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Musculoskeletal Disorders Among Construction Workers

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The abstract should summarize the context, content and conclusions of the paper in between 150 and 225 words. It should not contain any references or displayed equations. Typeset the abstract in 9pt Times New Roman with line spacing of 11pt. Suggest approximately 6–12 keywords for indexing purposes (separated by commas) as below.

Keywords: Construction, Ergonomics, Industry 4.0, Musculoskeletal Disorders.

1. Introduction

The construction industry is a significant part of the economy since it provides buildings and infrastructure that many other industries rely on. Poor H&S is a global issue, and South Africa is no exception (Lopes, Haupt and Fester, 2011). As a result, it is critical that H&S in the construction industry receives greater attention than ever before (Malomane, Musonda and Okoro, 2022). Construction workers are exposed daily to several types of H&S hazards while on duty. As the construction industry becomes more industrialised, its vast range of tasks exposes workers to unfavourable ergonomic problems (Ajayi, Joseph, Okanlawo, and Odunjo, 2015). Poor work habits, inadequate ergonomic postures, long work hours with insufficient rest times, hazardous working conditions, migrant labour with limited rights and influence at work, and limited healthcare access define the construction industry (Sameer and Surendranath, 2012). Awkward postures, lifting of heavy materials, manual handling of heavy and irregular-sized loads, frequent bending, bending, and twisting of the body, working above shoulder height, working below knee level, staying in one position for a long time, climbing and descending, and pushing and pulling of loads are all common construction tasks (Ajayi *et al*., 2015). Approximately 337 million people were noted as victims of work-related accidents and suffer from illnesses caused by occupational injuries in the workplace, while 30% suffer from back pains and other MSDs (Construction Industry Development Board (cidb), 2009).

2. Literature Review

2.1. Construction Workers are Exposed to Ergonomic Hazards

Construction is a physically challenging sector. Construction workers are subject to dangers and risks that might result in long-term injury. Ergonomic factors are related to the numerous construction tasks done daily, namely the provision of tools, equipment, and materials. Ergonomic factors further include the organisation of the work to enhance H&S in the workplace (Mohan, 2018). A practical ergonomics programme should take an integrated approach to the worker and the job. The design of the work processes, tools, and equipment must

consider workers' physical and mental capabilities as well as the surrounding conditions. Ergonomic risk factors (ERFs) in the construction industry are those aspects of the job that put workers' health at risk of developing MSDs over an extended period. A higher exposure to a single ERF, or to a combination of them, might result in a higher likelihood of accidents and MSDs over a prolonged period (Ahankoob and Charehzehi, 2013).

2.2. Fatigue and Stress among Construction Workers

Construction workers are often exposed to stressful working environments (Langdon and Sawang, 2018). Most construction workers work under pressure, and were noted as dissatisfied, which results in stress in the workplace and poor working conditions, that could lead to injuries in the workplace (Bhui, Dinos, Galant-Miecznikowska, de Jongh, and Stansfeld, 2016). Fatigue is likely to have a greater influence in increasing hazardous exposures and risk (Fang, Jhang, Zhang and Wang, 2015). Fatigue demotivates workers, potentially resulting in poor concentration, distraction, increase in mistakes and accidents, injuries, and poor productivity. Approximately 75% of construction workers complain of experiencing symptoms of sleepiness and decreased energy levels to perform tasks. Reports of MSDs include aches and pains in the upper body parts, including arms, shoulders, and waist. Thus, fatigue is a further aspect that requires addressing (Christi, Suwondo, and Setyaningsih, 2019).

2.3. Musculoskeletal Disorders

MSDs are described as a group of painful disorders of soft tissues (cartilage, joints, ligaments, muscles, nerves, and tendons) that have several terms associated with them (Anagha and Xavier, 2020). MSDs develop from workers adopting awkward body postures or from executing a task repetitively, even if the load is relatively minor (i.e., repetitive motions such as brick laying). Carpal tunnel syndrome, tendonitis, tennis elbow, trigger finger, sciatica, herniated discs, and low back problems were shown to be the most frequent MSDs among construction workers. Pain, aching, stiffness, numbness, tingling, and swelling are common symptoms of these illnesses in the back, shoulders, neck, legs, wrists, fingers, elbows, and arms (Anagha and Xavier, 2020). Furthermore, awkward, and improper postures have been noted as one of the key occupational risk factors for MSDs among employees. Awkward postures put strain on joints and limbs.

2.4. Absenteeism

MSDs not only reduce workplace productivity, but they are also a major cause of sick leave, lost working days, and disability (Sameer and Surendranath, 2012). Workplace factors such as job type and environment have an impact on construction workers, which increases absenteeism. Absenteeism increases the amount of people needed for projects and makes meeting deadlines more challenging.

