

Original Research

Received 06 July 2026

Revised 07 Aug 2026

Accepted 20 Aug 2026

Natural Resources for Human Health 2026, Vol. 6 (17s): 351–362

KEYWORDS:

occupational disease; occupational medicine; medical surveillance; early detection; biological monitoring; screening; workplace health; Vision 2030; Saudi Arabia

Early Detection of Occupational Diseases Through Occupational Medicine Programs

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ABSTRACT: Occupational diseases remain one of the largest and least visible burdens on global public health. Unlike occupational injuries, which are immediate and easily attributed to the workplace, occupational diseases typically develop silently over years or decades, are multifactorial in origin, and are frequently misattributed to lifestyle or ageing. As a result, they are systematically under-recognised, under-reported, and under-compensated. Occupational medicine programs — structured systems of pre-placement assessment, periodic medical surveillance, biological monitoring, exposure assessment, and sentinel-event reporting — offer the principal mechanism through which these conditions can be identified at a pre-clinical or early, reversible stage.

This paper reviews the conceptual foundations, components, and evidence base of early detection within occupational medicine programs. It examines detection strategies across the major disease groups, including occupational lung disease, noise-induced hearing loss, work-related musculoskeletal disorders, occupational dermatoses, occupational cancers, heat-related illness, and work-related psychological disorders. The analysis is anchored in the Wilson and Jungner screening principles, Donabedian's structure–process–outcome model, Reason's Swiss model, and the three levels of prevention. Particular attention is given to the Saudi Arabian context, where rapid industrial diversification, a large expatriate workforce, extreme heat exposure, and the Vision 2030 Health Sector Transformation Program create both pressing need and substantial opportunity.

The paper identifies key barriers — fragmented data, limited occupational history-taking, worker fear of job loss, latency, and weak coverage of small enterprises — and proposes the

DETECT Framework, an integrated model built on six pillars: Data-driven surveillance, Exposure characterisation, Targeted screening, Early intervention, Collaborative governance, and Tracking for continuous improvement. Recommendations are offered for policymakers, employers, occupational health professionals, and researchers. The paper concludes that early detection is not a single clinical act but a system property, achievable only when clinical, regulatory, informational, and organisational components are deliberately aligned.

1. INTRODUCTION

Work is a central determinant of health. For most adults, the workplace is where they spend the largest share of their waking hours, and it is the setting in which they encounter chemical, physical, biological, ergonomic, and psychosocial hazards that may not exist anywhere else in their lives. The International Labour Organization (ILO) estimates that close to three million workers die each year from work-related causes, and that the overwhelming majority of these deaths — well over 2.5 million — result

not from accidents but from work-related diseases (ILO, 2023). The joint WHO/ILO estimates similarly attribute almost two million deaths annually to selected occupational risk factors, led by long working hours, airborne particulate matter, gases and fumes, and occupational injuries (WHO & ILO, 2021). Despite this scale, occupational diseases occupy a curiously marginal position in health systems. They are rarely visible in routine clinical encounters, where the question "What do you do for work?" is often omitted or recorded without detail. Their long latency means that the worker who develops mesothelioma, silicosis, or bladder cancer may have left the exposing employment decades earlier. Their symptoms — cough, breathlessness, hearing difficulty, back pain, skin rash, fatigue, low mood — are non-specific and readily attributed to smoking, age, or personal habits. Consequently, the true burden of occupational disease is consistently and substantially underestimated in national statistics (Takala et al., 2014; Spreuwers et al., 2010). Occupational medicine emerged precisely to close this gap. Its distinctive contribution is to look at the worker and the work together: to anticipate disease from known exposures, to detect early biological or functional change before clinical disease is established, and to link individual findings back to workplace conditions so that the hazard itself can be controlled. In this sense, early detection in occupational medicine serves two patients simultaneously — the individual worker, whose prognosis is improved by timely diagnosis, and the workforce as a whole, which benefits when a detected case triggers a review of exposure controls.

In occupational medicine, every early-detected case is both a diagnosis and a warning signal: it identifies a worker who needs care and a workplace that needs correction.

In the Kingdom of Saudi Arabia, the relevance of this agenda has intensified. Vision 2030 is driving rapid expansion in manufacturing, mining, construction, logistics, energy, tourism, and healthcare itself. The Health Sector Transformation Program emphasises prevention, population health management, and value-based care, all of which align naturally with occupational surveillance. At the same time, the country faces distinctive occupational challenges, including extreme ambient heat, a large and diverse expatriate workforce, and a substantial small and medium enterprise (SME) sector in which formal occupational health services are often limited.

