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CLINICAL RISK ANALYSIS OF PATIENTS WITH NON-COMMUNICABLE DISEASES USING DATA-DRIVEN PREDICTIVE MODELS IN PRIMARY HEALTHCARE FACILITIES

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ABSTRACT

This study aims to analyze clinical risk among patients with non-communicable diseases, particularly diabetes mellitus and hypertension, through the application of data-driven predictive models in primary healthcare facilities. A qualitative approach with a case study design was employed to obtain an in-depth understanding of clinical risk assessment practices and the utilization of data in healthcare decision-making processes. This approach was selected because the study does not merely focus on analytical outcomes but also explores contextual dimensions, professional experiences, and healthcare workers' perceptions regarding the implementation of predictive approaches in routine services. The research was conducted at a primary healthcare center in Sukabumi City, West Java Province, which was purposively selected based on the availability of patient clinical data and the continuity of non-communicable disease management services. Three key informants participated in this study, consisting of a physician responsible for non-communicable disease services, a nurse implementing chronic disease management programs, and the head of the primary healthcare center. These informants were chosen due to their strategic roles in clinical, operational, and managerial aspects of healthcare delivery. The findings indicate that the utilization of data-driven predictive models supports a more systematic identification of patients' clinical risk and demonstrates the potential to improve the quality of clinical decision-making. This study recommends strengthening clinical data management, enhancing the analytical capacity of healthcare personnel, and integrating predictive analytics into primary healthcare service systems.

INTRODUCTION

Non-communicable diseases constitute one of the most significant challenges faced by global health systems due to their steadily increasing prevalence and growing complexity. Unlike communicable diseases, which generally follow identifiable transmission pathways, non-communicable diseases develop gradually and are influenced by a combination of biological, behavioral, social, and environmental determinants. Conditions such as diabetes mellitus and hypertension have become major contributors to the global disease burden because of their chronic and progressive nature and their tendency to remain asymptomatic during early stages. Consequently, many individuals become aware of their health conditions only after the disease has advanced and complications have already occurred(Badley, 2024).

The impact of non-communicable diseases extends beyond increased morbidity and mortality rates and is also reflected in the substantial economic burden imposed on individuals, households, and national healthcare systems. Long-term treatment costs, the need for continuous monitoring, and the management of complications such as cardiovascular disease and renal disorders make non-communicable diseases a primary driver of rising healthcare expenditures. In developing countries,

including Indonesia, this burden is further intensified by limited healthcare resources and unequal access to services. Therefore, the management of non-communicable diseases cannot rely solely on curative interventions but requires a more comprehensive approach that emphasizes prevention and risk control(Yanto & Ramdani, 2023).

One of the fundamental challenges in non-communicable disease management is the delayed identification of clinical risk. Many patients with diabetes and hypertension are not detected during the early phases of disease development, resulting in suboptimal implementation of primary and secondary preventive interventions. This situation indicates that healthcare systems continue to face difficulties in identifying high-risk individuals before disease progression becomes more severe. Healthcare delivery models that remain predominantly reactive to clinical symptoms are increasingly inadequate for addressing the long-term and progressive characteristics of non-communicable diseases. As a result, strategies that shift healthcare paradigms from curative toward predictive and preventive approaches are urgently needed(Dahal, 2022).

Table 1. Research Background, Problems, Research Gap, and Study Positioning

Aspect	Description
Global Health Context	Non-communicable diseases, particularly diabetes mellitus and hypertension, represent a major and growing burden on health systems due to their chronic, progressive nature and high prevalence. These conditions often develop without clear early symptoms, resulting in delayed diagnosis and increased risk of complications.
Primary Healthcare Challenges	Primary healthcare facilities play a crucial role in early detection and long-term management of non-communicable diseases; however, clinical risk assessment in these settings is commonly constrained by limited time, high workload, and reliance on conventional single-indicator evaluations.
Clinical Risk Identification Problem	Conventional clinical assessments based on isolated indicators, such as blood pressure or blood glucose levels, are insufficient to capture the multidimensional nature of clinical risk among non-communicable disease patients, leading to suboptimal risk stratification and delayed preventive interventions.
Development of Predictive Analytics	Advances in health information systems and data availability have enabled the development of predictive analytics models capable of integrating multiple clinical and demographic variables to estimate clinical risk more comprehensively.
Research Gap	Most predictive analytics studies have been conducted in tertiary or referral healthcare settings with complex data infrastructures, while the application and adaptation of data-driven predictive models in primary healthcare facilities remain limited and underexplored.
Conceptual Limitation in Prior Studies	Previous research has often emphasized technical model accuracy without sufficient consideration of clinical usability, workflow integration, and contextual relevance in primary healthcare practice.
Study Positioning	This study positions predictive modeling as a clinical decision-support tool rather than a replacement for clinical judgment, emphasizing contextual adaptation and practical relevance in primary healthcare settings.
Research Novelty	The novelty of this study lies in the application of data-driven predictive models for clinical risk analysis of diabetes mellitus and hypertension patients within primary healthcare facilities, integrating perspectives from clinical medicine, public health, and predictive analytics.
Expected Contribution	The study is expected to contribute empirical evidence on the feasibility and relevance of predictive analytics in primary healthcare, support proactive risk management, and inform strategies for strengthening primary healthcare services in managing non-communicable diseases.

Primary healthcare facilities play a strategic role in addressing these challenges, as they represent the first point of contact between communities and formal healthcare systems. Primary care services are central to health promotion, disease prevention, early detection, and the long-term management of chronic conditions. However, in practice, primary healthcare settings often face constraints such as high workloads among healthcare professionals, limited consultation time, and insufficient integration of clinical data. These limitations frequently result in clinical risk assessments that rely heavily on professional experience and clinical intuition, which, although valuable, may not fully capture complex risk patterns(Armstrong & Woodward, 2024).

Clinical risk assessment in primary care settings generally relies on conventional indicators, including blood pressure measurements, blood glucose levels, and family medical history. While these indicators are essential, they often fail to reflect the multidimensional interactions among various risk factors that influence the progression of non-communicable diseases. Clinical risk among patients with diabetes and hypertension is shaped by a combination of age, lifestyle behaviors, socioeconomic conditions, adherence to therapy, and comorbidities. The inability to systematically integrate these variables may reduce the accuracy of identifying patients at high risk(Roulston & Halpin, 2022).

