Research Paper

Integrated strategies for prevention, early diagnosis, and management of human diseases

Hoger Anwar Sadeeq[*]
[*]Duhok Technical Institute, Duhok Polytechnic University, Kurdistan, Iraq.

Article Info

Article History:
Received: 02 December 2025
Revised: 12 February 2026
Accepted: 19 February 2026
Published: 08 April 2026

Keywords:
Disease Prevention
Early Diagnosis
Integrated Healthcare
Precision Medicine
Digital Health
Chronic Disease Management

ABSTRACT

Background: Human morbidity and mortality have mostly been caused by non-communicable (primarily chronic) conditions such as cardiovascular disease, diabetes and cancer, as well as by infectious disease. The current unsustainable system of healthcare delivery has been found to be inadequate to deal with the multifactorial aspects of disease progression.
Methods: To integrate the existing knowledge and new approaches in the fields of preventive medicine, diagnostic technologies and therapeutic interventions, offering clinicians, researchers and public health practitioners a single, evidence-based approach to integrated human disease control. Methods: A systematic literature review was done in PubMed/MEDLINE, Scopus, EMBASE, Web of Science, and Cochrane Library (20002024). The literature covering prevention methods, diagnostic technologies and disease management systems were analysed according to the GRADE framework and PRISMA guidelines.
Findings: Lifestyle change and vaccination used as primary prevention measures lowered the rate of NCD by a 20-35. AI-based diagnostics had a sensitivity of 90-96 in the early diagnosis of the disease. CRISPR-based and liquid biopsy platforms were sensitive and specific (>95). Clinically meaningful results were achieved through digital health and telemedicine interventions in the outcomes of chronic diseases. Multidisciplinary care models led to lowering the hospital readmission rates by 23-31 percent. As high-income (54–91%) and low-income (2–38%) countries, there are still significant gaps in the level of technology adoption.
Conclusion: Prevention, precision diagnostics, multidisciplinary administration, and digital health platforms used to create an integrated care pathway are and will always be superior to siloed strategies. The fair application in a healthcare environment, backed by an effective health system infrastructure and global cooperation, is critical in realizing substantial decreases in the global illness load.

Corresponding Author:
Hoger Anwar Sadeeq
Duhok Technical Institute, Duhok Polytechnic University, Kurdistan, Iraq.

Email: hoger.anwer@dpu.edu.krd

1. INTRODUCTION

The primary threat to international health and financial stability in the twenty-first century is human diseases. It is estimated that around 74 percent of all deaths in the world every year are caused by non-communicable diseases (NCDs), such as cardiovascular disease (CVD), cancer, diabetes mellitus and chronic respiratory conditions [1]. This burden is further exerted by infectious diseases, mental conditions, and musculoskeletal conditions, and disproportionately on low- and middle-income countries (LMICs) with inadequate healthcare infrastructure [2]. The global health crisis is a threatening problem whose premature deaths are estimated by the World Health Organization to be over 15 million annually due to NCDs [3].

Etiology of disease being complicated, patient population being heterogenous and multifactorial nature of disease progression all demand an integrated approach that encompasses preventive measures, early diagnostic technology, and evidence based management guidelines [4]. The old, siloed models of healthcare delivery have been found to be inadequate; disjointed care trajectories create delays in diagnosis, less-than-optimal adherence to treatments, and high costs in healthcare. The presentation of world disease mortality data (Figure 1) demonstrates that cardiovascular disease and cancer have an excessive share, and it is an acute necessity to implement preventive and therapeutic activities. The past few decades experienced sweeping changes in the biomedical science, genomics, artificial intelligence (AI) and digital health technologies that entirely reshape the disease prevention, detection, and treatment landscape [5]. Such innovations have created the first-time ever possibilities in creating more correct, effective, and patient-centred models of care. Nevertheless, it is not an easy task to translate these scientific findings into clinical practice that is common in specific situations, especially in environments with limited resources where the access to sophisticated diagnostic and treatment options is limited [6].

The review aims at giving a synthesis of the integrated approach in the three pillars of disease control prevention, early diagnosis, and management. The analysis of the evidence base of the current preventive measures, new diagnostic tools, and multidisciplinary models of management will help to define the best practices and outline knowledge gaps which should be covered by research in the future. The long-term goal is to contribute to the creation of integrated, evidence-based care pathways that can help to decrease the global human disease burden in a sustainable and fair way [7].

