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PHYSICAL OVEREXERTION AND CHRONIC FATIGUE AMONG AUTOMOTIVE INDUSTRY WORKERS: A PREVENTIVE MEDICINE AND OCCUPATIONAL HYGIENE APPROACH

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Abstract: Physical overexertion and chronic fatigue are among the most common occupational health problems in the automotive industry, where workers are exposed to high physical loads, repetitive movements, prolonged standing, shift work, and psychosocial stress. This review examines physical overexertion and chronic fatigue as key risk factors affecting the health, productivity, and safety of automotive industry workers. The article analyzes physiological and pathophysiological mechanisms underlying fatigue development, its impact on musculoskeletal, cardiovascular, and nervous systems, and its association with occupational injuries and chronic diseases. Epidemiological data indicate a high prevalence of fatigue-related disorders among automotive workers, particularly in assembly lines and maintenance operations. Special attention is given to preventive strategies within occupational hygiene and preventive medicine, including workload optimization, ergonomic interventions, and health surveillance. It is concluded that effective prevention of physical overexertion and chronic fatigue is essential for preserving workers' health and ensuring sustainable industrial productivity.

Keywords: physical overexertion, chronic fatigue, automotive industry, occupational health, preventive medicine, ergonomics, work fatigue

ФИЗИЧЕСКОЕ ПЕРЕНАПРЯЖЕНИЕ И ХРОНИЧЕСКАЯ УСТАЛОСТЬ СРЕДИ РАБОТНИКОВ АВТОМОБИЛЬНОЙ ПРОМЫШЛЕННОСТИ: ПОДХОД С ТОЧКИ ЗРЕНИЯ ПРОФИЛАКТИЧЕСКОЙ МЕДИЦИНЫ И ГИГИЕНЫ ТРУДА

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Аннотация: Физическое перенапряжение и хроническая усталость являются одними из наиболее распространенных проблем со здоровьем на рабочем месте в автомобильной промышленности, где работники подвергаются высоким физическим нагрузкам, повторяющимся движениям, длительному стоянию, сменной работе и психосоциальному стрессу. В данном обзоре рассматриваются физическое перенапряжение и хроническая усталость как ключевые факторы риска, влияющие на здоровье, производительность и безопасность работников автомобильной промышленности. В статье анализируются физиологические и патофизиологические механизмы развития усталости, ее влияние на опорно-двигательную, сердечно-сосудистую и нервную системы, а также ее связь с производственными травмами и хроническими заболеваниями. Эпидемиологические данные указывают на высокую распространенность заболеваний, связанных с усталостью, среди работников автомобильной промышленности, особенно на сборочных линиях и в цехах технического обслуживания. Особое внимание уделяется профилактическим

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

стратегиям в рамках гигиены труда и профилактической медицины, включая оптимизацию рабочей нагрузки, эргономические мероприятия и медицинский осмотр. Сделан вывод о том, что эффективная профилактика физического перенапряжения и хронической усталости имеет важное значение для сохранения здоровья работников и обеспечения устойчивой производительности труда в промышленности.

Ключевые слова: физическое перенапряжение, хроническая усталость, автомобильная промышленность, гигиена труда, профилактическая медицина, эргономика, профессиональная усталость.

Relevance: The automotive industry is one of the largest industrial sectors worldwide, employing millions of workers in manufacturing, assembly, maintenance, and logistics. Despite advances in automation, a significant proportion of tasks remain physically demanding and repetitive. Workers are often exposed to prolonged static postures, manual handling of loads, high work pace, and time pressure. These conditions contribute to physical overexertion and the development of chronic fatigue, which are recognized as major occupational health concerns.

According to the International Labour Organization, work-related musculoskeletal disorders and fatigue-related conditions account for up to 30–40% of occupational diseases in industrial sectors [1]. In the automotive industry, fatigue is not only a health issue but also a safety concern, as it increases the risk of errors, accidents, and reduced productivity. Studies show that fatigued workers have a 1.5–2 times higher risk of occupational injuries compared to non-fatigued workers [2].