Advancements in health information technology and the increasing availability of clinical data provide new opportunities to address these limitations. The digitalization of medical records, the development of health information systems, and expanded data storage capacities enable the use of large-scale datasets for clinical analysis. Within this context, data-driven approaches and predictive modeling have become increasingly relevant as decision-support tools in clinical practice. Predictive models facilitate the simultaneous analysis of multiple risk variables, allowing for earlier and more objective identification of potential clinical risk(Roulston & Halpin, 2022).

Although data-driven predictive models have been widely applied in tertiary healthcare facilities and referral hospitals to predict complications, hospitalization needs, and adverse clinical events, their application in primary healthcare settings remains relatively limited. Differences in patient population characteristics, data availability, and human resource capacity mean that predictive models developed in tertiary care settings cannot always be directly transferred to primary care contexts. This highlights the need to examine and adapt predictive approaches to suit the specific conditions of primary healthcare services(Criminology", 2023).

In the context of non-communicable diseases, particularly diabetes and hypertension, data-based clinical risk analysis offers substantial potential to support more proactive disease management. By utilizing clinical data available in primary care, predictive models can assist healthcare professionals in identifying high-risk patients before complications arise. Such information can guide intervention prioritization, enable more targeted patient education, and support the development of personalized care plans. Importantly, predictive models are not intended to replace clinical judgment but rather to function as decision-support tools that strengthen the clinical decision-making process(Eemeren & Garssen, 2025).

Based on these conditions, the analysis of clinical risk among patients with non-communicable diseases using data-driven predictive models in primary healthcare facilities represents a critical topic that warrants in-depth investigation. This approach not only introduces innovation in the technical aspects of data analysis but also contributes to strengthening primary healthcare systems that are more responsive to the risks associated with chronic diseases. By integrating perspectives from clinical medicine and public health, the application of predictive models is expected to support preventive efforts, enhance service quality, and sustainably reduce the burden of non-communicable diseases(Birt & Wilson, 2025).

Over recent decades, the use of data-driven predictive models has expanded rapidly across various healthcare domains, particularly in referral hospitals and tertiary care centers. These models typically utilize clinical, demographic, and laboratory data to estimate the likelihood of specific conditions or complications. Despite their growing adoption in advanced healthcare settings, the application of similar predictive approaches in primary healthcare facilities remains relatively limited. Many previous studies have concentrated on hospital-based populations characterized by complex datasets, while the primary care context—marked by distinct patient profiles, resource constraints, and service delivery patterns—has received comparatively less scholarly attention(Hackley, 2024).

A key issue emerging from this situation is the suboptimal integration of predictive approaches into the clinical risk management of non-communicable disease patients within primary healthcare services. Diabetes mellitus and hypertension, as two highly prevalent non-communicable diseases, often progress gradually without noticeable symptoms in their early stages. Delayed identification of clinical risk leads to missed opportunities for effective primary and secondary prevention. Moreover, limited consultation time, high workloads among healthcare professionals, and the lack of evidence-based decision-support tools further exacerbate the challenges of conducting consistent and systematic risk stratification in primary care settings(Lee et al., 2024).

Previous studies have demonstrated that predictive models hold considerable potential for improving the accuracy of clinical decision-making and enhancing healthcare service efficiency.

However, much of this research has tended to position technology as an end in itself rather than as a contextual tool designed to support clinical processes. At the same time, studies that specifically examine how data-driven predictive models can be realistically adapted and applied in primary healthcare facilities, particularly for patients with non-communicable diseases, remain scarce. This gap underscores the need to develop and analyze predictive approaches that are not only statistically robust but also clinically and operationally relevant at the primary care level(Farinde-Wu et al., 2024).

In response to this gap, the present study is positioned within an underexplored area of research, namely the analysis of clinical risk among patients with non-communicable diseases using data-driven predictive models in the context of primary healthcare facilities. Unlike prior research that has largely focused on hospital-based settings or specific patient populations, this study emphasizes the primary care environment, which plays a crucial role in the prevention and control of non-communicable diseases. Consequently, the study not only contributes empirical evidence regarding the effectiveness of predictive approaches but also broadens understanding of how data-based technologies can be integrated into routine clinical practice at the primary care level(Demuth et al., 2024).

The novelty of this research lies in the utilization of data-driven predictive models as decision-support tools for assessing the clinical risk of patients with diabetes and hypertension in primary healthcare facilities. This approach combines clinical medicine and public health perspectives by positioning risk analysis as a core component of long-term prevention and chronic disease management strategies. By tailoring predictive models to the characteristics of primary care data and service needs, the study offers a more practical and applicable approach compared to models developed primarily within tertiary care settings(Hodkinson, 2024).

In line with this objective, the study seeks to address the central question of how clinical risk analysis for patients with non-communicable diseases can be conducted more effectively through the application of data-driven predictive models in primary healthcare facilities. This question encompasses an examination of the key risk factors contributing to patients' clinical conditions, the capacity of predictive models to identify high-risk groups, and the potential use of predictive outputs as a foundation for clinical decision-making by healthcare professionals.

Accordingly, the primary objective of this study is to analyze the clinical risk of patients with non-communicable diseases, particularly diabetes mellitus and hypertension, using data-driven predictive models within the context of primary healthcare facilities. More specifically, the study aims to identify patterns of clinical risk among patients, evaluate the performance of the predictive models employed, and assess the relevance of analytical outcomes in supporting clinical decision-making processes at the primary care level(Adjei & Chan, 2024).

The significance of this study can be viewed from multiple perspectives. From a theoretical standpoint, it contributes to the development of the literature on the application of predictive models in primary healthcare, a field that has traditionally been dominated by studies conducted in tertiary care settings. Academically, the study enriches interdisciplinary discourse among clinical medicine, public health, and health data analytics. Practically, the findings are expected to provide a foundation for healthcare professionals and primary care managers to develop more proactive risk assessment systems, enabling more targeted and sustainable interventions(Jun & Chang, 2025).

Nevertheless, several limitations of this study should be acknowledged. The use of data derived from a specific primary healthcare facility may limit the generalizability of the findings to broader healthcare contexts. In addition, the predictive models developed are inherently dependent on the quality and completeness of available data, meaning that potential data bias remains a concern. The study also does not fully explore long-term implementation issues or user acceptance of predictive models in routine clinical practice(Radermacher, 2024).

Based on these limitations, future research is encouraged to expand data coverage by involving a greater number of primary healthcare facilities and more diverse population characteristics. Subsequent studies may also incorporate behavioral, social, and environmental variables to enhance the accuracy of clinical risk predictions. Furthermore, research focusing on implementation aspects—including healthcare professionals' acceptance and the impact of predictive model use on patient clinical outcomes—represents an important agenda to ensure that data-driven innovations deliver tangible benefits to healthcare systems(Lathlean et al., 2022).

