Review Article

Evolution of Occupational Health: From Industrial Medicine to the Digital-Era

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The conceptualisation of occupational health has evolved substantially over the past three centuries, transitioning from narrow industrial medicine approaches focused on physical injuries and acute health problems to broader frameworks addressing physical, mental, social, and organisational wellbeing. This article explores the historical evolution of occupational health definitions, highlighting milestones from the World Health Organisation and International Labour Organisation (WHO-ILO) Joint Committee in 1950 to the expanded 1995 definition, analysing scientific, socio-political, and economic drivers for change. The article proposes that occupational health requires a further conceptual expansion in order to address the challenges posed by digitalisation, platform-based gig work, and artificial intelligence to address algorithmic management, data rights, and non-standard employment arrangements. The article concludes with proposed recommendations on an improved framework on occupational health in the 21st century, which integrates principles of digital fairness, human oversight, and universal access to preventive services, aiming to safeguard worker health, dignity, and equity in an increasingly technology-mediated world.

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Introduction

Occupational health definitions provide basic conceptual frameworks that define professional responsibilities, influence legislation, guide resource allocation, and shape societal understandings of worker protection. From its early roots in the Industrial Revolution and grounded in Bernardino Ramazzini's recognition of occupational diseases, occupational health has continually evolved in response to transforming work environments and advancing scientific knowledge. As the world of work transitions from traditional factories to digital ecosystems shaped by artificial intelligence (AI), and

global interconnectivity, existing definitions must be critically examined and expanded to remain relevant and inclusive [1][2].

Transition from Industrial Medicine to Holistic Occupational Health

Phase I (1700-1940s, Industrial Medicine): The book "De Morbis Artificum" by Bernardino Ramazzini in 1700 provided the basic premises in occupational medicine by cataloguing diseases across 54 occupations. However, industrial medicine emerged as a distinct speciality only during the Industrial Revolution from mid-18th to early 20th century, characterised by reactive medical treatment of acute injuries and disease, employer-centric orientation, and a narrow focus on production workers in manufacturing sectors. Early factory acts and workers' compensation systems (late 1800s–early 1900s) formalised medical examination processes but perpetuated biomedical reductionism that neglected environmental control and organisational factors [3][4].

Phase II (1950 WHO/ILO Definition: Occupational Health): The first joint World Health Organisation (WHO) and International Labour Organisation (ILO) Committee on Occupational Health (1950) produced a landmark definition:

> "Occupational health should aim at the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; the prevention amongst workers of departures from health caused by their working conditions; the protection of workers in their employment from risks resulting from factors adverse to health; the placing and maintenance of the worker in an occupational environment adapted to his physiological and psychological capabilities and; to summarize: the adaptation of work to man and of each man to his job" [1][5].

This definition advanced beyond the limited focus of industrial medicine, incorporating the WHO's holistic health concept, extending coverage to all workers in all occupations, emphasising health promotion and prevention, and establishing ergonomic principles. The definition, however, largely retained an individualist approach, and very little attention was given to organisational, psychosocial, and systemic determinants of worker health.

Phase III (1950-1995): Drivers of Evolution in Occupational Health Definition:

The third phase in the evolution of occupational health was shaped by three major drivers:

(A) Scientific Progress (B) International Legal Framework (C) Work Organisation Paradigm Shifts

A. **Scientific Progress – Expanding the determinants of Employee Health**

Since the 1950s, the scope of occupational health progressively broadened from physical and chemical hazards to encompass psychosocial, behavioural, and organisational determinants of health. Landmark studies, including those carried out by the Whitehall researchers, demonstrated social gradients in cardiovascular disease associated with job control and demand, and Karasek and Theorell's (1990) Job Demand-Control Model established psychosocial work characteristics like job design and control as independent health determinants. Advances in the fields of occupational cancer epidemiology, reproductive toxicology, and musculoskeletal disorder studies have widened the scope of worker health [6][7]. These developments led the WHO/ILO Joint Committee to go beyond the 1950 definition's focus on the physical, mental, and social well-being, toward a more multidimensional and dynamic understanding of worker health.

B. **International Legal Framework - Preventive and Participatory Strategy**

The 1980s marked the beginning of an important transition in the international occupational health policy through the adoption of two key ILO conventions. Convention 155 on Occupational Safety and Health (1981) formalised the need for comprehensive national Occupational Safety and Health (OSH) policies, emphasising systematic risk prevention, worker participation, and continuous improvement. Convention 161 on Occupational Health Services (1985) formalised occupational health services as essentially preventive, promoting multidisciplinary collaboration and adaptation of work to workers' physical and mental capacities. Collectively, these conventions upgraded the conceptual foundation of occupational health from curative and hazard-specific interventions toward integrated, preventive systems and human-centred work design, principles that directly influenced subsequent WHO/ILO deliberations in the 1990s [8].