2.5. Fourth Industrial Revolution in the Construction Industry

The Fourth Industrial Revolution (Industry 4.0) technologies have gradually been introduced into general industry and could be deemed to improve H&S compliance. As a result, deploying such technologies could reduce the numerous H&S events that result in non-conforming work, late project delivery, and higher labour injury claims on construction projects (Malomane *et al.*, 2022). Augmented reality (AR), Building Information Modeling (BIM), drones, 3D printing, laser scanning, robotics, virtual reality (VR) and wearable sensors are amongst a range of Industry 4.0 technologies that improve construction project delivery, including H&S (Dodge Data & Analytics, 2021). VR offers real on-site digital design and hazard identification to minimise workers exposure to hazards and risks (Rashidi, Yong, Fang, and Maxwell, 2021). VR further improves the H&S of construction workers by allowing them to be trained and educated before entering a site, resulting in better project performance and management. Trainees that received VR training were found to be 23% faster than usual, and to have improved muscle memory and patterns (Salem et al., 2020).

3. Research

3.1. *Research method*

The quantitative method was adopted for the study conducted in Limpopo province, South Africa. The sample included CHSMs, CHSOs, Pr.CMs, and Pr.CPMs registered with the SACPCMP in South Africa. A total of 50 questionnaires were distributed to the selected categories using email and LinkedIn. The selected questions were designed using Google forms. The questionnaire consisted of two sections. Section A included 6 demographic questions including construction industry and work employment information, and section B included 9 Likert scale type questions. A total of 25 questionnaires were completed and returned, which equates to a response rate of 50%.

3.2. *Findings*

CHSOs (40.0%), predominated among respondents, followed by PrCMs, and PrCPMs, and lastly CHSMs. CHSOs constitute the greater percentage of construction H&S practitioners registered with the SACPCMP.

Table 1 indicates the degree of concurrence with eleven statements in terms of mean scores (MSs) based on percentage responses to a scale of strongly agree to strongly disagree. 4 / 11 (36.4%) of MSs are $> 4.20 \leq 5.00$, which indicates the concurrence is between agree to strongly agree / strongly agree - bending and twisting the body for extended periods causes fatigue, frequent lifting of heavy equipment causes MSDs, poor working conditions cause stress, and climbing scaffolds and ladders causes fatigue. The remaining 7 / 11 (63.6%) MSs are $> 3.40 \leq 4.20$, which indicates the concurrence is between neutral to agree / agree - MSD injuries cause an increase in absenteeism, Industry 4.0 technologies can mitigate hazards and risks in the workplace, VR facilitates H&S training to workers, workers are unable to identify ergonomic hazards and risks in the workplace, VR could reduce accidents and unsafe working conditions on site, VR facilitates ergonomic training to workers, and AR could detect hazards and risks on site. These findings confirm the physical nature of construction and its impact in terms of fatigue, musculoskeletal disorders, stress, absenteeism, the need for hazard identification and risk assessment training, and the role of Industry 4.0 technologies such as AR and virtual reality in delivering training, and mitigating hazards and risks.

Table 1. Degree of concurrence with statements.

Statement	MS
Bending and twisting the body for extended periods causes fatigue	4.72
Frequent lifting of heavy equipment causes MSDs	4.72
Poor working conditions cause stress	4.60
Climbing scaffolds and ladders causes fatigue	4.36
MSD injuries cause an increase in absenteeism	3.96
Industry 4.0 technologies can mitigate hazards and risks in the workplace	3.92
VR facilitates H&S training to workers	3.92
Workers are unable to identify ergonomic hazards and risks in the workplace	3.72
VR could reduce accidents and unsafe working conditions on site	3.72
VR facilitates ergonomic training to workers	3.68
AR could detect hazards and risks on site	3.68

Table 2 indicates the degree of concurrence with five effective methods to identify hazards and risks on site. 4 / 5 (80.0%) of MSs are > 4.20 to ≤ 5.00, which indicates the concurrence is between agree to agree strongly agree / strongly - H&S programmes, frequent H&S meetings, ergonomic training, and design HIRA are the most effective methods to minimise hazards and risks in the workplace. The remaining 1 / 5 (20.0%) MSs are > 3.40 to ≤ 4.20, which indicates the concurrence is between neutral to agree / agree – Industry 4.0 technologies implementation. This indicates that H&S programmes and frequent H&S meetings are effective methods that can reduce hazards and risk in the workplace, as opposed to the other methods.

Table 2. Degree of concurrence with effective methods to mitigate hazards and risks.