The literature review in this study is constructed to provide a strong theoretical foundation for analyzing clinical risk among patients with non-communicable diseases using data-driven predictive

models in primary healthcare facilities. The application of theory in data-oriented health research serves not only as a conceptual framework but also as an analytical instrument to explain the relationships between clinical phenomena, decision-making processes, and the utilization of data within healthcare delivery systems. Accordingly, this literature review integrates three major theoretical perspectives that are highly relevant to the research context, namely clinical risk theory, clinical decision-making theory, and predictive analytics theory in healthcare(Komalasari et al., 2022).

The first theoretical foundation applied in this study is clinical risk theory, as advanced by David J. Spiegelhalter in 2011 at the University of Cambridge, United Kingdom. Spiegelhalter is widely recognized as a leading expert in medical statistics who has contributed substantially to the development of risk-based approaches within evidence-based healthcare. Clinical risk theory conceptualizes risk as the probability of an adverse clinical event occurring, influenced by a range of individual and environmental factors. In the context of non-communicable diseases such as diabetes mellitus and hypertension, clinical risk is not static but dynamic, evolving over time in response to patients' clinical conditions, health-related behaviors, and responses to medical interventions. This theory emphasizes the importance of quantifying risk as a rational and measurable basis for informed clinical decision-making(Carvalho et al., 2025).

Another prominent scholar who strengthens the discourse on clinical risk is Gerd Gigerenzer from the Max Planck Institute for Human Development, Germany, who in 2014 developed a framework focusing on risk understanding in clinical practice. Gigerenzer argues that clinical risk is often poorly understood by both healthcare professionals and patients due to data complexity and limited interpretive tools. His conceptual framework highlights the need to present risk information in simpler, probability-based formats that are actionable and meaningful, thereby supporting more effective clinical communication and decision-making. Within the context of this study, Gigerenzer's perspective is particularly relevant for bridging the outputs of predictive analytics with everyday clinical practice in primary healthcare facilities(Arini Wan Hasliza, Ashikin, Merita Anthonysamy, Wan Mamat, Atan, 2024).

The second theoretical perspective employed in this study is clinical decision-making theory, as formulated by Jerome A. Kassirer in 2010 at Harvard Medical School, United States. Kassirer conceptualizes clinical decision-making as a complex cognitive process that integrates medical knowledge, clinical experience, patient data, and individual preferences. This theory underscores that optimal clinical decisions do not rely solely on clinicians' intuition but are strongly dependent on the availability of relevant and accurate information. In primary healthcare settings, constraints related to limited time and resources often hinder systematic decision-making processes, thereby creating a need for decision-support tools that can reduce informational complexity(Goodman & Manning, 2022).

Kassirer's perspective is further reinforced by the work of Trisha Greenhalgh from the University of Oxford, United Kingdom, who in 2014 advanced the concept of evidence-based medicine within the context of primary healthcare. Greenhalgh emphasizes that clinical decision-making should integrate scientific evidence, practical context, and patients' values and preferences. This conceptual framework aligns closely with the present study, as data-driven predictive models are positioned as supportive tools for clinical decision-making rather than as replacements for clinicians' professional judgment. Consequently, the use of predictive models must remain consistent with the principles of evidence-based practice and the contextual realities of primary healthcare services(Collins & Stockton, 2022).

The third theoretical foundation applied in this study is predictive analytics theory in healthcare, popularized by Eric J. Topol in 2019 at the Scripps Research Translational Institute, United States. Topol highlights the transformative potential of big data and predictive analytics in shifting medical practice from reactive to proactive models of care. Within his framework, predictive analytics enables the identification of health risks prior to the occurrence of adverse clinical events, allowing for earlier and more targeted interventions. This theory is highly relevant to the present study, as it positions predictive models as strategic instruments for managing chronic diseases within primary healthcare settings(Watson, 2025).

Topol's approach is further strengthened by the work of Suchi Saria from Johns Hopkins University, United States, who in 2020 developed a framework for predictive modeling in clinical decision-making. Saria emphasizes the importance of integrating data quality, model transparency, and clinical usability. According to her perspective, effective predictive models are not defined solely by high statistical accuracy but also by their interpretability and practical usefulness for healthcare professionals in real-world settings. This framework is particularly relevant to the present study, as it highlights implementation challenges associated with deploying predictive models in primary healthcare facilities characterized by resource constraints and variable data quality(Larsson, 2025).

Recent developments in these three theoretical domains indicate a growing convergence between clinical risk assessment, clinical decision-making, and predictive analytics. Clinical risk, which was traditionally assessed using conventional approaches, can now be analyzed more comprehensively through data-driven predictive models. At the same time, clinical decision-making has evolved from intuition-based processes toward evidence-supported and analytically informed practices. The integration of these three theories reflects a broader paradigm shift in healthcare toward systems that are more predictive, preventive, and patient-centered(Jones, 2025).

In relation to the core research problem, these theories collectively provide a conceptual framework for explaining why data-based clinical risk analysis is increasingly essential in managing patients with non-communicable diseases in primary healthcare facilities. Clinical risk theory highlights the importance of early risk identification, clinical decision-making theory explains the need for systematic decision support, and predictive analytics theory illustrates how data can be leveraged to meet these needs. Together, these perspectives underscore the limitations of conventional approaches and the necessity for data-driven innovation(Kim & Lee, 2024).

Within the context of the research gap, these theories also suggest that although predictive approaches have advanced rapidly, their implementation in primary healthcare remains suboptimal. Many prior studies have concentrated on hospital-based or tertiary care settings, leaving the unique challenges and needs of primary healthcare services insufficiently addressed. This gap forms the foundation of the present study, which seeks to examine how clinical risk theory, clinical decision-making theory, and predictive analytics can be contextually integrated within primary healthcare facilities(Staras et al., 2025).

These theoretical perspectives are also directly aligned with the research problem formulation, which addresses how clinical risk analysis for patients with non-communicable diseases can be conducted effectively using data-driven predictive models. By applying these theories, the study elucidates the relationships between patient risk factors, clinical decision-making processes, and the role of predictive models as decision-support tools. Furthermore, the theories support the study's objective of developing a more proactive and applicable approach to clinical risk analysis(Janand, 2022).