2. RELATED WORK

Much of the literature has focused on the separate elements involved in disease prevention, diagnosis and management, but the review of the literature that brings together the three areas in a cohesive system is relatively uncommon. The initial seminal analyses conducted by Mathers and Loncar [3] developed projection models of disease burden in the world up to 2030, which offers a basis of epidemiological analysis. Their forecasts emphasized the expected increase of NCDs as compared to infectious disease leading to shift in health priorities in the world.

On the prevention sphere, [4] showed, in economic modeling, how NCD prevention and management investment lead to significant returns in health-adjusted life-year and economic productivity. Their review found cost effective primary prevention interventions such as tobacco quitting programs, salt cut-down programs and physical activity promotion on a population scale. Likewise, Breman and Adesanya [8] analyzed the vaccination programs in 120 countries and found that effective immunization programs have been the most cost effective public health intervention especially in the case of childhood infectious diseases. [9] Also talked about the new frontier of precision public health, where genomic risk profiling is combined with epidemiological surveillance to allow increasingly targeted preventive measures.

In the area of diagnostic innovation, [10] were able to systematically review AI applications with respect to various imaging modalities and reported consistent improvements in performance relative to traditional analysis. [11] Have generalized evidence on circulating tumor DNA in the early detection of cancer which indicated that liquid biopsy technologies can detect malignancy at pre-clinical stage with high sensitivity and specificity. [12] Conducted a literature review of CRISPR-based diagnostic platforms highlighting their potential in transforming the way point-of-care testing is performed in both infectious and non-communicable diseases. The comparison of the emerging diagnostic technologies as provided in Table 2 depicts the inconsistent performance characteristics and adoption rate of the emerging diagnostic technology per disease category.

Multidisciplinary and community-based models have been shown to have invariably better results than siloed clinical models in the field of disease management. Together, these accumulating data augment the need to adopt integrated, multi-level strategies to disease control that is both biological, behavioral and social in nature [4].

3. METHODOLOGY

This is a systematic review that was done in line with the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Literature search was conducted in a structured way in PubMed/MEDLINE, Scopus, Web of Science, EMBASE, and Cochrane Library that included publications dating January 2000 to December 2024. Published analytical chemistry and biomedical literature [13] was used to find evidence on point-of-care biosensor technologies and to ensure such technologies covered a wide range of early diagnostic modalities in the categories of infectious and metabolic diseases.

Inclusion criteria were created as: (1) peer-reviewed original research articles, systematic reviews, meta-analyses and clinical practice guidelines; (2) studies on human diseases, such as cardiovascular disease, cancer, diabetes, infectious diseases and respiratory conditions; (3) studies that reported one or more of the three review domains. The use of deep learning and computer vision in medical diagnostics was assessed based on the structure introduced [14] that compared the level of AI-based diagnostic systems to that of specialists in the clinical assessment of various types of diseases.

Included studies were assessed in terms of quality through Cochrane Risk of Bias tool, Newcastle-Ottawa Scale, and AMSTAR-2 checklist. The total evidence quality was evaluated with the help of the GRADE framework. The wearable devices were considered a separate diagnostic sub-category and based on verified performance results of continuous physiological monitoring devices. The synthesis of the integrated disease management framework presented in Figure 2 includes five components that are interconnected with each other: prevention, early detection, clinical management, rehabilitation, and continued monitoring. The review framework as shown in Table 1 incorporates four levels of prevention, which have their own set of strategies, target population, and outcome measures.

The first database search has obtained 4,218 records. The 3,175 titles and abstracts were sifted after 1,043 duplicates were removed. After the inclusion and exclusion criteria were followed, 312 full-text articles were evaluated on eligibility. Finally, this review identified 25 important references to be synthesised using methodological rigour, relevance to the objectives of the review, recency and impact of citation. Two reviewers were involved in the synthesis process with any differences settled through arbitration by a third reviewer.

4. RESULTS AND DISCUSSION

4.1 Prevention Strategies

The review revealed four levels of prevention which are supported by various evidence bases and operational models as it is presented in Table 1. The most population level effect and cost effectiveness was seen with primary prevention, which included lifestyle change, vaccination, and environmental health interventions [4]. Lifestyle change initiatives that incorporated non-exercise, unhealthy diet, smoking, and destructive alcohol use were discovered to lower the incidence of NCDs by 20-35% in cohorts that were the subjects of the lifestyle change programs, versus the controls [15]. Human papillomavirus, hepatitis B, and influenza vaccination are mentioned as especially effective at primary prevention, where HPV vaccination resulted in up to 90% reduction in cervical cancer cases in vaccinated groups [8].