C. **Work Organisation Paradigm Shifts - Structural and Demographic Changes**

The growth in the service industry since 1970 has led to the emergence of psychosocial hazards, different from the traditional industrial exposures. Globalisation created transnational production networks, challenging national regulatory systems and identifying disparities in workers' protection across borders. Rising participation of the female workforce highlighted greater attention to gender-specific occupational health issues, including reproductive health and work–family conflict. Simultaneously, technological transformation through computerisation created new occupational health concerns like ergonomic and mental health issues, such as repetitive strain injuries and technostress [9]. These developments, in sum, exemplified that workers' health and

well-being depend as much on psychosocial and organisational adaptation as on the control of physical and chemical hazards.

D. **Health Policy Innovations – Health Promotion and Equity in Mainstream Practices**

Two major landmarks in global health policy catalysed occupational health's expansion beyond disease prevention. The Alma-Ata Declaration (1978) redefined health as a fundamental human right and emphasised equity, community participation, and intersectoral collaboration. These principles closely align with occupational health's preventive ethos, underscoring the need for universal access and service availability for all categories of workers. The Ottawa Charter for Health Promotion (1986) introduced health promotion as distinct from disease prevention, focusing on enabling individuals to gain greater control over their health through supportive environments, policy advocacy, and personal skill development. Together, these frameworks advanced occupational health toward a comprehensive, participatory, and empowerment-based model—linking worker health not only with hazard control but also with workplace culture, social justice, and organisational wellbeing [10][11].

Phase IV: (The 1995 Definition: A Holistic Approach): The Twelfth Session of the Joint ILO/WHO Committee in 1995 reaffirmed the 1950 definition while introducing critical expansions articulating three main objectives:

  i. The maintenance and promotion of workers' health and working capacity;
  ii. The improvement of working environment and work to become conducive to safety and health, and
  iii. Development of work organisations and working cultures in a direction which supports health and safety at work and, in doing so, also promotes a positive social climate and smooth operation and may enhance productivity of the undertakings.

The inclusion of the working capacity addresses the recognition that health and functional capacity are related, though different, concepts, and this has become increasingly important in supporting work ability throughout one's lifespan, particularly in an ageing workforce with chronic illnesses. Emphasis on work environment improvement reflected a shift toward proactive, continuous advancement beyond mere regulatory compliance, aligning occupational health with principles of total quality management and continuous system improvement. Most notably, the addition of work organisation and culture formally recognised organisational values, management systems, and psychosocial climate as legitimate

determinants of occupational health, reflecting growing evidence that these factors influence worker wellbeing and productivity independently of technical or engineering controls [5][12].

Current Challenges: Digitalisation, the Gig Economy, and Artificial Intelligence
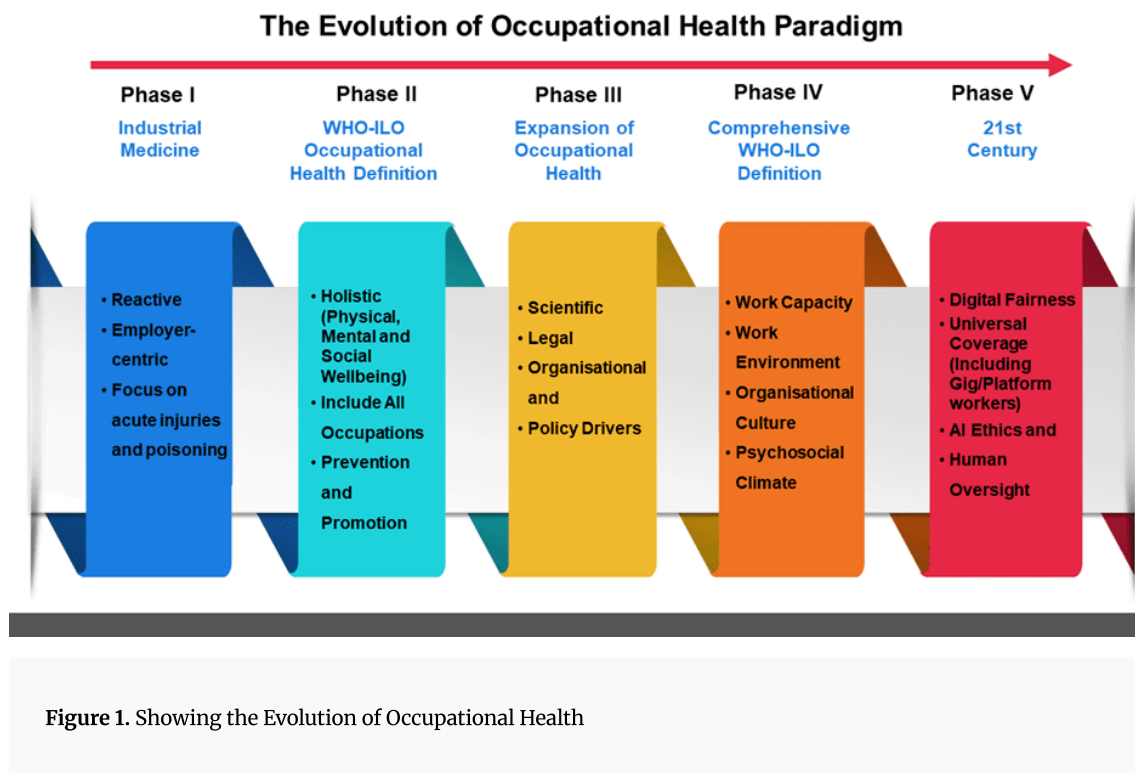
Despite the incorporation of important refinements in the 1995 ILO/WHO definition, contemporary developments in work organisation and technology have exposed enduring conceptual and practical limitations in current frameworks on occupational health. The definition presumes stable employment relationships, identifiable employers, and physically bounded workplaces; however, such assumptions, in effect, are progressively becoming less adequate in light of the increasingly fragmented, digital, and globally networked mode of work.