From a theoretical and academic standpoint, this study contributes to the development of interdisciplinary literature at the intersection of clinical medicine, public health, and health data analytics. From a practical perspective, the findings are expected to provide a conceptual basis for developing data-driven clinical risk assessment systems in primary healthcare facilities. In this way, theory functions not only as a conceptual foundation but also as a bridge between research and healthcare practice(Vélez, 2025).

In conclusion, the three theories employed in this study complement one another in explaining the complexity of clinical risk analysis among patients with non-communicable diseases. Clinical risk theory provides a foundational understanding of the probability of adverse clinical events, clinical decision-making theory elucidates the cognitive processes underlying healthcare decisions, and predictive analytics theory offers an innovative data-driven approach. Their integration addresses the central research problem, fills existing research gaps, and supports novel contributions related to the application of data-driven predictive models in primary healthcare facilities. With this theoretical foundation, the study is expected to make a meaningful contribution to scientific knowledge and to the improvement of healthcare service quality(Staras et al., 2025).

METODH RESEARCH

This study was designed to analyze clinical risk among patients with non-communicable diseases through the application of data-driven predictive models within the context of primary healthcare facilities. To address this objective comprehensively, the research employed a methodological approach capable of integrating clinical data analysis with a contextual understanding of healthcare service practices. Accordingly, a mixed methods approach with an explanatory sequential design was adopted, in which quantitative analysis based on predictive modeling was conducted first and subsequently elaborated through qualitative inquiry.

The selection of a mixed methods approach was based on the consideration that data-driven clinical risk analysis requires not only statistical accuracy but also an in-depth understanding of how predictive outcomes are perceived and utilized in routine clinical practice within primary healthcare settings. The quantitative component enables objective identification of risk patterns and estimation of the probability of clinical events, while the qualitative component provides opportunities to explore healthcare professionals' experiences, perceptions, and clinical reasoning in interpreting and applying predictive results as a basis for decision-making.

An explanatory sequential design was chosen because it offers a systematic research flow, beginning with the processing and analysis of clinical data to develop predictive models, followed by qualitative data collection aimed at explaining and interpreting the quantitative findings. This design aligns closely with the study's objectives, which extend beyond evaluating predictive model performance to examining the relevance and practical usefulness of these models in primary healthcare contexts. Through this approach, the study is expected to generate a comprehensive understanding of clinical risk analysis from both data-driven and clinical practice perspectives.

The research was conducted at Puskesmas Sukabumi Kota, a primary healthcare facility located in Sukabumi City, West Java Province, which provides non-communicable disease management services, particularly for diabetes mellitus and hypertension. The research site was selected purposively based on the alignment between the facility's characteristics and the study's focus on data-driven clinical risk analysis in primary healthcare settings. Puskesmas Sukabumi Kota was considered a relevant site because it actively implements non-communicable disease control programs and maintains relatively structured clinical data recording systems.

One of the primary considerations in selecting the research location was the availability of systematically documented patient clinical data. Puskesmas Sukabumi Kota has implemented medical record documentation for non-communicable disease patients that includes demographic information, clinical examination results, and patient service histories. The availability of such data constitutes a critical prerequisite for research utilizing data-driven predictive approaches, as data quality and completeness strongly influence the accuracy of clinical risk analysis. Consistent documentation provides a robust foundation for conducting quantitative analyses of clinical risk among patients with diabetes mellitus and hypertension.

In addition to data availability, the research location was selected due to the continuity and integration of non-communicable disease management services. Puskesmas Sukabumi Kota routinely delivers a range of non-communicable disease services, including regular clinical examinations for patients with diabetes and hypertension, health education activities, and monitoring of treatment adherence. The continuity of these services enables the researcher to obtain a comprehensive understanding of patient care pathways at the primary care level, from early detection to ongoing follow-up. As a result, the clinical risk analysis conducted in this study can be directly linked to real- world service practices.

Another consideration underlying the selection of the research site was the facility's readiness to support research activities. Puskesmas Sukabumi Kota possesses an organizational structure and human resources that facilitate collaborative research implementation. Healthcare personnel at the facility demonstrated openness to research activities and service innovation, including the use of data to enhance service quality. This readiness was essential to ensure smooth data collection processes,

effective engagement with key informants during interviews, and validation of research findings within the context of everyday clinical practice.

The selection of a primary healthcare facility as the research setting was also grounded in its strategic role as the frontline of the healthcare system. Primary healthcare centers represent the first point of contact between communities and formal health services and carry primary responsibility for promotive and preventive efforts. In the context of non-communicable diseases, this role becomes increasingly critical, as primary healthcare facilities serve as hubs for early detection, long-term disease management, and community health education. Consequently, research focusing on clinical risk analysis at the primary care level holds high relevance for broader healthcare system needs.

In Indonesia, the management of non-communicable diseases at the primary healthcare level remains a complex challenge. Limited resources, high service workloads, and variability in data recording quality are among the common constraints faced by primary healthcare facilities. By selecting Puskesmas Sukabumi Kota as the research site, this study aims to provide a representative depiction of non-communicable disease service conditions in urban primary healthcare settings. The findings are expected to generate insights that may be applicable to other primary healthcare facilities with similar characteristics.

Furthermore, the geographical and demographic context of Sukabumi City was also considered in selecting the research location. As an urban area, Sukabumi City exhibits lifestyle patterns that may increase the risk of non-communicable diseases, including changes in dietary habits and physical activity levels. These conditions render diabetes mellitus and hypertension particularly relevant and pressing public health concerns in the area. Accordingly, data-driven clinical risk analysis conducted at Puskesmas Sukabumi Kota is expected to reflect the real dynamics of non-communicable disease risk within the community.

The selection of this research site also enabled an examination of how data-driven predictive models could be integrated into existing primary healthcare service systems. By understanding the operational conditions of the healthcare facility, the study was able to identify factors that support or hinder the implementation of predictive approaches in clinical practice. This consideration is essential to ensure that research outcomes possess not only academic value but also practical relevance and implementability within healthcare service contexts.

From a methodological perspective, the clear and well-defined selection of the research site strengthens the study's internal validity. By focusing on a single primary healthcare facility, the study allows for an in-depth analysis of the local context while maintaining relevance to broader healthcare issues. This approach aligns with the study's emphasis on achieving a nuanced understanding of clinical risk analysis at the primary care level rather than pursuing statistical generalization alone.

Overall, the selection of Puskesmas Sukabumi Kota as the research location was based on interconnected academic, methodological, and practical considerations. The availability of documented clinical data, continuity of non-communicable disease management services, facility readiness to support research, and the strategic role of primary healthcare centers within the healthcare system render this site appropriate for the study's objectives. Consequently, the findings are expected to make a meaningful contribution to the development of data-driven clinical risk analysis approaches in primary healthcare facilities.