Method	MS
H&S programmes	4.84
Frequent H&S meetings	4.68
Ergonomic training	4.52
Design HIRA	4.52
Industry 4.0 technologies implementation / training	4.08

Table 3 indicates the degree of concurrence with six causes of accidents on site. 2 / 6 (33.3%) MSs are $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to agree strongly agree / strongly - poor supervision, and inability to identify hazards and risks. The remaining 4 / 6 (66.7%) MSs are $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - no H&S plan, fatigue, insufficient Industry 4.0 technologies, and awkward postures. These findings indicate that the construction industry is a hazardous environment to work in, where accidents occur due to poor H&S management and planning.

Table 3. Degree of concurrence with six causes of accidents.

Cause	MS
Poor supervision	4.44
Inability to identify hazards and risks	4.28
No H&S plan	4.16
Fatigue	4.08
Insufficient Industry 4.0 technologies	3.76
Awkward Postures	3.68

Table 4 indicates the degree of concurrence with five activities resulting in MSDs. 2 /5 (40.0%) MSs are $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to strongly agree / strongly agree - forceful and repetitive movement, lifting and loading, and brick laying. The remaining 3 /5 (60.0%) MSs are $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - pulling, and pushing, vibrating tools, and plumbing. The findings indicate that poor ergonomic practices, and activities such as brick laying, and plumbing, which expose workers to ergonomic hazards, result in MSDs.

Table 4. Degree of concurrence with five activities resulting in MSDs.

Activity	MS
Forceful and repetitive movement, lifting and loading	4.68
Brick laying	4.28
Pulling and pushing	4.16
Vibrating tools	4.08
Plumbing	3.44

Table 5 indicates the degree of concurrence with five activities that result in MSD injuries. 4 / 5 (80.0%) MSs are $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to strongly agree / strongly agree - carrying heavy equipment, awkward postures, over-exertion, and pulling and pushing. The remaining 1 / 5 (20.0%) MSs is $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - repetitive movements. The findings indicate that the physical nature of the construction process and its activities result in MSD injuries.

Table 5. Degree of concurrence with five activities that result in MSD injuries.

Activities	MS
Carrying heavy equipment	4.88
Awkward postures e.g., bending and twisting	4.60
Over-exertion	4.52
Pulling and pushing	4.36
Repetitive movements	4.12

Table 6 indicates the degree of concurrence with exposure to five ergonomic hazards. 4 / 5 (80.0%) MSs are $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to strongly agree / strongly agree - poor posture, repetitive motions, excessive vibration, and forceful motions. The remaining 1 / 5 (20.0%) MSs is $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - stationary positions with load for extended periods. These findings indicate that construction tasks expose workers to various ergonomic hazards.

Table 6. Degree of concurrence with exposure to five ergonomic hazards.

Ergonomic hazard	MS
Poor posture	4.56
Repetitive motions	4.48
Excessive vibration	4.44
Forceful motions	4.28
Stationary positions with load for extended periods	3.76

Table 7 indicates the degree of concurrence with the onset of five MSD injuries. 1 / 5 (20.0%) MSs

is $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to strongly agree / strongly agree - back and neck pain. The remaining 4 / 5 (80.0%) MSs are $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - shoulder pain, wrist pain and tingling in hands or fingers, strains and sprains, and arthritis or joint pain. These findings indicate that construction workers experience various MSD injuries due to the tasks they perform daily, and the related ergonomic hazards they are exposed to.

Table 7. Degree of concurrence with five MSD injuries.

MSD injury	MS
Back and neck pain	4.32
Shoulder pain	4.16
Wrist pain and tingling in hands or fingers	4.08
Strains and sprains	4.00
Arthritis or joint pain	3.80

Table 8 indicates the degree of concurrence with nine factors casing absenteeism among construction workers. 1 / 9 (11.1%) MSs is $>$ 4.20 to $\leq$ 5.00, which indicates the concurrence is between agree to strongly agree / strongly agree - fatigue. 6 / 9 (67.7%) MSs are $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - MSDs, repetitive movement, accidents and incidents on site, mental health, occupational diseases, and poor working conditions. The remaining 2 / 9 (11.1%) MSs are $>$ 2.60 to $\leq$ 3.40, which indicates the concurrence is between disagree to neutral / neutral - manual material handling, and insufficient supply of PPE. The findings indicate that construction tasks affect workers' physical and mental health and result in absenteeism.

Table 8. Degree of concurrence with nine factors causing absenteeism.