1.1 Aim and Objectives

The aim of this paper is to provide a comprehensive, evidence-informed review of how occupational medicine programs enable the early detection of occupational diseases, and to propose an integrated framework suited to the Saudi health and labour context. Its specific objectives are to:

- ◆ clarify the concepts of occupational disease, work-related disease, and early detection;
- ◆ examine the theoretical models that underpin occupational surveillance and screening;
- ◆ describe the core components of an effective occupational medicine program;
- ◆ review detection approaches across the principal occupational disease groups;
- ◆ analyse the Saudi regulatory and institutional context in light of Vision 2030;
- ◆ identify barriers to early detection and propose an integrated framework and practical recommendations.

1.2 Methodological Approach

This paper adopts a narrative, integrative review design. It synthesises international guidance from the ILO, WHO, and the International Commission on Occupational Health (ICOH); peer-reviewed literature on surveillance, biomonitoring, and disease-specific screening; and Saudi policy documents relating to occupational safety and health and the health sector transformation. The intention is conceptual and practical synthesis rather than a quantitative meta-analysis, and conclusions are presented with corresponding caution.

2. CONCEPTUAL FOUNDATIONS

2.1 Defining Occupational and Work-Related Disease

The ILO distinguishes between **occupational diseases**, in which a specific workplace exposure is the principal or necessary cause — for example, silicosis from respirable crystalline silica or asbestosis from asbestos fibres — and **work-related diseases**,

in which work is one of several contributing causes, as with hypertension, low back pain, or depression aggravated by job strain. The ILO List of Occupational Diseases (revised 2010) groups recognised conditions by causal agent (chemical, physical, biological), by target organ system (respiratory, skin, musculoskeletal, mental and behavioural), and by occupational cancer, and it includes open-ended items that permit recognition of new conditions where a causal link is scientifically established (ILO, 2010). This distinction matters for early detection. Classic occupational diseases often have well-characterised exposure–response relationships and validated screening tools, such as spirometry and chest radiography for pneumoconioses or audiometry for noise. Work-related diseases are more diffuse; their detection relies on broader health surveillance, psychosocial risk assessment, and integration with general primary care.

2.2 The Natural History of Occupational Disease

Most occupational diseases follow a recognisable trajectory: exposure, internal dose, early biological effect, altered structure or function, clinical disease, and finally disability or death (Schulte, 1989). Early detection seeks to intervene in the window between early biological effect and established clinical disease — the "detectable pre-clinical phase". The length of this window varies greatly. For noise-induced hearing loss, a temporary threshold shift may be detectable within hours of exposure and a permanent notch at 4 kHz within months. For pneumoconioses and occupational cancers, the pre-clinical phase may span ten to forty years, making long-term follow-up, exposure records, and post-employment surveillance essential.

Table 1. Major Occupational Disease Groups and Early Detection Tools

Disease Group	Typical Exposures / Sectors	Early Detection Tools
Pneumoconioses & occupational lung disease	Silica, coal dust, asbestos, metal fumes; mining, quarrying, construction, foundries	Spirometry, ILO-classified chest radiography, low-dose CT (selected), respiratory questionnaires
Occupational asthma	Isocyanates, flour, latex, cleaning agents, enzymes	Symptom questionnaires, serial peak-flow monitoring, specific IgE, challenge testing
Noise-induced hearing loss	Manufacturing, construction, aviation, oil and gas	Baseline and annual pure-tone audiometry, standard threshold shift analysis
Musculoskeletal disorders	Manual handling, repetition, awkward posture, vibration; healthcare, logistics	Symptom surveys (e.g., Nordic questionnaire), ergonomic assessment, clinical examination
Occupational dermatoses	Wet work, solvents, cement, rubber chemicals; healthcare, cleaning, construction	Skin inspection, symptom questionnaires, patch testing
Occupational cancers	Asbestos, benzene, silica, diesel exhaust, ionising radiation	Exposure registries, targeted screening (e.g., LDCT), long-term follow-up
Chemical toxicity	Lead, mercury, organophosphates, solvents	Biological monitoring (blood lead, cholinesterase, urinary metabolites)
Heat-related illness	Outdoor construction, agriculture, oil fields	Heat stress indices, physiological monitoring, renal function and hydration markers
Work-related mental disorders	Job strain, shift work, violence, long hours; healthcare, security	Validated screening scales, psychosocial risk assessment, burnout inventories

Source: compiled from ILO (2010), Blanc et al. (2019), Nelson et al. (2005), and WHO & ILO (2021).