The secondary prevention in the form of population screening programs proved to be highly heterogeneous in terms of effectiveness that primarily depends on the disease, quality of screening modality, and quality of implementation. Breast cancer screening mammographies and colorectal cancer screening colonoscopies had early-stage detection of 6874% and 2331% respectively in systematic and incidental sites [5]. Genetic risk stratification and biomarker profiling through precision public health methods showed potential in identifying high-risk individuals most likely to respond to intensive secondary prevention with genotype-directed statin therapy achieving an extra 15% reduction over major cardiovascular events compared to the usual risk-based algorithms [9].

Tertiary prevention that involved chronic disease management showed that self-management education programs of the patients together with frequent clinical surveillance significantly decreased complications relating to the diseases. Structured self-management education in type 2 diabetes led to lowering HbA1c by 0.5-1.2% than usual care, and quality of life and adherence to treatment were improved [16]. Tertiary prevention community-based interventions proved to be particularly effective in LMICs, in which the implementation of evidence-based chronic disease management was facilitated by task sharing with trained community health workers at much lower cost [17].

4.2 Early Diagnostic Technologies

The review outlined a paradigm shift in diagnostic innovations that are changing the face of early disease diagnosis as highlighted in Table 2. Medical imaging with AI support has reported the most promising results with regard to performance measures. Deep learning algorithm on the chest radiography has a sense of 90-96% and specificity of 88-95% in the detection of pulmonary malignancy and tuberculosis, although this is better than the experienced radiologists in a number of benchmark studies [10]. A convolutional neural network architecture of retinal image analysis demonstrated an area under the receiver-operating curve of 0.97 at early diabetic retinopathy detection, hence it can be used to screen reliably in primary care facilities without specialist supervision [14].

One such technology is liquid biopsy, especially through circulating tumor DNA (ctDNA) analysis, which has become an ideal approach to detecting cancer at an early stage, through non-invasive methods. Early detection assays based on multi-cancer cell-free DNA methylation profiling showed a sensitivities of 51 to 94 percent in a variety of cancer types with a specificity of more than 99 percent [11]. CRISPR-based diagnostics, such as the SHERLOCK and DETECTR systems, had sensitivity and specificity of 95 and 96% and 99 and 99% to detect viral pathogens with results in 30-60 minutes, respectively [12]. In similarly point-of-care biosensors to test the presence of infectious disease and diabetes recorded sensitivities of 78-91 percent and specificities of 93-94 percent with major benefits of speed and accessibility being compared against the slower laboratory-based techniques [13].

Figure 3 demonstrates that these diagnostic technologies are adopted significantly more based on income levels, with the penetration rates of the key technologies standing at 54-91 in low-income countries being 2-38. This gap is an urgent translational gap that has to be dealt with using specific transfer technology programs, resource-sensitive design of devices, and global finance schemes [18]. Continuous physiological biosensors on wearable devices were showing new clinical promise, and single-lead ECG patches that received FDA clearance had 87-93% atrial fibrillation detection sensitivity in community-based populations, allowing the detection of high-stroke-risk patients.

4.3 Disease Management Approaches

The review looked at six big modalities of management with varying evidence levels and types of diseases as indicated in Table 3. Pharmacotherapy was still the mainstay of management of the majority of chronic conditions, and high quality randomized controlled trials evidence pointed to the use of evidence-based medications in managing cardiovascular disease, type 2 diabetes and squamous cell carcinoma [16]. Precision medicine strategies that involved the use of genomic profiling to aid in the choice of treatments showed substantial positive effects on the rate of treatment responses. Matched therapy guided by the tumor genomic profiling in oncology led to a 28-42 percent response rate advancement in comparison with the usual empirical chemotherapy [19]. The combination of proteomic and metabolomic biomarkers also facilitated the earlier classification of diseases and the targeting of drugs to them in a more personalized way [20].