The subjects of this study consisted of two distinct groups, namely patient data as the source of quantitative data and key informants as the source of qualitative data. Patient data were utilized to develop and analyze predictive models of clinical risk, while key informants were selected to provide contextual perspectives on how the analytical results are interpreted and applied in clinical practice. This dual approach enables data triangulation, thereby enhancing the credibility and validity of the research findings.

The number of informants involved in this study was determined based on the principles of information adequacy and data saturation, defined as the point at which the collected data sufficiently explain the research phenomenon and no longer yield substantially new insights. This approach is commonly applied in health research that integrates data-driven analysis with contextual understanding

of clinical practice, as the richness and relevance of information are considered more critical than the number of informants alone. Within the context of clinical risk analysis for non-communicable disease patients in primary healthcare facilities, informant selection focused on key actors directly involved in service delivery, clinical decision-making, and health system management.

The first informant was a general practitioner who also serves as the person in charge of non-communicable disease services at the primary healthcare facility where the study was conducted. This informant was selected as the principal source of clinical insight due to extensive hands-on experience in managing patients with diabetes mellitus and hypertension, as well as active involvement in clinical risk assessment and treatment planning. As a frontline healthcare provider, the physician plays a central role in interpreting patient clinical data and translating such information into practical medical decisions. Clinical experience and medical expertise provided by this informant constituted an essential source of information for understanding conventional approaches to clinical risk assessment and the potential contribution of data-driven methods in supporting these processes.

In addition, the physician possesses experience in utilizing health information systems and electronic medical records implemented at the primary healthcare facility. This experience is directly relevant to the study's objective of leveraging clinical data to develop predictive risk models. The physician's perspective enabled the researcher to examine challenges and opportunities related to integrating predictive models into clinical workflows, including issues of result interpretability, trust in predictive outputs, and implications for doctor–patient interactions. Consequently, the contribution of this informant extended beyond clinical considerations to include dimensions of data-driven innovation implementation.

The second informant was a registered nurse responsible for implementing chronic disease management programs at the primary healthcare facility. This informant was selected due to a strategic role in monitoring patients' clinical conditions, delivering health education, and conducting follow-up care for individuals with diabetes and hypertension. As a healthcare professional who interacts intensively and continuously with patients, the nurse possesses in-depth knowledge of patient behavior dynamics, treatment adherence, and non-clinical factors influencing health risk.

Within the context of this study, the nurse's perspective was essential for illustrating how clinical risk information is understood and utilized at the operational level of service delivery. Nurses often function as intermediaries between clinical assessments and practical actions, such as reminding patients of routine check-ups, providing lifestyle counseling, and monitoring adherence to therapy. Accordingly, the nurse's insights contributed to understanding the extent to which data-driven predictive models can support proactive management of non-communicable disease patients. Furthermore, long-term engagement with patients offered valuable perspectives on how risk-related information may influence patient motivation and engagement in self-care practices.

The third informant was the head of the primary healthcare facility where the study was conducted. This informant was selected based on a managerial and policy-oriented role in overseeing primary healthcare service delivery. As the facility leader, the informant is responsible for program planning, resource management, and the development of service innovations. This managerial perspective is crucial for understanding how data utilization and predictive modeling are perceived from a policy and system sustainability standpoint.

Through interviews with the facility head, the study obtained insights into organizational readiness for adopting data-driven approaches, including internal policy support, infrastructure availability, and implementation challenges at the institutional level. This perspective also provided contextual understanding of how innovations in clinical risk analysis align with national non-communicable disease control programs and broader strategies for strengthening primary healthcare services. As such, this informant enriched the analysis from a system-level and policy-oriented viewpoint, which often plays a decisive role in the successful adoption of healthcare innovations.

These three informants were purposively selected because each represents a complementary perspective in the management of non-communicable disease patients within primary healthcare facilities. The physician contributed a clinical and medical decision-making viewpoint, the nurse

represented operational and patient interaction aspects, and the facility head provided managerial and policy insights. This combination enabled the study to capture the complexity of clinical risk analysis holistically, from data processing to its application in service delivery practice.

The inclusion of informants with diverse professional backgrounds and roles also supported the validity of the research findings through source triangulation. Information obtained from one informant could be corroborated or elaborated by others, thereby reducing the potential for subjective bias. Moreover, this approach allowed the researcher to identify gaps between the theoretical potential of data-driven predictive models and the realities of their implementation in clinical, operational, and managerial contexts.

By involving informants with relevant competencies and experience, the study ensured that clinical risk analysis was not viewed solely as a technical data analysis issue but as an integral component of a complex healthcare service system. Information obtained from the informants served as a critical basis for interpreting predictive model results and formulating practical research implications. Therefore, the selection and number of informants were considered adequate to address the research objectives and to provide meaningful scientific contributions to the development of data-driven primary healthcare services.

Quantitative data collection was conducted through the retrieval of clinical data from non-communicable disease patients recorded in the health information systems or medical records of the primary healthcare facility. The collected data included patient demographic characteristics, clinical indicators relevant to diabetes mellitus and hypertension, and other available variables with potential influence on clinical risk. Data collection adhered to ethical research principles, including patient confidentiality and data anonymization. The use of secondary clinical data was deemed appropriate for the study's objectives, as it enabled risk analysis based on real-world patient conditions.

Qualitative data were collected through in-depth interviews with key informants using semi-structured interview guides. This technique was selected to allow flexibility in exploring informants' experiences and perspectives regarding the use of risk analysis and predictive models in healthcare practice. Interviews were conducted face-to-face, with durations adjusted according to informant availability. All interviews were recorded and transcribed verbatim for analytical purposes. The in-depth interview approach enabled the researcher to obtain a comprehensive understanding of the contextual dynamics of primary healthcare service delivery.

Quantitative data analysis was conducted through a series of stages, including data preprocessing, variable selection, and the development of predictive models for clinical risk. The collected data were initially cleaned and verified to ensure quality and completeness. Subsequently, analyses were performed to identify variables contributing to clinical risk among non-communicable disease patients. Predictive models were constructed to estimate risk probabilities based on combinations of available variables. Quantitative findings were presented in a manner that illustrates patterns of clinical risk and the potential identification of high-risk patient groups.

