conception of a safe climate or workplace. The initial category consists of individual-level analysis that describes departments or units within a firm. The second category operates at the group level and considers safety at the organisational level, referring to management attitudes and business rules [12]. In addition, the psychological safety environment is linked to employees' views of safety within the organisational structure of the company concerning specific policies and practices, such as employee training on safety and security measures [13], [14], [15].

In today's world, a wide variety of risk identification tools and processes are available, including record assessment, information gathering approaches, checklist analysis, assumption analysis, causal mapping and various other approaches to reducing the impact of a hazardous workplace [16], [17], [18]. The importance of risk identification in the workplace is a major issue in industrial tendencies in the current setting, and the objective of the research is to bring value to the field.

As a primary workplace hazard, poor ergonomics is the leading cause of work-related problems in industry. As shown in Figure 1, a cause-and-effect analysis is applied to prevent musculoskeletal disorders. As the primary intent, the understanding of safety science is the primary factor in the application to identify a solution [19].

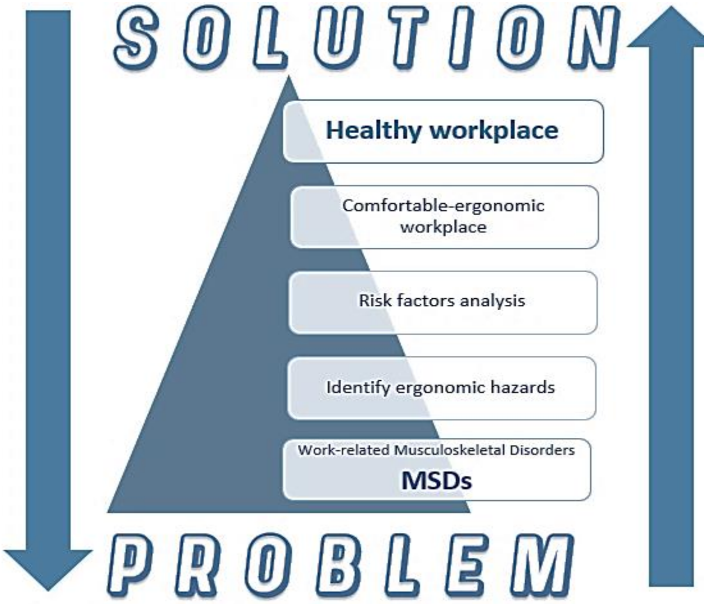

Figure 1: Overview of cause-and-effect relationships between healthy workplaces and biomechanics.

Since workplace safety has a direct impact on workers' well-being, corporate productivity, and the sustainability of economic activity, the importance of this cannot be overstated. Stress is a major psychological hazard that can be caused by heavy workloads, unrealistic deadlines, a lack of control over tasks, and poor relationships at work. Therefore, it is imperative that workplaces reduce stress because excessive stress has a negative impact on employees' well-being and overall organisational performance.

A safe workplace must meet the parameters established to guarantee it in this definition. These specific parameters are divided into groups: i) Physical work environment. ii) Psychosocial work environment, as shown in Figure 2, which asserts that lowering biomechanical ergonomic risk factors at work is directly related to improving the physical work environment. [19]. In today's digitised workplaces, task performance relies heavily on cognitive capacity, which encompasses mental processes involved in information processing such as memory retention, attention, decision making and learning. The cognitive demands of job-related tasks often rise above the intrinsic boundaries of human cognitive capacities, but strain can also be raised by working environments. As research on disruptions and interruptions has shown, many working conditions impede cognitive performance [20], [21].

Figure 2: Identified needs to achieve a healthy workplace

Inadequate stress management can result in serious mental and physical health problems, such as anxiety, depression, burnout, heart disease, and musculoskeletal illnesses. This causes companies to lose a lot of money because it not only lowers production but also raises absenteeism and turnover rates [22].