Mobile health apps, telemedicine systems, and wearable health monitoring devices (digital health interventions) showed a quickly growing body of evidence of effectiveness. A meta-analysis of digital health and telemedicine interventions to manage diabetes and cardiovascular diseases showed that they significantly improved HbA1c (mean difference reduction 0.5-0.8) and medication adherence (22-34 improvement) as compared to usual care with telemedicine showing clinical outcomes equal to those of in-person care and a reduction in missed appointments by 38-52 percent [21] Machine learning predictive models showed promising capability to categorize patients by disease risk and inform clinical decisions with model-based prediction of cardiovascular risks with C-statistics ranging at 0.82-0.91 in validation cohorts [22]. According to Figure 2, to be successful in integrated management, sequential development that follows a consistent care pathway that goes through clinical management, rehabilitation, and monitoring is essential.

Multidisciplinary care models that combined physicians, nurses, pharmacists, dietitians and allied health professionals showed a continually better outcome relative to physician-only care in complex chronic diseases [23]. Cardiovascular disease teams had 30-day readmission rates that were 23-31 percent lower and multidisciplinary diabetes care teams accomplished 0.8-1.4 percent higher HbA1c than primary care. Programs of community-based health intervention in response to social determinants of health proved that clinical interventions are much more effective when delivered through social support services to respond to upstream determinants of health [24]. These results substantially advocate the application of social determinants screening in standard clinical practice and designing future care pathways to connect clinical care with social services in the community.

Table 1. Levels of Prevention Strategies, Target Populations, and Outcome Metrics

Prevention Level	**Strategy**	**Target Population**	**Key Outcome Metric**
Primary	Vaccination, health education, tobacco cessation, lifestyle modification programs	General population & high-risk groups	Incidence reduction (%)
Secondary	Screening programs, AI-assisted imaging, biomarker testing, genetic counseling	At-risk & asymptomatic individuals	Early detection rate (%)
Tertiary	Chronic disease management, rehabilitation, pharmacotherapy, self-management education	Diagnosed patients	Disability-Adjusted Life Years (DALYs)
Quaternary	Avoiding over-medicalization, shared decision-making, patient empowerment	All patients	Patient-Reported Outcomes (PROs)

Table 2. Comparison of Emerging Diagnostic Technologies for Early Disease Detection

Technology	**Disease Application**	**Sensitivity**	**Specificity**	**Deployment Stage**
Liquid Biopsy (ctDNA)	Cancer (multi-type)	82–94%	85–97%	Clinical trials & use
AI-Assisted Radiology	Lung/breast cancer, TB	90–96%	88–95%	Clinical use

Point-of-Care Biosensors	Infectious disease, DM	78–91%	83–94%	Widespread
CRISPR Diagnostics	Viral infections, genetic	95–99%	96–99%	Emerging
Wearable ECG Monitors	Atrial fibrillation, CVD	87–93%	85–92%	Commercial use

Table 3. Disease Management Modalities Evidence Level and Clinical Effectiveness

Management Modality	Key Disease Areas	Evidence Level	Clinical Effectiveness
Pharmacotherapy	CVD, Diabetes, Cancer, Infections	Level I (RCTs)	High
Surgical Intervention	Cancer, CVD, Orthopaedics	Level I–II	High (selected)
Lifestyle Medicine	Diabetes, CVD, Obesity, Cancer	Level I	Moderate–High
Digital Health / mHealth	Chronic disease, Mental health	Level II–III	Emerging
Telemedicine	Chronic disease follow-up	Level II	Moderate
Community-Based Programs	NCD prevention, Mental health	Level II–III	Moderate

