

HEALTHCARE ERGONOMICS: DESIGNING SAFER, EFFICIENT AND HUMAN-CENTERED HEALTHCARE SYSTEMS

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Abstract

Healthcare ergonomics is a specialized application of ergonomics and human factors engineering aimed at optimizing the interaction between healthcare professionals, patients, technologies and work environments. Modern healthcare systems are characterized by high physical demands, complex technologies, time pressure and essential decision-making, all of these factors present healthcare professionals and patients at risk when systems are inadequately designed. Healthcare ergonomics aims to reduce work-related injuries, minimize medical errors, enhance patient safety and improve the overall quality of care by aligning healthcare tasks and environments with human capabilities and limitations. Healthcare ergonomics applies human-centered design principles to clinical environments to enhance worker safety, patient care and system efficiency. By optimizing tasks, tools and workflows, ergonomic interventions reduce injury risks, support clinical performance and develop sustainable healthcare delivery across diverse medical settings.

Keywords: Healthcare ergonomics; Human factors; Patient safety; Musculoskeletal disorders; Healthcare workers

Introduction

Healthcare is one of the most demanding and safety-essential sectors, requiring continuous interaction between humans, technology, and complex organizational systems. Healthcare professionals such as physicians, nurses, technicians and support staff frequently work long hours, perform physically strenuous tasks and make quick decisions that can have life-or-death consequences. These conditions expose workers to physical injuries, cognitive overload, emotional stress and fatigue, while patients face risks related to medical errors, poor system design and unsafe environments.

Healthcare ergonomics applies ergonomic principles to healthcare systems with the aim of improving safety, efficiency and well-being for both providers and patients. Unlike traditional ergonomics, which evolved primarily in industrial contexts, healthcare ergonomics addresses unique challenges such as patient handling, clinical workflow complexity, medical device usability and interdisciplinary teamwork. As healthcare systems worldwide face increasing patient volumes, staff shortages and technological advancements, the importance of ergonomics has become increasingly evident.

Foundations of healthcare ergonomics

Healthcare ergonomics is founded in ergonomics and human factors science, integrating knowledge from anatomy, biomechanics, psychology, systems engineering and organizational behaviour. It recognizes healthcare as a sociotechnical system in which human performance is influenced by physical, cognitive and organizational factors.

Healthcare ergonomics extends across hospitals, clinics, laboratories, long-term care facilities and home healthcare environments. It addresses the design of workspaces, tools, equipment, information systems and workflows to ensure that healthcare tasks align with human abilities and limitations. By adopting a systems technique, healthcare ergonomics aims to optimize both individual performance and overall system outcomes.

Domains of healthcare ergonomics

Healthcare ergonomics can be broadly categorized into physical, cognitive and organizational domains, each addressing different aspects of healthcare work.

Physical ergonomics: Physical ergonomics focuses on the interaction between healthcare workers and physical job demands. Common concerns include manual patient handling, prolonged standing, awkward postures, repetitive movements and exposure to vibration. Nurses and caregivers are particularly vulnerable to musculoskeletal disorders due to frequent lifting, transferring and repositioning of patients. Ergonomic solutions such as mechanical lifting devices, adjustable beds and optimized workstation layouts significantly reduce physical strain and injury risk.

Cognitive ergonomics: Cognitive ergonomics addresses mental processes such as perception, attention, memory and decision-making. Healthcare professionals frequently manage large volumes of information, respond to alarms and make significant decisions under time pressure. Poorly designed information systems, excessive alarms and unclear interfaces contribute to cognitive overload and errors. Cognitive

ergonomic interventions focus on improving interface design, information presentation and decision support to enhance accuracy and reduce mental fatigue.

Organizational ergonomics: Organizational ergonomics examines how work schedules, staffing levels, communication patterns, teamwork and organizational culture affect performance and well-being. Shift work, long hours and inadequate staffing contribute to fatigue and burnout. Organizational ergonomic strategies include optimizing shift schedules, improving team coordination, fostering a safety culture and involving staff in system design decisions.

Material and Methods

Ergonomic risk factors in healthcare settings

Healthcare environments present numerous ergonomic hazards that vary across departments and roles. Manual patient handling remains one of the leading causes of work-related injuries in healthcare. Tasks frequently involve irregular loads, awkward postures, and limited space, increasing the risk of back and shoulder injuries. Prolonged static postures during surgical procedures and diagnostic tasks contribute to musculoskeletal discomfort and fatigue.

Repetitive tasks such as documentation, medication preparation and equipment handling can lead to cumulative trauma disorders. Additionally, high cognitive workload, frequent interruptions and emotional stress increase the probability of errors and burnout. Identifying and addressing these risk factors is a central goal of healthcare ergonomics [Table 1].

Ergonomic design of healthcare work environments

The design of healthcare environments plays a significant role in supporting safe and efficient work.

Clinical workstations: Ergonomically designed clinical workstations accommodate a wide range of body sizes and work preferences. Adjustable desks, chairs and monitor placements help maintain neutral postures during documentation and monitoring tasks. Proper lighting and noise

control further enhance comfort and concentration.

