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Current Trends and Risk Factors in Low Back Pain: An Ergonomic Perspective on Prevention and Management

Ahmad Humaizi Hilmi[1], Asna Rasyidah Abd Hamid[1] and Wan Abdul Rahman Assyahid[1]

[1] Fakulti Kejuruteraan & Teknologi Mekanikal, Universiti Malaysia Perlis

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ABSTRACT

Low back pain (LBP) is a global health concern, impacting individuals across various professions and age groups. This review explores the critical role of ergonomic factors in the prevention and management of LBP. Occupational risk factors, including heavy lifting, prolonged sitting, non-neutral postures, and repetitive motions, contribute significantly to the rising prevalence of LBP. Professions such as healthcare, law enforcement, and office work are particularly vulnerable due to their physical demands and static postures. Ergonomic interventions, including task redesign, assistive technologies, and workplace modifications, have proven effective in reducing the incidence of LBP. Dynamic seating, lumbar support devices, and wearable technology are among the innovations that have been introduced to promote healthier postures and reduce musculoskeletal strain. Additionally, ergonomic training programs focusing on proper body mechanics and posture correction are essential for long-term prevention. Beyond physical factors, psychosocial and lifestyle elements, such as stress, sedentary behavior, and smoking, also play a role in the development of LBP. Combining ergonomic interventions with health-promoting behaviors, such as regular physical activity and stress management, can significantly reduce the burden of LBP. Technological advancements, including mobile applications and wearable devices, support adherence to home exercise programs, offering continuous feedback for posture correction and movement. This comprehensive review underscores the need for a multidisciplinary approach that integrates ergonomic interventions, technological tools, and lifestyle modifications to manage and prevent LBP effectively in both occupational and everyday settings.

Keywords: low back pain, ergonomic interventions, occupational risk factors, posture correction, musculoskeletal disorders, dynamic seating, wearable technology

1. INTRODUCTION

Low back pain (LBP) is a widespread health issue with considerable global impact. It is one of the leading causes of disability worldwide, affecting people across different age groups, regions, and professions. The burden of LBP has seen a steady increase in recent years, exacerbating socioeconomic costs and affecting the quality of life. Several studies emphasize the role of ergonomic factors in both the onset and management of LBP. Ergonomics involves designing work environments that enhance comfort and reduce strain, particularly on the musculoskeletal system. With this understanding, it becomes crucial to explore the ways in which ergonomic interventions can contribute to the prevention and management of LBP.

Several studies have highlighted the rising prevalence of LBP and its associated risk factors. In China, Fan, Li, and Wang (2023) conducted a study analyzing the trends in LBP from 1990 to 2019. The research found a significant increase in the number of LBP cases, particularly in the elderly population, with women experiencing a higher burden than men. Occupational ergonomics was identified as a key risk factor, with poor posture and physical strain contributing to the increased prevalence of LBP. Although interventions have been implemented to reduce the

disease burden, LBP continues to be a major health concern, particularly among women and older individuals (Fan et al., 2023).

Ergonomic factors in the workplace are a significant contributor to the development of LBP. Jahn et al. (2023) conducted a systematic review and meta-analysis on the association between occupational mechanical exposures and chronic LBP. The study found moderate evidence linking the lifting and carrying of heavy loads, non-neutral postures, and combined mechanical exposures to chronic LBP. Occupations that involve prolonged sitting, such as office work, also pose a significant risk of developing LBP. Kuśmierek et al. (2024) highlighted that many workers do not engage in preventive behaviors to protect their backs, despite the known risks associated with poor ergonomic practices. The study found that individuals with higher education levels and those who exercised regularly were more likely to adopt protective behaviors, such as adjusting their work environment to reduce strain on their lower back (Kuśmierek et al., 2024).

Specific professions are particularly vulnerable to LBP due to the nature of their work. Gemedo et al. (2023) explored the prevalence of LBP among high school teachers in Ethiopia, finding that nearly 64% of participants reported experiencing LBP. The study identified factors such as prolonged standing, lifting heavy loads, and psychological job demands as significant contributors to the condition. The study also found that regular physical activity and job satisfaction were effective in reducing the risk of LBP. Similarly, Range et al. (2023) examined LBP in police officers, a profession characterized by prolonged periods of sitting in vehicles. The review suggested that vehicle ergonomics, combined with training programs for trunk musculature and regular physical activity, could significantly reduce the risk of LBP in police officers (Range et al., 2023).