2.3 What "Early Detection" Means in Occupational Medicine

Early detection in this field encompasses more than screening tests. It includes: (a) **hazard surveillance**, which identifies exposures before disease occurs; (b) **medical surveillance**, the systematic, repeated assessment of exposed workers to identify early health effects; (c) **biological monitoring**, which measures the agent or its metabolites in body fluids to estimate internal dose; and (d) **sentinel surveillance**, in which a single recognised case triggers investigation of co-workers and workplace conditions (Halperin & Frazier, 1985; Rutstein et al., 1983). Together these activities shift detection upstream, from the specialist clinic to the workplace.

3. THEORETICAL FRAMEWORK

3.1 Wilson and Jungner Screening Principles

The ten principles articulated by Wilson and Jungner (1968) remain the benchmark for any screening program. They require that the condition be an important health problem; that its natural history be understood; that a recognisable latent or early symptomatic stage exist; that a suitable and acceptable test be available; that effective treatment or intervention be possible; and that case-finding be a continuous process rather than a one-time project. Occupational medicine adds a further, distinctive justification: even where individual treatment is limited — as in established silicosis — detection remains valuable because it identifies a failure of exposure control and protects co-workers.

3.2 The Levels of Prevention

Occupational health practice maps naturally onto the classic levels of prevention. **Primary prevention** removes or controls the hazard through the hierarchy of controls: elimination, substitution, engineering controls, administrative controls, and personal protective equipment. **Secondary prevention** — the focus of this paper — detects disease early, when removal from exposure and treatment can halt or reverse progression. **Tertiary prevention** limits disability through rehabilitation, accommodation, and supported return to work. A mature program uses secondary-prevention findings to strengthen primary prevention, creating a feedback loop rather than a linear sequence.

3.3 Donabedian's Structure–Process–Outcome Model

Donabedian's (1988) model offers a lens for evaluating the quality of occupational medicine programs. **Structure** refers to qualified occupational physicians and nurses, calibrated audiometric and spirometric equipment, information systems, and legal mandates. **Process** refers to the conduct of examinations, adherence to protocols, interpretation against baselines, notification, and follow-up. **Outcomes** include the stage at which disease is detected, incidence trends, avoided disability, and workplace exposure reductions. Many programs measure structure and process — the number of examinations completed — while neglecting outcomes, which obscures whether detection is actually occurring early.

3.4 Reason's Swiss Cheese Model

Reason's (2000) model, widely used in patient safety, is equally instructive for occupational disease. A case of occupational disease typically represents the alignment of multiple defensive failures: an inadequate risk assessment, failed engineering controls, inconsistent PPE use, absent or poor-quality surveillance, and a clinician who did not take an occupational history. Early detection constitutes one of the last defensive layers; when it functions, it can catch disease that has penetrated the preceding layers before it becomes irreversible.

3.5 Total Worker Health

The Total Worker Health approach advanced by the U.S. National Institute for Occupational Safety and Health integrates protection from work-related hazards with the promotion of overall wellbeing (Schill & Chosewood, 2013). This is particularly relevant because occupational and personal risk factors interact — smoking and asbestos exposure, for example, multiply lung cancer risk far beyond either alone (Schulte et al., 2012). Early detection programs that consider the whole worker are better positioned to identify and attribute disease accurately.

4. CORE COMPONENTS OF OCCUPATIONAL MEDICINE PROGRAMS

An effective early-detection program is not a collection of isolated examinations but an organised cycle. The following components, recognised across international guidance and the ICOH (2014) Code of Ethics, form its backbone.

4.1 Hazard Identification and Exposure Assessment

Detection begins with knowing what workers are exposed to. Workplace walk-throughs, job–exposure matrices, industrial hygiene sampling, and safety data sheets establish which hazards are present and at what intensity. Exposure assessment determines who requires surveillance, which tests are appropriate, and how frequently they should be performed. Without it, surveillance becomes either indiscriminate — wasting resources on low-risk workers — or blind to emerging hazards.

4.2 Pre-placement and Baseline Assessment

Pre-placement assessments serve two legitimate purposes: confirming fitness for specific job demands and establishing a health baseline against which later changes are measured. Baseline audiograms, spirometry, skin assessment, and relevant blood parameters are the reference points that make early detection possible. A 15% decline in FEV₁ is meaningful only if the worker's starting value is known; a population-reference comparison alone may not reveal a decline until substantial function has been lost. Ethically, pre-placement assessment must not become a tool of unjustified exclusion, and its findings should be confined to fitness conclusions rather than full clinical detail shared with employers (ICOH, 2014).

4.3 Periodic Medical Surveillance

Periodic surveillance is the engine of early detection. Its frequency and content are determined by the hazard and its exposure intensity. The critical analytical principle is **longitudinal comparison**: each result is interpreted against the individual's own baseline and trend, and aggregated results are analysed by work group to detect clusters. A single worker's standard threshold shift may reflect an off-the-job exposure; a pattern of shifts in one production line signals a control failure.