Patient care areas: In patient care areas, ergonomic design focuses on accessibility, space layout and equipment placement. Adequate space around beds, strategically located supplies and standardized room layouts reduce unnecessary movement and physical strain for caregivers.

Operating rooms and specialized units:

Operating rooms and intensive care units are highly complex environments. Ergonomic considerations include adjustable operating tables, optimal placement of displays and controls and coordinated teamwork. These design elements support precision, reduce fatigue, and enhance patient safety.

Table 1: Common healthcare ergonomic risks and mitigation strategies.

Ergonomic Risk	Example in Healthcare	Potential Impact	Recommended Mitigation
Manual patient handling	Lifting or transferring patients	Lower back injuries, shoulder strain	Mechanical lifts, team lifts, training
Repetitive tasks	Medication preparation, documentation	Hand/wrist disorders, fatigue	Adjustable workstations, job rotation, ergonomic tools
Prolonged standing	Surgery, ward rounds	Leg pain, fatigue	Anti-fatigue mats, scheduled breaks, supportive footwear
Awkward postures	Bedside care in confined spaces	Neck and back pain	Bed height adjustment, patient positioning, workspace layout
Cognitive overload	Managing multiple patients or alarms	Errors, stress, reduced attention	Decision support systems, clear interface design, workflow optimization

Role of medical devices and technology

Medical devices and digital technologies are integral to modern healthcare, making their ergonomic design essential.

User-centred design of medical devices improves usability and reduces errors. Clear displays, intuitive controls and feedback mechanisms enable clinicians to use equipment efficiently and safely. Poorly designed devices, in contrast, can increase workload and compromise patient safety. Electronic Health Records (EHRs) and clinical information systems significantly influence cognitive ergonomics.

Systems that are difficult to navigate or require excessive documentation time increase mental workload and reduce time available for patient care. Ergonomic evaluation and redesign of digital systems are essential.

Automation and robotics, such as robotic surgery

and automated medication dispensing, reduce physical workload and enhance precision. However, these technologies must be carefully integrated to ensure they support rather than hinder clinical performance.

Healthcare ergonomics and patient safety

Patient safety is a central concern of healthcare ergonomics. Many adverse events in healthcare are associated to system design flaws rather than individual failures. Ergonomic design reduces the probability of errors by simplifying tasks, standardizing procedures and improving communication.

Examples include color-coded medication labelling, standardized equipment layouts and clear alarm systems. By designing systems that account for human limitations, healthcare ergonomics creates safer environments for both patients and providers.

Results and Discussion

Education, training and participatory ergonomics

Education and training are essential for effective implementation of healthcare ergonomics. Healthcare workers must be trained in proper body mechanics; equipment use and ergonomic awareness. Early integration of ergonomics into medical and nursing education helps establish safe work habits.

Participatory ergonomics involves healthcare workers in identifying problems and developing solutions. This technique uses operational expertise, increases acceptance of ergonomic interventions, and develops a culture of safety and continuous improvement.

Benefits of healthcare ergonomics

The benefits of healthcare ergonomics are multifaceted. For healthcare workers, ergonomic interventions reduce injury risk, fatigue and burnout, improving job satisfaction and career longevity. For patients, ergonomics enhances safety, comfort and quality of care.

Healthcare organizations benefit from reduced absenteeism, lower compensation costs, improved productivity and enhanced service quality. By supporting human performance, healthcare ergonomics contributes to the sustainability and resilience of healthcare systems.

Challenges in implementing healthcare ergonomics

Despite its benefits, implementing healthcare ergonomics faces challenges such as limited resources, lack of awareness, resistance to change and competing organizational priorities. In fast-paced healthcare environments, ergonomic improvements may be perceived as secondary to immediate clinical demands.

Addressing these challenges requires leadership commitment, interdisciplinary collaboration and integration of ergonomics into policies, standards and design processes. Demonstrating the long-term cost-effectiveness of ergonomic interventions can further support adoption.

Future directions in healthcare ergonomics

The future of healthcare ergonomics provides in proactive, data-driven and human-centred techniques. Wearable sensors and motion analysis systems enable real-time monitoring of physical workload and posture. Artificial intelligence and data analytics support predictive risk assessment and workflow optimization.

Greater emphasis on resilience engineering, patient-centred design and system-level thinking will further strengthen healthcare ergonomics. As healthcare continues to evolve, ergonomics will remain essential for ensuring that technological advancements enhance rather than compromise human performance.

Conclusion

Healthcare ergonomics is an essential treatment that deals with the complex interactions between people, technology and healthcare systems. By applying ergonomic principles to physical, cognitive and organizational aspects of care, healthcare ergonomics improves worker safety, patient outcomes and system efficiency.

Its contributions to injury prevention, error reduction and quality improvement make it an indispensable component of modern healthcare. As demands on healthcare systems continue to grow, integrating healthcare ergonomics into design, education and policy will be significant for creating safe, efficient and sustainable healthcare environments.

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