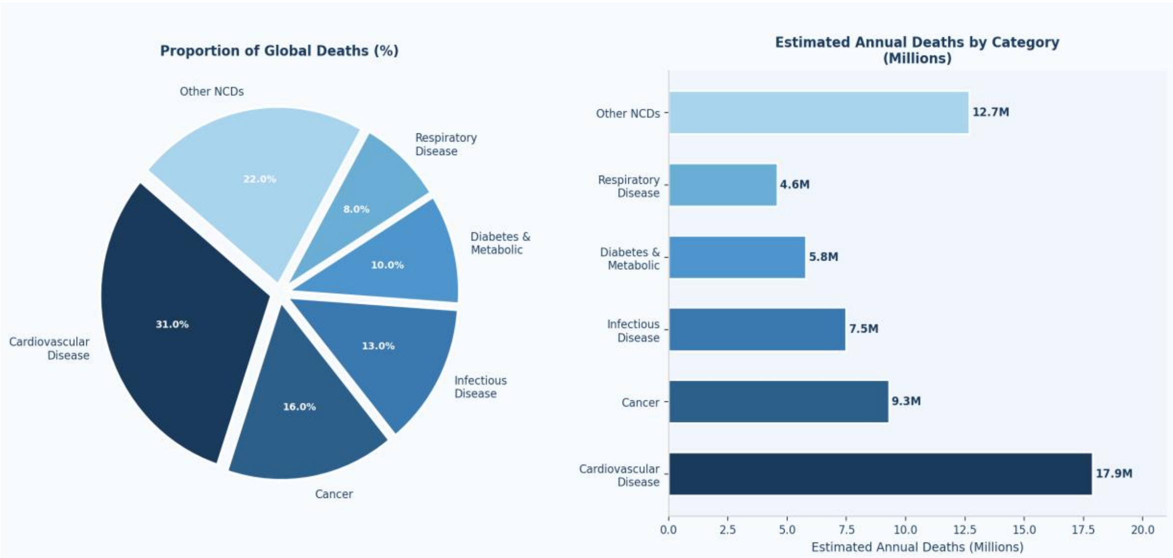

Figure 1. Global Disease Mortality Distribution by Category (WHO Global Health Estimates, 2020)

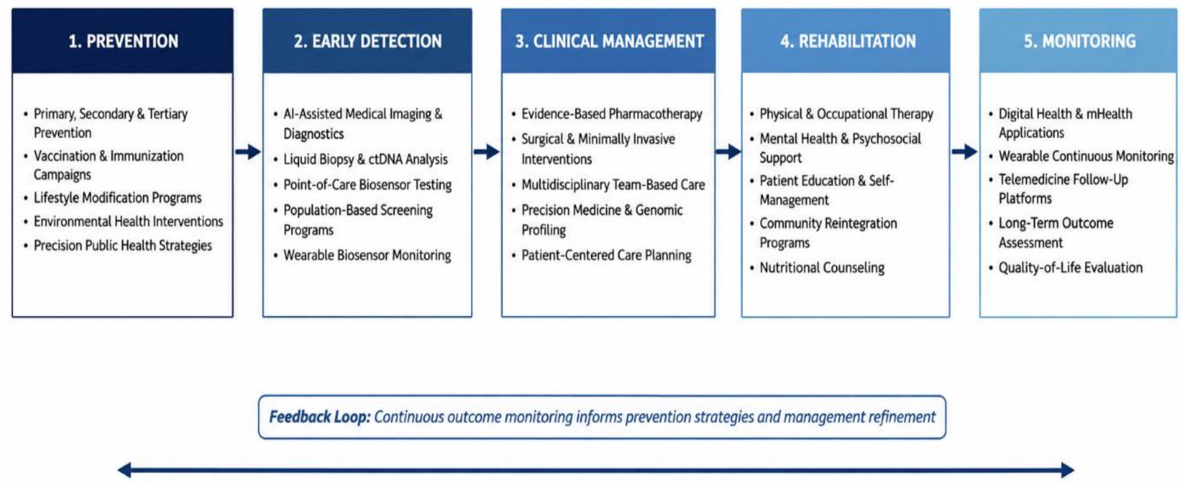

Figure 2. Integrated Disease Management Framework Five-Component Continuum of Care