Chronic fatigue develops when recovery mechanisms are insufficient to compensate for prolonged physical and psychological load. Unlike acute fatigue, which is reversible with rest, chronic fatigue leads to persistent functional impairments, decreased work capacity, and increased vulnerability to disease. Cardiovascular disorders, musculoskeletal pain syndromes, sleep disturbances, and mental health problems are frequently reported among workers experiencing chronic occupational fatigue [3].

For countries with developing and expanding automotive industries, including Central Asian states, the relevance of this issue is particularly high. Rapid industrial growth, extended working hours, and limited implementation of ergonomic standards exacerbate occupational health risks. Preventive medicine and occupational hygiene play a critical role in addressing physical overexertion and chronic fatigue, shifting the focus from treatment to early prevention and health preservation [4].

Materials and methods: This review is based on an analysis of international scientific literature addressing occupational fatigue, physical workload, musculoskeletal disorders, and health risks in the automotive industry. Sources were identified through PubMed, Scopus, Web of Science, and Google Scholar, as well as reports from the World Health Organization, International Labour Organization, and occupational health agencies.

Search terms included physical overexertion, chronic fatigue, occupational fatigue, automotive industry, musculoskeletal disorders, and occupational hygiene. Priority was given to peer-reviewed articles, systematic reviews, epidemiological studies, and occupational health guidelines published within the last 10–15 years. Qualitative content analysis was used to synthesize data on prevalence, mechanisms, and preventive strategies relevant to industrial workers [5,6].

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

Results and discussion: The automotive industry is characterized by diverse working conditions that impose significant physical demands on workers. Assembly line operations often require repetitive movements, awkward postures, and sustained muscle activation. Workers may perform the same task hundreds or thousands of times per shift, leading to cumulative physical load and localized muscle fatigue.

Manual handling of components, even with partial mechanization, remains common. Lifting, pushing, and carrying loads contribute to excessive strain on the musculoskeletal system. Prolonged standing and limited opportunities for rest further exacerbate physical fatigue. Studies indicate that more than 60% of automotive assembly workers report regular musculoskeletal discomfort, particularly in the lower back, neck, shoulders, and upper limbs [7].

Shift work and extended working hours are additional stressors. Night shifts disrupt circadian rhythms, impair recovery processes, and increase fatigue accumulation. Workers engaged in rotating shifts demonstrate higher levels of chronic fatigue and sleep disturbances compared to those working regular daytime schedules [8].

Physical overexertion results from an imbalance between workload and the body's capacity for adaptation and recovery. Sustained muscular activity leads to depletion of energy reserves, accumulation of metabolic byproducts, and microtrauma of muscle fibers. These changes activate inflammatory pathways and pain receptors, contributing to fatigue and discomfort.

At the cardiovascular level, prolonged physical load increases heart rate and blood pressure, placing additional strain on the cardiovascular system. Over time, inadequate recovery may contribute to hypertension and increased cardiovascular risk. Fatigue-related autonomic imbalance, characterized by reduced parasympathetic activity, has been observed in industrial workers exposed to chronic physical stress [9].

The nervous system also plays a central role in fatigue development. Central fatigue arises from altered neurotransmitter balance and reduced central nervous system drive, leading to decreased motor control and slower reaction times. This mechanism is particularly relevant in safety-critical tasks within the automotive industry.

Chronic fatigue is defined as a persistent state of physical and mental exhaustion lasting for weeks or months and not relieved by rest alone. In occupational settings, chronic fatigue is associated with reduced work performance, increased absenteeism, and long-term health consequences.

Epidemiological studies report that 25–35% of automotive industry workers experience symptoms consistent with chronic fatigue syndrome or severe occupational fatigue [10]. These symptoms include persistent tiredness, muscle pain, sleep disturbances, irritability, and cognitive impairment. Chronic fatigue often coexists with musculoskeletal disorders, forming a vicious cycle of pain, reduced activity, and further fatigue.

Fatigue significantly impairs cognitive and motor functions essential for safe work performance. Reaction time, attention, and decision-making capacity decline with increasing fatigue levels. Research indicates that fatigue-related errors account for up to 20% of industrial accidents, particularly in high-intensity production environments [11].

ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

From an economic perspective, chronic fatigue leads to decreased productivity, increased sick leave, and higher healthcare costs. Employers face indirect losses due to reduced work efficiency and staff turnover. These factors underscore the importance of preventive interventions targeting fatigue reduction.

Musculoskeletal disorders (MSDs) represent the most prevalent health outcome associated with physical overexertion in the automotive industry. Repetitive movements, forceful exertions, awkward postures, and prolonged static loads lead to cumulative trauma affecting muscles, tendons, ligaments, and joints. Assembly line workers, welders, painters, and maintenance personnel are particularly vulnerable due to task monotony and high biomechanical demands.

Epidemiological data indicate that MSDs account for up to 40–50% of all occupational diseases in the automotive sector [12]. Low back pain is the most commonly reported complaint, followed by neck and shoulder disorders and upper limb tendinopathies. Repetitive upper extremity tasks increase the risk of carpal tunnel syndrome and epicondylitis, while prolonged standing contributes to lower limb fatigue and venous disorders.

Physical overexertion accelerates the progression of MSDs by limiting tissue recovery and promoting chronic inflammation. Pain and discomfort reduce functional capacity and contribute to secondary fatigue, forming a feedback loop that further impairs work performance. Without early intervention, MSDs often become chronic, leading to long-term disability and early exit from the workforce.

In addition to physical load, psychosocial factors significantly contribute to fatigue development among automotive workers. High production targets, time pressure, job insecurity, and limited autonomy increase psychological stress, which interacts synergistically with physical overexertion. This combined physical and mental fatigue has more severe health consequences than either component alone.

Studies show that workers exposed to both high physical workload and high job strain have a 2–3 times higher risk of chronic fatigue compared to those exposed to physical load alone [13]. Psychosocial stress activates neuroendocrine pathways, leading to increased cortisol secretion and autonomic imbalance. Chronic stress impairs recovery processes and exacerbates musculoskeletal pain and sleep disturbances.

Shift work further intensifies combined fatigue. Rotating and night shifts disrupt circadian rhythms and impair hormonal regulation, reducing the body’s ability to recover from physical exertion. Workers engaged in shift work report higher levels of exhaustion, irritability, and reduced job satisfaction [14].

Chronic physical overexertion has significant implications for cardiovascular health. Sustained high workloads increase heart rate and blood pressure during working hours, and insufficient recovery prevents normalization of cardiovascular parameters. Over time, this pattern contributes to hypertension, endothelial dysfunction, and increased cardiovascular risk.

Occupational studies indicate that workers exposed to high physical demands have a 20–30% higher prevalence of hypertension compared to workers in less physically demanding jobs [15]. The combination of physical strain, stress, and irregular work schedules further elevates cardiovascular risk. Fatigue-related autonomic imbalance, characterized by reduced heart rate variability, has been identified as an early marker of cardiovascular strain in industrial workers [16].

Cardiovascular fatigue also reduces physical endurance and work capacity, contributing to decreased productivity and increased risk of errors. Preventive monitoring of cardiovascular

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

indicators is therefore an essential component of occupational health surveillance in the automotive industry.

Physical overexertion influences metabolic processes by increasing energy expenditure and altering nutrient utilization. Inadequate nutritional intake or irregular meal patterns, common in shift workers, exacerbate energy imbalance and contribute to fatigue accumulation. Workers experiencing chronic fatigue often report reduced appetite or unhealthy eating behaviors, which further impair recovery.

Metabolic disturbances associated with chronic occupational fatigue include impaired glucose regulation, increased oxidative stress, and low-grade systemic inflammation [17]. These changes increase the risk of metabolic syndrome, particularly when combined with sedentary behaviors during non-working hours due to exhaustion.

In the automotive industry, where workers may alternate between intense physical activity and prolonged rest, metabolic dysregulation poses a long-term health risk. Preventive interventions should therefore include nutritional counseling and promotion of balanced dietary practices.