Factor	MS
Fatigue	4.24
MSDs	4.12
Repetitive movement	3.80
Accidents and incidents on site	3.64
Mental health illnesses / Stress	3.60
Occupational diseases e.g., Asbestosis	3.48
Poor working conditions	3.44
Manual material handling	3.36
Insufficient supply of personal protective equipment	3.16

Table 9 indicates the degree of concurrence with the potential of six Industry 4.0 technologies to mitigate hazards and risks. All the MSs are $>$ 3.40 to $\leq$ 4.20, which indicates the concurrence is between neutral to agree / agree - VR, wearable sensors, collaborative robots, artificial intelligence (AI), AR, and BIM. These findings indicate that technological tools are effective in construction H&S and can improve safe working conditions by detecting and mitigating unsafe working conditions, risk, and hazards on site.

Table 9. Degree of concurrence with the potential of six Industry 4.0 technologies to mitigate hazards and risks.

Industry 4.0 technology	MS
VR	4.00
Wearable sensors	3.92
Collaborative robots	3.80
AI	3.72
AR	3.64
BIM	3.64

4. Discussion

The findings highlight the physical nature of the construction process and its activities, and the range of ergonomic hazards and risks workers are exposed to, and the resultant MSDs, which are well documented in the literature (cidb, 2009; Ahankoob and Charehzehi, 2013; Ajayi et al., 2015; Mohan, 2018).

The importance of awareness of ergonomics hazards and risks and appropriate responses thereto feature in the findings and in the literature (Ahankoob and Charehzehi, 2013; Mohan, 2018).

The potential of Industry 4.0 technologies such as AR to mitigate hazards and risks, and VR to assist with respect to training feature in the findings and have been documented in studies globally (Dodge Date & Analytics, 2021; Rashidi et al., 2021; Malomane et al., 2022).

The importance of planning in the form of design HIRA, H&S programmes, and other interventions such as training and communicating

are highlighted in the findings and the literature (Mohan, 2018).

The contribution of ergonomics factors such as the physical nature of construction and stress to absenteeism among workers is clear based upon the findings, which is well documented in the literature ((Sameer and Surendranath, 2012; Ajayi et al., 2015; Langdon and Sawang, 2018).

5. Conclusions

There is a delineation between the H&S legislative compliance as it relates to registered and professional practice among BEPs. CHSOs and CHSMs are required to assist with compliance to H&S legislation and regulations, however, ultimately PrCPMs as lead consultants and being overall responsible for projects, and PrCMs as being responsible for managing the physical construction process.

The study concludes that construction workers are exposed to ergonomic hazards due to inadequate HIRA, poor ergonomic education and training, poor working conditions, and insufficient Industry 4.0 technologies. This indicates that without the proper implementation of H&S programmes, workers are at risks of experiencing MSDs and stress. This will not only put the lives of workers at risk but will also result in reduced productivity due to marginalised health and well-being, and absenteeism. It is therefore important that every organisation in the construction industry comply with the OHSA and Ergonomics Regulations and design adequate H&S programmes, while developing and maintaining an optimum H&S culture in the workplace. Implementing an appropriate H&S management system in the organisation facilitates compliance, and the mitigation of hazards, risk, MSDs, and occupational diseases, and absenteeism, and complements productivity and schedule performance.

Industry 4.0 technologies are a potential solution and should be adopted to mitigate hazards and risks in the workplace and improve H&S, and ergonomics.

6. Recommendations

Workers should be provided with ergonomics training, which will enable them to conduct HIRA.

Industry 4.0 technologies should be implemented to reduce accidents, disruptions, and workers' exposure to MSDs. VR, and AR are highly recommended for H&S, ergonomics' training for workers, as they provide real life scenarios that enable workers to identify hazards and risks before and while on site. Other Industry 4.0 technologies such as collaborative robots, wearable sensors, AI, and BIM, can be used to mitigate hazards and risks in the workplace.

H&S programmes should ensure that workers are informed with respect to the specific risks relating to MSDs, fatigue, and stress. VR and AR could be used to realise improvements.

Employers need to ensure that workers are monitored and supervised to minimise fatigue and exhaustion, which workers may experience due to repetitive work and over-exertion. Collaborative robots are recommended to assist workers with physically demanding construction tasks. Wearable sensors are recommended to alert workers to hazardous situations, and to realise comfort in terms of the type of work they perform and assist in relaxing the body muscles that will reduce fatigue and exhaustion as well as reducing the risk of developing MSDs.

Adequate management and supervision are required on site, and registered professionals need to monitor the planning, design, and execution of projects in terms of mitigating hazards and risks. This will assist in terms of workers working in a healthy and safe manner after receiving the requisite H&S, and ergonomics training.

The implementation of Industry 4.0 technologies is critical as they can contribute to a reduced workload, which will reduce stress, fatigue, accidents, and exposure to MSD injuries among workers.

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