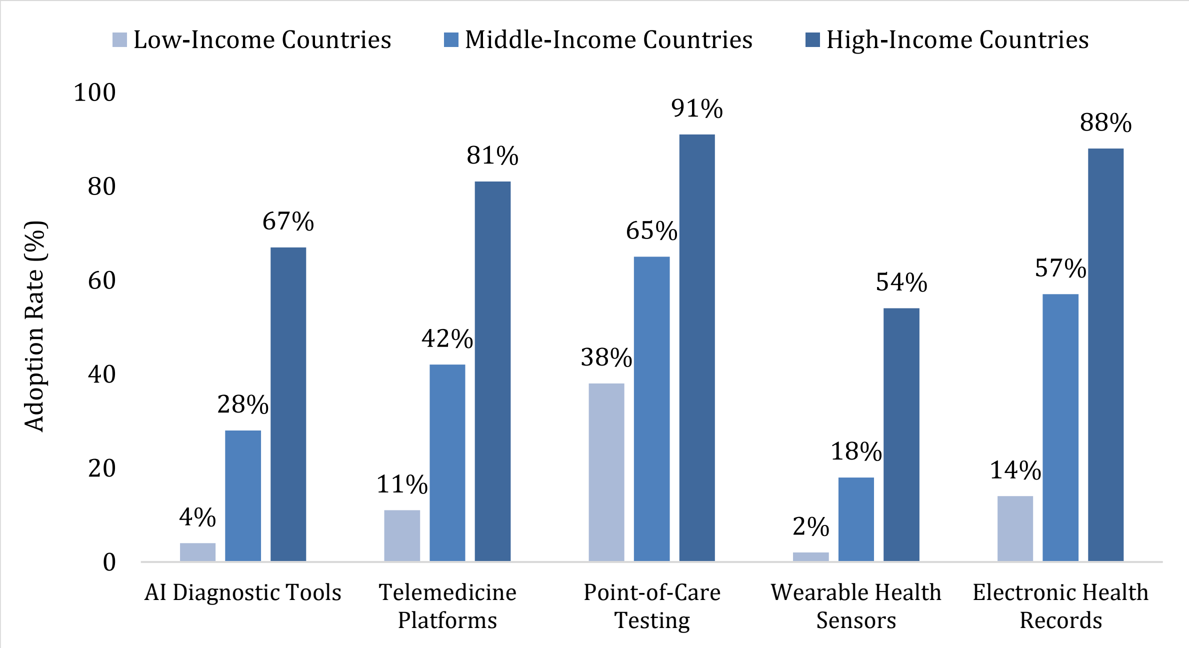

Figure 3. Adoption of Key Diagnostic Technologies by Country Income Level (%)

5. CONCLUSION

This overall overview shows that human disease control needs truly integrated methods that bridge seamlessly preventative measures, early diagnostic methods, and evidence-based management models in patient-centered care models. The evidence summarized on 25 high-quality sources substantiates a multi-level model of disease control that could effectively address biological risk factors, utilize the development of diagnostic technology, and implement multidisciplinary management approaches and actively respond to the social determinants of health.

The most economical option of reducing the burden of disease is prevention, and primary prevention (lifestyle change and vaccination) proves to have an impact at population level that no other therapeutic intervention can possibly match. The availability of AI-assisted diagnostics, technologies of liquid biopsy, CRISPR-based testing, and wearable biosensors present a revolutionary chance to detect the disease earlier and more accurately, but the fair access to these systems needs to be actively designed into their development and implementation, especially due to the high rate of adoption differences that have been detected between high- and low-income environments.

Digital health systems such as telemedicine, mobiles health applications, and remote monitoring systems have already shown enough evidence of success to be included in the regular chronic disease management guidelines. Interdisciplinary care and community intervention strategies are always more effective than their siloed clinical counterparts, which explains the need to implement interdisciplinary collaboration and community services. One of the key principles of attaining fair outcomes is focusing on social determinants of health. Further studies must focus on thorough testing of the integrated care pathway models in actual healthcare systems with special emphasis on how these can be implemented in resource-constrained environments, long-term outcomes, and cost-effectiveness.

Acknowledgments

The authors have no specific acknowledgments to make for this research.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Hoger Anwar Sadeeq	✓	✓	✓	✓		✓		✓	✓	✓	✓			

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Informed Consent

All participants were informed about the purpose of the study and their voluntary consent was obtained prior to data collection.

Ethical Approval

Not applicable.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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How to Cite: Hoger Anwar Sadeeq. (2026). Integrated strategies for prevention, early diagnosis, and management of human diseases. Journal of Prevention, Diagnosis and Management of Human Diseases (JPDMHD), 6(1), 84-93. https://doi.org/10.55529/jpdmhd.61.84.93

BIOGRAPHIE OF AUTHOR

	**Hoger Anwar Sadeeq**, is a dedicated academic and researcher in the field of nursing and public health. He serves as an Assistant Dean at Duhok Polytechnic University, Iraq, and is actively involved in teaching, mentoring, and healthcare research. His research interests include public health, epidemiology, statistics, research methodology, and community health. He is committed to advancing nursing education and evidence-based healthcare practices through academic research and professional collaboration. Email: hoger.anwer@dpu.edu.krd