4.4 Biological Monitoring

Biological monitoring measures a chemical, its metabolite, or an early effect in blood, urine, or exhaled air. It integrates exposure from all routes — inhalation, skin absorption, ingestion — and accounts for individual variation in work rate and hygiene. Established examples include blood lead, urinary mercury, red-cell cholinesterase for organophosphate pesticides, and urinary metabolites of solvents such as toluene and xylene. Biomonitoring for occupational health risk assessment allows intervention while biochemical changes are still reversible (Manno et al., 2010).

4.5 Sentinel Event Surveillance and Disease Registries

Rutstein et al. (1983) introduced the concept of the "sentinel health event (occupational)": an unnecessary disease, disability, or untimely death whose occurrence signals that prevention has failed and that other workers may be at risk. Mandatory notification, occupational disease registries, and linked compensation data enable national authorities to identify high-risk industries and to target inspections. Comparative evaluations show that the quality of national occupational disease surveillance varies widely and is strongly shaped by notification rules, physician training, and the link to compensation (Spreeuwerts et al., 2010).

4.6 Exit and Post-Employment Surveillance

Because many occupational diseases manifest after employment ends, exit examinations and post-employment surveillance for workers exposed to carcinogens or fibrogenic dusts are essential. Exposure records retained for the long term — ideally integrated with national health records — allow clinicians to recognise an occupational aetiology decades later.

Table 2. Components of an Occupational Medicine Program and Their Detection Role

Component	Primary Function	Contribution to Early Detection
Exposure assessment	Identify and quantify hazards	Defines who needs surveillance and which tests

Component	Primary Function	Contribution to Early Detection
Pre-placement assessment	Fitness and baseline	Provides the individual reference point for change
Periodic surveillance	Repeated health assessment	Detects pre-clinical change through longitudinal comparison
Biological monitoring	Estimate internal dose	Identifies excessive absorption before toxicity
Sentinel surveillance	Case-triggered investigation	Converts single cases into workforce protection
Exit / post-employment	Long-latency follow-up	Captures diseases appearing after exposure ends
Data management	Record, analyse, report	Enables group trend analysis and national statistics

5. EARLY DETECTION ACROSS MAJOR DISEASE GROUPS

5.1 Occupational Respiratory Disease

Occupational exposures contribute substantially to the global burden of non-malignant respiratory disease, including chronic obstructive pulmonary disease, asthma, and pneumoconioses (Blanc et al., 2019; Driscoll et al., 2005). Silicosis remains a major concern in construction, quarrying, tunnelling, and the engineered-stone industry, where new outbreaks with rapid progression have been reported internationally (Leung et al., 2012). Early detection relies on standardised respiratory questionnaires, spirometry interpreted against personal baselines, and chest radiographs read according to the ILO International Classification of Radiographs of Pneumoconioses. For occupational asthma, serial peak expiratory flow recordings at and away from work provide a sensitive, low-cost signal. Early removal from sensitising exposure is the single most important determinant of a favourable prognosis.

5.2 Noise-Induced Hearing Loss

Noise is among the most prevalent occupational hazards worldwide, and a substantial proportion of adult-onset hearing loss is attributable to occupational noise (Nelson, Nelson, et al., 2005). The disease is irreversible but entirely preventable, and it is ideally suited to early detection: the characteristic audiometric notch at 3–6 kHz appears well before the worker perceives difficulty with speech. Hearing conservation programs combine noise mapping, engineering controls, hearing protection, education, and annual audiometry with standard threshold shift analysis. The value of the program lies less in the audiogram itself than in the response it triggers — refitting protection, relocating the worker, and investigating the noise source.

5.3 Work-Related Musculoskeletal Disorders

Musculoskeletal disorders are the leading cause of work-related disability in many economies. Systematic evidence links ergonomic risk factors to osteoarthritis and other musculoskeletal diseases (Hulshof et al., 2021). Early detection here is primarily symptom-based: periodic administration of standardised questionnaires, combined with ergonomic risk assessment, identifies workers and tasks with emerging problems before chronic pain and functional limitation are established. Healthcare workers, particularly nurses and patient-handling staff, are a high-risk group that is often overlooked.

5.4 Occupational Skin Disease

Contact dermatitis, irritant and allergic, accounts for most occupational skin disease and is highly prevalent among healthcare, cleaning, hairdressing, food-processing, and construction workers. Simple periodic skin inspection and symptom questionnaires detect early changes, and patch testing identifies specific allergens. Early recognition allows substitution of the agent, glove selection, and skin-care programs that frequently prevent progression to chronic, career-ending dermatitis.