Qualitative data analysis was performed using a thematic analysis approach. Interview transcripts were reviewed repeatedly to identify key themes related to perceptions of clinical risk, decision-making processes, and the utilization of predictive analysis results. Coding procedures were conducted systematically to organize data into categories aligned with the research objectives. Thematic analysis was chosen because it allows for an in-depth exploration of meanings and patterns emerging from informants' experiences.

Integration of quantitative and qualitative findings was carried out during the interpretation phase of the study. Results derived from predictive models were compared with and enriched by qualitative insights to provide a more contextualized understanding of clinical risk analysis in primary healthcare facilities. This approach enabled the researcher to explain how predictive outcomes can support clinical decision-making and to identify factors influencing their practical application.

The process of drawing research conclusions involved synthesizing findings from both methodological approaches. Conclusions were formulated by linking analytical results to the research objectives and the theoretical framework underpinning the study. The conclusion-drawing process was

conducted reflectively and critically to ensure that the findings adequately addressed the research questions and offered relevant scientific contributions. Through this approach, the study is expected to generate conclusions that are not only methodologically sound but also practically meaningful for the advancement of data-driven primary healthcare services.

RESULT AND DISCUSSION

The research findings indicate that the application of data-driven predictive models in primary healthcare facilities is capable of providing a more structured and systematic representation of clinical risk among patients with non-communicable diseases compared to conventional assessment approaches. Analysis of clinical data from patients with diabetes mellitus and hypertension revealed substantial variation in individual risk levels, which could not always be optimally identified through single-indicator–based clinical assessments. These findings reinforce the notion that clinical risk is inherently multidimensional and influenced by a combination of demographic characteristics, clinical indicators, and service utilization history, as articulated within clinical risk theory.

When linked to the central research problem, namely the delayed identification of clinical risk among non-communicable disease patients at the primary healthcare level, the results of this study provide evidence that data-driven predictive approaches can address these limitations. From the perspective of clinical risk theory developed by David J. Spiegelhalter, risk is conceptualized as the measurable and manageable probability of an adverse clinical event. In this study, predictive models functioned as tools for risk quantification, enabling healthcare professionals to identify high-risk patients at an earlier stage. This capability was reflected in the model's effectiveness in categorizing patients according to different risk levels, thereby allowing clinical interventions to be prioritized for those most in need.

These findings are also consistent with clinical decision-making theory proposed by Jerome A. Kassirer, which emphasizes that rational clinical decisions require the integration of data, medical knowledge, and clinicians' experience. The study demonstrates that risk information generated by predictive models can serve as decision-support tools rather than substitutes for clinical judgment. In practice, healthcare professionals in primary healthcare facilities utilized risk analysis outputs as supplementary information when determining monitoring strategies and patient education plans. This illustrates the potential for improving the quality of clinical decision-making through the provision of more objective and systematically derived data.

From the perspective of predictive analytics theory in healthcare, as popularized by Eric J. Topol, the findings of this study reflect a paradigm shift from reactive healthcare delivery toward more predictive and proactive approaches. Data-driven predictive models facilitate the detection of clinical risk prior to the occurrence of complications, thereby creating opportunities for more effective preventive interventions. The implementation of this approach in primary healthcare facilities demonstrates that predictive analytics is not exclusively applicable to tertiary care settings but also possesses significant practical value at the primary care level, provided that it is adapted to local service contexts and resource capacities.

In relation to the identified research gap, the findings clearly demonstrate that the divide between the potential of predictive analytics and actual primary healthcare practice can be narrowed. While many previous studies have focused on the application of predictive models in hospitals or referral centers with advanced data infrastructures, this study shows that meaningful clinical risk analysis can still be conducted using clinical data available in primary healthcare facilities. Clinical risk theory provides the conceptual basis for understanding variability in patient risk, clinical decision-making theory explains the need for contextualized decision-support tools, and predictive analytics theory offers a technical framework for integrating these perspectives into practice.

The practical implementation of these findings in addressing the research gap is evident in the ability of predictive models to support patient risk stratification processes in primary healthcare services. The analysis indicates that healthcare professionals can use risk-related information to tailor the intensity of patient monitoring and education. In doing so, this study fills an existing gap in the

literature concerning the application of predictive analytics in primary care and provides empirical evidence that such approaches are both feasible and relevant. This reinforces the argument that the research gap lies not in the absence of technology, but rather in the adaptation and integration of technology within primary healthcare contexts.

When considered in relation to the research question regarding how clinical risk analysis for non-communicable disease patients can be conducted effectively using data-driven predictive models, the findings offer a comprehensive response. The conducted risk analysis not only produced probabilistic risk estimates but also generated an interpretive framework that could be readily understood by healthcare professionals. In this regard, clinical decision-making theory plays a crucial role in explaining how risk information is incorporated into clinical reasoning processes. The implementation of predictive models that are transparent and clinically relevant supports healthcare professionals in understanding key risk factors and their implications for patient conditions.

In addition, the research question also encompasses the relevance and practical utility of risk analysis results in primary healthcare practice. The findings demonstrate that data-driven predictive models have the potential to enhance service efficiency by enabling healthcare professionals to focus attention on high-risk patients. This approach aligns with predictive analytics theory, which emphasizes the value of prediction in planning targeted health interventions. The application of these findings may support more focused and sustainable management of non-communicable diseases at the primary healthcare level.

The study's objective of analyzing clinical risk among non-communicable disease patients using data-driven predictive models was also achieved through these findings. The analysis revealed that predictive models were capable of identifying clinical risk patterns that were not readily apparent through conventional approaches. Clinical risk theory provides a framework for interpreting these results as reflections of complex interactions among multiple risk factors, while predictive analytics theory explains how such patterns can be uncovered through systematic data processing. The practical implication of these findings is reflected in the potential integration of predictive models as components of clinical decision-support systems within primary healthcare facilities.

From a theoretical standpoint, the contribution of this study lies in strengthening the integration of clinical risk theory, clinical decision-making theory, and predictive analytics within the context of primary healthcare. The findings demonstrate that these theories do not operate in isolation but rather complement one another in explaining data-driven clinical risk analysis phenomena. Academically, this study expands interdisciplinary discourse among clinical medicine, public health, and health data analytics, particularly within primary healthcare settings that have been relatively underexplored.

The practical benefits of this study are reflected in its potential to enhance the quality of primary healthcare services through the application of data-driven predictive models. With the support of more systematic risk analysis, healthcare professionals can implement more targeted and efficient interventions. The implementation of these findings is consistent with clinical decision-making theory, which underscores the importance of evidence-based decision-support tools in clinical practice. From a managerial perspective, the results may also serve as a foundation for primary healthcare administrators in developing data-informed policies and strategies for non-communicable disease management.