The psychological demands of work are significant today and will remain so in the future. Although the cognitive load associated with work environments and work practices is widely recognised and actively debated as a significant risk factor, little research has directly and systematically sought to develop situations that support people in performing cognitively demanding tasks [22].

The cognitive demands of today's fast-paced, heavily technological workplaces have increased, making stress management even more crucial. Employees' cognitive capacity is frequently exceeded by workplace disturbances, multitasking, and information overload, which exacerbates stress levels. Stress reduction improves decision-making, creativity, and overall productivity in addition to improving the health of employees. Businesses may establish a more sustainable and healthy work environment that will ensure long-term success and employee retention by managing stress on both an individual and organisational level.

Formulation of the scientific problem

As the industry considers workplace safety and risk reduction, it is critical to consider the effects of different physical and psychological risk factors on employees' health and well-being. This demonstrates that addressing the primary risk factors in the workplace is essential.

The significant number of occupational accidents that occur each year, mainly resulting in days away from work, has become a major cause for concern. The main objective is to improve the organisational framework and prevent future occupational accidents.

A key professional issue is integrating ergonomic concepts with safety criteria. To promote decent work as a human right and strike a healthy balance between workplace design and new strategies, new approaches are needed. The importance of occupational health is stressed, particularly regarding safety issues in the workplace. It highlights the importance of analysing and assessing safety hazards, which can be either overt (physical) or covert (psychological).

Workstation engineering is a deliberate and scientific technique for measuring recurring and essential stresses in the workplace. The technical problem is to develop effective methods of using tools at workstations, considering individual variations in activities and applications, and satisfying the different needs of individuals while performing numerous tasks.

Scope

Cognitive load and psychological demands in the workplace are key elements that affect worker performance, and research is needed to design environments that support people in cognitively demanding activities. This reflects the complex nature of workplace safety, which includes physical and psychological risk concerns, organisational management, and the cognitive needs associated with modern digital workplaces. Identifying key workplace risk variables and providing key insights for occupational health and safety.

The scope of this research focuses on understanding and mitigating psychosocial risk factors associated with manual handling tasks in the workplace. By examining the effects of psychosocial stressors on employees' physical tasks, including lifting and posture, the study seeks to increase workplace safety. It emphasises how crucial it is to recognise and manage psychological as well as physiological dangers in order to establish a safer and healthier workplace.

The research will systematically identify psychosocial stressors and distractions that influence the risk of musculoskeletal disorders (MSDs) during manual material handling. It will analyse how these factors affect workers' physical responses and susceptibility to injury. In addition, technological devices will be used to assess the impact of stressors on posture and muscle strain, integrating biofeedback to develop preventive strategies to reduce the risk of MSDs.

Another important aspect of the study is to understand the workers' perspective on psychological risk factors. Using decision-making techniques, the research will assess how workers perceive and prioritise psychosocial stressors in manual handling tasks, providing insight into their role in workplace safety. Finally, controlled laboratory experiments will be conducted to quantify the impact of these identified stressors on manual handling performance, fatigue accumulation, and movement efficiency, contributing to a comprehensive risk prevention framework.

Objectives

- Demonstrating that increasing workplace comfort can prevent and reduce the risk of work-related illnesses, such as musculoskeletal disorders (MSDs) in manual handling scenarios, by managing the factors related to the psychosocial aspects that directly influence cognitive ergonomics, improves security and safety in the workplace.
- To analyse the influence of psychosocial factors on the risk of developing musculoskeletal disorders in manual handling activities, by the identification of the main psychosocial factors and their impact on physical effort and susceptibility to injury in the work environment.
- To identify the cognitive ergonomic factors at the workplace that influence occupational health problems, particularly those that are directly related to the prevention of MSDs; using a systematic literature review and word cloud analysis; to define the most important factors to consider in a manual handling task of lifting loads within the workplace.