In addition to occupational factors, ergonomic interventions in everyday activities can also play a role in preventing LBP. Govindaraj and Sudheep (2024) designed an ergonomic noseless bicycle seat with a backrest to reduce perineal pressure and support the lower back during cycling. This design aimed to address the issues faced by cyclists who experience LBP due to prolonged forward-bending postures and the pressure exerted on the perineal area by traditional bicycle seats. The study found that the new design significantly reduced the stress on the lower back and perineal area, providing a potential solution for cyclists who suffer from LBP (Govindaraj & Sudheep, 2024).

The management of LBP often involves a combination of ergonomic interventions and therapeutic practices. Budagher-Marshall and Alò (2023) explored the role of naprapathy, a form of manual therapy that emphasizes the treatment of connective tissue and ligamentous tension, in the management of musculoskeletal pain, including LBP. The therapy involves fascial manipulation, which helps relieve tension and improve musculoskeletal function. Naprapathy also incorporates dietary counseling and vitamin supplementation to reduce inflammation and support overall musculoskeletal health. This integrative approach offers a promising alternative for individuals suffering from LBP, particularly when combined with ergonomic interventions in the workplace and everyday activities (Budagher-Marshall & Alò, 2023).

Technological interventions also offer potential solutions for managing and preventing LBP. Lechauve et al. (2023) conducted a study evaluating the use of a smartphone application to improve adherence to home exercise programs for individuals with chronic LBP. The study found that participants who used the app demonstrated improved adherence to their exercise programs, which is critical for long-term management of LBP. By providing regular reminders and tracking progress, such technological tools can help individuals manage their condition more effectively, reducing the risk of chronic LBP (Lechauve et al., 2023).

Similarly, Channak et al. (2024) investigated the use of a dynamic seat cushion designed to promote postural shifts during prolonged sitting. The study found that the cushion significantly reduced the incidence of LBP and neck pain among high-risk office workers by encouraging

regular movement and reducing static sitting positions. These findings suggest that ergonomic interventions, such as dynamic seating solutions, can play a critical role in preventing LBP, particularly for individuals who spend long hours sitting in office environments (Channak et al., 2024).

2. PREVALENCE AND BURDEN OF LOW BACK PAIN

Low back pain (LBP) continues to be a major global health concern, affecting millions of people across various age groups and professions. Studies emphasize that the prevalence of LBP has been rising, leading to significant consequences for individuals' quality of life, economic productivity, and disability rates. Among the many factors contributing to this increase, occupational and ergonomic elements have been widely acknowledged as critical components in the onset and progression of LBP.

Research conducted in China by Fan, Li, and Wang (2023) provided a comprehensive analysis of the trends in LBP prevalence over a thirty-year period, from 1990 to 2019. Their study demonstrated that the number of LBP cases had increased significantly during this time. Factors such as aging populations and changing lifestyle patterns, including increased sedentary behavior, have contributed to this rise. The study also highlighted gender differences in LBP prevalence, with women experiencing a higher burden than men. Furthermore, individuals in the 70-year-old age group were particularly affected, underscoring the impact of aging on musculoskeletal health (Fan et al., 2023). This data reflects a broader global trend where older adults, particularly women, are more likely to suffer from LBP, which poses an increasing challenge for healthcare systems worldwide.

Gender and age-related variations in LBP burden have been well-documented in multiple studies. Adenis et al. (2024) conducted a randomized trial comparing different educational approaches in a multidisciplinary rehabilitation program for patients with persistent LBP. The study found that both men and women experienced significant reductions in pain and disability after receiving education and participating in rehabilitation, although the gender differences in response to treatment were not statistically significant. This finding aligns with broader research suggesting that while women tend to report higher rates of LBP, the effectiveness of interventions such as education and ergonomic training may not differ substantially between genders (Adenis et al., 2024).