Sleep is a critical determinant of recovery from physical exertion. Chronic fatigue among automotive workers is closely linked to sleep disturbances, particularly in those engaged in shift work or extended working hours. Insufficient sleep duration and poor sleep quality impair muscle recovery, cognitive function, and emotional regulation.

Studies show that up to 50% of shift workers in industrial settings experience chronic sleep problems, including insomnia and excessive daytime sleepiness [18]. Sleep deprivation reduces physical performance, increases pain sensitivity, and exacerbates fatigue symptoms. Furthermore, inadequate sleep is associated with higher rates of occupational injuries and absenteeism.

The cumulative effect of sleep deprivation and physical overexertion accelerates the transition from acute to chronic fatigue. Preventive strategies must therefore address work-rest schedules, shift design, and sleep hygiene to ensure adequate recovery.

Fatigue significantly increases the risk of occupational injuries in the automotive industry. Reduced alertness, slower reaction times, and impaired motor coordination compromise safety, particularly in environments involving machinery and manual operations. Studies indicate that fatigue-related factors contribute to approximately 15–25% of workplace accidents in industrial settings [19].

In assembly lines, fatigue increases the likelihood of repetitive strain injuries and acute accidents. In maintenance operations, fatigued workers are more prone to errors during equipment handling. These risks highlight the importance of fatigue management as a safety priority.

From a public health standpoint, physical overexertion and chronic fatigue among automotive workers represent not only individual health problems but also population-level occupational risks. High prevalence of fatigue-related disorders contributes to workforce morbidity, healthcare utilization, and economic losses.

Occupational hygiene aims to identify and control physical workload hazards through ergonomic assessment, workload optimization, and environmental modifications. Preventive medicine complements these efforts by focusing on early detection, health promotion, and worker education. Integrated approaches combining ergonomic, organizational, and health-based interventions are most effective in reducing fatigue-related outcomes [20].

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

Effective prevention of physical overexertion and chronic fatigue in the automotive industry requires a comprehensive and systematic approach that integrates ergonomic, organizational, medical, and educational measures. From the perspective of preventive medicine and occupational hygiene, the primary objective is to align physical workload with workers' physiological capacity while ensuring adequate recovery and long-term health preservation.

One of the most important preventive strategies is workload optimization. Ergonomic assessment of workstations allows identification of tasks associated with excessive physical load, awkward postures, and repetitive movements. Studies show that ergonomic redesign of assembly lines, including adjustment of working height, use of assistive devices, and reduction of manual handling, can decrease musculoskeletal complaints by 30–50% and significantly reduce fatigue levels [21]. Job rotation schemes further reduce localized muscle overload by distributing physical demands across different muscle groups.

Work–rest scheduling is another critical component of fatigue prevention. Short, regular rest breaks during shifts improve muscle recovery, reduce perceived exertion, and maintain work performance. Evidence indicates that introducing micro-breaks of 5–10 minutes every 1.5–2 hours can reduce fatigue-related symptoms and lower injury risk by up to 20% [12]. In shift work settings, optimizing shift duration and rotation patterns is essential to minimize circadian disruption and cumulative fatigue.

Ergonomic interventions represent one of the most effective tools for preventing physical overexertion. These interventions include mechanical aids for lifting, adjustable work surfaces, anti-fatigue flooring, and tools designed to minimize force requirements. In the automotive industry, automation and semi-automation of physically demanding tasks have been shown to significantly reduce physical strain and fatigue accumulation.

Postural ergonomics is particularly important in preventing chronic fatigue. Prolonged static postures, such as standing or bending, increase muscle tension and impair blood circulation. Introducing sit–stand workstations and encouraging posture variation can reduce lower back and leg fatigue. Occupational hygiene standards recommend maintaining neutral postures and minimizing static load to protect musculoskeletal health [13].

Environmental factors, including lighting, temperature, and noise, also influence fatigue development. Poor lighting increases visual strain and mental fatigue, while excessive noise contributes to stress and reduced concentration. Improving workplace environmental conditions enhances overall well-being and supports fatigue prevention.