Hypotheses of the research

Hypothesis 1 (H1): Pushing comfort in the workplace by properly managing psychosocial ergonomic factors helps optimise conditions during manual handling tasks, mitigates stress-induced muscular activity reduction (SMAR), and enhances occupational safety, reducing the risk of musculoskeletal disorders (MSDs).

Hypothesis 2 (H2): Systematic categorisation and prioritisation of psychosocial factors based on worker perceptions can effectively identify the most impactful stressors and distractors in manual handling tasks and allow for effective targeted interventions.

Hypothesis 3 (H3): The integration of psychosocial risk factors into manual handling has the potential to create distractions that can increase the risk of musculoskeletal disorders (MSDs) in the workplace.

Hypothesis 4 (H4): The application of recognised ergonomic principles, in combination with observational analysis and advanced machine learning techniques, enables highly accurate detection of stress-related physiological responses induced by psychosocial stressors, which significantly influence muscular activity patterns and increase the risk of work-related musculoskeletal disorders (MSDs) during manual handling tasks.

Research Methods and Challenges

In preparing my thesis, I have divided my research into three parts as shown in Figure 3. In the first part, I conducted a systematic review to determine the neurocognitive factors in manual handling aimed at preventing MSDs in the workplace, identifying factors related to neuroergonomics are considered. In the second part, I developed a survey and data analysis to determine workers' perceptions of different neuro ergonomic factors, as distractors can affect manual handling. In the third part, the experimental analysis is applied to determine the stress produced by the inclusion of the neuro ergonomic factors during manual handling tasks.