The impact of LBP on quality of life and disability is profound, often limiting individuals' ability to work, engage in physical activity, and perform daily tasks. In a study focusing on dairy farmers in rural India, Coates et al. (2023) found that nearly 65% of participants reported work-related musculoskeletal disorders (WRMSDs), with the lower back being the most frequently affected area. Long working hours, heavy lifting, and awkward postures were identified as key risk factors. This occupational exposure significantly reduced the quality of life for these workers, many of whom struggled to find relief due to limited access to healthcare and ergonomic interventions (Coates et al., 2023). Similar findings have been reported in other professions, where manual labor and poor working conditions exacerbate the prevalence of LBP and contribute to long-term disability.

The relationship between prolonged sitting and LBP has also been extensively studied, particularly in office environments where sedentary behavior is prevalent. Markova et al. (2024) utilized machine learning models to analyze the effects of poor posture and prolonged sitting on LBP development. Their study revealed that incorrect sitting postures significantly increased the risk of LBP, emphasizing the importance of ergonomic interventions, such as posture correction and the use of appropriate seating equipment, to mitigate this risk. These findings are consistent with other studies that have identified sedentary behavior as a key contributor to LBP,

particularly in office workers and professionals who spend extended periods sitting (Markova et al., 2024).

The impact of LBP on overall well-being extends beyond physical discomfort. Barbier et al. (2023) explored the effects of LBP during pregnancy, demonstrating how the condition can negatively affect both physical and mental health. Their research involved an intervention group that participated in an eight-week stretching program designed to alleviate LBP in pregnant women. The study found significant improvements in both pain levels and quality of life among the participants who engaged in the stretching regimen, further underscoring the importance of non-pharmacological interventions for managing LBP. For pregnant women, the physical burden of carrying a child, combined with the hormonal changes that affect musculoskeletal health, makes LBP a particularly common and debilitating condition (Barbier et al., 2023).

The growing prevalence of teleworking due to the COVID-19 pandemic has introduced new challenges for LBP management. Fadel et al. (2023) conducted a systematic review examining the effects of teleworking on musculoskeletal disorders, including LBP. Their findings indicated that while teleworking offers flexibility and convenience, it also increases the risk of developing LBP due to poor ergonomic setups at home and prolonged periods of sitting. In many cases, individuals working from home lack access to ergonomic furniture, leading to improper posture and increased strain on the lower back. The study highlighted the need for improved awareness and implementation of ergonomic principles in teleworking environments to reduce the growing burden of LBP (Fadel et al., 2023).

Efforts to address the rising prevalence of LBP have focused on both preventive and rehabilitative strategies. Ergonomic interventions, such as the development of specialized seating equipment and postural support devices, have been shown to reduce the incidence of LBP in high-risk populations. Sae-Lee et al. (2023) developed an ergonomic seat cushion designed to improve lumbo-pelvic posture and reduce perceived pain in office workers. The study demonstrated that the use of this cushion significantly improved sitting posture and reduced LBP, offering a practical solution for individuals who spend long hours sitting in office environments. These findings suggest that ergonomic innovations can play a crucial role in preventing LBP and improving the quality of life for affected individuals (Sae-Lee et al., 2023).

3. OCCUPATIONAL RISK FACTORS FOR LOW BACK PAIN

Occupational risk factors for low back pain (LBP) have been extensively documented, particularly in jobs involving heavy physical tasks, prolonged standing, and improper postures. Ergonomic risks in various occupations are often associated with the mechanical exposures employees face, which significantly influence the prevalence of LBP across different work settings. A study by Hafez, Jorgensen, and Amick (2023) compared different lifting assessment methods, finding that improper handling of lifting tasks, particularly those exceeding thresholds set by ergonomic guidelines, contributed to LBP risks. This indicates that lifting tasks, if not managed within ergonomic limits, can elevate the likelihood of low back disorders.