5.5 Occupational Cancers

Occupational carcinogens — including asbestos, crystalline silica, diesel engine exhaust, benzene, and ionising radiation — cause a significant share of cancers in exposed populations (Kauppinen et al., 2000). Early detection of occupational cancer faces the challenges of long latency and limited screening tools. Nonetheless, registries of exposed workers, long-term exposure records, and targeted screening for high-risk groups — for example, low-dose computed tomography for heavily asbestos-exposed smokers — can enable earlier diagnosis. Equally important is ensuring that oncologists routinely record occupational history so that cases are recognised and notified.

5.6 Heat-Related Illness

Occupational heat strain impairs both health and productivity; a systematic review found that a substantial proportion of workers in hot conditions experience heat strain, with measurable productivity losses and risk of acute kidney injury (Flouris et al., 2018). Early detection combines environmental monitoring using wet-bulb globe temperature, acclimatisation programs, supervisor and buddy recognition of early symptoms, and, in high-risk groups, periodic assessment of renal function. Climate change is expanding the geographic and seasonal reach of this hazard, making it a growing priority for occupational medicine.

5.7 Work-Related Mental Health Disorders

Psychosocial hazards — high demands with low control, effort–reward imbalance, long working hours, shift work, workplace violence, and bullying — are associated with depression, anxiety, burnout, and cardiovascular disease. The WHO/ILO joint estimates identified long working hours as the leading occupational risk factor for mortality through ischaemic heart disease and stroke (Pega et al., 2021). Early detection relies on validated screening instruments, organisational psychosocial risk assessment, and confidential access to occupational mental health services. Because stigma suppresses disclosure, confidentiality and a non-punitive culture are prerequisites.

6. THE SAUDI ARABIAN CONTEXT AND VISION 2030

6.1 Labour Market and Hazard Profile

Saudi Arabia's occupational health landscape is shaped by several distinctive features. The economy is undergoing deliberate diversification under Vision 2030, expanding sectors such as mining, manufacturing, construction of giga-projects, logistics, and tourism, each with its own hazard profile. The workforce includes a large share of expatriate workers, many employed in construction, maintenance, and services, who may face language barriers, shorter contracts, and limited continuity of care — factors associated internationally with elevated occupational risk and under-detection (Moyce & Schenker, 2018). Extreme summer temperatures make heat stress a structural hazard rather than an occasional one.

6.2 Regulatory and Institutional Landscape

Occupational safety and health responsibilities are distributed across several bodies. The Ministry of Human Resources and Social Development (MHRSD) sets and enforces workplace safety regulations, including the seasonal ban on outdoor work during peak midday hours in summer, which constitutes an important primary-prevention measure against heat illness. The General Organization for Social Insurance (GOSI) administers the occupational hazards branch, covering compensation and treatment for work injuries and occupational diseases. The Ministry of Health and the Public Health Authority contribute to surveillance and public health policy, and the establishment of a national council for occupational safety and health has strengthened inter-agency coordination. Within healthcare institutions, the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI) includes employee health requirements — immunisation, post-exposure management, and staff health screening — in its accreditation standards. The Saudi Commission for Health Specialties (SCFHS) oversees postgraduate training in occupational medicine and the professional registration of occupational health practitioners, which is fundamental to building the specialist workforce required for credible surveillance.

6.3 Alignment With the Health Sector Transformation Program

The Health Sector Transformation Program emphasises a shift from treatment toward prevention, the adoption of population health management, and the development of integrated digital health infrastructure (Health Sector Transformation Program, 2021). Occupational medicine aligns closely with each objective. Workplaces provide organised access to large adult populations

that may otherwise have little contact with preventive services. National digital platforms, including the unified electronic health record environment and the Nphies health information exchange, create potential to link occupational exposure data, surveillance findings, and clinical diagnoses, which would substantially strengthen recognition of occupational causation.

The workplace is one of the most efficient platforms for prevention: it brings together exposed populations, identifiable hazards, and an accountable employer.

6.4 Context-Specific Priorities

- ◆ **Heat stress surveillance** for outdoor workers in construction, oil and gas, and agriculture, including renal function monitoring in high-risk groups.
- ◆ **Silica and dust surveillance** in construction, quarrying, cement, and the growing mining sector.
- ◆ **Healthcare worker health**, covering blood-borne exposure, tuberculosis screening, musculoskeletal strain, dermatitis, and burnout.
- ◆ **Expatriate worker inclusion**, with multilingual communication, continuity of records across employers, and exit examinations.
- ◆ **SME coverage**, through shared or contracted occupational health services for enterprises unable to maintain in-house programs.