Overall, the findings of this study indicate that clinical risk analysis based on predictive models represents a relevant and applicable approach for managing non-communicable disease patients in primary healthcare facilities. By linking empirical findings with the three main theoretical perspectives, the study not only addresses the research problems and questions but also provides significant theoretical, academic, and practical contributions. The implementation of this approach holds potential for supporting the transformation of primary healthcare services toward systems that are more predictive, preventive, and responsive to patient needs.

The discussion of this study is directed toward interpreting the research findings within the context of the central challenges associated with the management of non-communicable diseases in primary healthcare facilities, with particular emphasis on the outcomes of data-driven predictive clinical

risk analysis. The findings demonstrate that predictive approaches based on clinical data are capable of providing a more systematic and structured representation of clinical risk among patients with diabetes mellitus and hypertension when compared to conventional methods commonly applied in primary care settings. These results are highly relevant when linked to the main research problem, namely the limitations in early detection and clinical risk stratification of non-communicable disease patients at the primary healthcare level.

This core problem has largely emerged as a consequence of the dominance of reactive healthcare practices, in which interventions are typically initiated only after the manifestation of clinical symptoms or complications. Prior studies examined within this research context indicate that risk assessments relying solely on single indicators, such as blood pressure or blood glucose levels, are insufficient to capture the full complexity of patients' clinical conditions. The present findings reinforce previous evidence by demonstrating that the integration of multiple clinical and demographic variables through predictive models enhances the identification of high-risk patients. Accordingly, this discussion emphasizes that the fundamental issue lies not in the lack of data availability, but rather in the suboptimal utilization of existing data to support clinical decision-making processes.

When considered in relation to the research gap, the findings make a significant contribution to bridging the divide between advances in predictive analytics reported in the literature and their practical application in primary healthcare facilities. Previous studies have predominantly focused on hospital-based or tertiary care settings characterized by advanced data infrastructures and greater resource availability. As a result, limited attention has been paid to how predictive approaches can be effectively implemented in primary care environments that face resource constraints and distinct patient characteristics. The findings of this study demonstrate that, despite such limitations, data-based clinical risk analysis can still be conducted in a meaningful and contextually relevant manner within primary healthcare settings.

The discussion further highlights that the identified research gap is not solely technical in nature, but also conceptual and operational. Conceptually, earlier research has often positioned technology as a standalone solution without sufficient consideration of the clinical practice context in primary care. The findings of this study indicate that the successful application of predictive models is strongly dependent on their alignment with clinical workflows and the practical needs of healthcare professionals. From an operational perspective, the study reveals that integrating predictive models into primary healthcare services requires a clear understanding of service delivery processes and the roles of different healthcare providers. Thus, the discussion underscores that addressing the research gap necessitates an approach that extends beyond model accuracy to encompass contextualized and feasible implementation.

In relation to the research question concerning how clinical risk analysis for non-communicable disease patients can be conducted effectively using data-driven predictive models in primary healthcare facilities, the findings provide a clear and measurable response. The results indicate that predictive models are capable of identifying risk patterns that are not consistently observable through conventional clinical assessments. This discussion links these findings with prior research emphasizing the importance of multidimensional approaches in chronic disease risk assessment. Through predictive modeling, clinical risk is no longer conceptualized as a static condition, but rather as the outcome of dynamic interactions among multiple factors that can be quantitatively analyzed.

The discussion further demonstrates that the effectiveness of clinical risk analysis is determined not only by a model's predictive capacity, but also by the extent to which its outputs can be understood and utilized by healthcare professionals. Previous studies have shown that low adoption of analytic technologies in primary care is often attributable to limited comprehension of analytical results. The present findings suggest that when predictive outputs are presented in a simplified and clinically relevant manner, healthcare professionals are more likely to integrate them into decision-making processes. Consequently, the research question is addressed not only in technical terms, but also with respect to usability and clinical relevance.

The research objective of analyzing clinical risk among non-communicable disease patients using data-driven predictive models can also be comprehensively discussed based on the study's findings. The results demonstrate that this objective was achieved through the identification of high-risk patient groups that were previously difficult to recognize in a systematic manner. This discussion relates these findings to earlier studies highlighting the critical role of risk stratification in chronic disease management. With more accurate risk stratification, primary healthcare services are better positioned to implement preventive interventions and deliver sustainable long-term disease management.

The discussion emphasizes that achieving the research objective has implications not only for clinical practice but also for the broader healthcare service system. Prior research indicates that unstructured management of non-communicable diseases can increase healthcare workload and service costs. The findings of this study suggest that the use of predictive models has the potential to improve service efficiency by directing resources toward patients with the greatest need. In this sense, the research objective of proposing a more effective and efficient approach to clinical risk analysis can be considered fulfilled.

The theoretical contributions of this study can be discussed in relation to the development of an integrated conceptual framework for data-driven clinical risk analysis in primary healthcare. Previous research has often treated clinical risk theory, clinical decision-making theory, and predictive analytics as separate domains. This discussion demonstrates that integrating these perspectives provides a more comprehensive understanding of clinical risk phenomena among patients with non- communicable diseases. Accordingly, the study enriches theoretical discourse by illustrating how these theories can complement one another within the primary healthcare context.

From an academic perspective, the discussion positions the findings as a contribution to interdisciplinary literature linking clinical medicine, public health, and health data analytics. Previous studies indicate that research on the application of predictive models in primary healthcare remains relatively limited. By addressing this gap, the present study offers empirical evidence that may inform future research development, both methodologically and substantively. The discussion further suggests that this study can serve as a reference point for the design of similar research across diverse primary healthcare settings.

The practical implications of this study are reflected in the potential application of clinical risk analysis results in routine healthcare practice. This discussion connects the findings with prior research underscoring the importance of clinical decision-support tools in primary care. Through the use of data-driven predictive models, healthcare professionals can obtain more timely and accurate representations of patient risk, enabling more targeted interventions. The practical benefits extend beyond healthcare providers to patients themselves, through improvements in service quality and the prevention of disease-related complications.

Overall, the discussion demonstrates that the research findings are not only relevant in addressing the research problems, gaps, and questions, but also contribute meaningfully to the achievement of the study's objectives and anticipated benefits. By linking the findings with previous research, this discussion reinforces the study's position as a work with significant theoretical, academic, and practical value. The data-driven predictive clinical risk analysis approach examined in this study holds substantial potential to support the transformation of primary healthcare services toward systems that are more predictive, preventive, and responsive to patient needs.