Specific occupations, such as those in healthcare and law enforcement, are considered high-risk due to the physical demands and prolonged periods of poor posture that are frequently required. Healthcare workers, for instance, face a significant risk of musculoskeletal disorders (MSDs) due to repetitive lifting and improper postures during patient care. In a study focusing on palm oil harvesters, Abdullah et al. (2023) reported that harvesters faced significant risks due to heavy physical exertion, with tasks requiring prolonged use of tools like sickles and chisels. The forces exerted during these tasks, along with poor postural alignment, contribute to LBP and other musculoskeletal issues. The study emphasized that tasks with high spinal loads, particularly in the L5-S1 region, exceed safety thresholds, resulting in increased risk for LBP.

Similar concerns have been observed in other physically demanding jobs. Chen and Luo (2023) examined work-related MSDs among workers in a Taiwanese tape manufacturing factory, where both Taiwanese and Thai workers experienced discomfort, particularly in the shoulders, lower back, and hands. Heavy-material handling and the biomechanical stress placed on the body during these tasks were found to be significant risk factors. The lower back was consistently one of the most affected areas, especially when workers handled materials exceeding 20 kg. This case study illustrates the broader impact of ergonomic risks in industrial settings, where tasks involving repetitive motions and heavy lifting are prevalent.

In the healthcare sector, particularly among radiography students and professionals, LBP has been noted as a frequent complaint due to the prolonged standing and awkward postures required during clinical tasks. Masondo and Khoza (2023) conducted research on undergraduate radiography students in South Africa, finding that a majority of participants reported experiencing MSDs, with lower back pain being the most common issue. The study pointed out that bending and maintaining static positions for extended periods significantly contributed to the development of LBP in these students. The findings suggest that the training environment, which involves long hours of clinical work with suboptimal ergonomic conditions, exacerbates the risk of LBP among healthcare students and professionals.

The impact of improper postures, particularly prolonged standing, has also been highlighted in case studies from other high-risk occupations. Gemedo et al. (2023) examined musculoskeletal risks among workers in the agricultural sector, noting that prolonged standing and awkward postures while handling heavy materials were key contributors to LBP. These findings align with those of Munhall et al., who focused on manual labor in the construction industry. In both studies, the repetitive nature of tasks, combined with the physical strain of standing for long periods, contributed to high incidences of LBP. Workers in these industries often lack adequate ergonomic support, further elevating their risk of injury.

Police officers also face significant ergonomic risks due to prolonged sitting, heavy equipment use, and physically demanding tasks. Studies have shown that extended periods of sitting, coupled with the need for sudden movements during high-stress situations, put additional strain on the lower back. Munhall et al. highlighted that police officers frequently report LBP due to the combination of sedentary duties, such as sitting in patrol cars for extended periods, and the physical exertion required during emergency responses. These factors create a unique risk profile for LBP among law enforcement personnel, as they must balance sedentary tasks with bursts of intense physical activity.

In factory settings, prolonged standing and repetitive motions are common causes of LBP. A study by Pehlevan and Şevgin (2024) emphasized the importance of ergonomic training and exercise programs in mitigating LBP risks among factory workers. The researchers found that workers who received ergonomics training and engaged in regular exercise experienced significant reductions in pain, disability, and fatigue. This suggests that incorporating ergonomic principles into daily tasks, along with regular physical exercise, can significantly reduce the risk of LBP in high-risk occupations.

Risk factors such as heavy lifting, prolonged standing, and improper postures are also prevalent in the healthcare sector. Nurses, in particular, face a high risk of developing LBP due to their frequent involvement in patient handling tasks. A study by Karki et al. (2023) found that nurses who worked long hours without sufficient rest breaks were significantly more likely to experience LBP. The research indicated that repetitive patient lifting, combined with the physical demands of working in the same position for long periods, contributed to the high prevalence of LBP among nurses. These findings highlight the need for ergonomic interventions in healthcare settings to reduce the risk of injury among nursing staff.