7. BARRIERS TO EARLY DETECTION

Despite well-established principles, early detection frequently fails in practice. The barriers are interlinked and operate at the level of the worker, the clinician, the employer, and the system.

Table 3. Barriers to Early Detection and Corresponding Strategies

Barrier	Consequence	Strategic Response
Omission of occupational history in routine care	Occupational causation is never considered	Brief structured occupational history fields in EHRs; clinician training
Long latency between exposure and disease	Link to past employment is lost	Long-term exposure records; post-employment surveillance
Worker fear of job loss or deportation	Symptoms concealed; screening avoided	Confidentiality safeguards; protection from discrimination; trust-building
Surveillance as a compliance formality	Tests done but not analysed or acted upon	Outcome-based audit; mandatory follow-up pathways
Limited occupational medicine workforce	Variable quality of interpretation	Expand specialist training; upskill primary care and nurses
Fragmented data systems	Clusters and trends remain invisible	Interoperable surveillance data linked to national platforms
Weak SME coverage	High-risk workers fall outside programs	Shared services, incentives, and targeted inspection
Under-reporting tied to compensation disputes	National burden underestimated	Separate notification from liability; simplify reporting

Ethical tensions deserve particular attention. Occupational physicians serve workers but are often employed or contracted by employers. The ICOH (2014) Code of Ethics is unequivocal that the primary aim of occupational health practice is to safeguard workers' health, and that medical information must remain confidential, with only fitness conclusions communicated to management. Where workers believe that a positive screening result will cost them their job, surveillance becomes an exercise in concealment, and early detection collapses. Building trust is therefore a technical requirement, not merely an ethical aspiration.

8. THE DETECT FRAMEWORK

Drawing on the preceding analysis, this paper proposes the **DETECT Framework**, an integrated model for organising occupational medicine programs around early detection. The framework treats early detection as a system property emerging from six mutually reinforcing pillars, linked through a continuous improvement cycle.

Table 4. The DETECT Framework for Early Detection of Occupational Diseases

Pillar	Core Question	Key Actions	Indicators
D — Data-driven surveillance	Are health data captured, linked, and analysed?	Standardised digital records; group-level trend analysis; linkage with national health platforms	Proportion of results analysed longitudinally; clusters identified
E — Exposure characterisation	Do we know who is exposed to what, and how much?	Hazard mapping; job–exposure matrices; industrial hygiene sampling	Workers with documented exposure profiles
T — Targeted screening	Are the right tests applied to the right workers at the right frequency?	Hazard-specific protocols; baseline and periodic testing; biomonitoring	Coverage of eligible workers; protocol adherence
E — Early intervention	Does an abnormal result lead to timely action?	Defined response pathways; exposure reduction; referral; job modification	Time from abnormal result to action
C — Collaborative governance	Are roles, ethics, and accountabilities clear?	Joint employer–worker–clinician committees; confidentiality policy; regulatory reporting	Notification rate; worker trust indices
T — Tracking & improvement	Is the program learning and improving?	Outcome audit; incidence trends; feedback into primary prevention	Stage at detection; incidence over time

8.1 Operating Logic of the Framework

The framework is cyclical. Exposure characterisation defines the population at risk; targeted screening generates findings; data-driven surveillance converts individual findings into group-level intelligence; early intervention addresses both the individual and the exposure; collaborative governance ensures that action is legitimate, confidential, and enforced; and tracking evaluates whether disease is being detected earlier and prevented more effectively, feeding lessons back into exposure control. In Donabedian's terms, D, E, and C strengthen structure; T and E strengthen process; and the final T measures outcomes.

8.2 Implementation Phasing

◆ **Phase 1 — Foundation (0–12 months):** hazard mapping, baseline assessments for high-risk groups, standardised digital records, and a confidentiality policy.

◆ **Phase 2 — Consolidation (12–24 months):** full periodic surveillance protocols, defined response pathways, group-level analysis, and regulatory notification.

◆ **Phase 3 — Maturity (24–36 months):** outcome-based audit, linkage with national health platforms, post-employment surveillance, and benchmarking across sites and sectors.

9. DIGITAL INNOVATION AND FUTURE DIRECTIONS

Digital technologies are reshaping the possibilities for early detection. Electronic occupational health records allow automatic comparison of each result with the worker's baseline and with peer groups, flagging significant shifts that might be missed in manual review. Integration of occupational fields into general electronic health records prompts clinicians to consider occupational causation in routine care.