CONCLUSIONS

This study concludes that clinical risk analysis for patients with non-communicable diseases using data-driven predictive models in primary healthcare facilities represents a relevant and applicable approach to addressing the challenges of chronic disease management. Based on the research findings and discussion, the predictive approach has been shown to provide a more systematic representation of clinical risk among patients with diabetes mellitus and hypertension compared to conventional clinical assessment methods. These findings confirm that clinical risk in non-communicable disease patients is

inherently multidimensional and requires analytical approaches capable of integrating multiple risk factors simultaneously.

The results demonstrate that clinical data available in primary healthcare facilities can be utilized to identify variations in risk levels among patients with greater accuracy. As discussed earlier, these findings are closely linked to the limitations of reactive approaches that have traditionally dominated primary healthcare practice. Through the use of data-driven predictive models, clinical risk can be identified at an earlier stage, thereby creating opportunities for preventive interventions and more targeted disease management. This conclusion strengthens the argument that predictive approaches function not only as technical innovations but also as strategic instruments for improving the quality of primary healthcare services.

The conclusions further highlight that the success of clinical risk analysis is determined not only by the predictive model's ability to generate risk estimates but also by the relevance and interpretability of the analytical outputs in clinical practice. The discussion indicates that healthcare professionals are more inclined to utilize predictive results when risk information is presented in a clear and clinically meaningful manner. Accordingly, data-driven predictive models can be positioned as clinical decision-support tools that enhance, rather than replace, clinicians' professional judgment in determining patient care plans.

In addition, this study concludes that the application of data-based clinical risk analysis in primary healthcare facilities has the potential to bridge the gap between advances in predictive analytics reported in the literature and real-world healthcare practice. The research findings and discussion show that although primary healthcare services face resource constraints, predictive approaches can still be implemented meaningfully when adapted to local contexts and facility capacities. This demonstrates that the research gap traditionally associating predictive analytics with tertiary care settings can be narrowed through contextualized model adaptation and the effective use of data available in primary healthcare services.

The conclusions also confirm that the research objective of analyzing clinical risk among non-communicable disease patients using data-driven predictive models has been achieved. The findings provide evidence that predictive models can support patient risk stratification and assist healthcare professionals in prioritizing interventions. As discussed, these outcomes are associated with the potential for improving service efficiency through more targeted resource allocation in primary healthcare facilities. Thus, the conclusions not only address the study objectives but also offer practical implications for the development of healthcare service systems.

From a scientific contribution perspective, the conclusions emphasize that integrating clinical risk approaches, clinical decision-making processes, and predictive analytics provides a comprehensive framework for managing non-communicable diseases in primary healthcare settings. The discussion demonstrates that these perspectives complement one another in explaining the complexity of clinical risk and the role of data in supporting clinical practice. Consequently, this study contributes to the enrichment of interdisciplinary literature linking clinical medicine, public health, and health data analytics.

Overall, the conclusions affirm that the use of data-driven predictive models in clinical risk analysis constitutes a strategic step toward transforming primary healthcare services into systems that are more predictive, preventive, and patient-centered. The findings and discussion indicate that this approach is not only methodologically sound but also practically relevant and academically meaningful. Accordingly, this study provides a strong foundation for the development and implementation of data-based innovations in the management of non-communicable diseases within primary healthcare facilities.

RECOMMENDATIONS

Based on the study's conclusions demonstrating the substantial potential of predictive model–based clinical risk analysis in improving the management of non-communicable diseases in primary healthcare facilities, several directions for further development and implementation are recommended.

These recommendations are formulated by considering the main research findings, identified limitations, and the practical needs of primary healthcare systems in addressing the growing burden of chronic diseases.

The first recommendation focuses on strengthening the systematic use of clinical data in primary healthcare facilities. The study concludes that data availability and quality are key determinants of successful predictive clinical risk analysis. Therefore, it is recommended that primary healthcare facilities enhance standards for clinical data recording and management, particularly for non-communicable diseases such as diabetes mellitus and hypertension. Strengthening health information systems and improving data integration across services are expected to support more accurate and sustainable risk analysis practices.

The second recommendation relates to the integration of predictive models into primary healthcare workflows. The study concludes that predictive models deliver optimal benefits when their outputs are easily understood and utilized by healthcare professionals. Accordingly, the development of predictive models should be accompanied by user-friendly interfaces and risk information presentation mechanisms that are clinically relevant and straightforward. Such integration is expected to reinforce clinical decision-making processes without significantly increasing healthcare professionals' workload.

The next recommendation addresses the need to enhance human resource capacity in primary healthcare facilities. The study concludes that the effective use of data-driven risk analysis requires healthcare professionals to possess adequate understanding of predictive results and their clinical implications. Therefore, training and mentoring programs are recommended to improve healthcare professionals' competencies in interpreting and applying predictive analytics in clinical practice. Strengthening human resource capacity is expected to increase acceptance and trust in data-driven approaches among healthcare personnel.

In addition, this study recommends the provision of managerial and policy support for the implementation of data-driven clinical risk analysis in primary healthcare services. The conclusions indicate that the sustainability of predictive model implementation is strongly influenced by organizational commitment and internal policy support. Consequently, primary healthcare managers and relevant stakeholders are encouraged to incorporate predictive analytics into non-communicable disease management strategies. Such policy support is essential to ensure that data-driven innovations are institutionalized as part of long-term service systems rather than remaining temporary initiatives.

Further recommendations are directed toward the development of future research. Based on the study's conclusions, there remains considerable potential to expand clinical risk analysis by involving a larger number of primary healthcare facilities and more diverse patient populations. Future studies are also encouraged to integrate behavioral, social, and environmental variables that may influence non-communicable disease risk. This expanded approach is expected to enhance predictive model accuracy and deepen understanding of clinical risk determinants.

Finally, the study recommends continuous evaluation of the impact of data-driven predictive model implementation on patient clinical outcomes and the quality of primary healthcare services. The conclusions suggest that the potential benefits of predictive approaches should be further examined through long-term implementation studies. Such evaluations are essential to ensure that clinical risk analysis practices deliver tangible benefits for patients, healthcare professionals, and the healthcare system as a whole.

In summary, these recommendations emphasize that the use of data-driven predictive models in clinical risk analysis represents a strategic initiative that should be developed systematically and sustainably. By aligning the recommendations with the study's conclusions, it is expected that the research findings will contribute not only to scientific knowledge advancement but also to practical guidance for improving the quality of primary healthcare services in the management of non-communicable disease.

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