4. INTERVENTIONS AND PREVENTIVE MEASURES

The implementation of ergonomic interventions is critical in mitigating the risk factors associated with low back pain (LBP) in various occupations. Adjustments to workplace design, proper equipment, and training programs have shown significant efficacy in preventing and managing work-related musculoskeletal disorders (WRMSDs). Tesfaye et al. (2024) emphasized the importance of ergonomic workplace adjustments in reducing the prevalence of WRMSDs among shopkeepers in Ethiopia. The study found that prolonged sitting and improper ergonomic setups contributed to high rates of lower back pain. Such findings align with recommendations for ergonomic interventions, where properly designed workstations and equipment adjustments can play a pivotal role in reducing the burden of musculoskeletal disorders in vulnerable populations. Training programs aimed at improving workplace ergonomics can also prevent LBP by promoting proper body mechanics during tasks that involve lifting, standing, or repetitive movements. Joseph et al. (2023) evaluated the causal relationship between risk factors and WRMSDs among professional drivers, identifying that prolonged exposure to awkward postures and whole-body vibrations were significant contributors to musculoskeletal issues, including lower back pain. The study suggested that training drivers on proper seat adjustments and posture could alleviate the ergonomic stress that exacerbates LBP. Such ergonomic training programs, when applied consistently, can result in significant reductions in LBP among workers in physically demanding jobs.

The effectiveness of dynamic ergonomic interventions, such as the use of seat cushions or other workplace aids, has been explored as well. Pehlevan and Şevgin (2024) demonstrated the benefits of ergonomic training combined with exercises, noting substantial reductions in pain and improved functionality among factory workers who utilized such interventions. The study highlighted that seat cushions and other supports, which help maintain proper posture during long work hours, can reduce discomfort in the lower back and other body regions. The use of dynamic interventions, therefore, presents a cost-effective and non-invasive method for managing LBP in work environments that require prolonged sitting or standing.

In addition to ergonomic interventions, alternative therapies such as naprapathy—a form of manual soft tissue manipulation—have been explored as a treatment for LBP. Naprapathy focuses on the manipulation of soft tissues to relieve pain and restore musculoskeletal function. Baklouti et al. (2023) discussed the role of naprapathy and similar therapies in alleviating LBP among teachers in Southern Tunisia. The study found that teachers who engaged in physical therapies, including soft tissue manipulation, reported lower incidences of severe LBP. This suggests that naprapathy and other forms of manual therapy can serve as effective preventive and treatment measures for individuals experiencing chronic back pain due to work-related stress.

Health behaviors and lifestyle factors also contribute significantly to the prevention of LBP. Preventive strategies that incorporate exercise, proper nutrition, and stress management can enhance musculoskeletal health and lower the risk of developing LBP. A study by Bucher et al. (2023) on health professionals transitioning from student life to full-time work found that many professionals experienced LBP even before starting their careers, attributing this to poor health behaviors during their studies. The research recommended that universities incorporate preventive health strategies, such as promoting regular exercise and ergonomic practices, to reduce the early onset of LBP in students. This highlights the importance of fostering health-conscious behaviors that can protect against the development of LBP throughout one's professional life.

Similarly, Patel and Ghosh (2023) examined the prevalence of musculoskeletal disorders among fish processing workers and found that ergonomic improvements, combined with lifestyle modifications like regular stretching and physical activity, were crucial in reducing the risk of

LBP. The study emphasized that integrating health behaviors into the daily routines of workers in physically demanding jobs could mitigate the long-term effects of poor ergonomics and repetitive strain on the lower back. These findings underscore the need for comprehensive preventive strategies that address both workplace ergonomics and individual health habits to combat LBP effectively.

Furthermore, studies have shown that a multi-faceted approach to LBP prevention, combining ergonomic interventions with behavioral changes, yields the most significant results. For instance, Xiang et al. (2023) explored the effectiveness of lumbar support exoskeletons for manual handling tasks and found that these devices, when used alongside proper posture training and regular exercise, significantly reduced lumbar strain and the risk of LBP. This study supports the notion that technological interventions, such as exoskeletons or other assistive devices, can complement traditional ergonomic adjustments and preventive strategies to create a more holistic approach to managing and preventing LBP.

5. ROLE OF TECHNOLOGY IN MANAGING LBP

Technology plays an increasingly significant role in the management and prevention of low back pain (LBP), particularly in ergonomic contexts. Apps and wearables are commonly used to enhance adherence to home exercise programs, enabling individuals to better manage their condition. Several studies highlight the effectiveness of these technologies in improving patient outcomes by promoting consistent exercise routines and providing real-time feedback.