Wearable sensors now permit continuous monitoring of noise dose, heart rate, core temperature estimates, and posture, providing individualised exposure data that previously required costly hygiene surveys. Artificial intelligence applications are being developed for automated reading of chest radiographs for pneumoconiosis, analysis of audiometric trends, and prediction of musculoskeletal risk from movement data. These tools are promising but carry real risks: algorithmic bias, privacy breaches, and the potential misuse of continuous worker monitoring for performance surveillance rather than health protection. Their adoption should be governed by clear data-protection rules, worker consultation, and validation in local populations.

Future research priorities include rigorous evaluation of surveillance programs against outcome measures rather than activity counts; national studies estimating the burden of occupational disease in Saudi Arabia; evaluation of heat-stress interventions under local climatic conditions; and implementation research on extending occupational health services to SMEs and mobile workforces. Evidence from low- and middle-income settings indicates that well-chosen essential interventions can be both effective and affordable (Verbeek & Ivanov, 2013).

10. RECOMMENDATIONS

10.1 For Policymakers and Regulators

- ◆ Strengthen mandatory notification of occupational diseases and separate notification from compensation disputes to reduce under-reporting.
- ◆ Establish a national occupational exposure and disease registry linked to digital health platforms.
- ◆ Develop national hazard-specific surveillance standards for silica, noise, heat, and chemical exposures.
- ◆ Provide incentives and shared-service models to extend occupational health coverage to SMEs.

10.2 For Employers

- ◆ Conduct and regularly update workplace exposure assessments as the foundation of surveillance.
- ◆ Treat abnormal surveillance results as prompts to improve controls, not as grounds for exclusion.
- ◆ Guarantee worker confidentiality and protection from discrimination following positive findings.

10.3 For Occupational Health Professionals

- ◆ Interpret results longitudinally against personal baselines and analyse group-level trends.
- ◆ Maintain defined response pathways with time standards from abnormal result to action.
- ◆ Educate primary care and specialist colleagues to record occupational history routinely.

10.4 For Educators and Researchers

- ◆ Expand occupational medicine training capacity and integrate occupational health into undergraduate medical and nursing curricula.
- ◆ Generate local evidence on the burden of occupational disease and the effectiveness of surveillance programs.

- ◆ Evaluate digital and AI-based detection tools for accuracy, equity, and ethical acceptability.

11. CONCLUSION

Occupational diseases are, in principle, among the most preventable of all diseases: their causes are known, their settings are identifiable, and an accountable party exists to control them. Yet their latency, non-specific presentation, and the social and economic sensitivities surrounding them allow them to remain hidden. Occupational medicine programs offer the principal mechanism for bringing these conditions to light early enough to make a difference — to the affected worker through timely treatment and removal from exposure, and to the wider workforce through corrected workplace conditions.

This review has shown that early detection depends on far more than the availability of screening tests. It requires sound exposure assessment, personal baselines, longitudinal and group-level analysis, defined response pathways, trustworthy and ethical governance, and the continuous use of findings to improve primary prevention. The proposed DETECT Framework organises these elements into a coherent cycle that can guide program design, implementation, and evaluation.

For Saudi Arabia, the convergence of rapid economic diversification, distinctive hazards such as extreme heat, a diverse workforce, and an ambitious health sector transformation creates a timely opportunity. By embedding occupational surveillance within national digital health infrastructure, strengthening regulatory coordination, and investing in the occupational health workforce, the Kingdom can ensure that the economic gains of Vision 2030 are matched by a healthier, more productive, and better-protected workforce.

REFERENCES

- [1] Blanc, P. D., Annesi-Maesano, I., Balmes, J. R., Cummings, K. J., Fishwick, D., Miedinger, D., Murgia, N., Naidoo, R. N., Reynolds, C. J., Sigsgaard, T., Torén, K., Vinnikov, D., & Redlich, C. A. (2019). The occupational burden of nonmalignant respiratory diseases: An official American Thoracic Society and European Respiratory Society statement. *American Journal of Respiratory and Critical Care Medicine*, 199(11), 1312–1334.
- [2] Donabedian, A. (1988). The quality of care: How can it be assessed? *JAMA*, 260(12), 1743–1748.
- [3] Driscoll, T., Nelson, D. I., Steenland, K., Leigh, J., Concha-Barrientos, M., Fingerhut, M., & Prüss-Üstün, A. (2005). The global burden of non-malignant respiratory disease due to occupational airborne exposures. *American Journal of Industrial Medicine*, 48(6), 432–445.
- [4] Flouris, A. D., Dinas, P. C., Ioannou, L. G., Nybo, L., Havenith, G., Kenny, G. P., & Kjellstrom, T. (2018). Workers' health and productivity under occupational heat strain: A systematic review and meta-analysis. *The Lancet Planetary Health*, 2(12), e521–e531.
- [5] Halperin, W. E., & Frazier, T. M. (1985). Surveillance for the effects of workplace exposure. *Annual Review of Public Health*, 6, 419–432.
- [6] Health Sector Transformation Program. (2021). *Health Sector Transformation Program delivery plan*. Vision 2030, Kingdom of Saudi Arabia.
- [7] Hulshof, C. T. J., Pega, F., Neupane, S., Colosio, C., Daams, J. G., Kc, P., et al. (2021). The effect of occupational exposure to ergonomic risk factors on osteoarthritis of hip or knee and selected other musculoskeletal diseases: A systematic review and meta-analysis from the WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury. *Environment International*, 150, 106349.
- [8] International Commission on Occupational Health. (2014). *International code of ethics for occupational health professionals* (3rd ed.). ICOH.
- [9] International Labour Organization. (2010). *List of occupational diseases (revised 2010)*. ILO.
- [10] International Labour Organization. (2023). *A call for safer and healthier working environments*. ILO.
- [11] Kauppinen, T., Toikkanen, J., Pedersen, D., Young, R., Ahrens, W., Boffetta, P., et al. (2000). Occupational exposure to carcinogens in the European Union. *Occupational and Environmental Medicine*, 57(1), 10–18.
- [12] Leung, C. C., Yu, I. T. S., & Chen, W. (2012). Silicosis. *The Lancet*, 379(9830), 2008–2018.