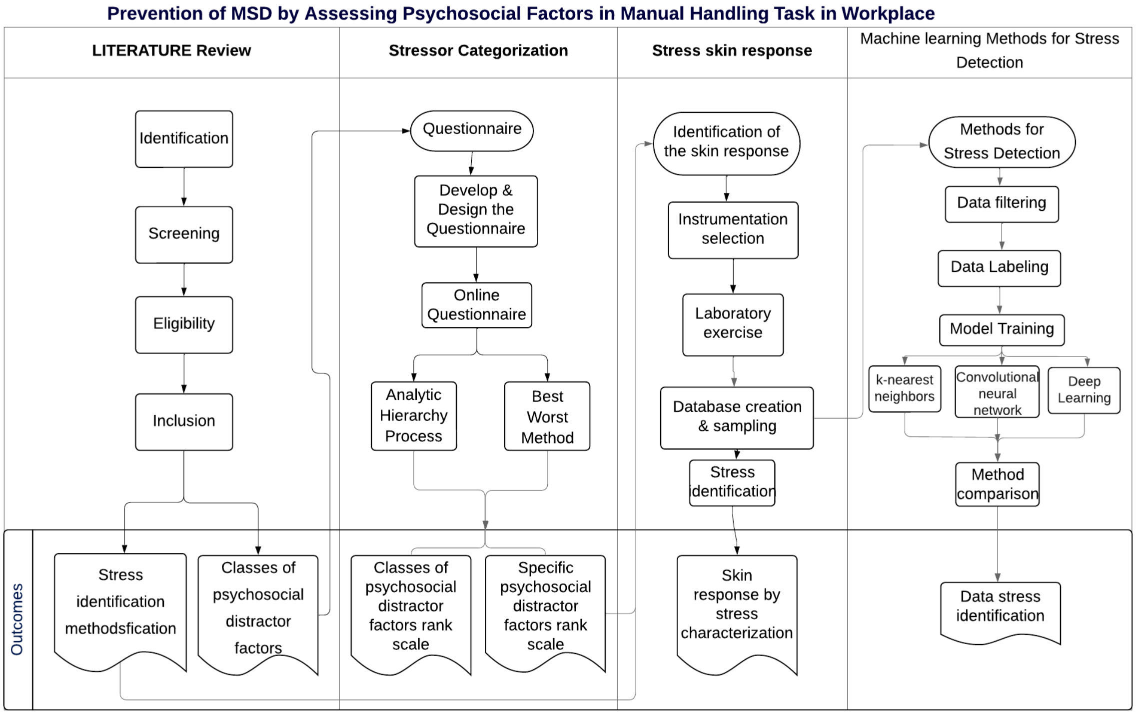

Figure 3: Structure of the dissertation

New Scientific Results

My research aimed to show how important it is to make workplaces more comfortable to avoid and reduce work-related illnesses, such as musculoskeletal disorders (MSDs), in situations involving manual handling and how the psychosocial factors exert influence on the neurocognitive elements in the NIOSH (National Institute for Occupational Safety and Health) MSD prevention equation.

Therefore, my new scientific results are as follows:

- **Thesis (T1):** With a systematic PRISMA literature review and using a correlation analysis of the studies (which presented an index $r = 0.480$ and $p < 0.001$), I proved that psychosocial distractor factors, mainly worker control, conflict resolution, and scheduling, induce mental stress causing muscular activity reduction (SMAR), which has a direct impact on the risk of musculoskeletal disorders (MSDs) in manual handling.
- **Thesis (T2):** By applying MCDM to categorize the psychosocial factors in a sample of 283 participants (185 men and 98 women), with a 95% confidence level and 5.83% margin of error, I proved that 'Worker control' is the main psychosocial category affecting manual handling tasks since its weight of importance is 67.42% in the HP method (CI: 0065), and cross-validated by the BWM at 68.52% (ks_i^*: 0.13). And inside the Worker control' class 'Overcontrol' is the most important factor with 71.72% in the AHP method (CI: 0.071), cross-validated by 71.43% in the BWM method (ks_i^*: 0.159).
- **Thesis (T3):** Applying a bio data (GSR and BPM) system in a controlled laboratory setting with 13 participants. I proved that the 'Overcontrol' psychosocial risk factors introduced during manual handling tasks produce a variation in the autonomous nervous system response, generating a heart rate mean increase from 76 to 126 beats per minute, thus a higher mean of GSR under a stressful environment with a $p < 0.01$. The Skin response represented by the peak impedance mean significantly differs under stress and non-stress conditions, with impedance values of 8.13 µS and 6.62 µS, respectively.
- **Thesis (T4):** In a controlled laboratory setting with 13 participants, comparing the 4 most common machine learning models for stress data classification, I have proved that k-NN+Deep Learning models have the highest level of accuracy of 100%, showing 0.9996 as R^2 (coefficient of determination) and a p-value of 3.66e-06 for stress detection.

Possibility to utilise the Results

Industries need to take a methodical and structured approach to address the psychological and physical risk factors that affect the health and well-being of their employees. Prioritising the integration of ergonomic principles into workplace operations and design is important. This involves reducing musculoskeletal disorders (MSDs) by using tools such as the NIOSH lifting equation and teaching employees safe manual handling practices. Additionally, industries should leverage technology, such as machine learning models, to monitor workplace ergonomics and ensure proper techniques are used during manual handling tasks.

To mitigate the detrimental consequences of overcontrol on manual handling tasks, companies should concentrate on enhancing employee autonomy and modernising management procedures. This can be performed using participatory decision-making, giving workers autonomy in how they complete tasks, and educating managers on how to lead with more cooperation rather than micromanagement or overcontrol.

Future research should investigate how Psychosocial factors associated with manual handling tasks may be affected after prolonged exposure. It should also focus on the use of advanced technologies, such as wearable sensors, AI-based ergonomic assessments and augmented reality tools, to provide real-time feedback and improve workers' posture and movement during manual tasks.

Future studies should use larger and more varied samples of participants to validate the machine learning models and apply them in real employment settings. This would involve incorporating the models into mobile or wearable platforms and assessing their performance in providing managers and employees with real-time feedback. Studies should also investigate the long-term effects of such systems on reducing psychosocial stress and preventing musculoskeletal disorders (MSDs), as well as issues with user acceptance, data privacy, and alert fatigue.

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