Concurrently, the World Health Assembly (WHA) Resolution 60.26 (2007) drew attention to the uneven coverage, quality, and accessibility of occupational health services worldwide and urged their universal extension through the Global Plan of Action on Workers' Health (2008-2017). Today, almost two decades later, these concerns remain significant, as less than one-third of the global workforce has access to basic occupational health services, and the goal of achieving universal coverage is further challenged by non-standard, platform-based, and remote work arrangements. These shifts challenge the foundational assumptions of occupational health practice, specifically who the "worker" is, where "work" occurs, and how responsibility for worker health is defined and enforced [13][14].

The gaps in existing occupational health (OH) frameworks have become increasingly evident in the face of developments in digitalisation, the rise in non-standard employment, and the emergence of algorithmic management. Digital technologies have transformed how work is organised, monitored, and delivered and have fragmented the traditional employer–employee relationship, giving rise to new forms of work that operate across multiple jurisdictions, often outside conventional regulatory and social protection systems [15][16][17].

Gig and platform workers, remote freelancers, and crowd workers engage in an algorithmically mediated environment where work conditions, number of hours worked, and work risks remain unclear and fluctuating [18]. The use of AI-driven management systems has increased across different sectors, and the automation process has extended from the physical tasks in the factory environment to the decision-making and supervision tasks within the management domain. Today, the AI management system

oversees the assignment process, boosts worker productivity, and enables performance analysis and prediction. While AI management systems can enhance safety through predictive analytics and personalised interventions, there could be risks of novel threats, including work intensification, algorithmic discrimination, privacy intrusion through continuous digital surveillance, workers' deskilling, loss of worker autonomy, and accountability gaps when AI systems make decisions affecting health and safety[15][19][20]. These aspects challenge the foundational principles of occupational health, particularly the accountability of employers, the scope of preventive services, and the mechanisms for worker participation and representation as well as blur the boundary between human and machine agency, challenging existing ethical and regulatory safeguards in occupational health practice, necessitating a re-examination of how occupational health is defined, delivered, and governed in the digital age.

The Evolution of Occupational Health Paradigm

Phase I	Phase II	Phase III	Phase IV	Phase V
Industrial Medicine	**WHO-ILO Occupational Health Definition**	**Expansion of Occupational Health**	**Comprehensive WHO-ILO Definition**	**21st Century**
• Reactive • Employer-centric • Focus on acute injuries and poisoning	• Holistic (Physical, Mental and Social Wellbeing) • Include All Occupations • Prevention and Promotion	• Scientific • Legal • Organisational and • Policy Drivers	• Work Capacity • Work Environment • Organisational Culture • Psychosocial Climate	• Digital Fairness • Universal Coverage (Including Gig/Platform workers) • AI Ethics and • Human Oversight