- [13] Manno, M., Viau, C., Cocker, J., Colosio, C., Lowry, L., Mutti, A., Nordberg, M., & Wang, S. (2010). Biomonitoring for occupational health risk assessment (BOHRA). *Toxicology Letters*, 192(1), 3–16.
- [14] Moyce, S. C., & Schenker, M. (2018). Migrant workers and their occupational health and safety. *Annual Review of Public Health*, 39, 351–365.
- [15] Nelson, D. I., Concha-Barrientos, M., Driscoll, T., Steenland, K., Fingerhut, M., Punnett, L., Prüss-Üstün, A., Leigh, J., & Corvalan, C. (2005). The global burden of selected occupational diseases and injury risks: Methodology and summary. *American Journal of Industrial Medicine*, 48(6), 400–418.
- [16] Nelson, D. I., Nelson, R. Y., Concha-Barrientos, M., & Fingerhut, M. (2005). The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine*, 48(6), 446–458.
- [17] Pega, F., Náfrádi, B., Momen, N. C., Ujita, Y., Streicher, K. N., Prüss-Üstün, A. M., et al. (2021). Global, regional, and national burdens of ischemic heart disease and stroke attributable to exposure to long working hours for 194 countries, 2000–2016. *Environment International*, 154, 106595.
- [18] Reason, J. (2000). Human error: Models and management. *BMJ*, 320(7237), 768–770.
- [19] Rutstein, D. D., Mullan, R. J., Frazier, T. M., Halperin, W. E., Melius, J. M., & Sestito, J. P. (1983). Sentinel health events (occupational): A basis for physician recognition and public health surveillance. *American Journal of Public Health*, 73(9), 1054–1062.
- [20] Schill, A. L., & Chosewood, L. C. (2013). The NIOSH Total Worker Health™ program: An overview. *Journal of Occupational and Environmental Medicine*, 55(12 Suppl), S8–S11.
- [21] Schulte, P. A. (1989). A conceptual framework for the validation and use of biologic markers. *Environmental Research*, 48(2), 129–144.
- [22] Schulte, P. A., Pandalai, S., Wulsin, V., & Chun, H. (2012). Interaction of occupational and personal risk factors in workforce health and safety. *American Journal of Public Health*, 102(3), 434–448.
- [23] Spreeuwes, D., de Boer, A. G. E. M., Verbeek, J. H. A. M., & van Dijk, F. J. H. (2010). Evaluation of occupational disease surveillance in six EU countries. *Occupational Medicine*, 60(7), 509–516.
- [24] Takala, J., Hämäläinen, P., Saarela, K. L., Yun, L. Y., Manickam, K., Jin, T. W., et al. (2014). Global estimates of the burden of injury and illness at work in 2012. *Journal of Occupational and Environmental Hygiene*, 11(5), 326–337.
- [25] Verbeek, J., & Ivanov, I. (2013). Essential occupational safety and health interventions for low- and middle-income countries: An overview of the evidence. *Safety and Health at Work*, 4(2), 77–83.
- [26] Wilson, J. M. G., & Jungner, G. (1968). *Principles and practice of screening for disease* (Public Health Papers No. 34). World Health Organization.
- [27] World Health Organization & International Labour Organization. (2021). *WHO/ILO joint estimates of the work-related burden of disease and injury, 2000–2016: Global monitoring report*. WHO & ILO.