Afzal et al. (2024) discussed the prevalence of work-related musculoskeletal pain in primary health care providers, emphasizing the benefits of home exercise interventions. They noted that the integration of technology, such as mobile apps, into treatment plans can significantly improve adherence to prescribed exercises, thus reducing the incidence of LBP. This aligns with findings by Vorensky et al. (2023), who demonstrated that self-management apps are effective in helping individuals with chronic low back pain (CLBP) manage symptoms, especially when these tools are coupled with psychosocial interventions.

Similarly, wearables such as smart devices offer valuable support in monitoring biomechanical movements and posture during daily activities, as discussed by Hislop et al. (2024). Wearable technology can be programmed to alert users when they adopt poor posture or engage in repetitive activities that contribute to the onset of LBP. By tracking movements and providing feedback, wearables can reduce the risk of aggravating existing back conditions or developing new ones.

Virtual ergonomics and biomechanical assessments are other technological advancements contributing to injury prevention in ergonomic contexts. These methods allow for more accurate assessments of individuals' work environments, highlighting areas where interventions could be implemented to minimize musculoskeletal strain. Davidson et al. (2024) explored the benefits of dynamic sitting and lumbar support devices in virtual ergonomic setups, finding that these interventions promote healthier postures and reduce discomfort. Their findings suggest that combining virtual ergonomic assessments with physical interventions such as seat cushions or lumbar supports can effectively prevent and manage LBP in office workers and other sedentary professionals.

In clinical environments, where LBP is highly prevalent among healthcare providers and surgeons, ergonomic interventions are becoming essential. The study by Afonso et al. (2023) noted that spine surgeons frequently experience LBP due to long hours spent in fixed, uncomfortable postures. The integration of ergonomic devices and virtual tools in operating rooms can mitigate these risks, as shown by studies that examine the impact of physical support

devices during surgeries. These tools reduce the strain on the spine and other musculoskeletal regions, ultimately preventing LBP and enhancing performance during lengthy procedures.
Moreover, Alostaz et al. (2024) systematically reviewed ergonomic practices in spine surgery, highlighting the effectiveness of technology-assisted assessments. Virtual ergonomic tools, which simulate various surgical positions and analyze the physical demands on surgeons, have proven to reduce musculoskeletal discomfort. These tools allow for personalized ergonomic adjustments, minimizing the risk of developing chronic LBP. Studies focusing on these interventions emphasize the importance of implementing ergonomic designs in the operating room to safeguard the health of surgeons while ensuring optimal patient care.

Wearable technologies and virtual ergonomic assessments also extend their utility to industrial settings. In a study by Lerche et al. (2024), industrial workers using the "Goldilocks" work intervention, which combines real-time monitoring of physical behaviors with virtual ergonomic assessments, showed improved musculoskeletal health. By optimizing the balance between sitting, standing, and active work through technological interventions, these workers experienced a reduction in LBP after the intervention.

These findings underscore the importance of integrating technology into the prevention and management of LBP, particularly in occupational settings. Wearables, virtual ergonomic assessments, and mobile apps not only enhance adherence to treatment programs but also provide continuous feedback that helps individuals adjust their behaviors, preventing the onset of LBP. By promoting ergonomic practices and supporting regular physical activity, these technologies serve as valuable tools in the long-term management of low back pain.

6. PSYCHOSOCIAL AND LIFESTYLE FACTORS

The relationship between low back pain (LBP) and psychosocial and lifestyle factors is an area of ongoing research. Psychological stress, job satisfaction, and lifestyle habits are significant risk factors for LBP. Job-related stress, for instance, is consistently linked to higher instances of musculoskeletal pain, especially in occupations that demand high physical exertion or involve poor ergonomics. Several studies have shown that the psychological strain stemming from prolonged stress exacerbates musculoskeletal discomfort, with the low back being a primary area of concern (Das, 2022). Workers facing consistent job dissatisfaction tend to report higher levels of LBP, indicating a correlation between psychological well-being and physical discomfort. Psychosocial factors, such as perceived inadequacy of income, job monotony, and rigidity in work methods, are similarly associated with an increased likelihood of developing LBP (Ghaneh-Ezabadi et al., 2022).