Occupational health services play a central role in preventing and managing physical overexertion and chronic fatigue. Regular health surveillance allows early identification of fatigue-related disorders, musculoskeletal problems, and cardiovascular risk factors. Periodic medical examinations should include assessment of physical workload tolerance, musculoskeletal health, sleep quality, and fatigue symptoms.

Preventive counseling provided by occupational physicians and preventive medicine specialists can significantly improve workers' awareness of fatigue risks and healthy work practices. Studies indicate that targeted health education programs increase compliance with ergonomic recommendations and reduce self-reported fatigue levels [14]. Early intervention prevents progression from acute to chronic fatigue and reduces long-term disability.

Occupational health services also contribute to workplace risk assessment and policy development. Collaboration between health professionals, engineers, and management is essential for implementing effective preventive measures tailored to specific job demands.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

Health promotion programs aimed at improving physical fitness, nutrition, and stress management are important complementary strategies. Physical conditioning programs enhance muscular endurance and reduce susceptibility to fatigue. Workers with better physical fitness demonstrate greater tolerance to physical load and faster recovery [15].

Nutritional education supports energy balance and recovery. Adequate intake of macro- and micronutrients is essential for muscle function and metabolic health. Shift workers, in particular, benefit from guidance on meal timing and composition to reduce fatigue and metabolic disturbances.

Education on sleep hygiene is crucial for preventing chronic fatigue. Promoting regular sleep schedules, optimizing sleep environments, and managing shift-related sleep disruption improve recovery and cognitive function. Worker education initiatives that address lifestyle factors strengthen overall resilience to occupational fatigue.

At the organizational level, fatigue management should be recognized as a priority for occupational safety and health. Employers play a key role in establishing policies that support reasonable workloads, adequate staffing, and realistic production targets. Evidence suggests that organizations implementing comprehensive fatigue management systems experience lower injury rates, reduced absenteeism, and improved productivity [16].

Policy-level interventions include enforcement of occupational health regulations, development of industry-specific guidelines, and integration of fatigue prevention into labor standards. National occupational health policies that emphasize prevention contribute to improved workforce health and sustainability, particularly in labor-intensive industries such as automotive manufacturing.

Chronic fatigue has long-term implications for workers' health, quality of life, and socioeconomic outcomes. Persistent fatigue contributes to early onset of chronic diseases, reduced work ability, and premature exit from the labor market. These outcomes impose significant costs on healthcare systems and employers.

Preventive strategies targeting physical overexertion yield long-term benefits by preserving work ability and extending healthy working life. Economic analyses indicate that investments in occupational fatigue prevention generate returns through reduced healthcare costs, lower injury rates, and improved productivity [17]. From a public health perspective, preventing chronic fatigue supports workforce sustainability and economic development.

Conclusions: Physical overexertion and chronic fatigue represent major occupational health challenges in the automotive industry, with significant implications for workers' health, safety, and productivity. This review demonstrates that high physical workload, repetitive tasks, shift work, and insufficient recovery contribute to the development of fatigue-related disorders affecting the musculoskeletal, cardiovascular, metabolic, and nervous systems.

Chronic fatigue is not merely a transient state of tiredness but a complex condition with long-term health consequences. Evidence presented in this article highlights that physical overexertion significantly increases the risk of musculoskeletal disorders, cardiovascular strain, sleep disturbances, and occupational injuries. These effects underscore the necessity of shifting from reactive treatment to proactive prevention within occupational health systems.

Preventive medicine and occupational hygiene offer effective frameworks for addressing fatigue-related risks. Ergonomic interventions, workload optimization, work–rest scheduling, and health surveillance are key components of comprehensive fatigue prevention strategies. The involvement of occupational health services, combined with worker education and organizational commitment, enhances the effectiveness of preventive measures.

AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 12. December ,2025

In conclusion, preventing physical overexertion and chronic fatigue among automotive industry workers is essential for safeguarding workforce health and ensuring sustainable industrial productivity. Integrated preventive approaches grounded in scientific evidence and occupational health principles can significantly reduce fatigue-related morbidity, improve quality of life, and contribute to long-term economic and social well-being.

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