Figure 1. Showing the Evolution of Occupational Health

Inadequacies in Existing Frameworks

Although comprehensive for its time, the 1995 ILO/WHO definition of occupational health no longer fully reflects contemporary work realities. The change in the world of work brought about by the digitalisation of labour and the rise of non-standard and platform-based work has challenged the assumptions

included in the conventional framework, stable employment, fixed workplaces, and clear employer accountability. The key gaps include:

i. **Employment relationships:** The platform and gig work relationship often lack an employment relationship, hence constraining the statutory OH responsibilities.

ii. **Workplace boundaries:** Virtual and mobile work complicates ergonomic and environmental risk assessments.

iii. **Organisational belonging and participation:** Work culture and collective participation mechanisms presume stable membership, which is absent in task-based or transient work.

iv. **Algorithmic management:** Automated decision-making lacks transparency, challenging oversight of workload, performance, and safety.

v. **Data governance:** Increasing reliance on digital monitoring raises ethical and legal concerns regarding privacy, consent, and discrimination.

These structural and ethical gaps highlight the need for policies that extend the coverage of the fundamental principles of occupational health in relation to all workers, ensuring digital equity, protecting the data rights of workers, and achieving universal access for all in preventive services, in line with the WHO Global Plan of Action on Workers' Health and the ILO Future of Work agenda [13][21].

Towards a 21st-Century Occupational Health in the Digital Era:

Building on historical evolution and emerging challenges, occupational health in the 21st century requires an integrated, systems-level policy response rather than merely revising conceptual definitions. The World Health Assembly (WHA) Resolution 60.26 (2007) and the Global Plan of Action on Workers' Health (2008-2017) emphasised universal coverage, preventive focus, and intersectoral collaboration as pillars of worker health protection. However, persistent inequities and emerging risks from digitalisation, platform-based employment, and artificial intelligence (AI) call for renewed commitments [13][14][15][16][17].

1. **Broadening Universal Coverage to All Forms of Employment**

   Policies need to ensure that all workers, irrespective of their employment status or contractual forms, have access to occupational health services. This could include community and sector-specific frameworks related to occupational health, mobile and digital service delivery, and

integration with primary healthcare, in accordance with WHO's "Health for All" strategy and the ILO's Decent Work agenda [11][21].

2. **Strengthening Governance and Accountability in Digital Work**

National frameworks should clarify employer responsibilities in algorithmically managed or multi-party work arrangements. Regulatory innovations such as the EU's Platform Work Directive (2021) and algorithmic transparency requirements offer models for ensuring accountability and protecting worker rights [22][23].

3. **Protection of Employee Data, Privacy, and Freedom**

The integration of artificial intelligence and digital surveillance needs the development of updated standards of data governance, consent and ethical oversight. The WHO report on "Ethics and Governance of Artificial Intelligence for Health" provides principles that should extend to occupational settings, prioritising transparency, fairness, and human oversight [24].

4. **Psychosocial and Organisational Integration**

With the changes in social relations brought about by remote and gig work, psychosocial risk management, organisational justice, and work–life balance must become vital elements of occupational health policy. This is in alignment with the ILO's Centenary Declaration on the Future of Work in 2019, which calls for human–centred approaches to digital transformation [25].

5. **Research, Capacity Building, and Multi-Stakeholder Engagement**

In the future, policies should focus on resource investment in the area of digital work-related health outcomes, training of OH professionals in AI ethics and digital ergonomics, and strengthen collaboration among governments, employers, worker representatives, and technology developers [15].

Conclusion

Occupational health has continually evolved in response to transformations in work organisation, technology, and social expectations, from Ramazani's early recognition of occupational diseases to the industrial and organisational health paradigms of the 20th century. The current digital transformation, encompassing platform work, automation, and algorithmic governance, marks the era of changes comparable in magnitude to the industrial revolution. The bulk of workers in non-standard and/or digitally mediated work categories are at risk of being excluded from basic health protections.

Integrating principles of digital fairness, accountability in algorithmic governance, and universal access to occupational health services into policy frameworks can strengthen resilience and equity in the future of work. Initiatives such as the EU Platform Work Directive (2021) and other emerging models of participatory governance provide evidence that regulatory innovation can align flexibility with social protection [21][22].

The 21st-century vision of occupational health must focus on the protection of all types of workers, irrespective of the work arrangement, embedding worker participation and human oversight in the application of technology, capacity building for digital risk assessment within occupational health services, and strengthening data governance and ethical accountability mechanisms. Ultimately, the goal is to prevent harm and to foster human flourishing in a digital world, where work promotes dignity, fairness, social protection, and environmental sustainability, echoing the spirit of the Sustainable Development Goals [15][17][21].

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Author Contribution

Ashish Trivedi contributed in conceptualisation, review literature and finalisation of manuscript and Aadhya Trivedi contributed in review literature and drafting the manuscript.

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Declarations