Additionally, the sedentary lifestyles that have become more prevalent due to modern working conditions, such as prolonged sitting during office work, have been linked to higher rates of LBP. Research shows that sedentary behavior not only contributes to physical deconditioning but also increases body mass index (BMI), which has been shown to correlate with higher incidences of back pain (Alzahrani et al., 2022). Specifically, those with higher BMI experience greater stress on the spine due to increased body weight, leading to greater discomfort during physical activities or prolonged periods of sitting (Gashawbeza & Ezo, 2022). This relationship between sedentary behavior and BMI is critical, as many workers experience musculoskeletal pain due to poor posture, prolonged sitting, and inadequate workplace ergonomics (Leivas et al., 2022).

Smoking, another lifestyle factor, has also been associated with poor physical health outcomes, including LBP. Research indicates that smokers are more likely to experience chronic pain compared to non-smokers. The chemicals in tobacco can reduce the blood supply to the spine, leading to the degeneration of spinal structures such as the intervertebral discs (de Luca et al., 2022). Furthermore, studies have suggested that smokers are less likely to engage in physical

activity, a behavior that further contributes to deconditioning and increases the risk of developing LBP (Iqbal et al., 2022). Inactivity compounds the negative effects of smoking, making individuals more prone to musculoskeletal issues, including chronic back pain.

Poor physical activity levels are another key lifestyle factor influencing LBP. A lack of exercise weakens the muscles that support the spine, leading to instability and a higher risk of injury during routine activities (Yang et al., 2021). Sedentary workers who fail to engage in regular physical activity are especially vulnerable to LBP due to muscle imbalances and weakness (Shih et al., 2021). Research has shown that introducing physical exercises targeting the lumbar region, such as lumbar stabilization exercises, can help mitigate the negative effects of prolonged sitting and poor posture (Saraceni et al., 2022). These exercises can reduce the risk of LBP by improving core stability and spinal alignment, which are critical for maintaining a healthy posture during daily activities.

7. FUTURE DIRECTIONS AND RESEARCH GAPS

Low back pain (LBP) continues to be a significant public health concern, affecting a wide range of individuals across different professions and activities. As studies have shown, ergonomic factors play a crucial role in the development and management of LBP. Recent literature provides insight into both emerging technologies for ergonomics and existing gaps in research, particularly in terms of standardizing risk assessments and policy recommendations to mitigate the burden of LBP.

Research has highlighted various ergonomic risk factors associated with LBP in specific populations, particularly in professions that involve prolonged sitting or repetitive tasks. A study by Purushothaman et al. (2023) on recreational cyclists showed that 55.3% of the participants reported a lifetime prevalence of LBP, with 35.5% having experienced it within the last year. Despite the prevalence, there was a lack of significant association between risk factors and LBP occurrence, and knowledge about injury prevention was low. This points to an urgent need for better education on bicycle ergonomics and the importance of appropriate modifications to reduce LBP risk.

In a similar vein, occupational factors contribute to LBP in various professional settings. For instance, Bertelmann et al. (2021) reported that German ophthalmologists suffer from a high prevalence of back pain, with 53% experiencing LBP, which was particularly common among those performing surgeries. The occupational demands, such as maintaining static postures during surgeries, exacerbated these issues, calling for ergonomic interventions like workplace optimization and promoting physical activities aimed at reducing the musculoskeletal burden. Likewise, Peng et al. (2023) highlighted work-related musculoskeletal disorders in pharmaceutical workers, noting that LBP was the most prevalent symptom. This study emphasizes the need for workplace interventions and ergonomic adjustments, especially among workers aged 50 and above.

Technological interventions are also gaining ground in addressing LBP. Johnson et al. (2023) introduced a seated vertical lumbar traction device that allowed computer work while relieving spinal pressure. This innovation demonstrated significant improvement in spinal height and LBP relief, especially when compared to seated computer work without the traction intervention. Such emerging technologies offer promising alternatives for individuals who spend prolonged hours at desks or workstations, providing ergonomic relief without compromising productivity.
However, despite these advancements, substantial research gaps persist, particularly regarding the standardization of methods for evaluating LBP risk. For example, while ergonomic interventions have been shown to improve conditions for workers, there is a lack of consensus on standardized approaches to risk assessment across different industries and professions. The

study by Chokprasit et al. (2022) on rubber harvesters, for instance, identified several predictors of LBP, such as prolonged standing and lack of ergonomic training, but also indicated that more comprehensive frameworks for assessing and mitigating risk are needed.

Another significant challenge lies in policy implementation. Terfa et al. (2022) and Kurtul and Güngördü (2022) both emphasize the need for policies that address the ergonomic needs of workers in developing countries, particularly those in physically demanding jobs. Policy recommendations include the incorporation of regular ergonomic training and the adaptation of tools and workstations to suit the needs of older workers and those at higher risk for musculoskeletal disorders.

The growing body of research on LBP also points to the need for more multidisciplinary approaches to both prevention and management. Participatory ergonomics, where workers are actively involved in developing ergonomic solutions, has shown promise. Sormunen et al. (2022) conducted a randomized clinical trial that involved participatory ergonomics interventions for workers with LBP, and while the results did not show significant differences in self-assessed work ability between intervention and control groups, there were positive within-group changes in the intensity of LBP and sickness absence days. This underscores the potential of involving workers in designing ergonomic solutions tailored to their specific needs.

8. CONCLUSION

The conclusion of this review paper emphasizes the critical role that ergonomic factors play in both the development and management of low back pain (LBP). Across a range of occupations, LBP remains a significant public health issue with substantial economic and personal costs. The increasing prevalence of LBP, driven by poor posture, prolonged sitting, heavy lifting, and static postures, necessitates focused interventions that prioritize both ergonomic modifications and preventive strategies. A central theme emerging from the literature is that specific professions, such as healthcare, law enforcement, manufacturing, and teaching, exhibit heightened vulnerability to LBP due to the physical demands placed on the body. The risk is compounded by a lack of adequate ergonomic support, leading to long-term consequences, including chronic pain, disability, and reduced quality of life. Furthermore, sedentary behaviors, particularly in office environments, also contribute significantly to the onset of LBP, highlighting the importance of interventions that address poor posture and prolonged sitting. In terms of prevention, ergonomic interventions have been shown to be highly effective. Simple workplace adjustments, such as improved seating, posture correction, and the use of lumbar supports, are widely recognized as practical solutions to alleviate strain on the lower back. The research also underscores the need for continuous ergonomic training, which fosters better awareness of proper body mechanics during physically demanding tasks, such as lifting or repetitive movements. Alongside workplace adjustments, incorporating regular physical activity and exercises targeting core strength and lumbar stability are essential in preventing the onset of LBP. Technology also plays an increasingly significant role in the prevention and management of LBP. Wearable devices, smartphone applications, and dynamic ergonomic tools that promote posture correction and encourage regular movement have proven to be effective in reducing the risk of LBP. These interventions not only enhance workplace ergonomics but also encourage individuals to be more proactive in managing their musculoskeletal health. The review also highlights the importance of addressing lifestyle and psychosocial factors that exacerbate LBP. Stress, poor mental health, and unhealthy habits like smoking and physical inactivity increase the likelihood of experiencing LBP. Therefore, promoting a holistic approach that combines ergonomic interventions with lifestyle changes, such as regular exercise, proper nutrition, and stress management, is key to reducing the long-term burden of LBP. Future research should focus on the standardization of ergonomic risk assessments across various professions and the development of comprehensive policies to promote ergonomic practices, particularly in high-risk occupations. Furthermore, more attention

should be given to the implementation of participatory ergonomics, where workers are actively involved in developing and applying ergonomic solutions tailored to their specific needs. In conclusion, preventing and managing LBP requires a multidisciplinary approach that integrates ergonomic interventions, technological tools, lifestyle modifications, and psychosocial support. By adopting these strategies, individuals and organizations can reduce the prevalence of LBP, improve quality of life, and enhance productivity across different sectors.

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